Bio Factsheet

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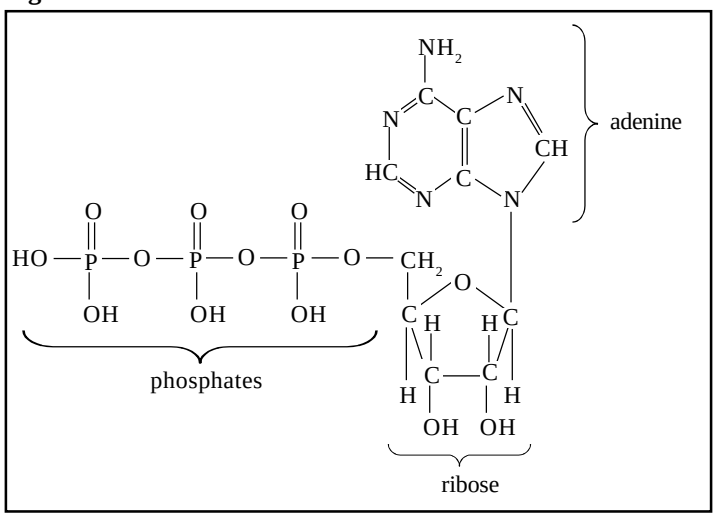
ATP -What it is, What it does

ATP is a nucleotide composed of adenine (a nitrogenous base), ribose (the 5-carbon or pentose sugar found in RNA) and three phosphate groups (Fig 1).

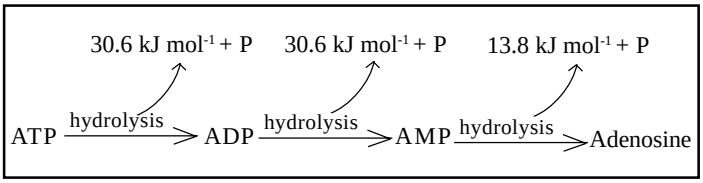
Fig 1. Structure of ATP



The combination of adenine with ribose makes adenosine. If one phosphate group is attached we have adenosine monophosphate (AMP). If a second phosphate becomes attached we have adenosine diphosphate (ADP) and a third phosphate gives us ATP.

ATP is sometimes referred to as energy currency. This is because all living organisms – from bacteria to nettles to crocodiles – use ATP for energy conversion. ATP is small and water soluble, properties which make it easy to transport. When ATP is hydrolysed into ADP i.e when one of the phosphate groups is removed in a reaction involving water, 30.6 kJ mol^{-1} energy is released. Similarly, the hydrolysis of ADP into AMP releases 30.6 kJ mol^{-1} of energy. Finally, the hydrolysis of AMP into adenosine yields 13.8 kJ mol^{-1} (Fig 2).

Fig 2. Hydrolysis of ATP



This energy can be used by the cell for hundreds of different chemical reactions or for muscle contraction or active transport etc. (Fig 3)

Equally importantly, when energy is released by, for example, the breakdown of carbohydrate during respiration, the released energy is captured by ADP that is thus converted into ATP. The interconversion of ADP into ATP and vice versa is, in fact, constant in a cell. Very little quantities of ATP are ever stored and a typical mammalian cell turns over – i.e. completely breaks down and replaces – its entire ATP pool every 1-2 minutes. In other words, an adult converts a quantity of ATP corresponding to about half his or her body weight every day, and nearly a ton during a day of hard work.

Energy for ATP synthesis

In all living things there are just two ways of supplying the energy for ATP production.

1. Substrate level phosphorylation. At AS/A2 level you do not need to know this term. Suffice to say that this is the process that makes ATP in glycolysis and in the Krebs cycle, for example.

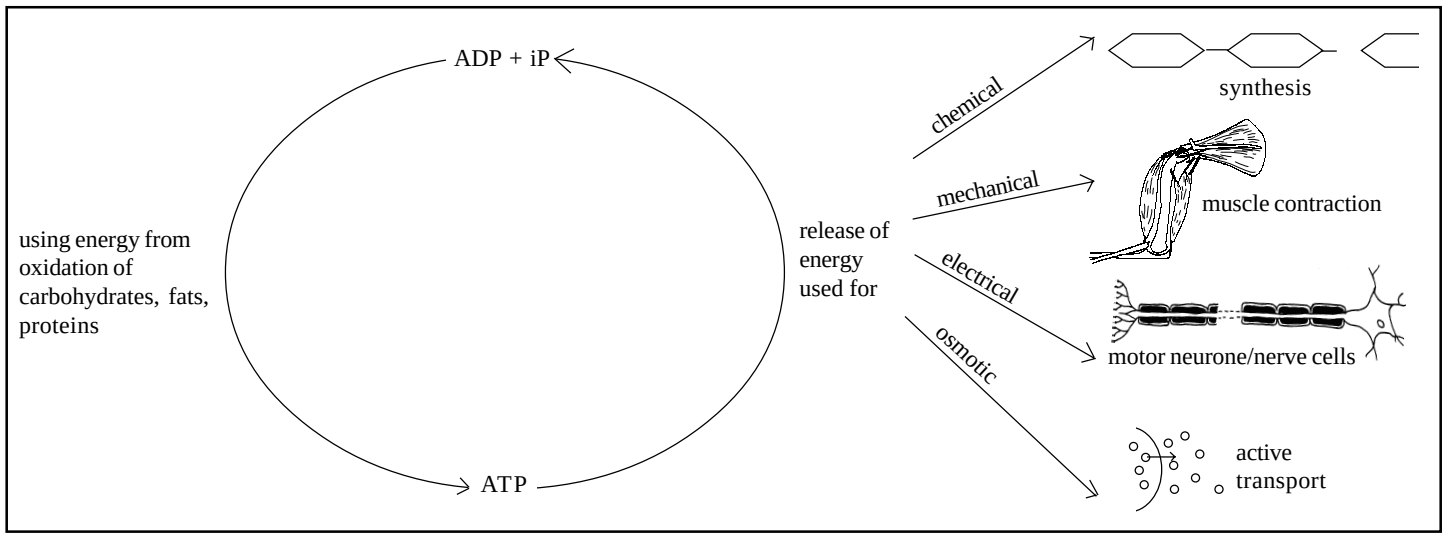
2. Chemiosmosis . Again, you do not need to know this term but it is described in detail in all of the common A level textbooks and it is useful to know a little because it helps to make sense of what happens to the electrons in the electron transfer chain (ETC) in the cristae of the mitochondria (Fig 4).

Remember

Respiration = glycolysis (cell cytoplasm) + Krebs cycle (matrix of mitochondria) + ETC (cristae of mitochondria)

See Factsheet 12 Respiration for more detail

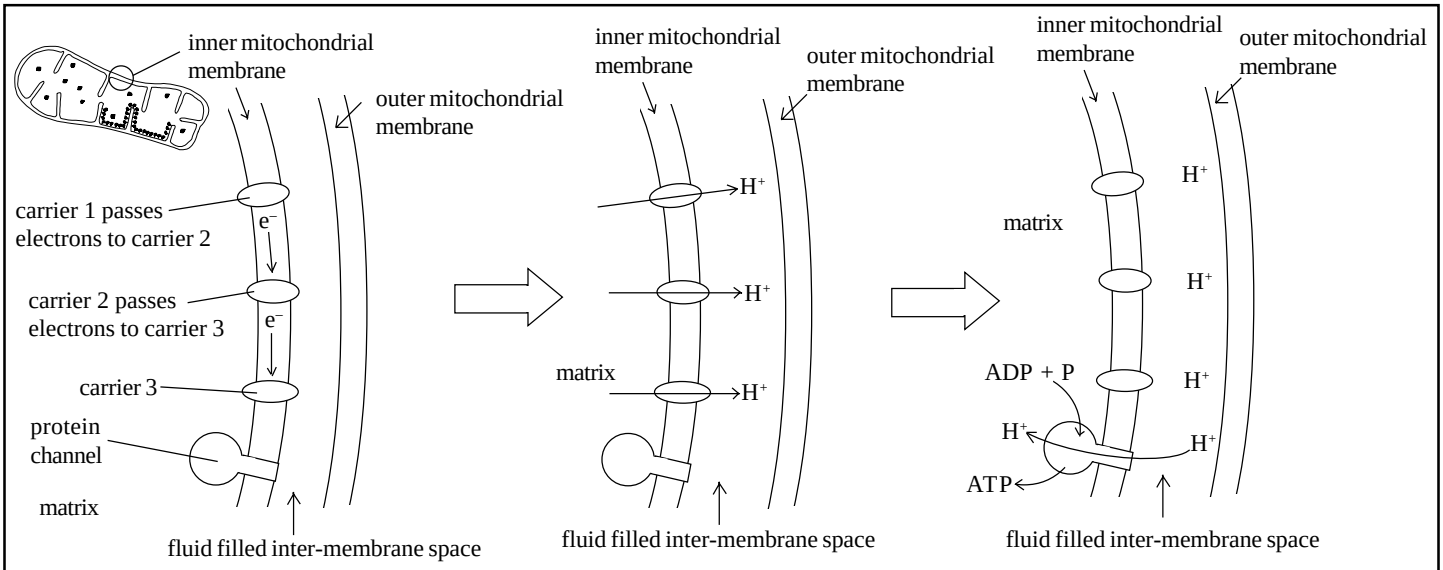
Fig 3. Uses of ATP



Chemiosmosis and the ETC

The main points are summarised in Fig 4.

Fig 4. Releasing electrons to make ATP



1. Electrons are passed from one electron carrier to another. Carriers include molecules such as NAD and FAD. The carriers are at progressively lower energy levels. As an electron passes from a carrier which is at a high energy level to a carrier that is at a lower energy level, energy is released.

2. This energy is used to pump H^+ ions into the space between the two membranes of the mitochondrial envelope. The concentration of H^+ ions inside the inter-membrane space then exceeds the concentration in the matrix; a concentration gradient has been established.

3. H^+ ions then move back into the matrix through protein channels in the inner membrane. These channels also contain the enzyme ATPase (ATP synthase or synthetase in some books). The electrical potential energy of the H^+ ions is used by the enzyme ATPase to make ATP from ADP and inorganic phosphate.

What is ATP used for?

Table 1 summarises some of the important uses of ATP that appear on A level specifications

Table 1 uses of ATP

Use	Example
Active transport	Pumping Na^+ ions out of cells
Condensation reactions	Joining two peptides into a dipeptide
Glycolysis	Glucose + ATP……..glucose-6-phosphate
Protein synthesis	Attaching a specific amino acid to its t-RNA molecule
Cell division	Chromosome movement towards the spindle pole
Muscle contraction	ATP energy needed to swivel the myosin head
Movement	Flagella of sperm, cilia
Bioluminescence	In fire-flies
Photosynthesis	Provides energy for Light Independent stage when CO_2 is reduced

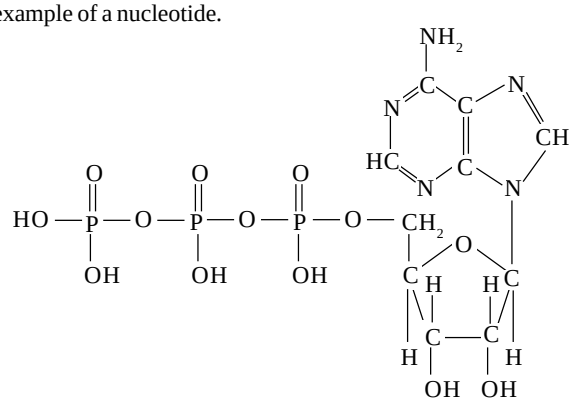
Answers

1. Nucleotides consist of a nitrogen-containing base, a pentose sugar and one or more phosphate groups;
In ATP the base is adenine, the sugar ribose and there are 3 phosphate groups;

2. ATP occupies intermediate energy level;
Molecules above it in the table will lose a phosphate group and the energy released will be used to convert ADP into ATP;
Molecules below it will stimulate hydrolysis of ATP, releasing energy for other chemical reactions/energy – requiring processes etc;

Practice Questions

1. The diagram shows the structure of ATP. Explain why ATP is an example of a nucleotide. **2**



2. The table shows the energy content of some metabolites.

Metabolites	Energy content (k cal mol^{-1})
phosphoenolpyruvate	-14.8
1,3-Biphosphoglycerate	-11.8
Ceratine phosphate	-10.3
Adenosine triphosphate	-7.3
Adenosine diphosphate	-6.6
Glucose-1-phosphate	-5.0
Fructose-6-phosphate	-3.8
Adenosine monophosphate	-3.4
Glucose-6-phosphate	-3.3
Glycerol-3-phosphate	-2.2

Suggest why these data help explain the universal role of ATP as an energy conversion molecule. **3**

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Curriculum Press, Bank House, 105 King Street, Wellington, Shropshire, TF1 1NU