Energy for living cell (A2)

Living things require a continuous supply of energy for:

- mechanical work such as muscle contraction.
- the transport of molecules and ions through cell membranes into and out of cells.
- the synthesis of molecules such as proteins, starch, fats, vitamins and coenzymes.

In animals, this energy comes from the oxidation of food especially carbohydrates and fats.

The process is called respiration.

Oxygen is required to fully oxidise foods to carbon dioxide and water.

The first part of metabolic pathway of respiration takes place in the cytoplasm of the cell.

The second part involves a series of redox reactions which take place in the mitochondria.

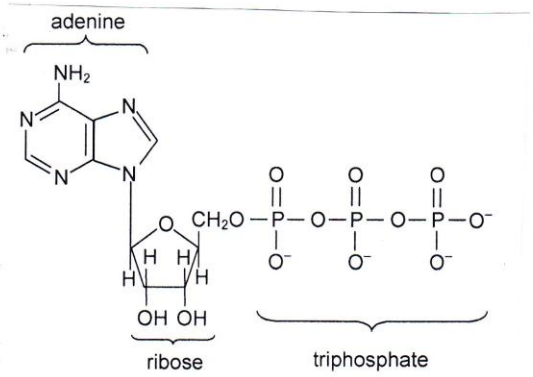
In the mitochondria, a nucleotide triphosphate called adenosine triphosphate (ATP) is synthesised.

ATP molecule has an important role to play in the energy transfers in the cell.

ATP – life's energy currency

ATP consists of:

- three linked phosphate groups – a single inorganic phosphate group is often abbreviated P_i)
- a sugar ribose
- a base adenine



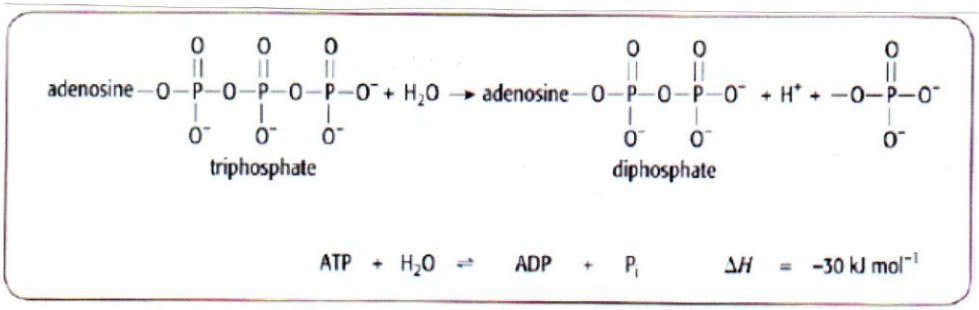
the structure of ATP

The active form of ATP in cell is usually a complex of ATP with Mg^{2+} ions.

ATP can be hydrolysed to adenosine diphosphate (ADP).

This hydrolysis reaction is an exothermic process, releasing energy.

- the release of the end phosphate group is favoured by the repulsion between the negatively charged O atoms on adjacent phosphate groups.
- ADP and P_i are more stable due to a greater delocalisation of charge on their ions compared with ATP.



The hydrolysis of ATP.

ATP is produced during the oxidation of food.

When ATP is hydrolysed, energy is released.

This energy must be released in a controlled manner so that it is available for cellular process.

ATP is hydrolysed in the presence of enzymes to achieve this control.

Enzymes help to lower the high Ea of the reaction.

ATP in energy transfers

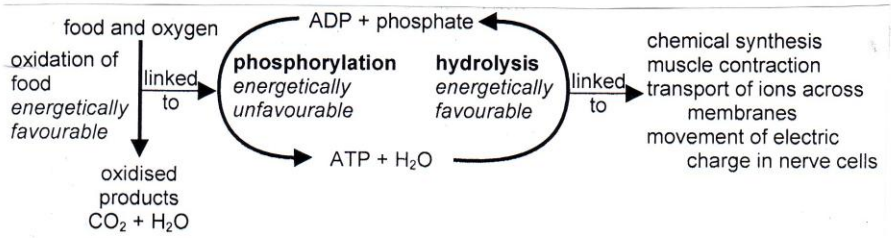
In the cell, metabolic pathways build up complex substances from simpler ones.

Most of these pathways require energy - endothermic process.

The energy released when ATP is hydrolysed in the presence of enzymes is not wasted as heat.

It is linked to energetically unfavourable reactions in the cell.

Enough energy is provided by the hydrolysis of ATP to drive reactions which require an input of energy.
Cellular metabolic activity requires continuous supply of energy from hydrolysis of ATP.
Mitocondria is an organelle which makes ATP to replenish its level.
In the mitochondria ADP + P_i is converted to ATP.
This synthesis is linked to a series of redox reactions involving cytochromes, coenzymes (such as $NADH^+$) and oxygen.
This process of making ATP is called oxidation phosphorylation.
This series of reactions will only carry on in the presence of oxygen.
As long as aerobic respiration is occuring, the ATP production in the cell is kept fairly constant.
The maximum amount of ATP produced from the oxidation of 1 mole of glucose is 38 moles of ATP.



the role of ATP in metabolism

Exercise 1

What class of compound does ATP belong to?

Workings

nucleotide triphosphate.

Exercise 2

List the three main components of an ATP molecule.

Workings

- adenine: nitrogen-containing base.
- ribose: 5-carbon sugar/pentose
- triphosphate: 3 linked phosphate groups.

Exercise 3

i) Give the full name of ADP

ii) How does ADP differ from ATP?

Workings

i) ADP – adenosine diphosphate.

ii) ADP has one phosphate group less than ATP.

Exercise 4

Where in the cell is ATP mainly synthesised?

Workings

Organelle mitochondria.

Exercise 5

Explain how ATP is used in the cell to drive unfavourable reactions.

Workings

Hydrolysis of ATP is exothermic process.
Cellular metabolic reactions are endothermic process.
With the help of enzymes, energy released on ATP hydrolysis can be used to drive the cellular metabolic reactions in the forward direction.

Exercise 6

What is the name of the metabolic process in which glucose is oxidised to carbon dioxide and water?

Workings

aerobic respiration

Exercise 7

What conditions are needed for the synthesis of ATP in the mitochondria?

Workings

Oxygen must present to drive a series of redox reactions
Required substrates are ADP and inorganic phosphate.
Reduced forms of coenzymes must also be present so that they can be oxidised by oxygen.

Exercise 8

What does the term oxidative phosphorylation mean in relation to ATP?

Workings

oxidative phosphorylation — the production of ATP from ADP and P_i in the presence of oxygen / oxidising conditions.