Introduction

Lost in the desert, Mauro Prosperi searched for the energy to survive. Food was scarce, but he knew if he did not find something to nourish his cells, his body would give out. Food is our primary cellular fuel, and the macromolecules we ingest are the raw material needed to create the body’s energy currency, the amazing molecule, adenosine triphosphate (ATP). ATP is to cells what gasoline is to your car. This molecule provides the usable energy needed to carry out all body processes. One of the most amazing things about the body is its ability to create, store and recycle ATP. It is one of the most efficiently used compounds in nature. Your body breaks down the food you eat and stores the energy released in a form that can be utilized by the cells to do work.

Some people might think recycling is a relatively new concept. In actuality, cells have been recycling substances since the beginning of time. ATP is one of those recycled substances. As you might imagine, creating all the ATP you need from scratch is not very efficient. The body needs a quick and easily accessible source of ATP all the time. In fact, 10 million molecules of ATP are used and regenerated per second per cell! Now that’s a lot of energy. So how does food provide us with ATP and what does it really mean when we say this molecule is recycled? In this activity, you will explore the structure of ATP and delve deeper into how this powerful molecule functions in our cells.

Procedure

1. Use the Internet to research the structure and function of the molecule ATP and complete the exercises below. The following websites may be helpful, but you may search the Internet for additional reliable resources.
   - Dr. Leif Saul’s Biology in Motion (try the animations) http://biologyinmotion.com/amp/index.html
   - Bristol University - ATP: Molecule of the Month http://www.bristol.ac.uk/Depts/Chemistry/MOTM/atp/atp.htm
   - ATP – Adenosine Triphosphate http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/ATP.html
   - Adenosine Triphosphate http://hyperphysics.phy-astr.gsu.edu/hbase/biology/atp.html

2. Think about how the structure of ATP is related to its ability to supply energy.

3. Note that ATP is a nucleic acid. Think about what you know about the structure of nucleic acids such as DNA. Remember that the basic structure of each nucleotide consists of a nitrogenous base, a sugar and a phosphate group. The building block of ATP takes this same structure. List the sugar and the base found in molecules of ATP in the space below.

   Sugar **Ribose**   Base **Adenine**

4. Draw a diagram of the ATP molecule. Each of the three components of the molecule should be a different color and each part should be clearly labeled.

5. Where is the energy located in the ATP molecule? Indicate on your drawing in the previous step where the energy is being stored.
6. Review the equation for the breakdown of ATP and the release of energy shown below.

\[ \text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{P}_i + \text{energy} \]

ATP has 3 phosphates
ADP has 2 phosphates

7. What do we call the type of chemical reaction that occurs in #6? Explain how the name of this type of reaction relates to a key resource other than food.

Hydrolysis - "hydro" means water is used and "lysis" means to break so water is added to break ATP into ADP and phosphate. This is a catabolic reaction.

8. What is ADP and how is it generated?

ADP is Adenosine Di-phosphate.
It is a byproduct of ATP being used as energy. It is ATP with a P broken off.

9. We have said before that ATP is recycled. What do you think is the simple equation for reforming ATP?

\[ \text{ADP} + \text{P} \rightarrow \text{ATP} + \text{H}_2\text{O} \]

10. Name the process human cells use to generate more ATP. Where in the cell does this process occur?

Cellular Respiration in the mitochondria.

11. The general chemical equation for the ATP generating process in cells is listed below. If necessary, research the identity of each item. Write the common name underneath each reactant (what goes in to the reaction?) and product (what comes out of the reaction?).

Cell Respiration: \[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP} \]

↑ Glucose  ↓ oxygen gas  ↑ carbon dioxide  ↑ water  ↑ Adenosine Tri-phosphate

12. The process of cellular respiration shown in #11 produces ATP by rejoining a phosphate group with the ADP molecule. Where do you get the \( \text{C}_6\text{H}_{12}\text{O}_6 \) and \( \text{O}_2 \) that is required for this process?

\( \text{C}_6\text{H}_{12}\text{O}_6 \) is glucose and comes from eating carbohydrates.
\( \text{O}_2 \) is oxygen gas we get by breathing.

13. What happens to the \( \text{CO}_2 \) that is produced in the reaction?

It travels through the bloodstream to the lungs to be exhaled.
14. Which types of cells in the body would you expect to require the most ATP? Support your answers with evidence.

- **Muscles**: Movement requires a lot of energy.
- **Neurons**: Always working (thinking in brain) and requires a lot of energy.

15. Draw diagram to show the biochemistry behind the breaking and reforming of ATP.

**Breaking**: Hydrolysis (to give off energy)

One H+ in water is given to the APD, the OH- in water is given to the phosphate group.

**Reforming**: Dehydration Synthesis (Condensation Reaction)

16. Read the article "Lighting up the Heart" found at http://www.bristol.ac.uk/news/2006/5067.html and answer the following:

- **How has a process in nature been used as a medical intervention?**
  Luciferase, an enzyme that allows fireflies to light up in the presence of ATP may be used in the human heart to show how much ATP is being produced. The more ATP the better the heart function.

- **What does the level of ATP tell scientists about the functioning of the heart?**

  ![ATP levels and heart function]

- **What are potential applications of this research? How can this type of test help patients?**
  Can tell how well heart is functioning (heart health) in cardiac patients.
Conclusion Questions

1. Based on what you learned in PBS, what are three foods that would be considered good energy sources?
   Explain your choices.
   
   Pasta, Bread, Crackers, etc...
   Anything heavy in carbohydrates has lots of glucose that can be converted to ATP for energy.

2. Name three specific body processes that require energy in the form of ATP.
   
   - Digestion
   - Beating Heart
   - Thinking

3. You hear someone mention the molecule "AMP." Based on what you learned about the structure of ATP and the way in which energy is released, what do you think AMP stands for and how do you think it would be created?
   
   AMP may be produced during ATP synthesis by the enzyme adenylate kinase by combining 2 ADP molecules.
   
   \[ 2\text{ADP} \rightarrow \text{ATP} + \text{AMP} \]
   
   Adenosine monophosphate

4. Explain how the recycling of ATP helped save Mauro Prosperi. Why is the ability to recycle this molecule an advantage?
   
   The parts of ATP are recycled so when Mauro got little bits of nutrients from the bats, lizards and snakes he ate it served as energy to reassemble ATP from ADP and P. ATP does not have to be created from scratch so it is easily produced from glucose. This helped Mauro because even though his food was scarce the little he found was enough to keep ATP being made and keep him alive.

5. Based on what you have read in this activity, explain the role food, water and oxygen play in the creation of ATP or the release of energy from this molecule.
   
   Food gives glucose, which is a non-usable form of energy and must be converted to ATP which can be used. O2 is required for aerobic cellular respiration and we get this by breathing. Water is needed when ATP is used for energy. It is used in the hydrolysis reaction that breaks off a P, releasing energy.