7-4 Respiration and Energy Transfer

If you completed the previous lab activity, you now know some of the details of the respiration process. You will find that this knowledge will enable you to understand many other important biological concepts.

1. Why must animals obtain energy?

Objective

You will be required to write a balanced equation for animal respiration and explain where the energy produced comes from and how it is stored.

This equation goes on in every animal and plant cell twenty-four hours a day. That's right, even in plant cells. During the day, the plant cell is carrying out photosynthesis which masks respiration and makes it difficult to detect. Here's how it works:

In light: (The size of letters indicates the amount of reaction taking place.)

(1) $CO_2 + H_2O + \text{light energy} \xrightarrow{\text{enz.}} O_2 + C_6H_{12}O_6$

(2) $O_2 + C_6H_{12}O_6 \xrightarrow{\text{enz.}} CO_2 + H_2O + \text{energy}$

2. What are the names for equations (1) and (2)?

3. Which equation requires CO_2 and which equation produces CO_2?

At night, when the sun sets, the photosynthesis reaction stops but the respiration reaction continues:

$O_2 + C_6H_{12}O_6 \xrightarrow{\text{enz.}} CO_2 + H_2O + \text{energy}$

This is why plants like *Elodea* can be shown to use CO_2 in light and give off CO_2 in the dark. The balanced equation for respiration is as follows:

$$\mathbf{6\ O_2 + C_6H_{12}O_6 \xrightarrow{enz.} 6\ CO_2 + 6\ H_2O + energy}$$

Balanced equations show the number of molecules of each required reactant and the number of each product molecule.

4. In respiration, how many molecules of water will be produced for every one molecule of glucose that breaks apart?

5. In respiration, how many molecules of oxygen will be required for every 12 molecules of carbon dioxide produced?

During the respiration reaction, the $C_6H_{12}O_6$ and O_2 molecules are pulled apart by enzymes. As the bonds in the glucose and oxygen molecules are broken, the atoms rearrange into the products carbon dioxide and water, releasing energy in the process.

6. During respiration, which reactant molecules do the C atoms in CO_2 come from? Do they come from the oxygen or the glucose? Explain your choice.

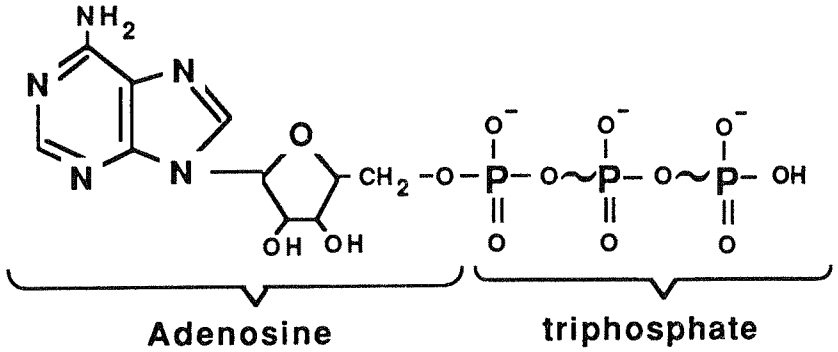
In respiration, humans breathe oxygen into their lungs. The **oxygen** enters the blood stream which takes it to all body cells. The blood also brings needed **glucose** from the digestive system to the cells. Each cell now uses numerous respiration enzymes to help break the $C_6H_{12}O_6$ and O_2 apart. As the gucose is pulled apart, the **energy** that is holding the glucose molecule together is transferred to another form and is stored for later use by the cell. In muscle cells, great amounts of energy need to be stored to be available for muscle contraction. The energy produced in respiration is stored by a unique molecule known to biochemists as **ATP**.

7-5 In-Depth Enrichment: ATP, The Energy Storage Units of the Cell

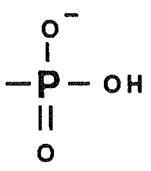
Objective

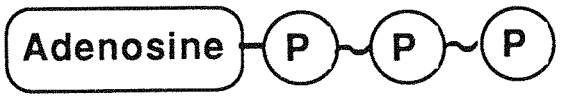
You should be able to describe how ATP and ADP are involved in the storage and release of energy produced during respiration.

ATP is short for **adenosine triphosphate.** Examine the following structure of ATP:



The hexagon and pentagon symbols in **ATP** are used by chemists to represent rings of C atoms. C atoms are found at the points of the hexagon and pentagon. One half of the molecule is called **adenosine** and the other half consists of **3 phosphate groups**. A phosphate group is made of one phosphorus (P) atom with 3 O atoms and one H atom clustered around the P atom as shown at the right. The **phosphate group** can be symbolized as a circle with a P in the middle. Using these symbols, ATP can be symbolized in the following way:

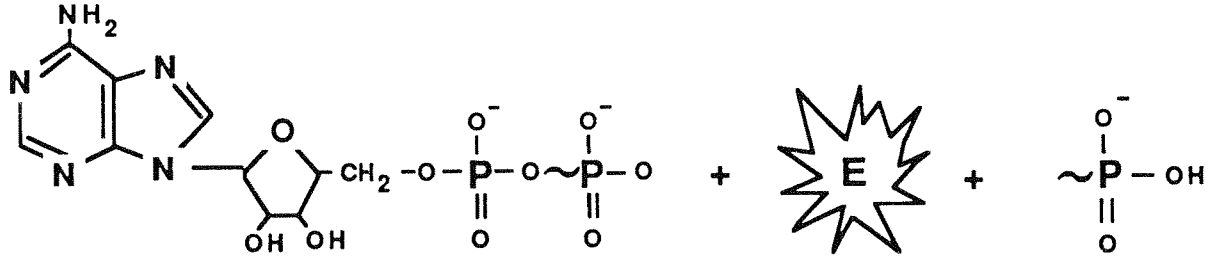




1. What atoms are found in each phosphate group?

2. Draw the actual structural formula for the adenosine part of the ATP molecule that shows where each C, H, O and N atom is located.

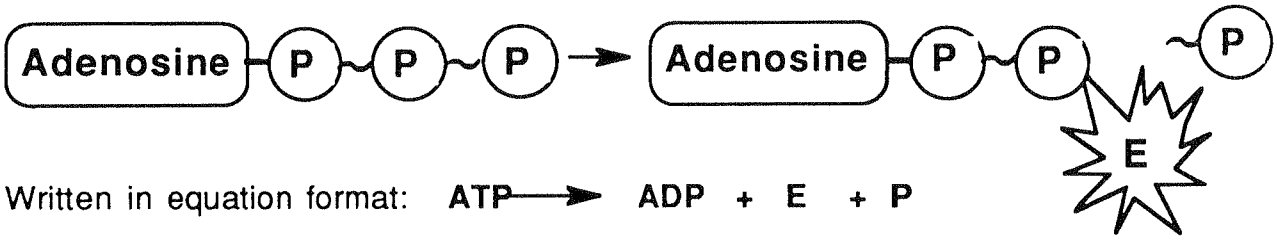
The bonds between phosphates are represented with a ~ . This symbol represents a **high energy bond.** When a high energy bond is broken, the amount of energy released is greater than when a regular bond is broken. ATP stores its energy in these high energy bonds. **The energy comes from respiration.** When the high energy bond connecting the last phosphate group to ATP breaks, the energy is released and the products are symbolized as follows:



Adenosine diphosphate (ADP) + energy + phosphate

Notice that when one phosphate group breaks off of the larger part of the ATP molecule, the remainder is called adenosine **di**phosphate because it has only **two** phosphates attached.

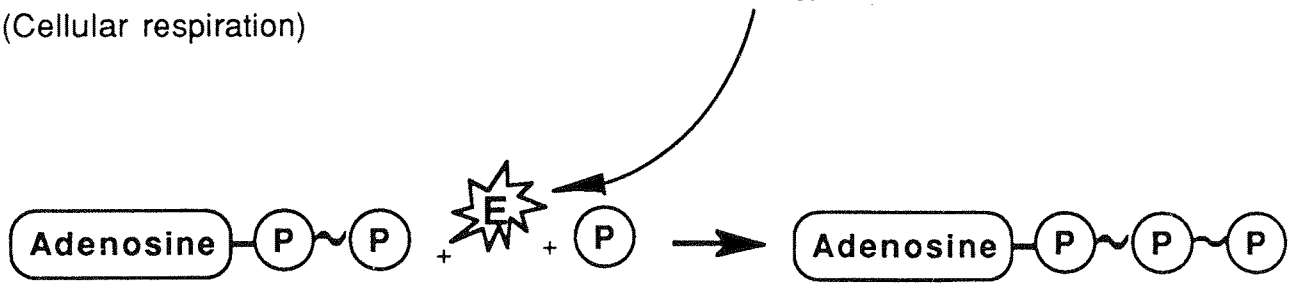
Another way to visualize how ATP stores and releases energy is as follows:



Written in equation format: **ATP ⟶ ADP + E + P**

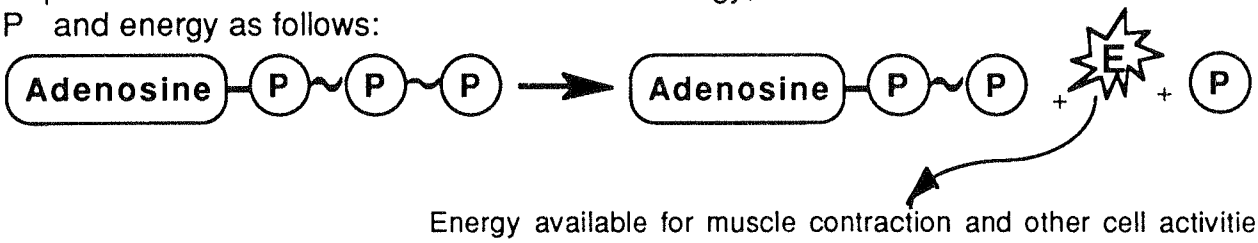
Adenosine triphosplate (ATP) breaks apart to produce adenosine diphosphate (ADP), energy (E) and phosphate (P). The following diagram shows the energy for the breaking of bonds in glucose during respiration, transferring to ATP:

O_2 + $C_6H_{12}O_6$ ⟶ CO_2 + H_2O + energy
(Cellular respiration)



The above shown in the short version: ADP + E + P ⟶ ATP

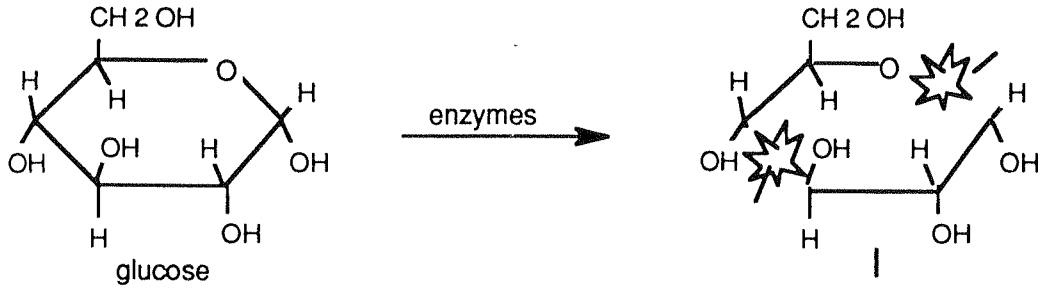
The energy given off from respiration is used to link the phosphate (P) to the ADP molecule. The resulting product is **ATP**. The ATP stores this energy from respiration in the last bond to the last P group. Millions of ATP molecules are built when energy requirements are low. When the cell needs energy, it converts the ATP back to ADP and P and energy as follows:



The above can be shown in the short version as follows:

ATP ⟶ ADP + P + E

The energy is used by the cell for any cell activity requiring it. In muscle cells, the released energy can be used to contract the muscle. In summary, this is how it works. The glucose, shown below, is broken apart in steps by a series of enzymes. Each time a bond in glucose is broken, the energy previously holding the atoms of glucose together, is released and will be transferred to ADP molecules.
The energy is represented by 

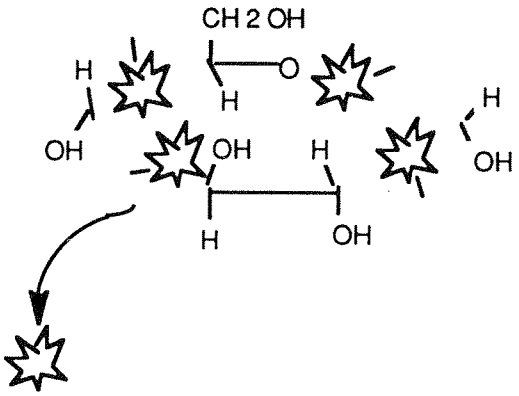


The energy from the bonds of glucose unites the P to ADP creating a molecule of ATP:

E + P + ADP ⟶ ATP

When the cell needs energy, the reaction reverses, and the ATP breaks apart to produce ADP, P and the needed **energy.**

For each one molecule of glucose that breaks down, 38 molecules of ATP are produced.



+ P + ADP ⟶ ATP

Respiration and ATP formation takes place in the **mitochondria** of every plant and animal cell. The steps involved in the breakdown of glucose are actually more complex than diagrammed above and are cyclic in nature. The cyclic part of the breakdown is known as the **Krebs Cycle.**

3. Explain how the energy in glucose is released during respiration and how it become stored in ATP. Use diagrams if you like.

4. Explain how ATP provides energy for the cell. Use equations or diagrams to supplement your explanation.