The Working Cell

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You can read these words because enzymes and membranes enable your cells to use energy. The light energy that bounces off the page enters your eyes and stimulates pigments held in special cell membranes. Enzymes make these pigments and convert them to a form that can absorb light. The eye cells can transmit signals through nerve cells to the brain because the membranes of these cells can selectively absorb and pump out charged particles. The energy for moving these particles comes from processes that make ATP. These processes take place through the action of enzymes on and between cell membranes. Every biological activity—not just reading, but walking, laughing, and thinking—depends on energy produced by processes that involve enzymes and membranes. Energy, enzymes, and membranes are the subjects discussed in this chapter.

Organizing Your Knowledge

Exercise 1 (Modules 5.1 – 5.5)

5A–B *See some chemical reactions and how enzymes can speed them up by looking at Activities 5A and 5B on the Interactive Study Partner CD-ROM.*

After reading Modules 5.1 – 5.5, review energy, chemical reactions, and the function of enzymes by filling in the blanks in the following story.

If you were to stop eating, you would probably starve to death in weeks or months. If you were unable to breathe, you would die in minutes. Organisms need the energy that is released when food and oxygen combine. This energy is used not only to move the body but also to keep it from falling apart.

Energy is the ability to perform [1] __Work__. The sun is the source of the energy that sustains living things. Sunlight is pure [2] __Kinetic__ energy, energy of movement that is actually doing work. In the process of photosynthesis, plants are able to use the energy of sunlight to produce food molecules. This process obeys the laws of [3] __Thermodynamics__, the principles that govern energy transformations. Plants do not make the energy in food. According to the [4] __First__ law of thermodynamics, energy can be [5] __Created__ or transferred, but it cannot be created or destroyed. In photosynthesis, no energy is created. Rather, the plant transforms the energy of sunlight into stored energy, called [6] __Potential__ energy, stored in molecules of glucose.

No energy change is 100% efficient, and the changes that occur in photosynthesis are no exception to this rule. Some of the energy of sunlight is not stored in glucose, but rather is converted to [7] __heat__, which is random molecular motion. The [8] __Second__ law of thermodynamics says that energy changes are always accompanied by an increase in [9] __Entropy__, a measure of disorder. One of the reasons living things need a constant supply of energy is to counter this natural tendency toward disorder.

The products of photosynthesis contain [10] __More__ potential energy than the reactants. This means that, overall, photosynthesis is an [11] __endergonic__ reaction. Such a reaction consumes energy, which in photosynthesis is supplied by the sun.

Photosynthesis produces food molecules, such as glucose, which store energy. An animal might obtain this food by eating a plant or an animal that has eaten a plant. The food molecules enter the animal's cells, where their potential energy is released in the process of cellular respiration. The products of this chemical reaction (actually a series of reactions) contain less potential energy than the reactants. Therefore, cellular respiration is an [12] __exergonic__ process; it [13] __releases__ energy. In fact, this is the same overall change that occurs when glucose in a piece of wood or paper burns in air. When paper burns, the energy escapes as the heat and light of the flames. In a cell, the reaction occurs in a more controlled way, and some of the energy is captured for use by the cell.

Energy released by the exergonic "burning" of glucose in cellular respiration is used to make a substance called [14] __ATP__. A molecule of [15] __ADP__ and a [16] __phosphate__ group are joined to form each molecule of ATP. This is an endergonic reaction, because it takes energy to assemble ATP. The covalent bond connecting the phosphate group to the rest of the ATP molecule is unstable and easily broken. This arrangement of atoms stores [17] __Potential__ energy. The [18] __hydrolysis__ of ATP is an exergonic reaction. When ATP undergoes hydrolysis, a [19] __Phosphate__ is removed, ATP becomes [20] __ADP__, and energy is released. Thus, ATP is a kind of energy "currency" that can be used to perform cellular [21] __Work__. Most cellular activities depend on ATP energizing other molecules by transferring its phosphate group to them—a process called [22] __phosphorylation__. It should be noted that energy is not destroyed when ATP is used to do work. When an ATP molecule is hydrolyzed to make muscles move, some of its energy moves the body, and some ends up as random molecular motion, or [23] __heat__.

A less obvious but important function of ATP is supplying the energy for fighting the natural tendency for a system to become disordered. A cell constantly needs to manufacture molecules to replace ones that are used up or damaged. Building a large molecule from smaller parts is an [24] __endergonic__ reaction. Energy released by the exergonic hydrolysis of ATP is used to drive essential endergonic reactions. The linking of exergonic and endergonic processes is called energy [25] __Coupling__, and ATP is the critical connection between the processes that release energy and those that consume it.

What prevents a molecule of ATP from breaking down until its energy is needed? Molecules can break down spontaneously; that is why ATP energy is needed to repair them. Fortunately for living things, it takes some additional energy, called energy of [26] ________, to get a chemical reaction started. This creates an energy [27] ________________ that prevents molecules from breaking down spontaneously. Energy barriers exist for both exergonic and endergonic reactions. Most of the time, most molecules in a cell lack the extra energy needed to clear the barrier, so chemical reactions occur slowly, if at all.

So what enables the vital reactions of metabolism to occur when and where they are needed, at a rate sufficient to sustain life? This is where enzymes come in. An enzyme is a special [28] ________________ molecule that acts as a biological [29] ________________. It [30] ________________ the rate of a chemical reaction without being [31] ________________ by it. An enzyme holds reactants in such a way as to [32] ________________ the energy barrier that prevents them from reacting. Even though reactants would not normally possess the

How Cells Harvest Chemical Energy

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You need to eat and breathe because your cells need food and oxygen for energy. In every cell in your body, organic molecules and oxygen interact in a complex process called cellular respiration. In this process, food molecules such as glucose are broken down and the energy contained in their chemical bonds is used to make ATP. The ATP made in cellular respiration is then used to drive cellular activities. Right now, ATP produced in cellular respiration is being used to generate the nerve impulses from your eyes to your brain, to move your muscles, and to drive your heartbeat. This chapter explains how your cells harvest the energy that keeps you alive.

Organizing Your Knowledge

Exercise 1 (Introduction – Module 6.3)

Review the basic terms and concepts of cellular respiration by filling in the blanks below.

Right now, you are breathing at a steady rate of 12 to 20 breaths per minute. Breathing, or 1 ______________, is necessary for life, but why? Breathing allows the body to take in 2 ______________ gas and expel waste 3 ______________. Your breathing is closely related to 4 ______________, the aerobic harvest of the energy in food molecules by cells. Your cells take in 5 ______________ and 6 ______________ from the blood. These two substances interact, the sugar is broken apart, and 7 ______________ and 8 ______________ are produced. In the process, some of the energy is stored in molecules of 9 ______________, which provide the energy for body activities. To make enough ATP for their needs, average human beings must take in food that provides about 10 ______________ kilocalories (kcal) of energy per day.

You require an 11 ______________ (oxygen-containing) environment to make enough ATP to supply your body's needs. During most day-to-day activities, including 12 ______________ exercise, the blood can deliver O_2 to the muscles as fast as they consume it. But if you exercise vigorously, muscle cells use up their oxygen and become 13 ______________. They can continue to produce some ATP under these conditions for a while, but much less efficiently. The cells also produce 14 ______________, a toxic waste product, which makes muscles 15 ______________ and 16 ______________.

Some organisms, such as the 17 ______________ described in the introduction to this chapter, can live in both aerobic and anaerobic environments. When first added to bread dough or a wine vat, yeast cells are in an 18 ______________ environment. They consume 19 ______________ and 20 ______________. The 21 ______________ they produce causes the dough to rise. In a sealed wine vat, oxygen is quickly used up, and the yeasts then must live under 22 ______________ conditions. They still consume 23 ______________, but under anaerobic conditions they produce 24 ______________ and 25 ______________ as waste products.