BIOLOGY CONCEPTS

Cellular Respiration

By Harvey D. Goodman, M.A.
Written in association with George Ridgeway

Please read TEACHING STRATEGIES, page 5, before using this program.
Total Running Time: 40 Minutes

Unit 1: 22 Min.
Unit 2: 18 Min.
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ABOUT THE AUTHOR

Harvey D. Goodman received his Master of Arts degree in Science Education from City College of New York and has completed extensive graduate work in curriculum development and advanced sciences. He has been a licensed biology teacher in New York City for over 30 years and has served as Director of Science Fairs for the borough of Queens, New York.

Mr. Goodman has been supervisor and chairperson of Biological and Physical Science Departments at Grover Cleveland High School in Queens for over 12 years and a principal at Catherine and Count Basie Junior High School. In addition, he has served as an assistant to the Superintendent of Schools in Queens as coordinator for Science and Mathematics.

Mr. Goodman wrote the Teacher’s and Student’s Guide for David Attenborough’s The Living Planet, produced on the Public Broadcasting System, and has written a Biology Resource Book that corresponds to the New York State Regents curriculum. Also authored by Mr. Goodman is an Extensive curriculum resource unit, A Guide to Establishing a Science/Mathematics Research Program in High School. Mr. Goodman writes for professional journals on the subjects of Science Fairs, Science Research, and Biology. He is coauthor of a high school biology text published by Harcourt, Brace, Jovanovich.

Mr. Goodman is now serving as Chairman of Biological and Physical Sciences at Newtown High School in Queens, New York.

George Ridgeway has written and produced many educational films and videos. Programs he has written for Educational Activities include Safety is a Full Time Job, Basic Electricity, Careers in the Computer Industry, and You Be the Reporter.
TEACHER INTRODUCTION

Students often confuse the process of breathing with the process of respiration. As a teaching strategy, it is useful to distinguish breathing as a process that enables the organism to come into contact with the gases in the atmosphere that will be involved in the process of respiration. Generally, breathing is a physical process, whereas respiration is a chemical process.

Respiration is the process by which energy is released from organic compounds (food) in a series of controlled steps, gradually being converted into energy that is stored in the ATP molecule.

This program compares anaerobic respiration, respiration occurring in the absence of oxygen, with the much more efficient aerobic respiration occurring in the presence of oxygen.

The process known as glycolysis is outlined, showing the conversion of glucose with the eventual release of 4 ATP molecules. However, in the absence of oxygen, the respiratory process cannot go any further.

In higher animals, a process known as aerobic respiration has evolved. Special cell organelles called mitochondria, contain the enzymes and surface that permits the release of more energy than was possible during the anaerobic phase (glycolysis).

The success of animals and plants in developing organ systems and adapting to their environment is directly related to the ability of their cells to produce the huge quantity of energy they require to carry out their life activities. Some estimates place the energy needs for each cell at 1,000,000,000 molecules of ATP every minute of every day.

For enrichment you may wish to discuss the origin of the mitochondria and the presence of mitochondria DNA which enables it to reproduce within the cell, quite separate from the cell’s mitotic division. Some scientists theorize that the mitochondria once lived outside the cell and gradually became a symbiont...a mutual relationship that now assures the survival of both.

In addition, for those classes capable of handling the chemistry of the Krebs cycle, a discussion of the enzyme interaction, by products formed, and the hydrogen acceptor system should prove challenging.

INTENDED AUDIENCE
Suitable for grades 6-10

PREREQUISITES
Elementary level science.

COURSE SUITABILITY
Introductory biology or any biology unit in a general science course.
PERFORMANCE OBJECTIVES
After viewing and interacting with this program, students will be able to:

1. State that cellular respiration is the process that releases energy from food molecules for use in life activities.
2. Explain why respiration and photosynthesis are basically opposites.
3. List the two types of respiration—anaerobic and aerobic—and state that anaerobic does not require oxygen and aerobic respiration does require oxygen.
4. Describe the basic process of aerobic respiration (glucose combines with oxygen to form water and carbon dioxide and release energy).

RATIONALE
Respiration is the process which releases energy from food molecules for all life activities. Without respiration, life would be completely different from anything we know. It is important for students to understand that respiration is fundamental to life as we know it and to understand how respiration takes place.

OVERVIEW
The program begins by stating that ENERGY is what cells need to survive and function in living things and that energy is provided by the process of respiration. The end products of respiration are carbon dioxide, water, and energy. The energy released is used to carry on all life activities.

During respiration energy from food molecules is converted to a useable form of energy—the ATP molecule. ATP has three phosphates but for it to release energy effectively it must lose one of its phosphate molecules—thus becoming ADP. During the respiration process the energy released from the food molecules are stored in the ATP molecule, and ADP is converted back to ATP.

The two forms of respiration are then discussed—Anaerobic Respiration which occurs without oxygen and Aerobic Respiration which requires oxygen. The initial steps of respiration are called glycolysis. Glycolysis is the process of breaking a glucose molecule in half for a gain of two ATP energy molecules.

In anaerobic respiration energy is obtained through glycolysis only. But the process is relatively inefficient because only a partial breakdown of the glucose molecule takes place. This method is adequate for the energy needs of many simple organisms such as yeast and bacteria.

The large variety of more complex organisms on Earth require a great deal of energy for their cellular activity. For this energy they rely on the process of aerobic respiration.

The program ends by asking students which types of people require more energy. (For example, an office worker or a construction worker.) Throughout the program, students are asked specific questions about the information they receive from the program and are asked to write the answers on the Video Activity Sheet. The correct answers are always given in the video.
TEACHING STRATEGIES Before Viewing

1. Use the technique of Semantic Mapping to elicit from students the knowledge they already have about respiration. Write the word "Respiration" on the board and draw a circle around it. Ask students to give you as many ideas and concepts as they can about ecology and cluster the ideas around the circle. Add to the map after the program. See the bibliography for a helpful booklet that describes semantic mapping in detail.

2. Define the word "respiration."

3. Have students look up the words on the WORD LIST in this guide. Have students use Dictionaries, Encyclopedias, or the Glossary in this guide.

4. Ask your students to write a short composition explaining what respiration is to somebody who has no knowledge of it.

5. Allow several students to make an oral presentation of their reports, and guide a discussion that leads to a summarization of similarities in each report.

   **CAUTION:** Do not make value judgements about any of the criteria or suggestions made by your students. Reserve this evaluation for the students to make themselves after the video is shown.

6. Hand out the interactive Activity Sheet, and then show the instructional video program.
TEACHING STRATEGIES After Viewing

1. Have students evaluate all their suggestions on how they would describe respiration and let the class prepare a final listing of the characteristics of respiration taught in the video.

2. Use any of the Additional Activities you desire.

3. Administer the Program 3 Exam.

ADDITIONAL ACTIVITIES

1. Have students compare their pulse rates before and after physical exercise. Perform a series of simple exercises for about two minutes. How long does it take for one’s pulse to return to normal? Compare results with other students in the class. Explain the differences.

2. Grow yeast in a variety of sugar compounds. Measure the amount of carbon-dioxide produced as an indicator of their rate of growth. Which sugar compound provides for the optimum growth?

3. Measure and compare the metabolic rate of several small mammals. Several biological supply houses stock metabolic measuring devices that may be used for this experiment. The devices do not harm the animals.

4. Culture yogurt bacteria. Test for the most optimum conditions needed for the growth of these organisms.

5. Green Plants produce oxygen as a by-product of Photosynthesis. Repeat the Elodea demonstration illustrated below. Test for the presence of oxygen by igniting a glowing splint.
ADDITIONAL ACTIVITIES (continued)

6. Create an aquarium balanced between plants and fish. Note the bubbles of oxygen being released by the aquatic plants. What will happen to the oxygen? (The fish will use the oxygen for respiration and release carbon dioxide into the environment for recycling by the green plants.)

7. Put yeast, sugar, and water into a test tube. Vent the gases produced into another test tube containing lime water. (After 24 hours the lime water should turn milky white, indicating the presence of carbon dioxide. Carbon dioxide is one of the by-products of respiration.)

8. Demonstrate the by-products of aerobic respiration by performing this very simple experiment. Have a student exhale through a straw into some lime water. Record the time it took for the lime water to turn milky white. Have the student do some strenuous exercises such as running in place. Then let the student exhale through the straw into another glass of lime water. Again record the time it took for the lime water to turn milky white. Compare the times and explain why the lime water turned milky faster after the student exercised. (Exercise produces an increase in carbon dioxide exhaled.)

9. Have a student breathe onto a mirror. Why does fogging result? (Water is one of the by-products of aerobic respiration.)
BIBLIOGRAPHY


Programs in the BIOLOGY CONCEPTS SERIES

1. Distinguishing Between Life and Nonlife VS 500
2. Photosynthesis: Maintenance in Living Things VS 501
3. Cellular Respiration VS 502
4. Mendelian Genetics VS 503
5. Modern Genetics VS 504
6. Applied Genetics VS 505
7. Ecology VS 506
8. Pollution VS 507
9. Theories of Evolution VS 509
10. Evidence of Evolution VS 510
11. Circulation VS 511
12. Cardiovascular Disease VS 512
13. Excretion VS 513
14. Asexual Reproduction VS 514
15. Sexual Reproduction VS 515
SUPPORT MATERIAL FROM EDUCATIONAL ACTIVITIES

Computer Programs
DK 23000 Classification of Living Things
DK 23020 Cells and Tissues
DK 23040 Green Plants
DK 23065 Introduction To Biochemistry

Video Programs
VS 404 Cells
VS 004 Problem Solving In Science
VS 242 Plant and Animal Reproduction

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SPECIAL THANKS TO
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American Farm Bureau Federation
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National Aeronautics and Space Administration
National Association of Home Builders
National Audio Visual Center
Sears Robuck and Company
Tennessee Valley Authority
Tomy Corporation
United States Forest Service
University of Mississippi
NOTE: We have listed only the answers which are not in the Glossary.

2. Describe how you think breathing and respiration might differ.

**Breathing is one stage of the process of respiration.** Breathing is a physical process that allows animals and humans to come into contact with the gases in the air. Respiration is a chemical process that takes place in the cells, during which energy is released from food molecules.

11. ATP is short for Adenosine-Tri-Phosphate. How many phosphate molecules do you think ATP contains?

**ATP has three phosphate molecules.**

16. How do you think the fish and the plants might interact in the aquarium?

**The fish release carbon dioxide which the plants use for photosynthesis and the plants release oxygen which the fish use during respiration.**

17. What are two kinds of cells or organs that might require greater amounts of energy than other cells?

**Brain cells need extra energy for nerve transmission and muscle cells need extra energy in order to contract.**

19. Which person in each of the following groups of individuals requires more calories?
   - A teenage boy or a teenage girl? (the same age and weight)
   - An office worker or a construction worker?
   - A baseball player or a football player?
   - A person walking or a runner?

**These are the individuals requiring the most energy:**
- the teenage boy
- the construction worker
- the football player
- the runner

*(Keep in mind that the energy needs of individuals vary depending on how active they are.)*
ANSWER KEY

PROGRAM 3 EXAMINATION

1. All of the following result from aerobic respiration except (a) oxygen.

2. Which of the following represents a balanced aquarium? (c) fish and green plants.

3. During the process of respiration, chemical energy in food is stored in molecules of (d) ATP.

4. The organelle in cells which controls the process of respiration is called the (b) mitochondria.

5. Essentially, the process of respiration is the opposite of (b) photosynthesis.

6. Which substance is not needed during the process of respiration (a) chloroplasts.

7. Anaerobic respiration differs from aerobic respiration in that anaerobic respiration does not need (c) oxygen.

8. The amount of calories needed by an organism is dependent upon its (d) all responses are correct. (height, size, activity)

9. The major purpose of the process of respiration is (b) energy storage and use.

10. The unit of measure used to describe the amount of potential energy in food is called a(n) (b) calorie.

ESSAY QUESTIONS:

1. Compare the process of respiration with the process of photosynthesis. Essentially, respiration and photosynthesis are opposites. Respiration produces water and carbon dioxide from food and oxygen. Photosynthesis produces food and releases oxygen as a by-product.

2. Why do most complex organisms undergo aerobic respiration rather than anaerobic respiration? More energy is released, allowing complex organisms to sustain themselves. Anaerobic respiration does not release enough energy for complex organisms.

3. Distinguish between anaerobic and aerobic respiration. Anaerobic respiration occurs in the absence of oxygen, aerobic in the presence of oxygen. Aerobic respiration releases more energy than anaerobic respiration and occurs in the mitochondria.

4. What function is served by the mitochondria? The mitochondria is the organelle which releases energy for use by the cell.

5. Explain the relationship between the energy needs of a cell and the number of mitochondria it contains. The cell requiring more energy generally contains a greater number of mitochondria.
WORD LIST

Please look up these words and write the definitions. Use Dictionaries, Encyclopedias, or the Glossary from this guide.

ATP (adenosine tri-phosphate) ________________________________

Aerobic ___________________________________________________

Air _______________________________________________________

Anaerobic ________________________________________________

Animal ___________________________________________________

Bacteria __________________________________________________

Breathing ________________________________________________

Burn _____________________________________________________

Calorie ___________________________________________________

Carbohydrates _____________________________________________

Carbon Dioxide __________________________________________

Cell _____________________________________________________

Cellulose _________________________________________________

Combustion ______________________________________________

Cytoplasm _______________________________________________

Energy ___________________________________________________

Enzymes _________________________________________________

Fats _____________________________________________________
<table>
<thead>
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GLOSSARY

ATP (adenosine tri-phosphate) - A compound formed as the result of energy released during the process of respiration. When the compound releases its energy to the cell it is converted to Adenosine Di-Phosphate. ADP, much like a discharged battery, can be recharged to ATP during the respiration process.

Aerobic - Occurring only with oxygen present.

Air - A colorless, odorless, tasteless, gaseous mixture, mainly nitrogen (78%) and oxygen (21%) with lesser amounts of argon, carbon dioxide, neon, helium, and other gases.

Anaerobic - Without the presence of oxygen.

Animal - A living being that generally differs from a plant by being able to move from place to place, by growing to a definite, limited size and shape, and by eating food rather than manufacturing it.

Bacteria - Simple organisms that consist of one cell. They are among the smallest of living things. Some scientists believe bacteria are plants. Others believe bacteria are neither plants nor animals.

Breathing - A physical process that allows organisms to come into contact with gases required for the process of respiration.

Burn - To undergo or cause to undergo a combination with oxygen or similar chemical agent, especially with the production of flames and heat.

Calorie - A unit used to measure energy. A calorie is the amount of energy needed to raise the temperature of one gram of water by one degree Celsius.

Carbohydrates - Any of a group of chemical compounds, including sugars, starches, and cellulose.

Carbon Dioxide - A colorless, odorless gas that does not burn. It is composed of carbon and oxygen and has the formula CO₂. It is produced in any process in which carbon combines with oxygen, such as burning, organic decomposition, and respiration.

Cell - The smallest unit of a living thing that is capable of independent functioning.

Cellulose - Main component of plant tissues. It is used in making a variety of products including paper, textiles, and cellophane.

Combustion - Burning, a chemical change, especially oxidation accompanied by the production of heat and light.

Cytoplasm - The fluid part of a cell, outside the nucleus.
GLOSSARY (continued)

**Energy** - The capability for doing work.

**Enzymes** - Catalysts in chemical processes that go on in living things.

**Fats** - Any one of a large number of oily compounds that are widely found in plant and animal tissues.

**Food** - Any substance that a plant or animal can take in and use for energy.

**Glucose** - A white crystalline sugar, about half as sweet as sucrose (table sugar). Glucose is produced during photosynthesis. It is one of the main food products which animals use for energy.

**Glycolysis** - The process of dividing a glucose molecule in half to produce four ATP energy carrying molecules.

**Inorganic** - Not composed of organic matter.

**Mineral** - Any natural substance that has a definite chemical composition and characteristic physical structure.

**Mitochondria** - A microscopic body found in the cells of almost all living organisms. It contains enzymes responsible for the conversion of food to useable energy. The organelle contains a network of membranes known as cristae that possess an assembly of enzymes allowing for the process of aerobic respiration.

**Nutrient** - Something that nourishes, especially an ingredient in food.

**Organelles** - Microscopic structures that perform specific functions within living cells.

**Organic** - Of, pertaining to, or derived from living things.

**Organism** - Any living thing, plant or animal.

**Oxidation** - The combination of a substance with oxygen.

**Oxygen** - One of the elements; a colorless, odorless, tasteless gas.

**Photosynthesis** - A food-making process that occurs in green plants. The word “photosynthesis” means “putting together with light.” Green plants use energy from light to combine carbon dioxide and water to make food. All food originally comes from this important activity of green plants.

**Plant** - A living thing that generally differs from an animal by being able to manufacture its own food, by being unable to move by itself from place to place, and by having cells with walls made of cellulose.
GLOSSARY (continued)

**Respiration** - The process by which energy is made available to the cell. It enables the cell to carry out its life activities. Anaerobic respiration occurs in the absence of oxygen; aerobic respiration occurs in the presence of oxygen.

**Starch** - Any of various nutrient carbohydrates that occur widely in nature, chiefly in plants.

**Sucrose** - A crystalline sugar found in many plants. Sucrose is the chemical name for common table sugar.

**Sugar** - A sweet crystalline belonging to a class of food called carbohydrates. Carbohydrates provide energy for plants and animals.

**Water** - A compound of hydrogen and oxygen having the formula H₂O; usually occurring as a liquid but can also occur as a solid at low temperature or a gas at high temperature.
VIDEO ACTIVITY SHEET

Introduction: Energy cannot be created or destroyed. Nor can it be increased or decreased. Energy can only be stored and released.

Cellular respiration is the process by which living things release energy from food.

UNIT 1

1. Energy is released

2. People often confuse the terms breathing and respiration. Describe how you think breathing and respiration might differ.

3. Breathing is

4. Cellular respiration is

5. Organelles are

6. The mitochondria

7. The combination

8. In living things

9. ATP is

10. In the mitochondria

11. ATP is short for Adenosine-Tri Phosphate. How many phosphate molecules do you think ATP contains?
UNIT 2

12. Anaerobic respiration is ____________________________________________________________

13. Aerobic respiration is _____________________________________________________________

14. Write the equation as directed by the video program.

15A. Write the equation as directed by the video program.

15B. Write the equation as directed by the video program.

16. How do you think the fish and the plants might interact in the aquarium?

___________________________________________________________________________________________

___________________________________________________________________________________________

17. What are two kinds of cells or organs that might require greater amounts of energy than other cells?

___________________________________________________________________________________________

18. A calorie ____________________________________________________________________________

___________________________________________________________________________________________

19. Which person in each of the following groups of individuals requires more calories?
   A teenage boy or a teenage girl? (the same age and weight) ____________________________
   An office worker or a construction worker? ___________________________________________
   A baseball player or a football player? ________________________________________________
   A person walking or a runner? _______________________________________________________
PROGRAM 3 EXAMINATION

For each statement or question, select the word or expression that best completes it.

1. All of the following result from aerobic respiration except:
   (a) oxygen  (b) carbon dioxide  (c) water  (d) ATP

2. Which of the following represents a balanced aquarium?
   (a) big fish and small fish  (b) fish and snails  (c) fish and green plants
   (d) algae and elodea (two green aquatic plants)

3. During the process of respiration, chemical energy in food is stored in molecules of:
   (a) H₂O  (b) CO₂  (c) ADP  (d) ATP

4. The organelle in cells which controls the process of respiration is called:
   (a) nucleus  (b) mitochondria  (c) cell membrane  (d) chromosome

5. Essentially, the process of respiration is the opposite of:
   (a) reproduction  (b) photosynthesis  (c) breathing
   (d) growth and development

6. Which substance is not needed during the process of respiration:
   (a) chloroplasts  (b) enzymes  (c) mitochondria  (d) oxygen

7. Anaerobic respiration differs from aerobic respiration in that anaerobic respiration does not need:
   (a) food molecules  (b) enzymes  (c) oxygen  (d) glucose

8. The amount of calories needed by an organism is dependent upon its:
   (a) height  (b) size  (c) activity
   (d) all responses are correct

9. The major purpose of the process of respiration is:
   (a) synthesis  (b) energy storage and use
   (c) to break down excess proteins  (d) to develop new cell organelles

10. The unit of measure used to describe the amount of potential energy in food is called a(n):
    (a) ATP molecule  (b) calorie  (c) pound  (d) metric unit
ESSAY QUESTIONS:

1. Write a brief essay comparing the process of respiration with the process of photosynthesis.

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2. Why do most complex organisms undergo aerobic respiration rather than anaerobic respiration?

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3. Distinguish between anaerobic and aerobic respiration.

___________________________________________________________________________________________
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4. What function is served by the mitochondria?

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5. Explain the relationship between the energy needs of a cell and the number of mitochondria it contains.

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SPECIAL EDUCATION SUPPLEMENT

INTRODUCTION

Green plants introduced oxygen into the primordial atmosphere, allowing life forms to obtain eighteen times more energy from the food they were eating. This extra burst of energy permitted organisms to grow larger and more complex. The energy-obtaining mechanism known as respiration shifted from anaerobic (without oxygen) to aerobic (with oxygen).

In this series, students work with the videos, answering critical thinking and creative problem solving type questions. They sometimes re-create or hypothesize about famous scientific experiments. The videos immediately give explanations that reinforce student learning and then direct attention to the next phase of instruction. Frequent reviews help all students retain information.

The Teacher's Guide provides Reproducible Black Line Masters, a bibliography and a host of enrichment activities that permit teachers to individualize their instructional programs.

INSTRUCTIONAL OBJECTIVES

After completing this program, the student will demonstrate an understanding of the fundamentals of Ecology by:

1. Distinguishing between anaerobic and aerobic respiration.
2. Describing the raw materials used in both forms of respiration.
3. Stating the products formed as a result of respiration.
4. Achieving 80% mastery on the unit test.

RELEVANT CONSIDERATIONS PERTAINING TO INSTRUCTORS

Teacher options include using BIOLOGY CONCEPTS to introduce a unit, review a subject, and, most significantly, as resource room material for independent individualized instruction. The format of the programs permits instructors to individualize lessons to meet the IEP for each of their students. They were designed to be used by the special education teacher who is a generalist rather than a subject area specialist.

STRATEGIES FOR TEACHING

Motivate the students by asking them to perform a simple exercise, for instance, running in place. Have them work in pairs, a runner and a recorder. Immediately after the runner runs for one minute, the recorder should write down the runner's pulse rate (rate of breathing). Wait one or two minutes and once more record the runner's pulse rate. Ask the students to explain the difference in rates. Summarize their answers through the use of semantic mapping. Do not comment on their responses.

Show the video.

Ask the students to review their original responses and add or delete any items that have become apparent as a result of viewing the program. Encourage the use of extended experiences for extra credit and/or enrichment. Suggest that the students include the Glossary and other Reproducible Masters in their notebooks.

Administer the examination.
INTERNET ACTIVITIES
Use the Internet to research your answers to each of the following questions:

• Compare the process of respiration in plants and animals.
• Why is aerobic respiration more effective than anaerobic respiration?
• How does rigorous exercise affect the rate of respiration?
• Who was Hans Krebs?
• What causes muscle fatigue?
• Why are both the baking industry and manufacturers of alcoholic beverages interested in the process of anaerobic respiration?

• Some people confuse breathing with respiration. What are the differences between these two processes and how are they related?

Internet Cellular Respiration Links

Plant respiration
http:/ /149.152.32.5/Plant_Biology/resp.html

Respiration physiology
http:/ /www.elsevier.com/locate/resphysiol

For additional Internet resources, search the keywords "cellular respiration" in one of the following search engines:

http:/ /www.altavista.digital.com
http:/ /www.askjeeves.com
http:/ /www.dogpile.com
http:/ /www.excite.com
http:/ /www.search.com
http:/ /www.yahoo.com