Phosphorylation, the addition of a phosphate to a molecule, requires a large amount of energy and results in a high-energy bond. Phosphate groups are negatively charged and therefore repel one another when they are arranged in series, as is the case with ADP and ATP. This repulsion makes the ADP and ATP molecules inherently unstable. Energy is released when ATP is hydrolyzed. The release of energy can be used to power active transport and other cellular processes (Figure 5.33).

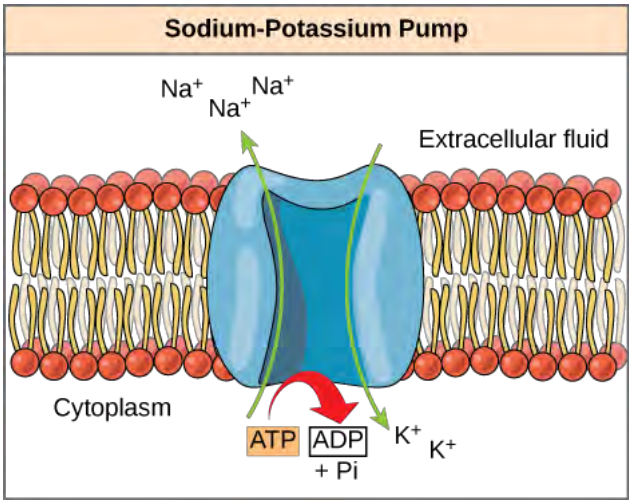

Figure 5.33 The energy derived from exergonic ATP hydrolysis pumps sodium and potassium ions across the cell membrane. (credit: Clark et al. / Biology 2E OpenStax)

How exactly does the energy released by ATP perform work inside the cell? This depends on a strategy referred to as **energy coupling**. Cells couple exergonic processes that release energy with those endergonic processes that require energy. In Figure 5.34, this sodium-potassium pump drives sodium out of the cell and potassium into the cell against its concentration gradient. For the pump to work, it requires energy in the form of ATP. When ATP hydrolyzes, its phosphate does not simply float away but is transferred onto the pump protein. When a phosphate group is attached, the Na^+/K^+ pump has more free energy and undergoes a conformational change. This change allows it to release Na^+ outside the cell. The pump then binds extracellular K^+, which, through another conformational change, causes the phosphate to detach from the pump. The detachment of the phosphate group triggers the K^+ to be released into the cell. Essentially, the energy released from ATP is coupled with the energy required to power the pump. ATP performs cellular work using energy coupling through phosphorylation.

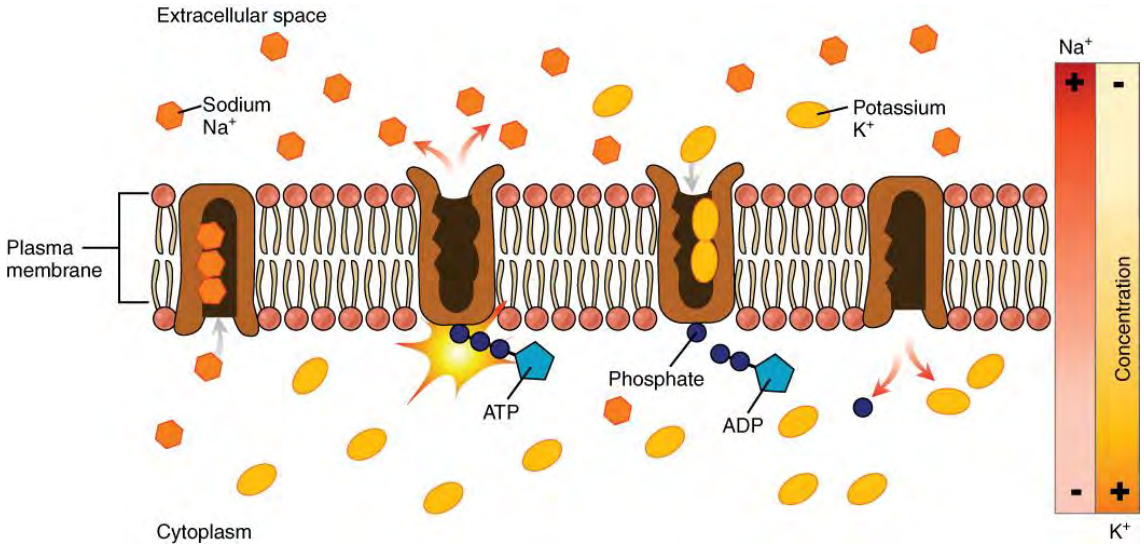

Figure 5.34 The sodium-potassium pump, which is powered by ATP, is found in many cell (plasma) membranes. (credit: Betts et al. / Anatomy and Physiology OpenStax)

Section Summary

Energy comes in many different forms. Kinetic energy is the energy of objects in motion. Objects that are not in motion may have the potential to do work, and thus, have potential energy. Molecules have potential energy because breaking molecular bonds has the potential to release energy. Living cells depend on harvesting potential energy from molecular bonds to perform work. Free energy is a measure of energy that is available to do work.

A reaction that releases energy is called an exergonic reaction. One that requires an input of energy is an endergonic reaction. Endergonic reactions' products have a higher energy state than the reactants.

ATP is the primary energy-supplying molecule for living cells. The bonds that connect the phosphates have high-energy content. The energy released from ATP hydrolysis into ADP + P_i performs cellular work.

Exercises

1. Your cells are producing proteins during translation. Is this an exergonic or endergonic reaction?
2. Which of the following is not an example of an energy transformation?
    a. Heating dinner in a microwave
    b. Solar panels at work
    c. Turning on a light switch
    d. All the above are examples of energy transformations
3. Which of the following is not true about ATP?
    a. It is the primary energy currency of all living cells.
    b. The phosphate-phosphate bonds represent large amounts of kinetic energy
    c. Phosphate-phosphate bonds repel one another and make the molecule unstable
    d. ATP has three phosphate groups
4. Think about a pendulum swinging. Which type of energy (kinetic or potential) is associated with the pendulum in the following instances:
    a. the pendulum is in motion between its highest and lowest positions
    b. the moment that the pendulum is in its most elevated position but is not moving

Answers

1. Endergonic
2. (d)
3. (b)
4. a. kinetic b. potential

Glossary

ATP: adenosine triphosphate; the cell's energy currency

chemical energy: type of potential energy that exists within chemical bonds

endergonic: describes a chemical reaction that results in products that store more chemical potential energy than the reactants

energy: the ability to do work

energy coupling: energy released from exergonic processes is used to support or transferred to endergonic processes

exergonic: describes a chemical reaction that results in products with less chemical potential energy than the reactants, plus the release of free energy

free energy: usable energy or energy that is available to do work

kinetic energy: the type of energy associated with objects in motion

phosphorylation: the addition of a phosphate to a molecule

potential energy: the type of energy that refers to the potential to do work