10.1 The Need for a Respiratory System

Without being aware of it, you take between 17 000 and 29 000 breaths every day, depending on your age and level of physical activity. That means you take about 500 million to 750 million breaths over the course of your life! You can stop breathing briefly, but it automatically resumes, regardless of how hard you try. Breathing is so important to us that it cannot be left to conscious control.

The air we breathe is a mixture of different gases: 78 % nitrogen, 21 % oxygen, 1 % argon, 0.04 % carbon dioxide, and lesser amounts of other gases. It is the oxygen in the air that we need. Without it, we can survive for only a few minutes.

Aerobic Cellular Respiration: The Need for Oxygen

aerobic cellular respiration the series of chemical reactions that occur in the cell that provide energy and consume oxygen

All animal and plant cells need oxygen to survive. These cells use oxygen to obtain energy from food. The process in which oxygen is used to obtain energy from food is called **aerobic cellular respiration**. Energy is released in a cell when glucose (a sugar molecule) reacts with oxygen to form carbon dioxide and water. The basic equation for aerobic cellular respiration is as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

(glucose + oxygen → carbon dioxide + water + energy)

About 64 % of the energy released during cellular respiration is released as thermal energy. This thermal energy helps birds and mammals maintain a constant body temperature. The rest of the energy, about 36 %, is stored in molecules called adenosine triphosphate (ATP). ATP is formed when energy from the breakdown of glucose is used to attach a phosphate group (P_i) onto a molecule called adenosine diphosphate (ADP). The process that forms ATP from ADP, phosphate, and energy is called **phosphorylation** (**Figure 1**). For each molecule of glucose that undergoes cellular respiration, 36 molecules of ATP are formed.

phosphorylation the addition of a phosphate group to a molecule; in aerobic cellular respiration the phosphate group is added to ADP, creating the ATP molecule in which energy is stored

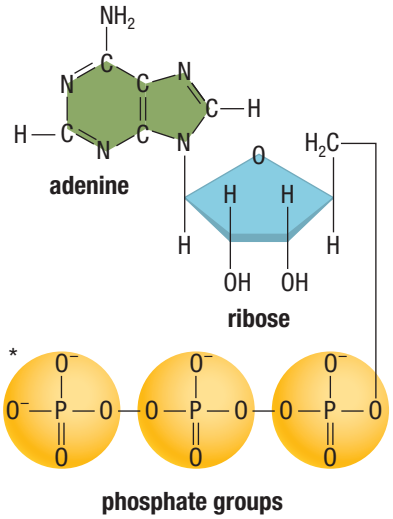

Figure 1 The ATP molecule is formed by adding a third* phosphate group to an ADP molecule.

Cells use ATP to power almost all of their energy-requiring processes, such as growth, movement, and building new molecules. Energy for these cellular processes is obtained when ATP reacts with other molecules, reforming ADP and the phosphate group. The released energy is then able to do work. The ADP and phosphate are continuously recycled and recharged with energy to form ATP molecules.

The following expanded formula for cellular respiration shows the storage of energy by the conversion of ADP to ATP and the release of some of the energy as thermal energy:

$$C_6H_{12}O_6 + 6O_2 + 36\ ADP + 36\ P_i \rightarrow 6CO_2 + 6H_2O + 36\ ATP + \text{thermal energy}$$

(glucose + oxygen + adenosine diphosphate + phosphate →
carbon dioxide + water + adenosine triphosphate + thermal energy)

The carbon dioxide and most of the water produced during cellular respiration are released to the environment as waste products.

Gas Exchange and Ventilation

gas exchange the processes whereby the body cells obtain oxygen and get rid of carbon dioxide

You have learned how oxygen is required to obtain energy from food in the process of aerobic cellular respiration. How is oxygen supplied to the body cells to make aerobic cellular respiration possible? **Gas exchange** is the process by which oxygen diffuses into the body cells and carbon dioxide diffuses out of the cells.

In simple organisms such as sponges and jellyfish, gas exchange is a simple process. Oxygen diffuses directly from the surrounding environment through the cell membrane into the cells. Carbon dioxide diffuses directly from the cells of these organisms through the cell membrane into the environment.

The process is different for humans, fish, and most other large multicellular animals because they contain many cells in their bodies that do not come in contact with the external environment (the air or water). These organisms have special organ systems that supply oxygen to all cells of the body and remove carbon dioxide.

In humans and other mammals, gas exchange occurs at two locations: the lungs (**Figure 2(b)**) and the body cells (**Figure 2(c)**). In the lungs, oxygen diffuses from the air into the bloodstream. Oxygen is transported through the bloodstream and diffuses into all the cells of the body. The cells of all tissues in the body are surrounded by a fluid called tissue fluid (also known as interstitial fluid). Oxygen diffuses from the blood into the tissue fluid, and from there into the cells. At the same time, carbon dioxide diffuses from the cells into the tissue fluid, then into the bloodstream. Carbon dioxide is transported through the bloodstream to the lungs, where it diffuses into the air. The process of moving oxygen-rich air to the lungs and carbon dioxide–rich air away from the lungs is called **ventilation**, or breathing (**Figure 2(a)**).

ventilation the process in more complex organisms that ensures a flow of oxygen-rich air to the lungs

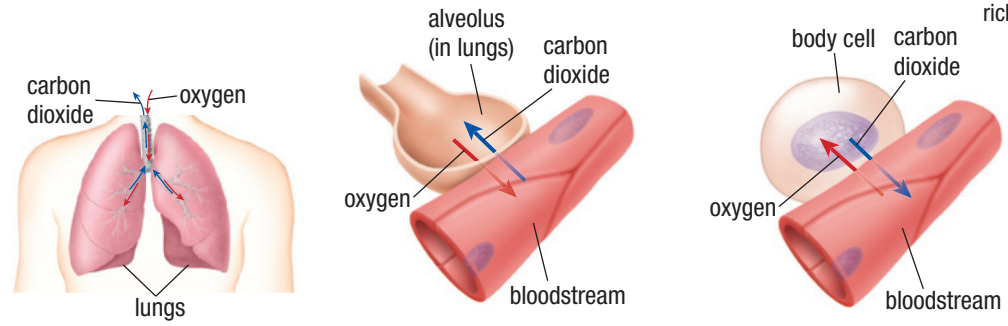

Figure 2 (a) Ventilation brings a supply of air containing oxygen to the lungs. (b) Gas exchange occurs in the lungs, where oxygen diffuses from the air into the bloodstream and carbon dioxide diffuses from the bloodstream into the air. (c) Gas exchange also occurs in the body cells. Oxygen diffuses from the bloodstream into each body cell. Carbon dioxide diffuses from the cells into the bloodstream to be carried back to the lungs for removal.

10.1 Summary

- All plants and animals require oxygen for aerobic cellular respiration.
- Aerobic cellular respiration is a series of chemical reactions that use oxygen to obtain energy from food molecules. The waste products of aerobic cellular respiration are water and carbon dioxide.
- Ventilation brings a continuous supply of air to the lungs.
- Gas exchange by diffusion occurs at two locations: the lungs and the body cells. In the lungs, oxygen diffuses into the bloodstream and carbon dioxide diffuses out of the bloodstream. At each body cell, oxygen diffuses from the bloodstream into the cell and carbon dioxide diffuses from the cell into the bloodstream.

10.1 Questions

1. What happens to the energy that is produced during aerobic cellular respiration? K/U
2. Explain the importance of the ATP molecule. K/U A
3. Phosphorylation is like charging a rechargeable battery. Explain this analogy. K/U T/I A
4. Explain the differences between ventilation and gas exchange. How are these processes related to aerobic cellular respiration? K/U T/I A
5. Use a two-column table to compare gas exchange in a jellyfish with gas exchange in a dog. K/U T/I C