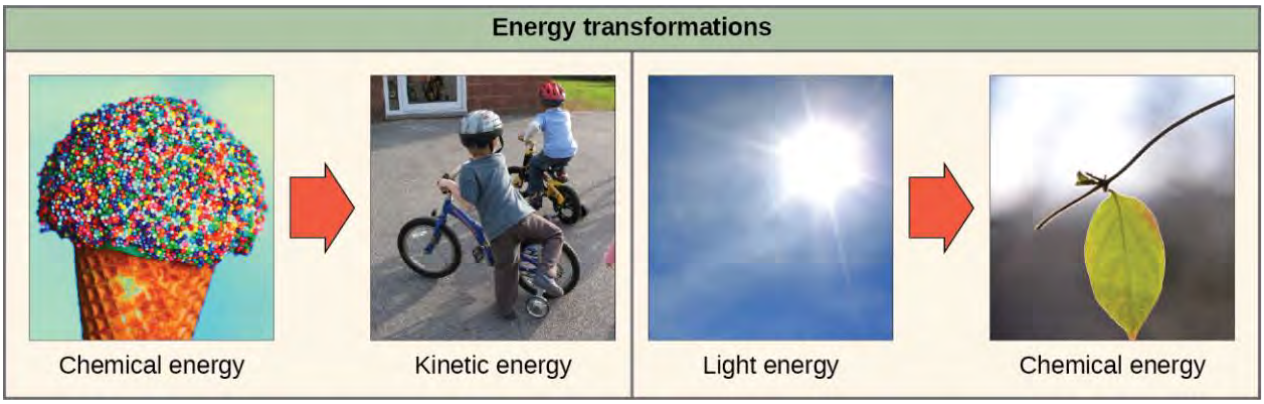


Figure 5.23 Here are two examples of energy transferring from one system to another and transformed from one form to another. (credit: "ice cream": modification of work by D. Sharon Pruitt; credit "kids on bikes": modification of work by Michelle Riggen-Ransom; credit "leaf": modification of work by Cory Zanker / Biology 2E OpenStax)

It may seem easy for living cells to obtain, transform, and use energy to do work; however, this is not the case. Energy transfers and transformations are never completely efficient. In every energy transfer, some amount of energy is lost in an unusable form. In most cases, energy is lost in the form of heat.

**Heat energy** is defined as the energy transferred from one object to another that is not being used for work. For example, when a light bulb is turned on, some of the energy being converted from electrical energy into light energy is lost as heat energy. Likewise, when an airplane flies, it loses some of its energy as heat due to friction with the surrounding air. During metabolic reactions, such as cellular respiration, some energy is also lost in the form of heat energy. Heat energy is good for warm-blooded organisms like us because it helps us maintain our body temperature.

The more energy that is lost, the less ordered and more random the system is. Scientists refer to the measure of randomness or disorder as **entropy**. The **second law of thermodynamics** states that every energy transfer or transformation increases the universe's entropy.

High entropy means high disorder and low energy (Figure 5.24). To better understand entropy, think of a student's bedroom. If no energy or work were put into it, the room would quickly become messy. It would exist in a very disordered state, one of high entropy. Energy must be put into the system, in the form of the student doing work, to bring the room back to a state of cleanliness and order. This state of cleanliness and order is one of low entropy.

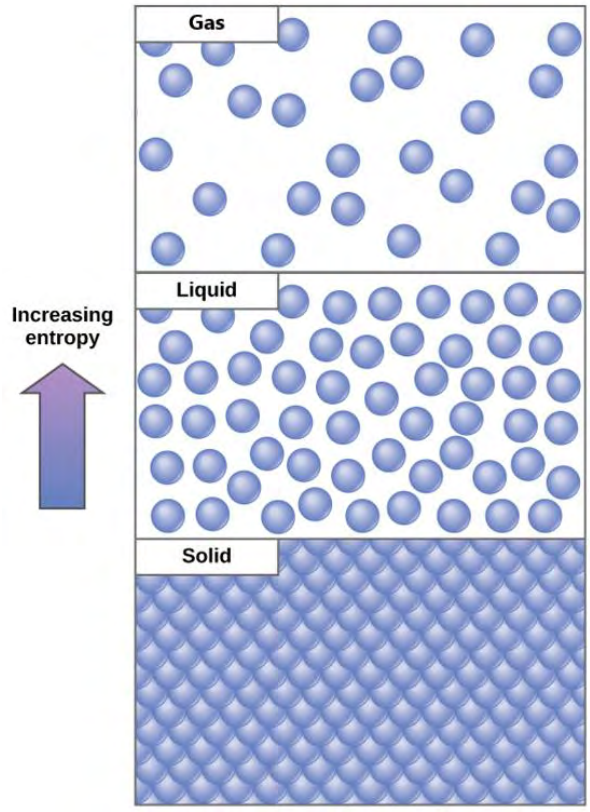


Figure 5.24 Entropy is a measure of randomness or disorder in a system. Gases have higher entropy than liquids, and liquids have higher entropy than solids. (credit: Modified by Jason Cashmore original work by Clark et al. / Biology 2E OpenStax)

Molecules also have varying amounts of entropy. For example, when molecules diffuse from an area of high concentration to an area of low concentration, entropy increases. A concentrated drop of food coloring has low entropy. As the food coloring molecules begin to slowly diffuse in a glass of water, the entropy increases (Figure 5.25).

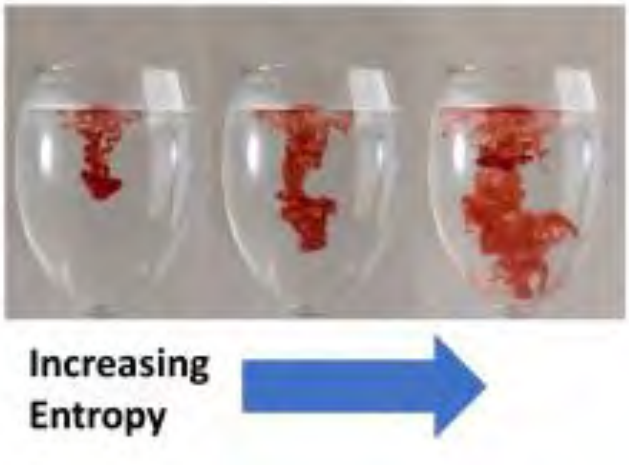


Figure 5.25 Entropy increases as molecules diffuse. (credit: Modified by Elizabeth O'Grady original work of Robby Remedi)

Living organisms are highly ordered. Organisms require a constant input of energy to maintain this state of low entropy. As living organisms take in energy and transform it through chemical reactions, some amount of usable energy is lost in the process. No chemical reaction is entirely efficient.

## Section Summary

The laws of thermodynamics are a series of laws that describe the properties and processes of energy transfer. The first law states that the total amount of energy in the universe is constant. This means that energy cannot be created or destroyed, only transferred or transformed. The second law of thermodynamics states that every energy transfer involves some loss of energy in an unusable form, such as heat energy. This results in a more disordered system. No energy transfer is completely efficient, and all transfers trend toward disorder.

## Exercises

1. High entropy means:
    a. high disorder and low energy
    b. high disorder and high energy
    c. low disorder and low energy
    d. low disorder and high energy
2. Thermodynamics refers to the study of:
    a. light
    b. sound
    c. energy
    d. equilibrium
3. Explain the second law of thermodynamics.

### Answers

1. (a)
2. (c)
3. All energy transfers and transformations are never completely efficient. In every energy transfer, some amount of energy is lost in an unusable form.

## Glossary

**energy:** the ability to do work or to create a change in matter

**entropy:** the measure of randomness or disorder within a system

**first law of thermodynamics:** states that the total amount of energy in the universe is constant and conserved

**heat energy:** the energy transferred from one system to another that is not work

**second law of thermodynamics:** states that every energy transfer or transformation increases the universe's entropy

**thermodynamics:** the science of the relationships between heat, energy, and work