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. Th at means you take about 500 million to 750 million breaths over the course of your life! You can stop breathing briefl y, but it automatically resumes, regardless of how hard you try. Breathing is so important to us that it cannot be left to conscious control.

Th e air we breathe is a mixture of diff erent 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

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

NH2

All animal and plant cells need oxygen to survive. Th ese cells use oxygen to obtain energy from food. Th e 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 mol ecule) reacts with oxygen to form carbon dioxide and water. Th e basic equation for aerobic cellular respiration is as follows:

C6H12O6 1 6O2 S 6CO2 1 6H2O 1 energy

1glucose 1 oxygen S carbon dioxide 1 water 1 energy2

About 64 % of the energy released during cellular respiration is released as thermal energy. Th is thermal energy helps birds and mammals maintain a constant body tem perature. Th e 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 (Pi) onto a molecule called adenosine diphosphate

N

C

C

N

H

(ADP). Th e process that forms ATP from ADP, phosphate, and energy is called phosphorylation (**Figure 1**). For each molecule of glucose that undergoes cellular res C

C C N

HO

N

H H adenine H

piration, 36 molecules of ATP are formed.

H2C

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 phos H

\*

O–

OH OH

ribose

O–

phate group. Th e released energy is then able to do work. Th e ADP and phosphate are continuously recycled and recharged with energy to form ATP molecules. Th e 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

O–

O– P O O

P

O O P

O

thermal energy:

O O

O

phosphate groups

C6H12O6 1 6O2 1 36 ADP 1 36 Pi S 6CO2 1 6H2O 1 36 ATP 1 thermal energy (glucose 1 oxygen 1 adenosine diphosphate 1 phosphate S

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

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

carbon dioxide 1 water 1 adenosine triphosphate 1 thermal energy)

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

Gas Exchange and Ventilation

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 diff uses into the body cells and carbon dioxide diff uses out of the cells.

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

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Th e process is diff erent for humans, fi sh, 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). Th ese 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 diff uses from the air into the bloodstream. Oxygen is transported through the bloodstream and diff uses into all the cells of the body. Th e cells of all tissues in the body are surrounded by a fl uid called tissue fl uid (also known as interstitial fl uid). Oxygen diff uses from the blood into the tissue fl uid, and from there into the cells. At the same time, carbon dioxide diff uses from the cells into the tissue fl uid, then into the bloodstream. Carbon dioxide is trans ported through the bloodstream to the lungs, where it diff uses into the air. Th e 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 fl ow of oxygen

oxygen carbon

alveolus

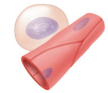
(in lungs) carbon dioxide

body cell carbon dioxide

rich air to the lungs

dioxide 

oxygen

oxygen 

lungs

(a)

bloodstream

(b)

bloodstream

(c)

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

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bloodstream into each body cell. Carbon dioxide diffuses from the cells into the bloodstream to be carried back to the lungs for removal.

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Illustrator

10.1 Summary Joel and Sharon Harris

Illustrator

Joel and Sharon Harris

Illustrator

Joel and Sharon Harris

• 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. Th e waste products of aerobic cellular respiration are water and carbon dioxide.

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• Ventilation brings a continuous supply of air to the lungs.

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• Gas exchange by diff usion occurs at two locations: the lungs and the body cells. In the lungs, oxygen diff uses into the bloodstream and carbon dioxide

mberC10-F04-OB11USB.ai Figure Number

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diff uses out of the bloodstream. At each body cell, oxygen diff uses from the Deborah Wolfe Ltd.

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bloo~~dstream into the cell and carbon dioxide diff us~~es from the cell into Creative

the b~~loodstream.~~

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10.1 ~~Questions~~

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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 jellyfi sh with gas exchange in a dog. k/U T/i C

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