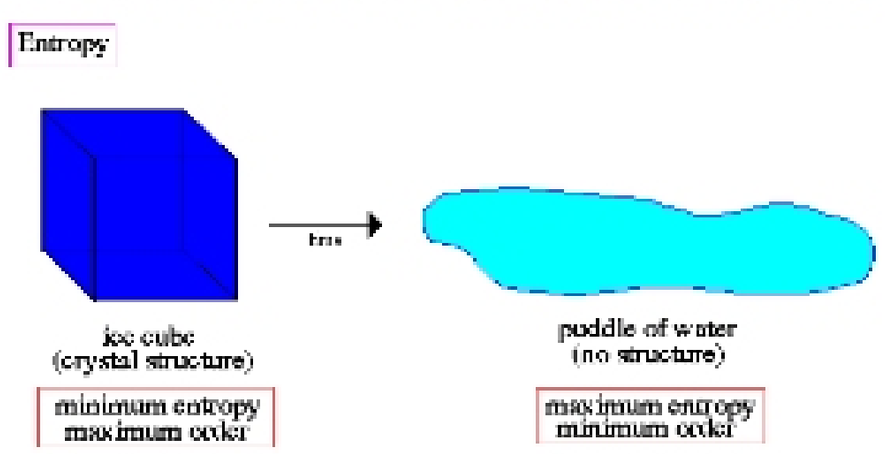
Chapter 6:

Energy Flow In the Life of a Cell

6.1 What Is Energy?

- **Energy** is the *capacity* to do work
- **Work** is a force acting on an object that causes the object to move
- **Chemical energy** is the energy that is contained in molecules and released by chemical reactions
    - Contained within sugar, glycogen, and fat
    - Cells use ATP to accept and transfer energy from one chemical reaction to the next
- 2 types of energy:
    1. **Potential energy** is **stored** energy
        - Ex.) Chemical energy in bonds, electrical charge in a battery, rock at top of a hill
    2. **Kinetic energy** is the energy of **movement**
        - Ex.) Light, heat, electricity, and the movement of objects
- The **laws of thermodynamics** describe the **quantity** (total amount) and the **quality** (usefulness) of energy
    - **The first law of thermodynamics** AKA **Law of conservation of energy**: energy can neither be created nor destroyed, but can change form
    - Total amount of energy within a **closed system** remains constant unless energy is added or removed
    - **Second law of thermodynamics**: the amount of useful energy decreases when energy is converted from one form to another
        - **Entropy** is a measure of **disorder**, or more precisely unpredictability
        - Systems move towards maximum entropy
        - Our ecosystem is becoming more random, more entropy

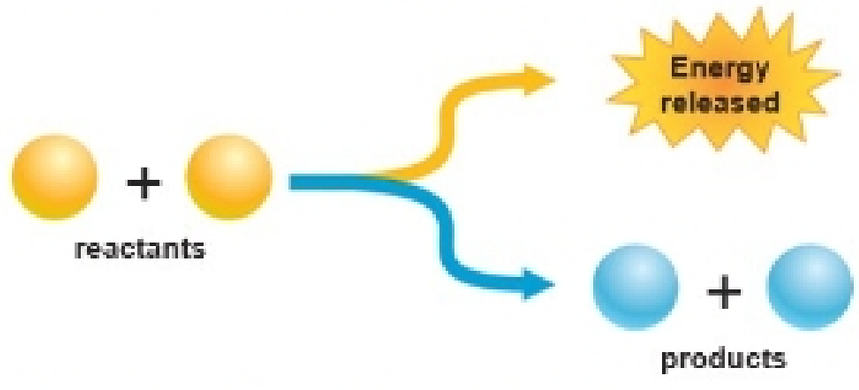


- **Energy Conversions Result in a Loss of Useful Energy**
    - When gasoline is burned, the orderly arrangement of 8 carbons bound together in a gasoline molecule are converted to 8 randomly moving molecules of carbon dioxide.

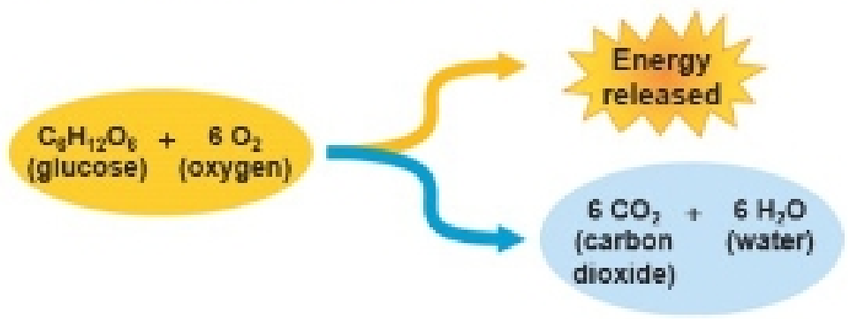
6.2 How Does Energy Flow In Chemical Reactions?

- A **chemical reaction** is a process that forms or breaks chemical bonds holding atoms together
    - Chemical reactions convert **reactants into products**
    - All chemical reactions require a **small input** of energy
    - "You have to give a little to get a little bit of energy"
    - **Exergonic** reactions **release** energy **(ATP → ADP+P)**

- Occur spontaneously
- Reactants contain **more** energy than products

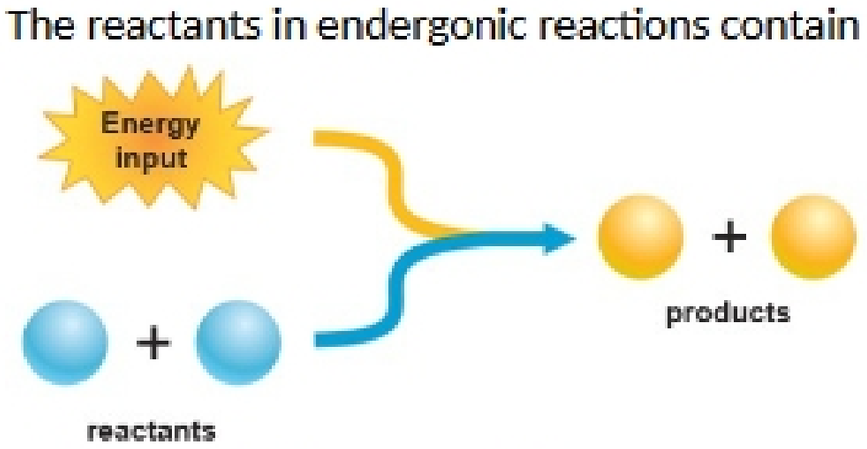


- Ex) The burning of glucose $C_6H_{12}O_6$
  - Overall: sugar combines with oxygen to produce carbon dioxide and water, **releasing** energy
  - Why? The molecules of sugar contain more energy than the molecules of carbon dioxide and water, the reaction releases energy

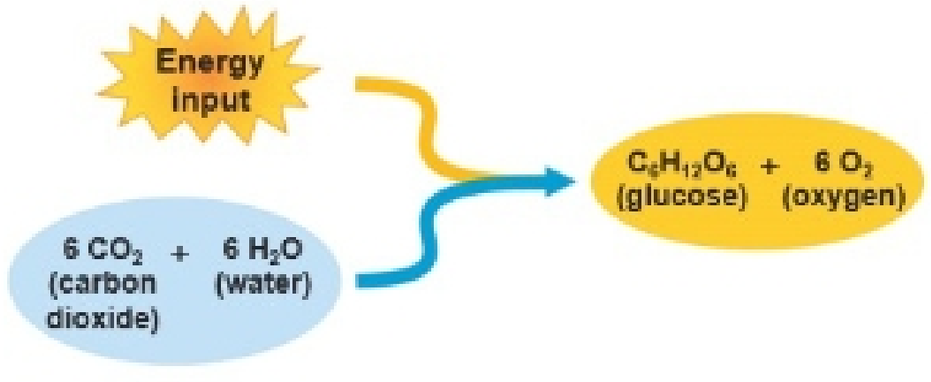


- **All chemical reactions** require an initial energy input (**activation energy**) to get started. The speed of a reaction is determined mostly by its activation energy
- The negatively charged electron shells of atoms **repel** one another and inhibit bond formation
- Molecules need to be moving fast to overcome electronic repulsion and react
- **Increasing the temperature increases kinetic energy** and, thus, the rate of reaction

- **Endergonic** reactions require a net **input** of energy **(ADP+P → ATP)**
  - The reactants in endergonic reactions contain **less** energy than the products



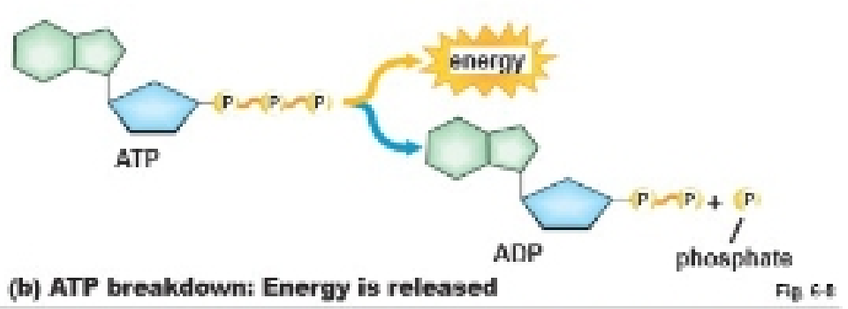
- Ex) Process of photosynthesis
  - Plants add the energy of sunlight to the lower-energy reactants water and carbon dioxide to produce the higher-energy product sugar



6.3 How Is Energy Transported Within Cells?

- Most organisms powered by **breakdown of glucose**
- Energy in glucose cannot be used directly to fuel endergonic reactions
- Energy **released** by glucose breakdown is 1st transferred to an **energy-carrier molecule**
    - High-energy, unstable molecules
    - Present at the site of an **exergonic reaction**
    - **Capture** some of the **released energy** from a reaction
    - **Transfer** energy **to** an **endergonic** reaction elsewhere in a cell
- **ATP** is the **principal energy carrier in cells**
    - **ATP synthesis**: Energy is stored in ATP
    - **ATP breakdown**: Energy is released
    - **Energy** is **stored** in **the high-energy phosphate bonds of ATP**
        - ATP is well suited to its role as an energy-carrier molecule in cells because the covalent bond between that last 2 phosphates can be broken to release substantial amounts of energy
    - The **formation of ATP** is an **endergonic** reaction
    - At sites in the cell where energy is needed, ATP is broken down into ADP + P and its stored energy is released
    - Unlike glycogen and fat, **ATP stores energy very briefly** before being broken down

(a) ATP synthesis: Energy is stored in ATP



(b) ATP breakdown: Energy is released Fig. 6-8

- **Electron carriers also transport energy** within cells
    - ATP is not the only energy-carrier molecule in cells
    - Energy can be transferred to electrons in **glucose metabolism** and **photosynthesis**
    - **Electron carrier molecules** such as **NAD** and **FAD** transport high-energy electrons
    - Electron carriers **donate** their high-energy electrons to other molecules, often leading to ATP synthesis
- Coupled reactions link exergonic with endergonic reactions