Name _______________________________ Date _______________________________

Cell Energy

18

Is energy free to slosh around inside living cells? The answer is *no*. Energy exists in the form of chemical energy. This chemical energy is part of a compound called adenosine triphosphate (ATP). ATP releases chemical energy for biological work in all living cells. However, it is changed to a new chemical compound called adenosine diphosphate (ADP) when energy is released. A change from ATP to ADP releases energy and uses up the original ATP. Does the cell have an endless supply of ATP? No, but ADP can change back to ATP. However, this requires energy. How is the cell able to solve its energy "budget" if it gives off energy during one change and then requires energy to change back to the original ATP?

In this investigation, it is expected that you:

(a) use paper model molecules to construct a molecule of adenosine triphosphate (ATP) and adenosine diphosphate (ADP)
(b) determine similarities and differences between an ATP and an ADP molecule
(c) discover how ATP releases energy when changed to ADP
(d) discover how glycolysis supplies energy for the changing of ADP back to ATP

Materials

scissors

Procedure

Part A. The Chemical Structure of Adenosine Triphosphate

ATP is made up of smaller molecules or subunits: ribose, adenine, and phosphoric acid.

Ribose Molecule

• Examine the structural formula and model of ribose on page 85. (These models do not represent the actual molecular shape of the molecules.)

1. What is the molecular formula of ribose? (Fill in the appropriate subscripts.) C H O

2. What is the ratio of hydrogen atoms to oxygen atoms in ribose? _______________

3. Glucose is a six-carbon monosaccharide or carbohydrate. Ribose is also a carbohydrate but differs from glucose in having how many carbon atoms? _______________

Adenine Molecule

• Examine the structural formula and model of adenine on page 85.

4. What is the molecular formula of adenine? (Fill in the appropriate subscripts.) C H N

5. What element in adenine is not in carbohydrates? ______________________

What element in carbohydrates is not in adenine? ______________________

6. What elements are found in both adenine and amino acids? ______________________

Phosphoric Acid

• Examine the structural formula and model of phosphoric acid on page 85.

7. Write the molecular formula of phosphoric acid. (Fill in the appropriate subscripts.)
H P O

Constructing an ATP Molecule

An ATP molecule is made up of one ribose molecule, one adenine molecule, and three phosphoric acid molecules joined together.

8. What does the prefix *tri-* mean in the name of the compound? ______________________

9. Adenosine is probably a word combination of what two molecule names? ______________________

• Cut out the models of adenine, ribose, and phosphoric acid from page 85. You may want to paste the page on lightweight cardboard before cutting out the models. *Cut along solid lines only.*

• Attempt to join the adenine and ribose molecules.

10. What parts must be lost from each molecule in order to join the molecules? ______________________

____

• Remove these parts. The adenine and ribose molecules can now be chemically joined together. New points of attachment or chemical bonds are formed.

11. What molecule is formed from the parts that are removed? ______________________

• Examine the phosphoric acid models.

12. Are all three molecules exactly alike? ______

13. Only one of the three can attach to the ribose molecule. What elements must be removed in order for the phosphoric acid to join with ribose?

____

• Attach this phosphoric acid molecule to ribose. This bond is called a low-energy bond.

• Attach the remaining phosphoric acid molecules to each other and then to the phosphoric acid already attached to ribose.

14. How many molecules of water are formed when a single ATP molecule is formed?

____

• Note the size of the two new bonds between phosphoric acid molecules. These are called high-energy bonds. The available chemical energy for all work is in the high-energy bonds of ATP molecules.

Part B. Gaining Energy from ATP as It Changes to ADP

High-energy bonds of ATP give up chemical energy for biological work when ADP is formed. Let us see how energy is made available as ATP changes to ADP.

• Remove one phosphoric acid molecule from the end of your ATP model.

15. Which bond type is broken in the process, low- or high-energy? ______________________

16. *The energy of this bond is now available energy for biological work.* How many phosphoric acid molecules are still attached to the original molecule? ______________________

17. This new compound with one fewer phosphoric acid molecule than before is called adenosine diphosphate (ADP). What does the prefix *di-* mean? ______________________

18. Answer the following questions comparing ATP to ADP:

(a) How many molecules of phosphoric acid does each compound have? ______________________

____

(b) How many adenine molecules does each compound have? ____________

(c) How many high-energy phosphate bonds does each have? ____________

____

(d) Which compound has more stored energy?

____

(e) Which compound results when energy is given off due to the breaking of one bond in ATP? ____________

Part C. Changing ADP to ATP

The amount of ATP in a cell is limited. However, the amount of energy needed by a cell is almost unlimited. The cell conserves its ATP by producing more from ADP. This appears to be simple: just attach a phosphoric acid molecule to an ADP and ATP results. However, energy is required to attach a phosphoric acid molecule to ADP. The source of this energy is *not* ATP.

- Construct an ADP molecule.

- Attach a phosphoric acid molecule to the ADP model. If necessary, remove any H or OH ends to provide the point of attachment. This forms an ATP molecule.

Part D. An Energy Source for Converting ADP to ATP

Where does the energy to form ATP come from? It could come from ATP, but soon no available energy would be left over. This is not an efficient system in terms of budgeting energy for living systems.

Another energy source is found in living things. This energy source is the food that consumers take in and producers manufacture. Energy is produced from food during chemical respiration.

Energy is "stored" in the chemical bonds of all compounds. Food such as glucose contains many of these bonds. Glucose is the major source of energy for ATP formation.

- Draw the structural formula of glucose. (See Investigation 6, if necessary.)

19. How many chemical bonds are there in glucose? ____________

Glycolysis is the name of the process for changing a glucose molecule into two smaller molecules called pyruvic acid. As this occurs, bonds in the glucose molecule are broken.

- Examine the structural formula of pyruvic acid (Figure 18–1).

20. How many chemical bonds are there in one molecule of pyruvic acid? ____________

21. The chemical change occurring during glycolysis can be represented by the equation:

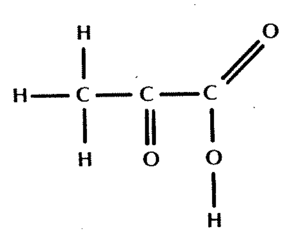
Glucose $\longrightarrow$ Pyruvic acid + Pyruvic acid

______ ______ ______

Write the number of chemical bonds below each chemical compound.

22. Does the total number of bonds in glucose equal the total number of bonds in both pyruvic acid molecules? ____________

23. Write the molecular formula of one molecule of pyruvic acid. (Fill in the appropriate subscripts.) C H O



pyruvic acid

Figure 18-1

24. How many atoms of carbon, hydrogen, and oxygen are in two molecules of pyruvic acid?

____

• Record in Table 18–1 the total number of atoms of each of the elements in glucose and the number in two molecules of pyruvic acid.

The breaking of chemical bonds and loss of elements result in the production of energy from the bonds of glucose. *This energy can be used to convert ADP to ATP.* A more complete equation for glycolysis would include the energy made available and the element left over from the glucose molecule:

$$\text{Glucose} \rightarrow \text{Pyruvic acid} + \text{Pyruvic acid} + \text{Energy} + 4\,H$$

Table 18–1. Comparison of Glucose and Pyruvic Acid

	Glucose	Two pyruvic acids
Carbon		
Hydrogen		
Oxygen		

Analysis

1. List the name and number of each molecule forming ATP. ______________________________

____

2. List the name and number of each molecule forming ADP. ______________________________

____

3. How do ADP and ATP differ in

   (a) number of phosphate molecules ______________________________

   (b) number of ribose molecules ______________________________

   (c) number of adenine molecules ______________________________

   (d) number of high-energy phosphate bonds ______________________________

4. Describe how energy results as ATP is converted to ADP. ______________________________

____

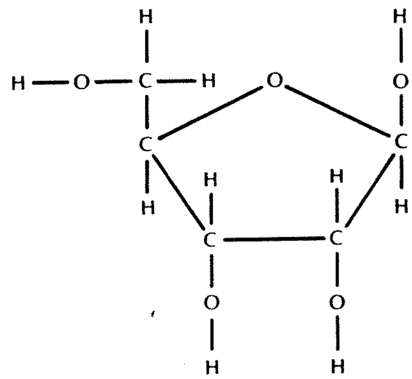
5. Where is the energy obtained to convert ADP to ATP? ______________________________

____

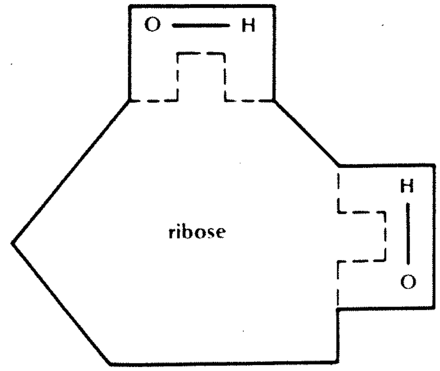
6. How does the cell use the energy obtained from glycolysis? ______________________________

____

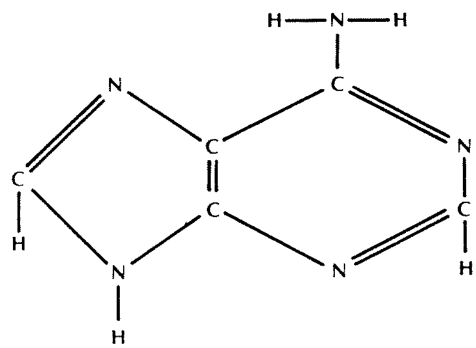
structural formula of ribose



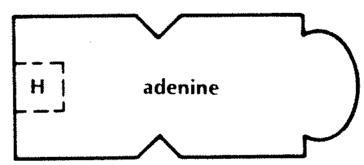
model of ribose



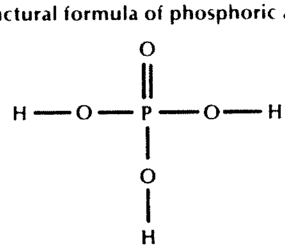
structural formula of adenine



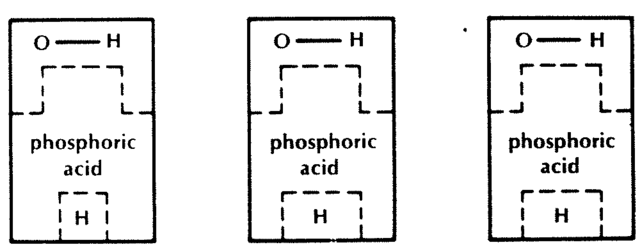
model of adenine



structural formula of phosphoric acid



model of phosphoric acid



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