Cellular Respiration

Biology Module 2

Arkansas SCIence KEYS

Learning Guide

Arkansas Department of Education
Leadership Support Service

Summer 2010

Module: Cellular Respiration

Module: Cellular Respiration

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Day 5/6	Aerobic Respiration Teachers Guide	81	10a
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Section 3: Resource Materials	***Documents listed below are available on the Wiki and Teacher Resource CD***		
Open Response	Cellular Respiration OR	Available on CD/wiki	1
CR Assessments	Cellular Respiration Formative Assessment	Available on CD/wiki	2a
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Articles:	Cellular Respiration Article	Available on CD/wiki	4a
	Bromothymol Blue Article	Available on CD/wiki	4b
	Fermentation History Article	Available on CD/wiki	4c
	The Strange Tale of Muscle Lactate	Available on CD/wiki	4d
Lessons and Websites	Effects of Closed Envioronment on Living Things Lesson	Available on CD/wiki	5a
	NettreKKer Web Sites - Cellular Respiration	Available on CD/wiki	5b
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	Reading Differetiation Extention Activity	Available on CD/wiki	5d
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	Investigating Cell Respiration Thru Kinestetics Lesson	Available on CD/wiki	5g
	Investigating Cell Respiration Thru Kinestrics Template	Available on CD/wiki	5h
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	Cooperative Learning Appointment Clock	Available on CD/wiki	5j
	Diner Menu Photosynthesis Idea	Available on CD/wiki	5k

* The "CD Reference number" referes to the file location on the Teacher Resource CD.

Section One

Cellular Respiration

Biology Module 2

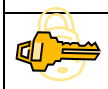
Arkansas SCIence KEYS

Learning Guide

Summer 2010

Biology Modules
Cellular Respiration

Participants will investigate cellular respiration. Materials will be provided for teacher use in the classroom. This module is part of a series of integrated, authentic inquiry-based modules aligned to the Arkansas Science Standards. All materials are provided free of charge. Instructional facilitation will also be provided for the teacher upon completion of this professional learning.

WORKSHOP AGENDA			
DAY 3 – BIOLOGY MODULE			
	Key Event	**Time Frame**	**Notes/Questions**
	**Introduction and Pre Test**	Workshop – 30 min	
	Safety KEY		
	Content KEY – Cellular Respiration	<u>Day 1 in the Classroom:</u> Elicit/Engage – 15 min Explore – 30 min Explain – 4 square exit slip	
	Elicit: Energy Transfer Demo		
	Engage: Discussion of Energy Transfer		
	Explore: 3D or paper model of cellular respiration		
	Explain: Magnet Overview		
	**Elicit:** 4 Square Activity	<u>Day 2 in the Classroom:</u> Elicit – 15 min Engage – 5 min Explore – 20 min Explain/Evaluate – 5 min lead in to Venn Diagrams for homework.	
	Engage: Mitochondria Video(s)		
	Explore: Create mitochondrion model		
	Explain/Evaluate: Venn Diagram to compare and contrast Mitochondria and Chloroplast and/or compare and contrast cellular respiration and photosynthesis as energy conversion pathways.		
	Explore Alternative: Salad Tray Models		
	**Elicit:** 6 grocery items that are fermented.	<u>Day 3-4 in the Classroom:</u> Elicit/Engage: 10 min Explore: 40 min Explain/Evaluate: 15 min Extend: 25 min	
	Engage: What do these items have in common?		
	Explore: Fermentation Lab		
	Explain/Evaluate: Answer questions and graph in class from fermentation lab.		
	Extend: Jigsaw Articles		
	**Elicit:** What is cellular respiration? What is the goal of cellular respiration?	<u>Day 5-6 in the Classroom:</u> Elicit: 10 min Engage: 5 min Explore: 40 min Explain: 35 min	
	Engage: Pearson Movie		
	Explore: Assemble flap book: Glycolysis sort, Glycolysis concept map, Citric Acid Model		
	Explain: Math Sheet	*Video may not be available	

Biology Module Yr 2- 2010

		Provided		Not Provided
Activity	**Materials**	**Facilitator**	**Teacher**	**Needed**
ELICIT/ENGAGE	Marshmallow pack			X
Activation Energy	Cashew pack			X
	Butane Lighter			X
	Test Tube- glass	X	X	
	Thermometer-Alcohol based	X	X	
	Vernier Go Temperature probe	X	X	
	Ring Stand		X	
	Buret (Test Tube) clamp	X	X	
	Modeling Clay			X
	Safety Goggle			X
	Gloves, heat resistent			X
	Paper Clips- Jumbo			X
EXPLORE	Lab Aids Molecule Kit- sets of 15 *Cellular Respiration Kit*	X	X	
Glucose Model	MollyMod Kit			X
	MollyMod Kit- Demo			X
	Ball and Stick kit- sets of 15			X
	Ball and Stick- Demo			X
	Energy Flow Magnet Sheets	X	X	
EXPLORE	AMW Disk pocket Scale	X		
Fermentation	50 ml Graduated Cylinder	X	X	
	250 ml beakers			X
	Stopwatches			X
	Burel Wide stem Disposable Pipets- 7.5ml	X	X	
	Yeast			X
	Sugar			X
	Graduated Medicine cups	X	X	
	Bromethyol Blue- 1000 ml bottle	X	X	
	HeX Nuts- 3/8 in			X
	CO2 Probe	X		
EXPLORE	Mitochondria paper templates			X
Model Mitochondria	glue sticks			X
	boX of small craft beads			X
	boX of medium craft beads			X
	Universal Rubber bands- size 10			X
EXPLAIN	Plain file folder			X
Graohic Organizer	Glue sticks			X
	1 hole punch			X
	zipper bags, qt or sandwich			X
	colored construction paper- I pack			X
Tubs for all materials		X	X	

SciKeys Biology Pre-Formative Assessment Yr 2

1. *Please enter the user ID that you created (for example: Batman22). Be sure to use the same ID on the Post-Assessment. [ ]

2. *Rate your understanding of the 7E model.
   a. Poor b. Fair c. Adequate d. Good e. Excellent

3. *I am adequately prepared to deliver instruction from this training to my students.
   a. Poor b. Fair c. Adequate d. Good e. Excellent

4. *Rate your understanding of "best practices" as they relate to science instruction.
   a. Poor b. Fair c. Adequate d. Good e. Excellent

5. *Rate your ability to apply 7E model to science instruction.
   a. Poor b. Fair c. Adequate d. Good e. Excellent

6. *Rate your understanding of inquiry-based instruction.
   a. Poor b. Fair c. Adequate d. Good e. Excellent

7. How are photosynthesis and cellular respiration similar?
   a. They occur in animal cells.
   b. They take place in the same organelle.
   c. They involve the conversion of energy.
   d. They produce the same complex carbohydrate.

8. What is formed during photosynthesis and broken down during cellular respiration?
   a. Water
   b. Glucose
   c. Lactic acid
   d. Carbon dioxide

9. Which process occurs in the mitochondria of cells?
   a. Reproduction
   b. Photosynthesis
   c. Protein synthesis
   d. Cellular respiration

10. Which is (are) true about both mitochondria and chloroplasts?
    a. Create and use ATP.
    b. Have structures that increase surface area.
    c. Need enzymes to assist with chemical reactions.
    d. All of the above.

11. Which energy carrier is generated during the Krebs cycle (Citric Acid Cycle)?
    a. CO_2
    b. ATP
    c. Pyruvate
    d. Glucose

12. What is the yield of ATP molecules from glycolysis?
    a. 2
    b. 4
    c. 36
    d. None

13. Which statement about anaerobic/fermentation is true?
    a. A lot of energy is produced.
    b. Occurs in the presence of O_2.
    c. Lactic acid or alcohol is produced.
    d. Includes the Citric Acid/Krebs cycle.

14. Why do large organisms such as humans commonly rely on aerobic respiration?
    a. CO_2 is abundant.
    b. High energy needs.
    c. Cannot metabolize alcohol.
    d. Lactic acid buildup causes muscle fatigue.

15. Which is (are) true about both respiration and photosynthesis as energy conversion pathways?
    a. Used by all eukaryotes
    b. Use enzymes to convert energy
    c. Convert light to chemical energy
    d. Convert chemical to ATP, heat, and/or light

SciKeys Biology Post-Formative Assessment Yr 2

1. *Please enter the user ID that you created (for example: Batman22). Be sure to use the same ID on the Post-Assessment. [ ]

2. *Rate your understanding of the 7E model.
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3. *I am adequately prepared to deliver instruction from this training to my students.
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Section Two

Cellular Respiration

Biology Module 2

Arkansas SCIence KEYS

Learning Guide

Arkansas Department of Education Leadership Support Service

Summer 2010

Cellular Respiration Comprehensive Unit Guide

Unit Overview

Unit Title: Cellular Respiration

Lesson Summary: Students Will:

- Observe the conversion of potential energy to kinetic (heat) energy that is evidenced by an increase in the temperature of water caused by burning a food source.
- Build the molecular model of cellular respiration reactants and products to demonstrate the conservation of matter (atoms) in the process. The models may also be used to demonstrate photosynthesis reactants and products.
- Create a model of a mitochondrion and use the model to compare and contrast the structure and function of a mitochondrion to a previously built chloroplast, and to compare and contrast cellular respiration and photosynthesis as energy conversion pathways.
- Create a model of a mitochondrion and use the model to compare and contrast the structure and function of a mitochondrion to a previously built chloroplast.
- Investigate the fermentation of yeast using various food sources.
- Construct a flap-book as a study resource and will model simplified reactions involved in the stages of aerobic respiration and calculate the total ATP produced during the process.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

Science Standards

- MC.1.B.4 Explain the role of energy in chemical reactions of living systems: activation energy, exergonic reactions, endergonic reactions.
- MC3.B.5 Compare and contrast cellular respiration and photosynthesis as energy conversion pathways.
- MC.3.B.1 Compare and contrast the structure and function of *mitochondria* and *chloroplasts*
- MC.3.B.3 Compare and contrast *aerobic* and *anaerobic respiration: lactic acid fermentation, alcoholic fermentation*
- MC. 3.B.2 Describe and model the conversion of stored energy in organic molecules into usable cellular energy (ATP): *glycolysis, citric acid cycle, electron transport chain*

Math Integration

- Measurement, graph data, investigate rates of change, and compare methods of reporting data to make inferences or predictions.

Literacy Integration

- Journal writing, compare and contrast using Venn diagrams
- Jigsaw activity

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

NS.9-12.3 Life Science:

Students should develop an understanding of the cell.

Students should develop an understanding of matter, energy, and organization in living systems.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:
Students Will:

- Observe that foods contain stored energy that can be released.
- See that the number and type of atoms in reactants equals the number and type of atoms in the products during cellular respiration (or photosynthesis) to help compare cellular respiration and photosynthesis.
- Construct a mitochondrion model and label the structures found in it
- Explain the location and function of a mitochondrion
- Compare/contrast the structure and function of a mitochondrion to a chloroplast.
- Compare/contrast cellular respiration and photosynthesis as energy conversion pathways
- Build a mitochondrion model and label the structures found in it
- Explain the location and function of a mitochondrion
- Compare/contrast the structure and function of a mitochondrion to a chloroplast.
- Compare and contrast aerobic and anaerobic respiration, including lactic acid and alcoholic fermentation.
- Determine the yield of energy carrier molecules produced by glycolysis.
- Identify the energy carrier molecules produced during aerobic respiration.
- Describe the three main stages of aerobic respiration.
- Model reactions of the Krebs cycle.
- Determine the efficiency of aerobic respiration by calculating the total production of ATP.

Focus Question:

- How do cells obtain and use energy?
- How do mitochondria and chloroplasts compare/contrast in structure and as energy converting structures?
- How do cells obtain and use energy?
- How are aerobic and anaerobic respiration alike and different?
- How do living cells carry out energy releasing reactions?

Prerequisites / Background Information:

- See individual Teacher Guides.

Timeline:

Preparation:
Elicit/Engage:
Explore:
Explain:
Cleanup:

- Whole unit should take approximately 6 days given a 45 minute class period.

Teacher Preparation:

- See individual Teacher Guides.

Materials:

- Complete unit guide materials list is provided.

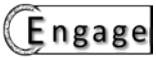
Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☒ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☒ Internet Connection	☐ Other:

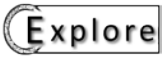
Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☒ Multimedia	☐ Other:
☒ Internet Web Browser	☐ Word Processing	

Internet Resources: List Resources Here or at End.

Procedures:	**Teacher's Notes:**
	
• Safety goggles must be worn. • Hot mitts if desired. • Be aware of students with nut allergies if you chose to use nuts. • Use caution with glue and small beads	
	
• Is there energy in a cashew or chip or marshmallow? • How will we know if the energy is released? • When I burn this cashew, how much change will we see in the temperature of the water? • Use the Energy Transfer Demonstration and discussion. • 4 square activity • Review the 4 square activity from previous lesson • What do pickles, bread, yogurt, wine, beer, and cheese have in common? • Briefly review anaerobic respiration and reinforce the idea that only small amounts of ATP are produced. • Ask students if they think that larger organisms (such as vertebrates) can depend on anaerobic respiration. Small organisms, such as yeast, have lower energy requirements than large vertebrates, i.e. less movement etc.	• Listen to student responses; tell students they will attempt to find out by burning a chip and measuring how much heat energy it releases.
	
• Measure initial temperature of water, remove thermometer, burn the cashew and measure the change in temperature.	• Or whatever you have chosen to use. • Videos on CD

- Ask students to reflect on what they have learned about energy stored in food molecules and relate it to the energy transfer they have just witnessed.
- Discuss that the activation energy was provided by the lighter.
- Ask students if this reaction would be acceptable in a living cell? Why or why not?
- Ask students to think about how living cells might carry out similar energy releasing reactions, but in a more controlled fashion by utilizing enzymes that lower the activation energy.
- Use the Energy Transfer Demonstration and discussion.
- Show one or more of the Mitochondria videos
- Blow carefully through a straw into BTB (bluish liquid) and watch it turn green then yellow before your eyes. Discuss the results. See "Engage" handout for more information.
- Students will create a "flap book" from a plain file folder. The front cover may be illustrated and additional pockets or charts may be glued to the back.
- As students progress through the lesson they will attach various materials to the folder and complete the activities.



- 3-d model of cellular respiration
- Build model molecules of glucose and 6 oxygen molecules using the student kits.
- Disassemble the molecules and see how many carbon dioxide and water molecules can be assembled
- Build models of mitochondria
- See Yeast Cell Respiration Lab handout
- Students will complete several exercises related to aerobic respiration.
- After each activity the finished materials will be attached to the inside of the flap book.
    - Paired reading on glycolysis
    - Class review of vocabulary
    - Determine the yield of ATP from glycolysis
    - Write a description of glycolysis
    - Construct a model of the Krebs cycle using colored punch dots
    - Calculate the Yield of ATP
    - Cellular Respiration Concept Map

Explain

- Discussion questions from 3-d model activity
- Students complete and discuss the Questions from the 3-d model
- Have students describe the location and function of a mitochondrion
- Label/describe the structure of the mitochondrion.
- Graph data from lab and complete analysis questions.
- Jigsaw Activity
- Students will answer the 8 questions and complete the general concept map provided for the flap book.

- Within almost all eukaryotic cells, site of cellular respiration/ATP production
- Include all the parts you desire

Elaborate

- Carbon Cycle graphic organizer activity using magnets or student handouts
- Carbon cycle graphic organizer using magnets or student handouts to connect
- Cellular respiration and photosynthesis
- Compare/contrast the mitochondrion to the chloroplast as an energy converting structure
- Discuss the reasons that the yield of ATP from respiration may vary among organisms.
- Compare and contrast the yield of aerobic respiration to anaerobic respiration.

- Venn diagram and key at bottom

Evaluate

Formative Assessment

- Students will explain what they discovered about the relationship of products and reactants of cellular respiration and/or photosynthesis.
- Ask questions of each group/student while students are creating models**.**
- Compare/contrast the structure and function of a mitochondrion to a chloroplast on a Venn diagram.
- Graph and Analysis Questions for Lab
- Questions to Jigsaw Articles
- Student responses to questions as they complete the “flap book”.

Summative Assessment

- Produce a foldable comparing products and reactants of cellular respiration.
- Use a Venn diagram to compare and contrast photosynthesis and respiration.

- Venn diagram and key at bottom

- Produce a 4 tab foldable of cellular respiration with word equation, symbol equation, and balanced chemical equation.
- Other graphic organizers as desired.

- Question-do all organisms use oxygen to produce energy?

Cross-Curricular

- List Information as Applicable with Bullets/Steps

Notes:

- List Information as Applicable with Bullets/Steps

Cellular Respiration- An Overview

Animal and other eukaryotic cells constantly need energy to function. The process through which energy is converted from the biochemical energy of foods to ATP is called **cellular respiration.** Most of this reaction occurs in the mitochondria, also nicknamed the "powerhouse" of the cell (Wikipedia and Glencoe Biology, 2007, page 228). This process is very complicated.

The chemical equation for cellular respiration is opposite to the equation for photosynthesis; however, the actual reactions are very different, using different organelles and requiring different enzymes.

Cellular Respiration

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_20 + \text{Energy (ATP)}$$

Cellular respiration is an example of a catabolic pathway, because the body is taking large, complex molecules such as sugars and breaking them down into smaller, simpler molecules of carbon dioxide and water. When the molecule is broken down, energy is released. It is this energy that is used to power cellular respiration (Wikipedia and Campbell et al., Biology, 8th edition, 2008, page 163).

There are two primary processes within cellular respiration, anaerobic and aerobic. Both share the common beginning pathway of glycolysis. The anaerobic process is glycolysis, the breaking down of glucose, and does not require oxygen to generate ATP. This process occurs outside the mitochondria in the cytoplasm. The aerobic process, on the other hand, requires the use of oxygen therefore glycolysis is followed by the formation of acetyl CoA, the Krebs cycle, the electron transport chain, and chemiosmosis (Wikipedia and Glencoe Biology, 2007, page 228-229). The aerobic processes are carried out in the mitochondria. The Krebs cycle occurs in the mitochondrial matrix, while the electron transport chain functions in the mitochondrial membrane.

Glycolysis begins both aerobic and anaerobic respiration. In order to start the process two ATP are spent to break the glucose apart. As the glucose is broken down into pyruvate, four ATP and two NADH are created, yielding a net result of two ATP and two NADH (Campbell Biology, 2008, page 167). Glycolysis, the anaerobic process, only creates two ATP molecules, but the Krebs cycle and the electron transport chain/chemiosmosis are design to extract the remaining available energy from the original glucose molecule, which is now in the form of two pyruvate molecules. Pyruvate enters through the mitochondrial membrane, reacts with coenzyme A and forms acetyl CoA which is introduced into the Krebs cycle, officially starting the aerobic process. The Krebs cycle is also known as the citric acid cycle or tricarboxylic acid cycle. It is important to remember that two pyruvate molecules were generated from glycolysis, allowing the Krebs cycle to "turn" two times. The net yield from the Krebs cycle includes six carbon dioxide, two ATP, eight NADH, and two $FADH_2$ molecules (Glencoe Biology, 2007, page 230).

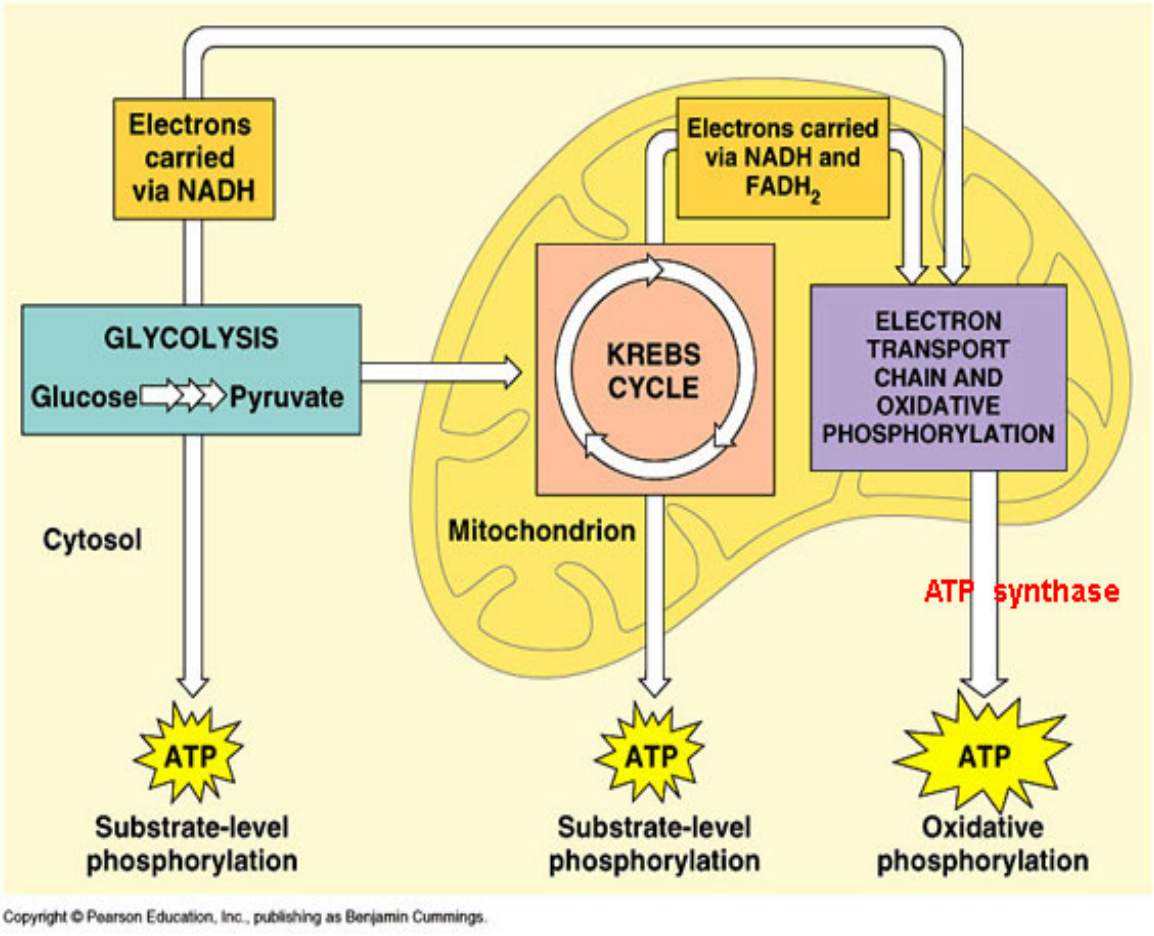
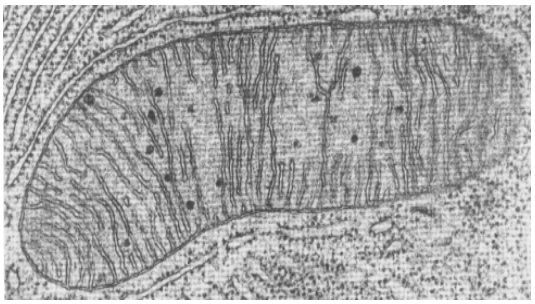
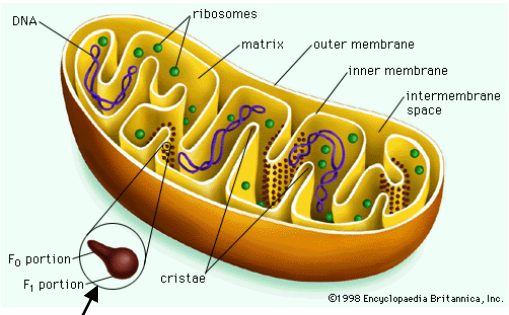


Image taken from http://www.bio.miami.edu/~cmallery/150/makeatp/c9x6cell-respiration.jpg

As in photosynthesis, the electron transport chain is the final step in the formation of energy for the cell and is the point at which most of the energy is created. High energy electrons and hydrogen ions are used to convert ADP to ATP producing a total of 24 ATP from the electron transport chain process. One glucose molecule will theoretically yield a net of 36-38 ATP. (Glencoe Biology, 2007, page 231.)



http://library.thinkquest.org/3564/Cells/cell119-3.gif



ATP Synthase

http://media-2.web.britannica.com/eb-media/89/22489-004-EE9DC4F5.gif

The electron transport chain is composed of many protein molecules that lie in the inner membrane of the mitochondria. The inner membrane folds numerous times creating cristae. This folding increases the surface area allowing for multiple units of the electron transport chain (Campbell et al., Biology, 8th edition, 2008, page 172).

Fermentation and anaerobic respiration

The distinction between anaerobic respiration and fermentation is based on whether an electron transport chain is present. The electron transport chain is called the respiratory chain because it functions in cellular respiration. True anaerobic respiration takes place in some prokaryotic organisms that live in anaerobic conditions, such as the bottom of an ocean. Some of these organisms may use the sulfate ion (SO_4^{2-}) to serve as a final electron acceptor and produce H_2S instead of H_2O (Campbell et al., Biology, 8th edition, 2008, pg 177). It is stinky perhaps, but effective.

When oxygen is not present in eukaryotic and some prokaryotic cells, pyruvate undergoes fermentation in the cytoplasm. Fermentation does not use oxygen or an electron transport chain; however, it allows the hydrogen carriers to be oxidized so they can undergo glycolysis again and also removes pyruvate. In human and other animal skeletal muscle, the waste product of fermentation is lactate, the ionized form of lactic acid, and the process is called lactic acid fermentation. When athletes use up the available oxygen in their system, the body will continue to break down glucose, but will not have all the necessary resources to carry the pyruvate through the aerobic cellular respiration process. The body simply provides the only materials it has available, usually NADH. "The lactate that accumulates was previously thought to cause muscle fatigue and pain, but recent research suggests instead that increased levels of potassium ions (K^+) may be to blame, while lactate appears to enhance muscle performance (Campbell et al., Biology, 8th edition, 2008 page 178). The dairy industry takes advantage of certain fungi and bacteria that use this method and produce cheese or yogurt.

Alcohol fermentation is carried out by yeast and many bacteria when conditions are anaerobic. Pyruvate is converted to acetaldehyde and then to ethanol. Humans have used this in brewing, wine making and baking. The CO_2 released from the process causes the bread to rise.

Some good websites for more information include:
http://en.wikipedia.org/wiki/Cellular_respiration
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/C/CellularRespiration.html
http://www.nclark.net/PhotoRespiration has activities about photosynthesis and respiration
http://biology.clc.uc.edu/Courses/Bio104/cellresp.htm has a song about respiration

Energy Transfer Demonstration

Lesson Overview

Unit Title: Cellular Respiration

Lesson Summary: Elicit and Engage: Students will observe the conversion of potential energy to kinetic (heat) energy that is evidenced by an increase in the temperature of water caused by burning a food source.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

MC.1.B.4 Explain the role of energy in chemical reactions of living systems: activation energy, exergonic reactions, endergonic reactions.

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

NS.9-12.3 Life Science:

Students should develop an understanding of the cell.

Students should develop an understanding of matter, energy, and organization in living systems.

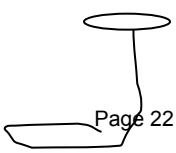
Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective: Students will observe that foods contain stored energy that can be released.

Focus Question: How do cells obtain and use energy?

Prerequisites / Background Information:

If students will be assisting you and you are using alcohol thermometers, students must be able to read the thermometer. Safety goggles are required.
If you use nuts, cashews work well, and make sure you use fresh nuts.
Stick the paper clip in some modeling clay to hold it to the stand. After lighting the cashew, adjust the test tube so that the flame just touches the bottom of the test tube (approximately 3-5 cm)



Timeline: 15 minutes of class time

Preparation:	10 minutes
Elicit/Engage:	10-15 minutes
Explore:	
Explain:	
Cleanup:	10 minutes

Teacher Preparation:

- Gather materials

Materials:

- Ring stand and test tube clamp
- Large test tube half full of water
- Jumbo paper clip
- Modeling clay
- Lighter-butane
- Potato chip, marshmallow, or cashew
- Thermometer-could use Vernier Go-Temp and computer or digital thermometer
- Safety goggles
- Hot mitts if desired

Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☒ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☒ Other: Go Temp

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☒ Other: logger lite/pro
☐ Internet Web Browser	☐ Word Processing	

Internet Resources:

Procedures:	**Teacher's Notes:**
	
• Safety goggles must be worn. • Hot mitts if desired. • Be aware of students with nut allergies if you chose to use nuts.	
	
• Is there energy in a cashew or chip or marshmallow? • How will we know if the energy is released? • When I burn this cashew, how much change will we see in the temperature of the water?	Listen to student responses; tell students they will attempt to find out by burning a chip and measuring how much heat energy it releases.

Engage

- Measure initial temperature of water, remove thermometer, burn the cashew and measure the change in temperature.
- Ask students to reflect on what they have learned about energy stored in food molecules and relate it to the energy transfer they have just witnessed.
- Discuss that the activation energy was provided by the lighter.
- Ask students if this reaction would be acceptable in a living cell? Why or why not?
- Ask students to think about how living cells might carry out similar energy releasing reactions, but in a more controlled fashion by utilizing enzymes that lower the activation energy.

- Or whatever you have chosen to use.

Explore

- 3-d model of cellular respiration

Explain

- Discussion questions from 3-d model activity

Elaborate

- Carbon Cycle graphic organizer activity using magnets or student handouts

Evaluate

Extend

Cross-Curricular

Notes:

3-D Model of the Cellular Respiration Equation

Lesson Overview

Unit Title: Cellular Respiration

Lesson Summary: Explore Explain, Elaborate, and Evaluate: Students will build the molecular model of cellular respiration reactants and products to demonstrate the conservation of matter (atoms) in the process. The models may also be used to demonstrate photosynthesis reactants and products.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

MC3.B.5 Compare and contrast cellular respiration and photosynthesis as energy conversion pathways.

Journal writing, compare and contrast using Venn diagrams

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

NS.9-12.3 Life Science:

Students should develop an understanding of the cell.

Students should develop an understanding of matter, energy, and organization in living systems.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:	Students will see that the number and type of atoms in reactants equals the number and type of atoms in the products during cellular respiration (or photosynthesis) to help compare cellular respiration and photosynthesis.
Focus Question:	How do cells obtain and use energy?

Prerequisites / Background Information:

Students must:

Be familiar with the cellular respiration and photosynthesis equations.

Be familiar with the terms: atom, molecule, product, reactant, yields, bonds, conservation of matter.

Timeline: 1 class period

Preparation:	15 minutes
Elicit/Engage:	Use the Energy Transfer Demo
Explore:	30-40 minutes
Explain:	10 minutes
Cleanup:	5 minutes

Teacher Preparation:

- Check molecular model kits
- Copy student handout

Materials:

- Student molecular kit
- Student handout

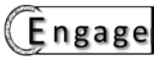
Technology – Hardware: (Click boxes of all equipment needed)

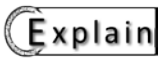
☐ Camera ☐ Computer(s) ☐ Digital Camera
☐ Projection System ☐ Television ☐ VCR
☐ Video Camera ☐ Internet Connection ☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet ☐ Multimedia ☐ Other:
☐ Internet Web Browser ☐ Word Processing

Internet Resources:

Procedures:	**Teacher's Notes:**
	
• Good classroom management.	
	
• Use the Energy Transfer Demonstration and discussion.	
	
• Use the Energy Transfer Demonstration and discussion.	
	
• Build model molecules of glucose and 6 oxygen molecules using the student kits. • Disassemble the molecules and see how many carbon dioxide and water molecules can be assembled	• Model how to connect the atoms. • Use student sheets attached • Discuss the conservation of mass • Discuss that the cellular respiration and photosynthesis FORMULAS are opposites, even though the reactions are very different.



- Students complete and discuss the Questions from the 3-d model

- Carbon cycle graphic organizer using magnets or student handouts to connect cellular respiration and photosynthesis

Formative Assessment

- Students will explain what they discovered about the relationship of products and reactants of cellular respiration and/or photosynthesis.
- Ask questions of each group/student while students are creating models**.**

Summative Assessment

- Produce a foldable comparing products and reactants of cellular respiration.
- Use a Venn diagram to compare and contrast photosynthesis and respiration.
- Produce a 4 tab foldable of cellular respiration with word equation, symbol equation, and balanced chemical equation.
- Other graphic organizers as desired.

Notes:

3D Model of Cellular Respiration

The process through which energy is converted from the biochemical energy of foods to ATP is called **cellular respiration.** Most of this reaction occurs in the mitochondria, also nicknamed the "powerhouse" of the cell (Wikipedia and Glencoe Biology, 2007, page 228). The chemical equation for cellular respiration is opposite to the equation for photosynthesis; however, the actual reactions are very different, using different organelles and requiring different enzymes.

This activity is a hands-on model of the simplest version of the cellular respiration equation and demonstrates the conservation of matter (atoms). The reverse reaction may be used to demonstrate the simplest version of the photosynthesis equation.

MC.3.B.5 Compare and contrast cellular respiration and photosynthesis as energy conversion pathways.

Objectives: Students will

- Construct models of the reactants of cellular respiration.
- Break those models apart and construct as many models of the products of cellular respiration as possible
- Explain how the reactants and products demonstrate the conservation of matter.

Materials:

- **Molecular model kit that contains at least**
  - 6 Carbon atoms-Black
  - 12 Hydrogen atoms-White
  - 18 Oxygen atoms-Blue
  - Connectors "bonds" for the atoms-White
  - Student handouts

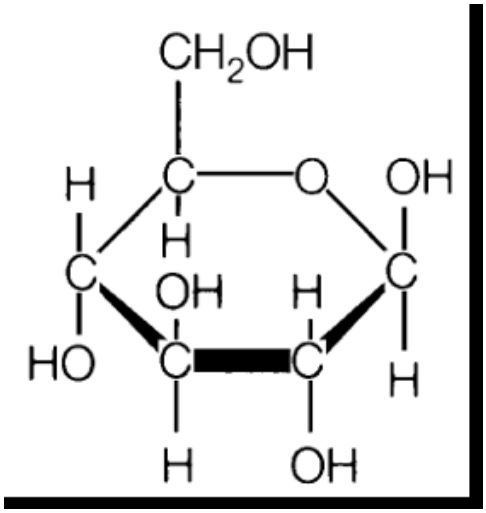
Procedure: B**uild the reactants of the cellular respiration equation.**

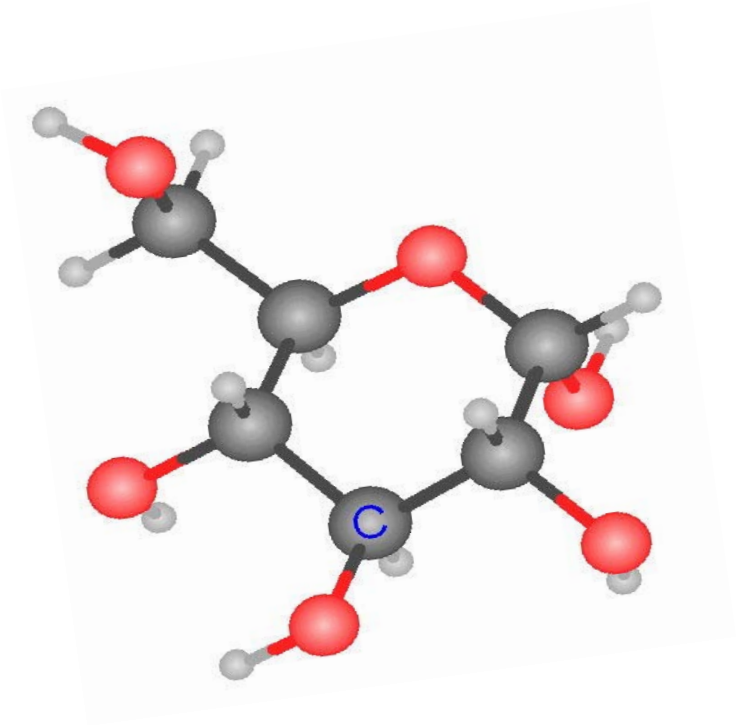
  - Build 6 diatomic molecules of oxygen.
  - Build a glucose molecule.
- **Show the rearrangement of atoms in cellular respiration by disassembling the reactants and creating the products.**
  - Construct as many CO_2 and H_2O molecules as possible using the materials from the reactants.
- **Remember:**
  - Carbon forms 4 bonds (Carbon is black in this kit)
  - Oxygen forms 2 bonds (Oxygen is blue in this kit)
  - Hydrogen forms 1 bond (Hydrogen is white in this kit)
  - Bonds are white also

3D Model of Cellular Respiration Student Handout

1. **Write the simple equation for cellular respiration.**

2. **Using the molecular kit provided, create the reactants of cellular respiration. Below are models of glucose to assist you. You may also use your textbook.**





http://home.hia.no/~stephens/glucose.gif
http://library.thinkquest.org/11226/image/glucose.jpg

3. **Take the reactants apart and create the products of cellular respiration. Make as many products as possible with the atoms you have.**

4. **How many glucose molecules were in the reactants?**

5. **How many O_2 molecules were in the reactants?**

6. **How many H_2O molecules are in the products?**

7. **How many CO_2 molecules are in the products?**

8. **How does this reaction demonstrate the conservation of matter?**

9. **How is energy involved in this reaction?**

10. **Complete a graphic organizer if assigned.**

The Conversion of Light Energy to Chemical Energy and the Carbon Cycle

Life on earth is solar powered. Chloroplasts capture light energy that has traveled 150 million kilometers from the sun and convert it to chemical energy in a process known as photosynthesis. This process stores the energy from light in sugar and other organic molecules. Photosynthesis nourishes almost the entire living world and occurs in plants, algae and a few protists and prokaryotes. Organisms that use light as a source of energy to convert CO_2 and other inorganic raw materials into organic molecules are called autotrophs, specifically photoautotrophs (phototrophs). Organisms that use inorganic chemical molecules instead of light for a source of energy are also autotrophs but chemoautotrophs (chemotrophs). Autotrophs sustain themselves without eating anything derived from living things and are commonly called producers. Heterotrophs, commonly called consumers, live on the compounds produced by other organisms (Campbell et al., Biology 8th edition, 2008).

The chemical energy from photosynthesis is used by both autotrophs and heterotrophs in a process known as cellular respiration, which generates ATP and the waste products carbon dioxide (CO_2) and water (H_2O). This conversion of inorganic carbon (CO_2) to organic compounds during photosynthesis and back to CO_2 during cellular respiration, decomposition, and the burning of organic materials and fossil fuels is known as the carbon cycle.

This activity may be used to introduce or review the conversion of light energy to chemical energy and/or the carbon cycle.

MC.3.B.5 Compare and contrast cellular respiration and photosynthesis as energy conversion pathways.
MC.2.B.6 Compare and contrast the functions of autotrophs and heterotrophs.

Objectives: Students will

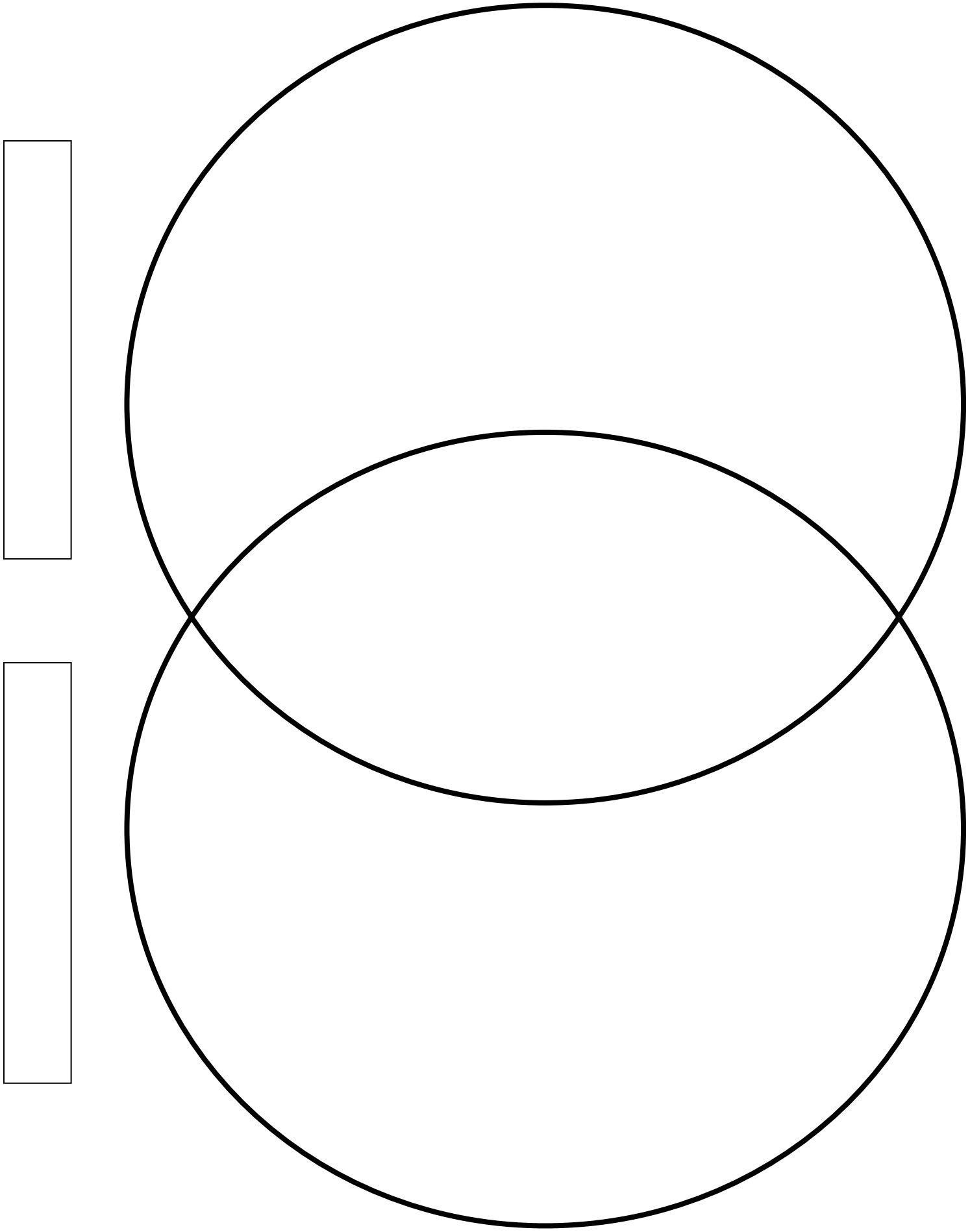
- Construct a model of the carbon cycle
- Relate the terms autotroph and heterotroph to the cycle
- Explain how light energy is converted to chemical energy
- Use a Venn diagram to compare and contrast cellular respiration and photosynthesis as energy conversion pathways
- Use a Venn diagram to compare and contrast the functions of autotrophs and heterotrophs

Materials:

- One set of magnets for the whiteboard
- One handout per group of 2 students-The Carbon Cycle-A desktop hands on model
- Scissors for each pair of students
- Key for The Carbon Cycle-A desktop hands on model
- Venn diagram for each student or pair of students if desired (students may make their own on notebook paper) for the desired SLE.

Directions:

Have students cut out the pieces of the desktop model and arrange them with or without resources and discuss/explain the diagram. The magnets may be used as a group activity for review, overview or assessment.



The Carbon Cycle-A Desktop hands-on Model

Cut out the 15 figures and illustrate the basic carbon cycle. You will also be demonstrating the conversion of light energy to chemical energy.

Light Energy

ATP

$CO_2 + H_2O$

Cellular Respiration in Mitochondria

Organic Molecules & O_2

Photosynthesis in Chloroplasts

Chemical Energy-used for metabolism, heat, light, etc.

The Carbon Cycle-A Desktop hands-on Model-Key-Modify as needed

Light Energy

Photosynthesis in Chloroplasts

$CO_2 + H_2O$

Organic Molecules & O_2

Cellular Respiration in Mitochondria

ATP

Chemical Energy-used for metabolism, heat, light, etc.

_____**Name**

4-Square

Complete the four squares shown below as related to cellular respiration.

Draw and label the reactants.	**Draw and label the products.**
Write the simple word equation for cellular respiration.	**Define cellular respiration and state where in the cell it occurs.**

Modeling the Mitochondrion

Unit (Lesson) Overview

Unit Title: Cellular Respiration

Lesson Summary: Students will create a model of a mitochondrion and use the model to compare and contrast the structure and function of a mitochondrion to a previously built chloroplast.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

Science Standards

MC.3.B.1 Compare and contrast the structure and function of *mitochondria* and *chloroplasts*

Math Integration

None

Literacy Integration

none

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

NS.9-12.3 Life Science:

Students should develop an understanding of the cell.

Students should develop an understanding of matter, energy, and organization in living systems.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective: Students will

- build a mitochondrion model and label the structures found in it
- explain the location and function of a mitochondrion
- compare/contrast the structure and function of a mitochondrion to a chloroplast.

Focus Question: How do mitochondria and chloroplasts compare/contrast as energy converting structures?

Prerequisites / Background Information:

- Students should have studied the structures of the eukaryotic cell.
- Students should have studied photosynthesis and the chloroplast in detail or it should follow.
- This lesson may be included in the study of cellular respiration and the mitochondria in detail.

Timeline:

Preparation:	10 minutes
Elicit/Engage:	10 minutes-5 to go over 4 square, 5 for video
Explore:	20 minutes to get materials, construct and label mitochondrion
Explain:	20 minutes for discussion and compare/contrast to chloroplast
Cleanup:	5 minutes

Teacher Preparation:

- Collect materials

Materials:

- 2 hotdog paper trays/student
- OR one hotdog paper tray and one plastic banana split tray /student
- Glue
- Sack of small craft beads-for knobs inside inner membrane
- Sack of tiny rubber bands-for circular DNA

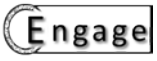
Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☒ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☒ Other: CD with video for engage
☐ Internet Web Browser	☐ Word Processing	

Internet Resources: List Resources Here or at End.

Procedures:	**Teacher's Notes:**
	
• Use caution with glue and small beads	Enter Notes as required.
	
• Review the 4 square activity from previous lesson	
	
• Show one or more of the Mitochondria videos	• On CD

Explore

- Build models of mitochondria

Explain

- Have students describe:
  The location and function of a mitochondrion
  Label/describe the structure of the mitochondrion

- Within all eukaryotic cells, site of cellular respiration/ATP production
- Include all the parts you desire

Elaborate

- Compare/contrast the structure and function of a mitochondrion to a chloroplast

- Venn diagram and key at bottom

Evaluate

Formative Assessment-Venn diagram

- Compare/contrast the mitochondrion to the chloroplast as an energy converting structure.

- Venn diagram and key at bottom

Summative Assessment

Extend

- Question-do all organisms use oxygen to produce energy?

Cross-Curricular

Notes:

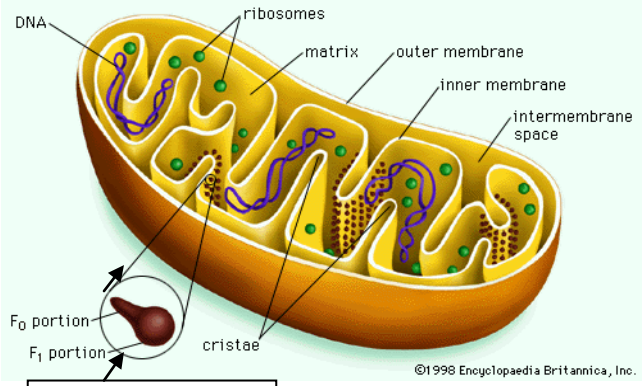
Background Information-Modeling the Mitochondrion

Mitochondria are spherical or rod-shaped organelles found within the cytoplasm of eukaryotic cells, and are referred to as the "powerhouse" of the cell since they act as the site for the production of high-energy compounds, such as ATP, which are a vital energy source for several cellular processes.

They produce large amounts of energy through oxidative phosphorylation of organic molecules during cellular respiration. That is, they are capable of using glucose and oxygen to produce energy (and releasing carbon dioxide and water in the process) for use in many metabolic processes. Thus, it is not surprising to find several mitochondria in high energy-requiring cells, such as muscle cells.

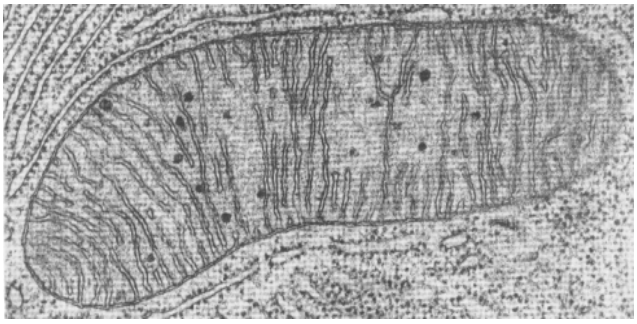
They are semi-autonomous, self-reproducing organelles because they contain their own genome. In fact, their DNA has become an important tool in tracking genetic histories since their genetic material is present in only one copy, and does not recombine in reproduction.

According to the endosymbiotic theory, mitochondria might have been the remnants of early bacteria engulfed by ancient eukaryotic cells a billion years ago that might have evolved and become energy-yielding structures within eukaryotic cells at present. http://www.biology-online.org/dictionary/Mitochondria



ATP Synthase

Image taken from http://media-2.web.britannica.com/eb-media/89/22489-004-EE9DC4F5.gif



http://library.thinkquest.org/3564/Cells/cell119-3.gif

Modeling the Mitochondrion

MC.3.B.5 Compare and contrast cellular respiration and photosynthesis as energy conversion pathways.

Objectives: Students will

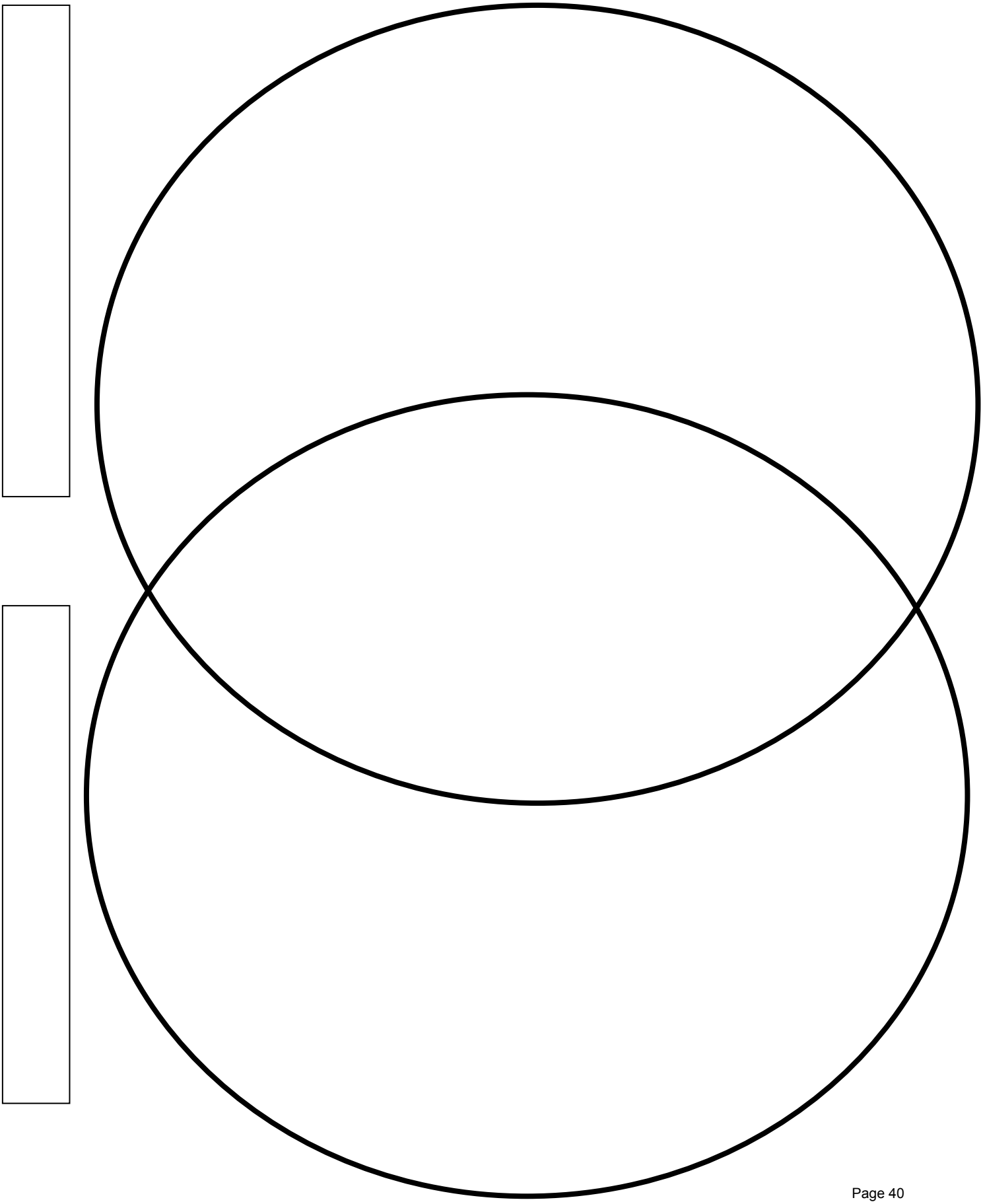
- Construct a model of a mitochondrion and label the structures found in it
- Explain the location and function of a mitochondrion
- Use a Venn diagram to compare and contrast cellular respiration and photosynthesis as energy conversion pathways
- Use a Venn diagram to compare and contrast the structure and functions of mitochondria and chloroplasts

Materials:

- Paper templates for mitochondrion model
- Glue (glue gun or sticks if desired)
- Sack/box of small craft beads-for knobs inside inner membrane
- Sack/box of medium craft beads for ribosomes
- Sack/box of tiny rubber bands-for DNA
- Venn diagrams for each student or pair of students if desired.

Directions:

Have students use the materials provided to construct a mitochondrion and label the structures in it. They may use the book or a diagram you provide as a guide. Use the Venn diagrams if desired.



Key for compare/contrast structure and function of mitochondrion and chloroplast

Mitochondrion	Both	Chloroplast
Glucose broken down	Creates and uses ATP	Glucose created
Cristae and other structures	Double membranes	Thylakoids and other structures
Not visible in cytoplasm	Similar shape	Visible in cytoplasm
CO_2 end product	Energy converting structures	O_2 end product
All eukaryotes	Have electron transport chains	Plants, algae, some protists
	Increased surface area	
	Intracellular	
	Similar in shape	
	Enzymes and chemical reactions	
And all you can think of!	And all you can think of!	And all you can think of!

Possible key for compare/contrast as energy converting structures

Mitochondrion	Both	Chloroplast
(bio)Chemical to ATP, heat, light	Convert energy	Light to chemical energy
Used by eukaryotes	Use enzymes	Used by photoautotrophs
	Take materials in and create a product	
For Activation energy to drive glycolysis	Require ATP to convert energy	For light independent reactions to occur
And all you can think of!	And all you can think of!	And all you can think of!

Mitochondrion Salad Tray Model

Lesson Overview

Unit Title: Cellular Respiration

Lesson Summary: Students will create a model of a mitochondrion and use the model to compare and contrast the structure and function of a mitochondrion to a previously built chloroplast.

Subject Area(s) and Grade Levels: Click box (es) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

MC.3.B.1 Compare and contrast the structure and function of *mitochondria* and *chloroplasts*

None

None

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

NS.9-12.3 Life Science:

Students should develop an understanding of the cell.

Students should develop an understanding of matter, energy, and organization in living systems.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective: Students will

- build a mitochondrion model and label the structures found in it
- explain the location and function of a mitochondrion
- Compare/contrast the structure and function of a mitochondrion to a chloroplast.

Focus Question: How do mitochondria and chloroplasts compare/contrast as energy converting structures?

Prerequisites / Background Information:

Students should have studied the structures of the eukaryotic cell.
Students should have studied photosynthesis and the chloroplast in detail or it should follow.
This lesson may be included in the study of cellular respiration and the mitochondria in detail.

Timeline:

Preparation: 10 minutes
Elicit/Engage: 10 minutes – 5 to go over 4 square, 5 for video
Explore: 15 minutes to get materials, construct and label mitochondrion
Explain: 20 minutes for discussion and compare/contrast to chloroplast
Cleanup: 5 minutes

Teacher Preparation:

• Collect materials

Materials:

- 4 clear, plastic salad tray lids or bottoms (or plastic banana split trays)/student
- Copy of the paper mitochondrion template/student
- 3-4 permanent markers of various colors/pairs of students
- Scissors for cutting out the paper mitochondrion template
- Scotch/masking tape to tape paper template to first tray

Procedure:

1. Cut out the mitochondrion template.
2. Tape the template face-down in the bottom of the first plastic tray.
3. Invert the tray and trace the outermost membrane of the mitochondrion. (The membranes and cristae show up best if using a black marker. Ribosomes and DNA can be different colors.) Do not trace the line that serves as the "window" for the internal view of the mitochondrion.
4. Trace the inside of the mitochondrion (cristae and several ribosomes, but not all of the ribosomes). Do not trace the DNA in this layer.
5. Place the second tray over the first tray and retrace everything exactly as it was traced onto the first tray.
6. Add the rest of the ribosomes to this layer. Using a new color, trace the DNA onto the second tray.
7. Place the third tray over the second tray and using the black marker, trace the outermost membrane and the line that serves as the "window" to the internal view of the mitochondrion.
8. Place the fourth tray over the third tray and using the black marker trace just the "window" to the internal view of the mitochondrion.
9. Remove the paper template and enjoy the colorful model of a mitochondrion.
10. Put away materials.

Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☒ Computer(s)	☐ Digital Camera
☒ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other:

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☒ Other: CD with video for engage
☐ Internet Web Browser	☐ Word Processing	

Internet Resources: List Resources Here or at End.

Procedures:	**Teacher's Notes:**
	
• Use caution with scissors.	

Elicit

- Review the 4 square activity from previous lesson
-

Engage

- Show one or more of the Mitochondria videos
- On CD

Explore

- Build models of mitochondria
-

Explain

- Have students describe: The location and function of a mitochondrion
- Within all eukaryotic cells, site of cellular respiration/ATP production
- Label/describe the structure of the mitochondrion
-

Elaborate

Formative Assessment – Use a Venn Diagram

- Compare/contrast the mitochondrion to the chloroplast as an energy converting structure.
-

Summative Assessment

Evaluate

-
-

Extend

- Question: Do all organisms use oxygen to produce energy?

Cross-Curricular

Notes:

Mitochondrion Salad Tray Model

Name:_____ Class:_____

Lesson Summary: Create a model of a mitochondrion and use the model to compare and contrast the structure and function of a mitochondrion to a previously built chloroplast.

Materials:

- 4 clear, plastic salad tray lids or bottoms
- Copy of the paper mitochondrion template/student
- 3-4 permanent markers (one should be a black marker) various colors/pairs of students
- Scissors for cutting out the paper mitochondrion template
- Scotch/masking tape to secure paper template to first tray

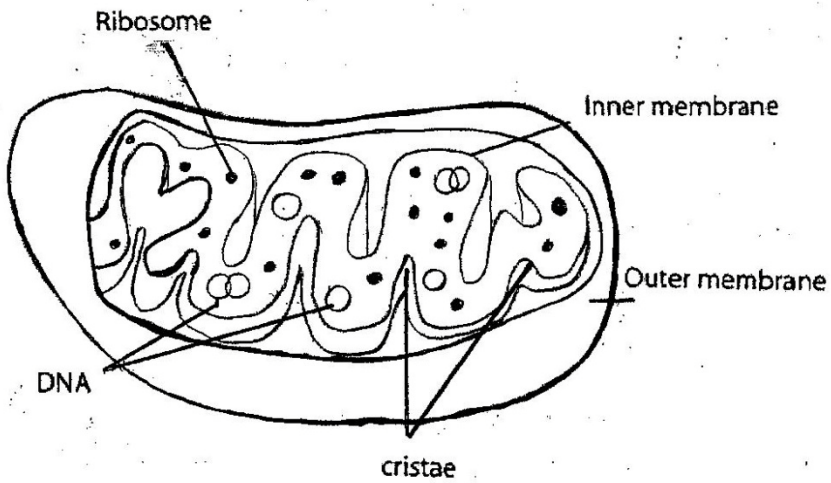
Procedure:

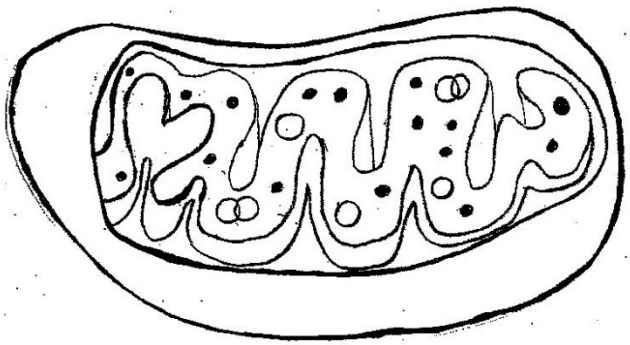
1. Cut out the mitochondrion template.
2. Tape the template face-down in the bottom of the first plastic tray.
3. Invert the tray and trace the outermost membrane of the mitochondrion. Do not trace the line that serves as the "window" for the internal view of the mitochondrion. (The membranes show up best if using a black marker.)
4. Trace the inside of the mitochondrion (outline the cristae and only a few of the ribosomes, but not all of the ribosomes). Do not trace the DNA in this layer.
5. Place the second tray over the first tray and retrace everything exactly as it was traced on to the first tray.
6. Add the rest of the ribosomes to this layer. Using a new color, trace the DNA on to the second tray.
7. Place the third tray over the second tray and using the black marker, trace the outermost membrane and the line that serves as the "window" to the internal view of the mitochondrion.
8. Place the fourth tray over the third tray and using the black marker, trace just the "window" to the internal view of the mitochondrion.
9. Remove the paper template and enjoy the colorful model of a mitochondrion.
10. Put away your materials.

Questions:

1. Describe the location and function of a mitochondrion.
2. Label and describe the structure of the mitochondrion.
3. Compare and contrast the structure and function of a mitochondrion to a chloroplast.

Mitochondrion Salad Tray Model





Cut out the mitochondrion and use to make the salad tray model.

Yeast Cellular Respiration

Lesson Overview

Unit Title: Cellular Respiration

Lesson Summary: Investigate the fermentation of yeast using various food sources.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

MC.3.B.3 Compare and contrast *aerobic* and *anaerobic respiration:*

- *lactic acid fermentation*
- *alcoholic fermentation*

- Measurement, graph data, investigate rates of change, and compare methods of reporting data to make inferences or predictions.

- Measurement, graph data, investigate rates of change, and compare methods of reporting data to make inferences or predictions.

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

NS.9-12.3 Life Science:

Students should develop an understanding of the cell.

Students should develop an understanding of matter, energy, and organization in living systems.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective:

- Students will compare and contrast aerobic and anaerobic respiration, including lactic acid and alcoholic fermentation.

Focus Question:

- How are aerobic and anaerobic respiration alike and different?

Prerequisites / Background Information:

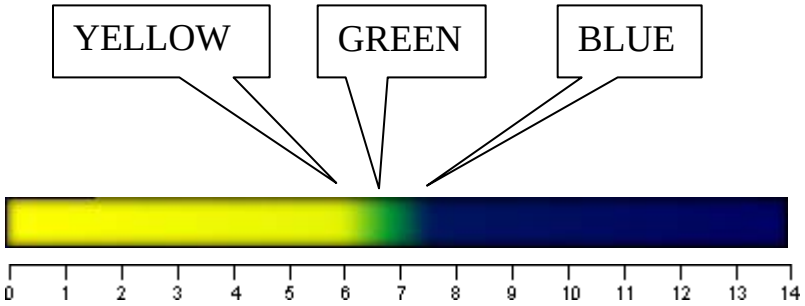
See Cellular Respiration-Background Information

For Yeast Cell Respiration Lab: Bromthymol blue (BTB) is a non-toxic acid-base indicator that can be used to indirectly measure levels of dissolved carbon dioxide (CO_2). The amount of CO_2 in a solution changes the pH. An increase in CO_2 makes a solution more acidic (the pH gets lower). A decrease in CO_2 makes a

solution more basic (the pH gets higher). The reason for this is that carbon dioxide that is dissolved in water is in equilibrium with carbonic acid (H_2CO_3). $CO_2 + H_2O \leftrightarrow H_2CO_3$

In any solution, while the majority of CO_2 stays as CO_2, some of it is converted to H_2CO_3, turning the solution slightly acidic. If CO_2 is added to the water, the level of H_2CO_3 will rise and the solution will become more acidic. If CO_2 is removed from the water, the amount of H_2CO_3 falls and the solution becomes more basic. Thus, acid-base indicators such as BTB can indirectly measure the amount of CO_2 in a solution.

Bromthymol Blue pH Color Chart



Also known as: 3',3''-dibromothymolsulfonephtalein

Type: $HIn + H_2O \rightleftharpoons In^- + H_3O^+$ **pK:** 7.30 **Approximate pH range for color change:** 6.0-7.6

Color of acid form: yellow **Color of base form:** blue

Source: http://antoine.frostburg.edu/chem/senese/101/acidbase/indicators.shtml, last accessed 25 Feb 2010.

Timeline:

Preparation:	1 hour
Elicit/Engage:	15 minutes
Explore:	35-40 minutes
Explain:	20 minutes
Cleanup:	5-10 minutes

Teacher Preparation:

Teacher Preparation – For 6 groups of 4 students

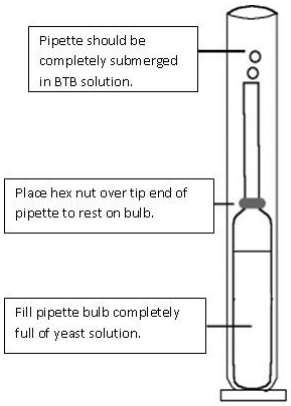
1. **Stock Yeast Solution:** At least 15 minutes prior to the lab, mix 2 packets (or 14 grams) of bread yeast with 120mL of **lukewarm** water (100°F/38°C). Stir for 2 minutes or until all the yeast is dissolved. Stir again just before use. (Yeast will survive an hour or more in solution.)
2. **Stock Sugar Solution:** Dissolve 15g of sugar in 120mL of lukewarm water. Stir for 2 minutes or until all the sugar is dissolved.
3. **Stock BTB Solution:** Just prior to use, add 100ml of 0.04% BTB solution to 900ml of warm (38° C) **distilled** water. When mixed with distilled water, the BTB solution will be green. The BTB solution must be held at approximately this temperature until use.
4. **Distilled Water:** 100mL at room temperature.
5. Divide the students into teams with 4 students in each. Be sure each team member understands their role. **Assign the following roles:** Manager/Timer, Control

Recorder/Observer, Experiment A Recorder/Observer, Experiment B Recorder/Observer.

Materials:

Materials Per Group:

- 10 - Medicine cups
- 1- 250mL Beaker
- 10 ml Distilled water
- 15mL of Stock Yeast Solution
- 10mL of Stock Sugar Solution
- 160mL of Stock Bromthymol Blue (BTB) Solution
- 3 - Disposable plastic pipettes
- 3 - Metal hex nuts
- 3 - 50mL Graduated cylinders
- 1- Stopwatch
- Safety goggles



Technology – Hardware: (Click boxes of all equipment needed)

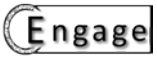
☐ Camera ☐ Computer(s) ☐ Digital Camera
☐ Projection System ☐ Television ☐ VCR
☐ Video Camera ☐ Internet Connection ☐ Other:

Technology – Software: (Click boxes of all software needed.)

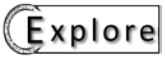
☐ Database/Spreadsheet ☐ Multimedia ☐ Other:
☐ Internet Web Browser ☐ Word Processing

Internet Resources: adapted from http://www.mysciencebox.org/bubblingyeast)

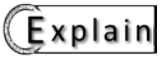
Procedures:	**Teacher's Notes:**
	
• Safety goggles	
	
• What do pickles, bread, yogurt, wine, beer, and cheese have in common? See "Elicit" handout for more information.	• All of these foods are made by fermentation. When you ferment a food, you encourage growth of "good" microorganisms in it, while preventing growth of spoilage-causing microorganisms. Doing this successfully may require special ingredients and carefully controlled conditions, such as temperature and pH. By eating spoilage-sensitive parts of the food, and releasing chemicals as a by-product, the microorganisms help preserve the food, and change its flavor and texture in interesting ways



- Blow carefully through a straw into BTB (bluish liquid) and watch it turn green then yellow before your eyes. Discuss the results. See "Engage" handout for more information.



- See Yeast Cell Respiration Lab handout



- Graph data from lab and complete analysis questions.
- Jigsaw Activity

- n/a

Formative Assessment:
Graph and Analysis Questions for Lab
Questions to Jigsaw Articles

Summative Assessment:

-

Cross-Curricular

- List Information as Applicable with Bullets/Steps

Notes:

- List Information as Applicable with Bullets/Steps

Elicit:

Place 6 common grocery store items on a table and ask the students what they have in common.
There is a list of items below from which to choose.
Ask questions to determine what the students know/understand about fermentation.

Examples of common grocery store items that have used fermentation in their production.

Sourdough breads	Yogurt	Vanilla	Olives
Chocolate	Cheese	Soy sauce	Tabasco
Black teas	Buttermilk	sauerkraut	Vinegar
Coffee	pickles	salami	ketchup

If you don't /can't have the real items available, use pictures of foods….the real thing on display would be best!

What do pickles, bread, yogurt, wine, beer, and cheese have in common?

All of these foods are made by fermentation. When you ferment a food, you encourage growth of "good" microorganisms in it, while preventing growth of spoilage-causing microorganisms. Doing this successfully may require special ingredients and carefully controlled conditions, such as temperature and pH. By eating spoilage-sensitive parts of the food, and releasing chemicals as a by-product, the microorganisms help preserve the food, and change its flavor and texture in interesting ways.

Here's a brief look at how fermentation is used to make different foods:

Pickled Vegetables: The vegetable is soaked in salt brine, allowing the growth of bacteria that eat the vegetable's sugars and produce tart-tasting lactic acid.

Wines: Yeasts, added to crushed grapes, eat the grapes' sugars and produce alcohol.

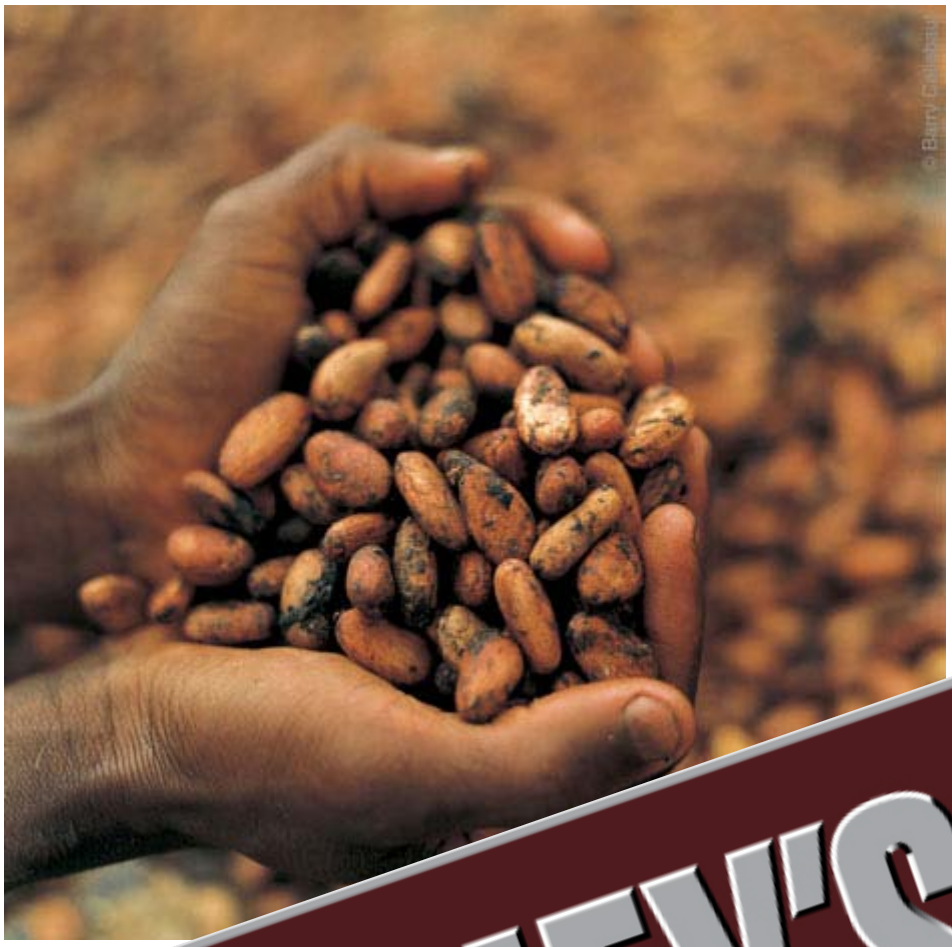
Breads: Yeasts, added to dough, digest sugars (derived from starches in dough) and produce carbon dioxide, causing the dough to rise.

Cheeses: Milk bacteria digest the milk sugar lactose and produce lactic acid, which acts with the added enzyme rennet to curdle the milk. The cheese maker drains off the whey and compacts the curds, which various microbes then ripen into a mature cheese.

http://www.exploratorium.edu/cooking/pickles/fermentation.html

Engage:

http://www.nsta.org/publications/download.aspx?id=Z349URi8cV4vjNX0iTUM!plus!43mJzqMOQheLGl2FTDOG6M



HERSHEY'S®
Chocolate World®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Sauerkraut

Sourdough Bread

http://outofthegarden.files.wordpress.com/2006/11/sourdough-bread.JPG


$3.59
37% LESS SODIUM
THAN KIKKOMAN REGULAR SOY SAUCE
ALL-PURPOSE
SEASONING
KIKKOMAN
NATURALLY BREWED
Less Sodium
Soy Sauce
20 FL OZ (591mL)
OVER 300 YEARS OF EXCELLENCE
SEE NUTRITION INFORMATION FOR SODIUM CONTENT


PLAIN
YOGURT
8 OZ.

Yeast Cellular Respiration Lab

(adapted from http://www.mysciencebox.org/bubblingyeast)

Teacher Background

Bromthymol blue (BTB) is a non-toxic acid-base indicator that can be used to indirectly measure levels of dissolved carbon dioxide (CO_2). The amount of CO_2 in a solution changes the pH. An increase in CO_2 makes a solution more acidic (the pH gets lower). A decrease in CO_2 makes a solution more basic (the pH gets higher). The reason for this is that carbon dioxide that is dissolved in water is in equilibrium with carbonic acid (H_2CO_3).

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

In any solution, while the majority of CO_2 stays as CO_2, some of it is converted to H_2CO_3, turning the solution slightly acidic. If CO_2 is added to the water, the level of H_2CO_3 will rise and the solution will become more acidic. If CO_2 is removed from the water, the amount of H_2CO_3 falls and the solution becomes more basic. Thus, acid-base indicators such as BTB can indirectly measure the amount of CO_2 in a solution.

Teacher Preparation – For 6 groups of 4 students

1. **Stock Yeast Solution:** At least 15 minutes prior to the lab, mix 2 packets (or 14 grams) of bread yeast with 120mL of **lukewarm** water (100°F/38°C). Stir for 2 minutes or until all the yeast is dissolved. Stir again just before use. (Yeast will survive an hour or more in solution.)

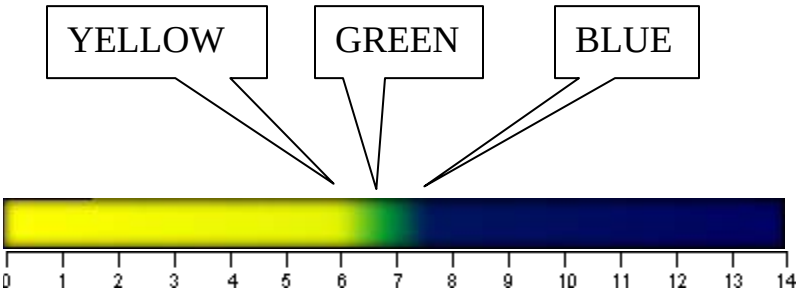
2. **Stock Sugar Solution:** Dissolve 15g of sugar in 120mL of lukewarm water. Stir for 2 minutes or until all the sugar is dissolved.

3. **Stock BTB Solution:** Just prior to use, add 100ml of 0.04% BTB solution to 900ml of warm (38° C) **distilled** water. When mixed with distilled water, the BTB solution will be green. The BTB solution must be held at approximately this temperature until use.

4. **Distilled Water:** 100mL at room temperature.

5. Divide the students into teams with 4 students in each. Be sure each team member understands their role. **Assign the following roles:** Manager/Timer, Control Recorder/Observer, Experiment A Recorder/Observer, Experiment B Recorder/Observer

Bromthymol Blue pH Color Chart



Also known as: 3',3''-dibromothymolsulfonephtalein

Type: $HIn + H_2O \rightleftharpoons In^- + H_3O^+$ **pK:** 7.30 **Approximate pH range for color change:** 6.0-7.6

Color of acid form: yellow **Color of base form:** blue

Source: http://antoine.frostburg.edu/chem/senese/101/acidbase/indicators.shtml, last accessed 25 Feb 2010.

Extension Activity:

Other Nutrient Sources for the yeast – 5ml per group (Most of these work better if diluted in water 1:1) milk, apple juice, soda, Kool-aid, potato starch solution, flour in water, chicken broth, etc..

Other Environmental Conditions: Choose way, *APPROVED BY YOUR TEACHER*, to alter the environmental conditions relative to the Control Group.

Yeast Cellular Respiration Lab

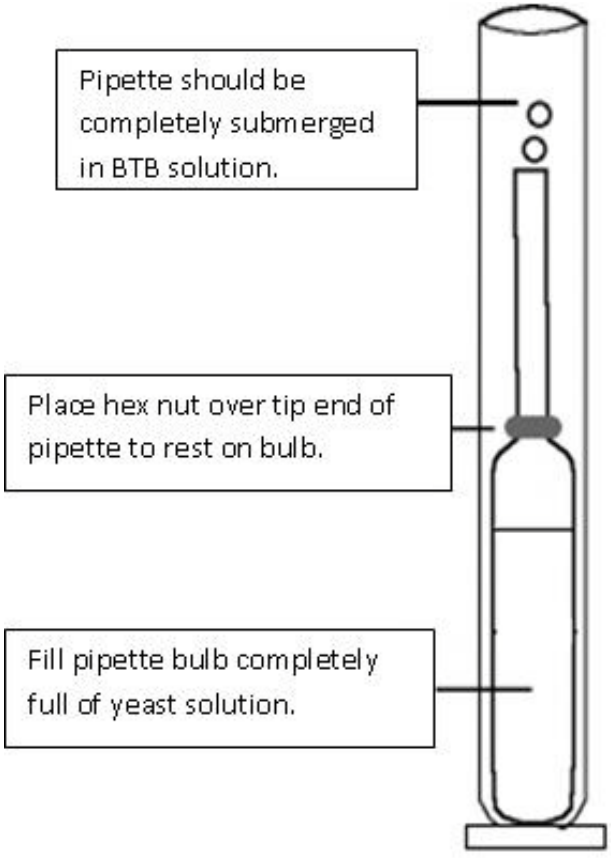
(adapted from http://www.mysciencebox.org/bubblingyeast)

Bubbling Yeast

Yeasts are single celled fungi and a great model organism for studying respiration in the classroom. The species *Saccharomyces cerevisiae* is commonly used for leavening bread. Other species, such as *Candida albicans,* are known to cause infections in humans (diaper rash being one of the most common). In this investigation, you will fill the bulb of a disposable pipette with a yeast solution and then submerge the pipette in a graduated cylinder filled with Bromthymol Blue solution. You can then measure the rate of respiration by counting the number of bubbles of carbon dioxide (CO_2) gas that emerge from the tip of the pipette in a period of time. *As BTB is an indicator of acids and bases, the student will determine if carbon dioxide is produced during cellular respiration*. By varying the conditions, you can discover what variables affect the rate of respiration in yeast.

Materials per Group:

- 10 - Medicine cups
- 1- 250mL Beaker
- 10 ml Distilled water
- 15mL of Stock Yeast Solution
- 10mL of Stock Sugar Solution
- 160mL of Stock Bromthymol Blue Solution
- 3 - Disposable plastic pipettes
- 3 - Metal hex nuts
- 3 - 50mL Graduated cylinders
- 1- Stopwatch
- Safety goggles



PROCEDURE:

GROUP MANAGER/TIMER
1. From the lab supply area, obtain the following items: beaker, 10 medicine cups, 3 pipettes, 3 hex nuts, 3 graduated cylinders, and a stop watch.
2. Divide the materials among the group members, keeping 3 medicine cups, the beaker, and the stop watch for your use.
3. Take the medicine cups to the supply area. Fill one with 15mL Stock Yeast Solution, one with 10mL Stock Sugar Solution, and one with 10mL of Distilled water.
4. Give the medicine cups containing the solutions to the group members. Remind the group members to prepare their mixtures **at the same time** and then finish assembling their materials as shown in the diagram on the first page.
5. Take the 250mL beaker and return to the supply area. Add 160mL of Stock Bromthymol Blue Solution to the beaker. Return to the group.
6. Each member will now pour the Bromthymol Solution into their cylinder until the tip of the pipette is covered.
7. **Wait 2 minutes!**
8. Begin timing and announce each minute to the group members so they can tally the number of bubbles per minute. **Continue for 10 minutes!**
9. Wait 2 minutes to allow the yeast time to equilibrate.
10. Count how many bubbles emerge from the top of the pipette every minute for 10 minutes.
11. Record this data on the table below.
12. Graph data from all experimental groups: Control, Experiment A, Experiment B.

PROCEDURE:

CONTROL RECORDER/OBSERVER
1. Measure 5mL of Stock Yeast Solution into a medicine cup.
2. Add 5mL of distilled water to the other medicine cup.
3. **Wait** until the other group members have measured the solutions into the cups before continuing!
4. Pour the distilled water into the yeast solution. Stir gently with the pipette to combine.
5. Carefully squeeze **all the air** out of the pipette bulb. You will need to flatten it completely. Draw up the solution into the pipette until it reaches the base of the bulb. Invert the pipette and let the solution run down into the bulb. You can tap the bulb of the pipette on the table to get the solution into the bulb. All three group members should have approximately the same amount of solution in each pipette.
6. Place a hex nut over the neck of the inverted pipette.
7. Gently drop the pipette with hex nut into the 50ml graduated cylinder, **bulb downward.**
8. Fill the graduated cylinder with **warm** (100°F/38°C) Bromthymol Blue solution until the pipette is completely submerged.
9. Wait 2 minutes to allow the yeast time to rest.
10. Begin counting when the manager/timer tells you to begin. Tally each bubble that rises from the pipette. The manager will signal in one minute intervals.
11. Record this data on the table below.
12. When the manager signals the experiment is completed, graph the data from all experimental groups: Control, Experiment A, Experiment B.

DATA TABLE

CONTROL		
5ml Yeast Solution		5ml Distilled Water
Time (minutes)	Number of Bubbles (Tally Marks)	Total Number of Bubbles
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

PROCEDURE

EXPERIMENT A RECORDER/OBSERVER
1. Measure 5mL of Stock **Yeast** Solution into a medicine cup.
2. Measure 5mL of Stock **Sugar** Solution into a medicine cup.
3. **Wait** until the other group members have measured their solutions into the cups before continuing!
4. Pour the sugar solution into the yeast solution. Stir gently with the pipette to combine.
5. Carefully squeeze **all the air** out of the pipette bulb. You will need to flatten it completely. Draw up the solution into the pipette until it reaches the base of the bulb. Invert the pipette and let the solution run down into the bulb. You can tap the bulb of the pipette on the table to get the solution into the bulb. All three group members should have approximately the same amount of solution in each pipette.
6. Place a hex nut over the neck of the inverted pipette.
7. Gently drop the pipette with hex nut into the 50ml graduated cylinder. **Bulb Downward!**
8. Fill the graduated cylinder with warm (100°F/38°C) Bromthymol Blue solution until the pipette is completely submerged.
9. Wait 2 minutes to allow the yeast time to rest.
10. Begin counting when the manager/timer tells you to begin. Tally each bubble that rises from the pipette. The manager will signal in one minute intervals.
11. Record this data on the table below.
12. When the manager signals the experiment is complete, graph the data from all experimental groups: Control, Experiment A, Experiment B.

DATA TABLE

EXPERIMENT A		
5ml Yeast Solution		5ml Sugar Solution
Time (minutes)	Number of Bubbles (Tally Marks)	Total Number of Bubbles
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

PROCEDURE:

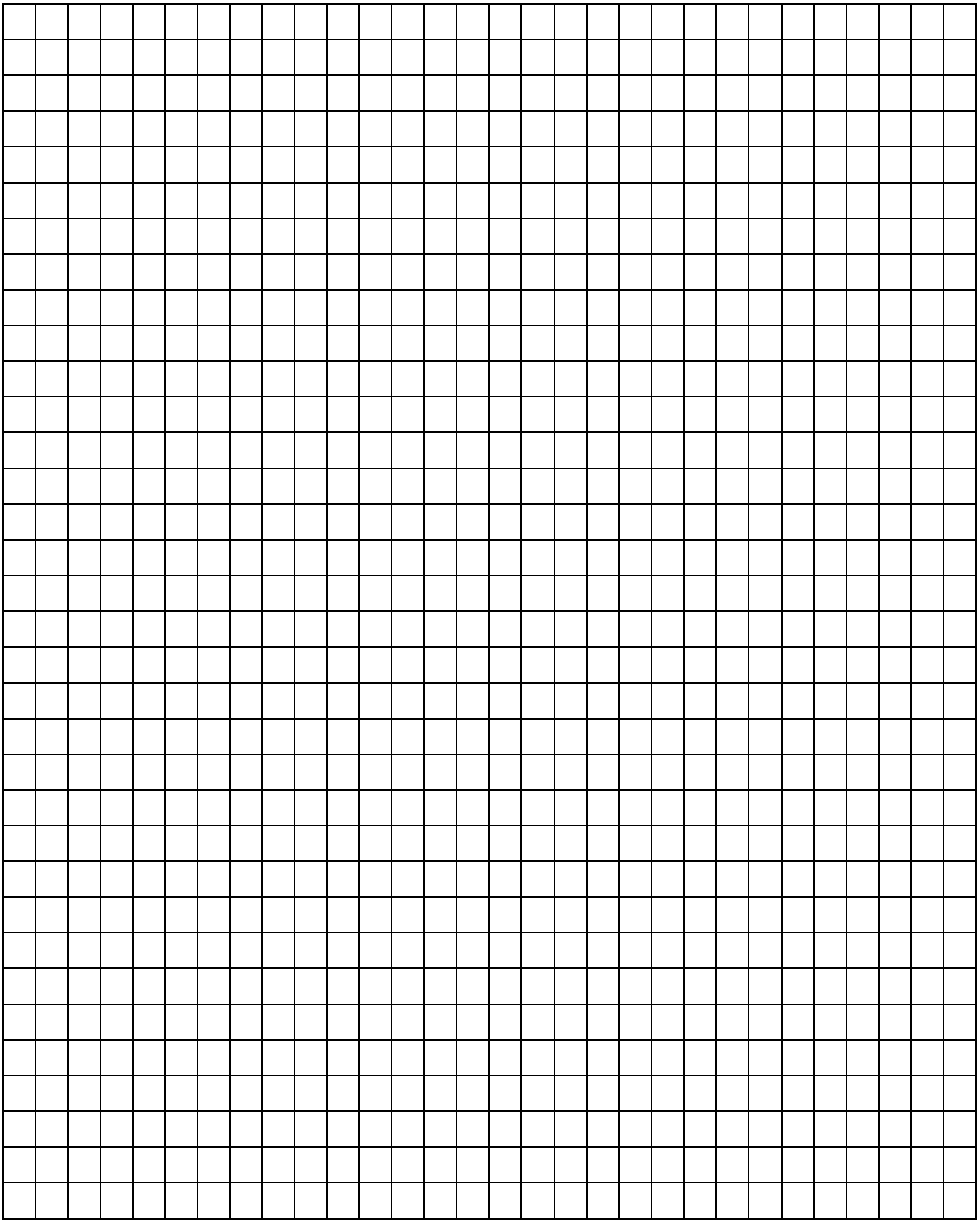
EXPERIMENT B RECORDER/OBSERVER
1. Use 3 of the medicine cups. Measure 5mL of Stock Yeast Solution into a medicine cup.
2. Measure 5mL of Stock Sugar Solution into a medicine cup.
3. Measure 5mL of Distilled Water into a medicine cup.
4. **Wait** until the other group members have measured their solutions.
5. Pour the sugar solution and the distilled water into the yeast solution. Stir gently with the pipette to combine.
6. Carefully squeeze **all the air** out of the pipette bulb. You will need to flatten it completely. Draw up the solution into the pipette until it reaches the base of the bulb. Invert the pipette and let the solution run down into the bulb. You can tap the bulb of the pipette on the table to get the solution into the bulb. All three group members should have approximately the same amount of solution in each pipette.
7. Place a hex nut over the neck of the inverted pipette.
8. Gently drop the pipette with hex nut into the 50ml graduated cylinder. **Bulb Downward!**
9. Fill the graduated cylinder with warm (100°F/38°C) Bromthymol Blue solution until the pipette is completely submerged.
10. Wait 2 minutes to allow the yeast time to rest.
11. Begin counting when the manager/timer tells you to begin. Tally each bubble that rises from the pipette. The manager will signal in one minute intervals.
12. Record this data on the table below.
13. Graph data from all experimental groups: Control, Exp. A, Exp. B.

DATA TABLE

EXPERIMENT B		
5ml Yeast Solution	5ml Sugar Solution	5 ml Distilled Water
Time (minutes)	Number of Bubbles (Tally Marks)	Total Number of Bubbles
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

DATA ANALYSIS

Graph data from ALL tables. Be sure to include a title, key, and label both axes.
REMEMBER THE UNITS!



Analysis Questions: Each person in the group should answer the questions individually.

1. Describe how “Experimental Set-ups” A and B differ from the “Control Set-up”.

2. What was the experimental design intended to measure? Was it successful? Explain.

3. After completing the activity and graph, analyze your graph and then describe your observations below, in as much detail as possible!

4. Describe any changes in the color of the BTB indicator solution. Explain why this color change occurred.

Teacher Key for Analysis Questions:
Each person in the group should answer the questions individually.

1. Describe how "Experimental Set-ups" A and B differ from the "Control Set-up".

Experimental Set-Ups	Yeast	Stock Sugar Solution	Distilled Water
Control	5 mL		5 mL
Experiment A	5 mL	5 mL	
Experiment B	5 mL	5 mL	5 mL

The control had no sugar, Exp A had 5 mL of Stock Sugar Solution, Exp. B had a diluted Stock Sugar Solution

2. What was the experimental design intended to measure? Was it successful? Explain.
The experiment was designed to indicate the CO_2 produced by the fermentation of yeast. The indicator showed no change in the control, but turned yellow in Exp. A faster than it turned yellow in Exp. B. (This may or may not be evident, but both A and B should indicate that carbon dioxide was produced….with less being evident in the dilute sugar solution.)

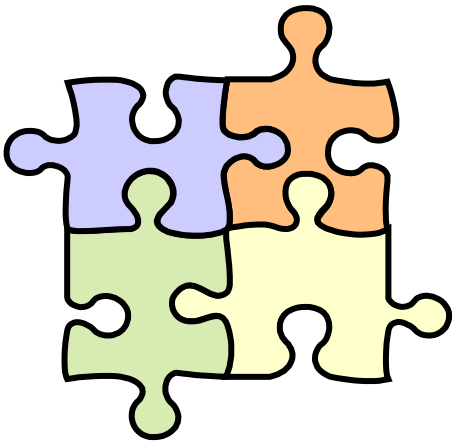
3. After completing the activity and graph, analyze your graph and then describe your observations below, in as much detail as possible!

The graph should indicate the results from the data…as predicted above….fewer bubbles in Exp. B and Exp. A…..less carbon dioxide produced in Exp. B and Exp. A.

4. Describe any changes in the color of the BTB indicator solution. Explain why this color change occurred.

   The BTB turned yellow when carbon dioxide is released in it. This change occurs because the carbon dioxide combines with water to form carbonic acid. BTB turns yellow in the presence of an acid.

Jigsaw Strategy



A Jigsaw Strategy is one way a teacher can cover a large amount of reading in a short period of time.

Implementation

1. Divide students into three, four, five, or six "jigsaw" groups depending on the number of articles to be read. In each group have students count off – 1, 2, 3, 4, etc.
2. Assign selected articles. These are the jigsaw "pieces". Give the first article to the 1's in the group, the second article to the 2's, etc.
3. Allow students enough time to read their article at least twice. It may be helpful to require students to make notes as they read (Examples of notes: main ideas, questions and answers, a chart or outline).
4. Next form new groups by having one student from each jigsaw group join students who have read the same article. Allow time for the new group to discuss the main points of their article.
5. Bring the students back into their original groups.
6. Have each student present his or her article to the group.

Other options:

Students can remain at their tables and present their article to their individual groups.

OR

Students can regroup as a whole class and all 1's can team teach, all 2's, all 3's, etc.

Implementation Tip:

Assign a team leader in each group to help move the participation along smoothly. The teacher should move from group to group and observe. Appropriate interventions may be necessary until the team leader becomes comfortable with the role.

Reading Log for “The Chemistry of Marathon Running”

1. Which types of respiration do humans use?

2. Compare aerobic and anaerobic respiration. You should find at least 4 comparisons.

Reading Log for “Food Microbiology”

1. Why would an organism use anaerobic respiration instead of aerobic respiration?

2. What type of organism is more likely to use anaerobic respiration?

3. During glycolysis and fermentation how many net ATPs are formed per glucose molecule. Explain.

Reading Log for “Aerobic Respiration in Humans”

1. Summarize “The Beginning of Respiration”.

2. Summarize “Glycolysis”.

3. Summarize “Kreb’s Cycle”.

4. Summarize “Electron Transport Chain”.

The Chemistry of Marathon Running

By Brian Rohrig

As the starting gun sounds, a sea of runners slowly surges forward. The 2007 Columbus Marathon has officially started. Over 3,000 runners begin a journey that will alternate between exhaustion and exhilaration, not to mention downright pain.

This is my fifth marathon, and my goal today is to qualify for the Boston Marathon. At 45 years of age, a time of 3 hours and 30 minutes gets me in. I am running with the 8-minute mile pace team. Eight-minute miles will get me to Boston.

First few miles

The first mile is slow—but that's not a bad thing. In past marathons, I have made the mistake of starting out too fast. For every minute that I go out too fast in the first half, I will lose four minutes in the second half.

Right now, my adrenalin is pumping. This hormone, secreted by the adrenal glands, which are located on top of the kidneys, works by putting more sugar into my blood and by breaking down fat. The release of adrenalin is like flooring the accelerator in a car. You get a little boost now, but you run out of gas sooner. Fortunately, this adrenalin rush is short-lived, and the elbow-to-elbow press of bodies prevents me from using up too much energy at the beginning.

Today is perfect marathon weather—sunny and in the low 50s. Before I reach the 1-mile mark, I am already hot. So I discard the old sweatshirt that kept me warm at the starting line. Just like a car burns fuel to move, my body burns fuel to run. At 155 pounds, for every mile I run, I burn about 100 kilocalories. (What we commonly refer to as Calories—with a capital C—are actually kilocalories.)

If I maintain my present pace, I will have burned over 3,000 kilocalories during the marathon, which is equivalent to losing one pound. That's a lot of work to lose just one pound!

Where does my energy come from?

I am breathing heavier than usual to increase my oxygen intake. Right now, my body combines this oxygen with fuel to produce energy. The fuel comes from the three main food nutrients: protein, fat, and carbohydrates (which are mostly starch and sugars).

Protein typically accounts for only 2% to 5% of the body's total energy expenditure, perhaps rising to as high as 8% during the marathon. Fat contributes to 60% of the energy produced when our bodies are at rest, but when we run, only 15% of the energy that we need comes from fat. So for the next few hours, my body will receive the bulk of its energy from glucose ($C_6H_{12}O_6$), a simple sugar resulting from the breakdown of most carbohydrates (Fig. 1).

The body's preferred fuels for marathon running are glucose, fat, or both, depending on the intensity of a runner's pace and the time point in the race.

During aerobic respiration, glucose combines with oxygen to form energy as follows:

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

For runners, the most efficient source of glucose is a large molecule called glycogen that is stored in the liver and muscles (Fig. 2). The average person has about 2,000 kilocalories worth of glycogen stored up, which is enough to run about 20 miles.

Early in the race, my body is getting most of its glucose from glycogen in my muscles. Then, as muscle glycogen becomes low, more glucose will come from liver glycogen. To increase my glycogen stores, three days

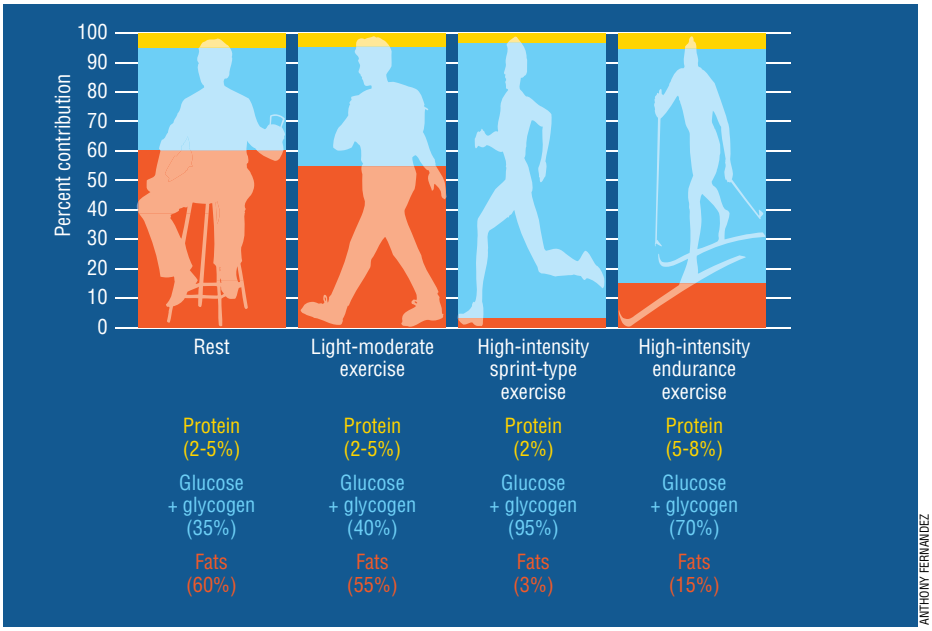
before the race, I ate a lot of carbohydrates—such as pasta, bread, and cereals—while training very hard. This combination of diet and training stimulated the production of glycogen in my muscles.

As I am running, my energy also comes from a process that doesn't use oxygen. Called anaerobic respiration, this process breaks down glucose into lactic acid ($C_3H_6O_3$) and energy as follows:

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + \text{energy}$$

As I am warming up, most of my energy comes from the anaerobic process. But after a few miles, as my heart rate increases and my blood receives more oxygen, the aerobic process becomes the predominant source of energy. Throughout the whole race, though, my energy will come from both processes, with the aerobic process dominating as I hit a steady state.

During these first few easy miles, it is tempting to want to go faster. I feel like I could run all day at this pace. The many miles of training make it seem easy so far, but the farthest I ran during training was 20 miles three weeks ago. After that, I tapered off to allow my body to recover. So I prefer to run at a steady pace to preserve my glycogen reserves and burn fat more efficiently.



ANTHONY FERNANDEZ

Illustration of the contribution of carbohydrates (blue), fat (pink), and protein (yellow) to energy metabolism during various intensities of excercise.

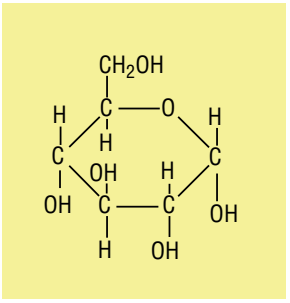


Figure 1. Structure of glucose.

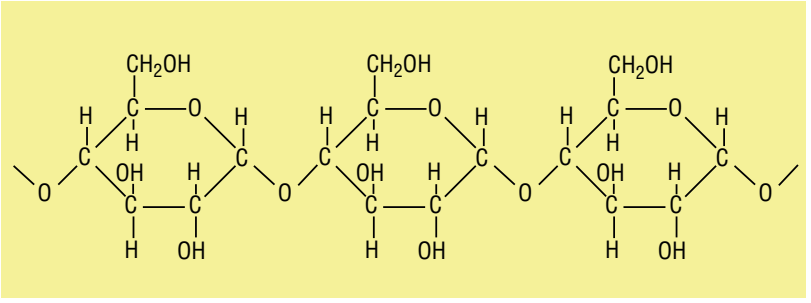


Figure 2 Stucture of glycogen.

ISTOCKPHOTO.COM

Staying hydrated

I bypass the first of the aid stations and then try to drink about 0.2 liter every 2 miles. I prefer Gatorade to water, since it provides sugar—in the form of sucrose and glucose—that gives me a continued energy boost. After just a few minutes, the sugar will pass through the stomach and into the small intestine, where it will be absorbed into the bloodstream.

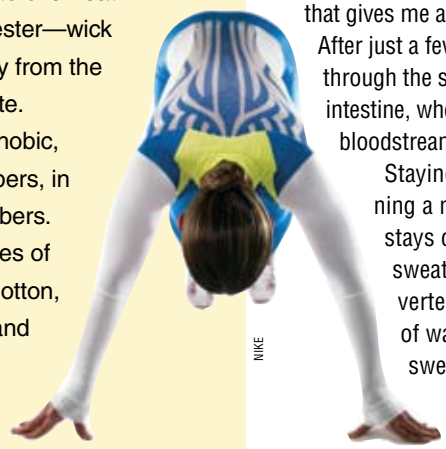
Staying hydrated is essential to running a marathon because the body stays cool by the evaporation of sweat. As carbohydrates are converted into energy, up to 0.5 liter of water per hour are lost through sweating. So I need to drink at least that much per hour to maintain good hydration.

Running Apparel that Wicks Away Sweat

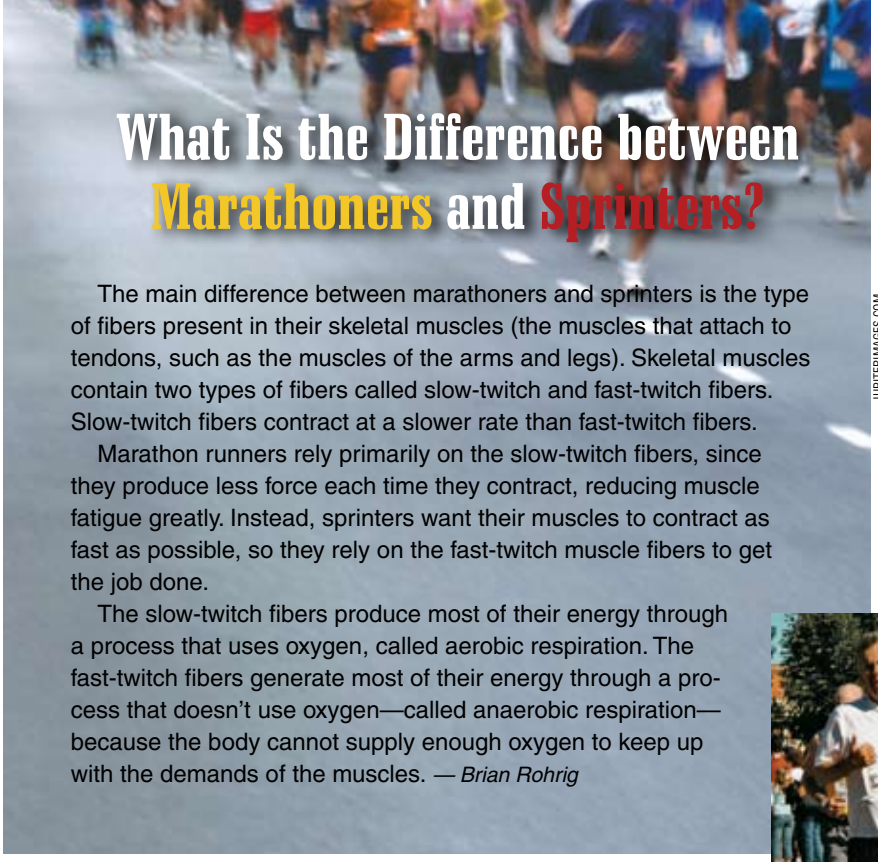
One of the cardinal rules of running is "ABC," or "anything but cotton." Cotton tends to hold in sweat, adding weight. Since a shirt remains wet for a long time, it is difficult for sweat to evaporate, which could cause a runner to overheat.

Instead, nearly all synthetic fabrics—such as nylon and polyester—wick away sweat and keep you dry. They work by drawing water away from the interior of the fabric to the outside, where it can quickly evaporate.

Synthetic fabrics are made of very thin fibers that are hydrophobic, that is, they repel water. These fabrics consist of a network of fibers, in which water can easily travel through the spaces between the fibers. As a result, water quickly and efficiently travels along the surfaces of these fibers without being absorbed by the fibers themselves. Cotton, on the other hand, is hydrophilic, which is why it attracts water and tightly absorbs it. — *Brian Rohrig*



NIKE



What Is the Difference between Marathoners and Sprinters?

The main difference between marathoners and sprinters is the type of fibers present in their skeletal muscles (the muscles that attach to tendons, such as the muscles of the arms and legs). Skeletal muscles contain two types of fibers called slow-twitch and fast-twitch fibers. Slow-twitch fibers contract at a slower rate than fast-twitch fibers.

Marathon runners rely primarily on the slow-twitch fibers, since they produce less force each time they contract, reducing muscle fatigue greatly. Instead, sprinters want their muscles to contract as fast as possible, so they rely on the fast-twitch muscle fibers to get the job done.

The slow-twitch fibers produce most of their energy through a process that uses oxygen, called aerobic respiration. The fast-twitch fibers generate most of their energy through a process that doesn't use oxygen—called anaerobic respiration—because the body cannot supply enough oxygen to keep up with the demands of the muscles. — *Brian Rohrig*

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Hitting wall after wall

Around mile 9, I am given a little packet of energy gel. These gels contain a mixture of simple carbohydrates (made of one or two sugar molecules) and complex carbohydrates (made of long chains of glucose molecules), which give you an energy boost. This energy boost will likely start to kick in around mile 10 or 11.

The midpoint of the race arrives. My time is 1 hour and 44 minutes—right on pace. The streets of downtown Columbus are lined with cheering spectators. This gives me a little energy boost—probably that adrenalin kicking in again. Since it draws from my glycogen reserves, it is best to not let my adrenalin get too out of hand. My glycogen levels are running dangerously low, as I am about to find out.

The next 3 miles begin a gradual uphill incline, hardly noticeable at first, but it begins to take a toll on my body. Around mile 14, the balloons that my pace group carry begin to recede in the distance. I never catch up with them again. Around mile 15, I feel like I have hit a wall. This is a bad sign, since it shouldn't happen until at least mile 20, due to my training routine.

This is where my glycogen reserves probably run very low, and my body has to rely on other fuels to get by. It's probably not really "the" wall or I may not have made it another 11 miles. Around mile 18, I feel like I hit another wall, so I receive another dose of energy gel, which I greedily gobble down. At mile 20, I feel like I hit yet another wall. Past mile 20, it's pretty much pure pain.

MARATHONFOTO.COM

Brian Rohrig runs the last miles of the Columbus Marathon.

Carbohydrates to the rescue

At any point of the marathon, I am using both glucose and fat as my fuel. At the beginning of the marathon, about 75% of my fuel is due to glucose metabolism and 25% is due to fat. As the race progresses, this ratio reverses. By mile 20, I feel as though I have no glycogen left in my body. In fact, glycogen never really runs out—it just runs low. I am hitting every aid station now, and it's the only thing that keeps me going. I gulp down Gatorade as if it were gold, coveting the few precious carbohydrates it supplies.

Once glycogen reserves are very low, my body relies on the next best thing to burn for energy—fat. At first glance, it may seem like fat is a far better energy source: It supplies 9 kilocalories per gram, while carbohydrates provide 4 kilocalories per gram. But the body likes its fat and is not ready to give it up quite so readily.

Even the skinniest runner has enough fat on his body to run 600 miles. Why then am I having trouble running these last six? The reason is that although a given amount of fat produces more than twice as much energy as the same amount of glucose, to break down each molecule of fat requires four times as many oxygen molecules than to break down each molecule of glucose. So my body simply can't take in oxygen and transport it fast enough to convert enough fat into energy.

The final stretch

Somehow, I make it through the last few miles. I try to put out of my mind thoughts of the very first marathon runner of ancient Greece, who dropped dead after finishing the world's first marathon. The last mile is lined by cheering spectators, and I even manage to pull out a respectable sprint over the last 0.2 mile. My final time is 3 hours, 46 minutes, and 41 seconds, not good enough for the Boston Marathon, but still my best marathon time ever!

I am given a lightweight shiny blanket, which reflects my body heat back into me, keeping me from getting chilled. Although my joints are stiff and I ache all over, I feel both exhausted and exhilarated. I grab a bagel, a banana, and some Gatorade. I am afraid to sit down for fear I will never get up again. Whereas a few miles back I was vowing never to do this again, I am already planning my next marathon. Boston, here I come!

Brian Rohrig teaches at Jonathan Alder High School in Plain City (near Columbus), OH. His most recent *ChemMatters* article, "The Chemistry of Arson Investigation," appeared in the April 2008 issue.

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Aerobic Respiration in Humans

Contributor
By JacobS, eHow Contributing Writer

Aerobic respiration is one of the most common processes found across a wide array of biological life. The primary definition is that aerobic respiration requires oxygen, whereas anaerobic respiration does not. Humans have a complex aerobic respiration process that requires oxygen to feed cells, the basic unit of life on Earth.

The Basic Units of Life

1. The term "cell" was first used in 1665 by Robert Hooke. Since then, the cell has revolutionized our understanding of biology. When we eat, we are really feeding the cell, which is one of the insights of cell theory developed in 1839. At the atomic level, life is primarily composed of carbon. Most molecules important to life are composed of a carbon backbone plus oxygen and hydrogen. Phosphate and nitrogen are also sometimes integral.

The Beginning of Respiration

2. Once digestion is complete, usable energy enters the cell in the form of glucose, a simple sugar (a carbohydrate) that is commonly found in nature. During the metabolic process, glucose and oxygen form the main reactants. The byproducts are carbon dioxide, water and ATP---the main energy carrier that is used throughout the body to sustain its basic functions. Respiration begins within the cell's cytoplasm, which is the fluid-filled area between the wall-like membrane and the central nucleus. From there, the process transfers into the mitochondrion, which is kind of like the power station in most complex cells. Prokaryotic cells, which are simpler and tend to be endemic to single-celled organisms, don't have a mitochondrion and are thus anaerobic.

Glycolysis

3. In the cytoplasm, the glucose undergoes a series of reactions called glycolysis. This requires an initial investment of two ATP, which breaks the glucose molecule into two separate molecules called PGAL. PGAL then undergo a series of reactions that begins a steady process of rearrangement. Both molecules lose two electrons and a hydrogen atom, which converts NAD+ to NADH. As the molecules undergo further change, two ATPs are produced, and water is given off. The end result of glycolysis is two molecules of pyruvate.

The Krebs Cycle

4. As respiration enters the mitochondrion, there are two separate processes. The first is called the Krebs Cycle (also known as the citric acid cycle). Before the cycle begins, the two pyruvate molecules are stripped of a carbon atom, which releases carbon dioxide. The molecules enter the cycle as acetyl-CoA and undergo constant rearrangement to become different molecules. Eventually, the process produces four molecules of carbon dioxide, six molecules of NADH, two molecules of FADH2, and two molecules of ATP. Oxaloacetate, a molecule with four carbons, is the final outcome of the pyruvate.

Electron Transfer Chain

5. The final step is the electron transfer chain. Electrons and hydrogen are taken from the NADH and FADH2 that formed in the Krebs Cycle. Electrons that are transferred through a series of chains galvanize positive hydrogen ions (atoms with an electric charge) to move back and forth across the mitochondrion membrane, which drives ATP synthesis. Thirty-two ATP are produced. The remaining electrons bind with oxygen to produce water. If oxygen is not present, then electrons become backed up, stopping the process in its tracks.

FOOD MICROBIOLOGY: THE BASICS AND THE DETAILS OF CHEESE PRODUCTION

By Grace Yim & Clive Glover

(August 2003)

Food spoilage has been an important problem throughout human history. Finding ways to overcome this problem was crucial as communities became larger and individuals no longer grew their own food. Some kind of system was needed to maintain the nutrient content of various food stuffs for long periods of time and prevent them from rotting and becoming inedible.

Early solutions to food spoilage

Food spoilage is caused by the growth of microorganisms, primarily bacteria and fungi, that convert nutrients into energy which they use for their own growth. Depletion of the nutrient content of food as well as the secretion of byproducts from this biochemical process are two things which contribute to the spoilage of food rendering it inedible. Since ancient times, humans have used many methods to extend the shelf life of food although not always understanding how these processes worked. Salting and drying are two very simple techniques that prevent rotting; both make the food an inhospitable environment for microorganisms. Canning is another technique first developed in the late 18th century by Nicholas Appert, a French confectioner, who, after 15 years of research, realized that if food is sufficiently heated and then sealed in an air tight container it will not spoil. Here the heating of food, kills all residual microorganisms present in the food and immediate sealing prevents the reentry of other contaminanting organisms. Napoleon immediately put this discovery to work in his armed forces and awarded Appert a prize of 12,000 francs for his discovery. Later, an Englishman, Peter Durand, took the process one step further and developed a method of sealing food into unbreakable tin containers. This was perfected by Bryan Dorkin and John Hall, who set up the first commercial canning factory in England in 1813. In 1859, Louis Pasteur definitively showed that microorganisms were responsible for food spoilage for the first time. This discovery led to the coining of the term “pasteurization” to describe the process where liquids with the potential to spoil (milk in particular) are heated for preservation.

Fermentation

In some cases, the growth of microorganisms in food can be put to good use for the production and preservation of various types of food. Fermentation is arguably the earliest example of biotechnology and refers to the metabolic process by which microbes produce energy in the absence of oxygen and other terminal electron acceptors in the electron transport chain such as fumarate or nitrate. In ancient times, it was considered as a way to both preserve food and to retain nutritional value. It was probably accidentally discovered in ancient Egypt when dough, made from ground up wheat and rye, was left for a period of time before cooking. In contrast to dough that was immediately cooked, it was observed that the aged dough expanded in size and when cooked produced tastier, lighter bread. The process was not completely reproducible: sometimes the uncooked dough yielded good bread and other times it did not. However if small amounts of good dough was added to the next batch, the bread was again tasty. The Romans went onto improve and perfect this process and popularized this sort of bread throughout the European continent. The discovery of fermentation in Egypt also led to the first production of wine and alcohol. All these discoveries were largely phenomenological and it would be another 3000 years before the exact cause of fermentation was uncovered. It was Louis Pasteur, again, in 1857 who was able to demonstrate that alcohol can be produced by yeast when grown in particular conditions. This discovery revolutionized the modern food industry: for the first time the agent of fermentation was identified and could be used commercially.

Industrial processes using fermentation

Fermentation by bacteria, yeast and mold is key to the production of fermented foods. Fermenting yeast produces the alcohol in beer and wine. In fact, the smell of fresh baked bread and rising dough can be attributed to alcohol produced from yeast. Fermentation is used to make many ethnic foods such as sauerkraut and miso. Soy sauce is produced by fermenting Aspergillus ortzae, a fungus, growing on soy beans. *Erwinia dissolvens*, another type of bacteria, is essential for coffee bean production; it is used to soften and remove the outer husk of beans. Finally, fermentation of milk produces most dairy products. Without microbes, we would not be able to eat many types of different food that we enjoy today. Table 1 shows example of several foods that are produced through fermentation with specific organisms.

Food	Raw Material	Fermentor
Pickles	Cucumber	*Leuconostoc mesenteroides* *Lactobacillus*
Chocolate	Cacao bean	*Saccharomyces cerevisiae* *Candida rugosa* *Kluyveromyces marxianus*
Bread	Flour	*Saccharomyces cerevisiae*
Coffee	Coffee bean	*Erwinia dissolvens*
Sauerkraut	Cabbage	*Leuconostoc plantarum*
Soy sauce	Soya bean	*Aspergillus oryzae*

Table 1. Some examples of foods which uses fermentation in their production. *Dairy products are described in more detail below.*

The biochemical process

All organisms need energy to grow. This energy comes from the reduction of adenosine triphosphate (ATP) into adenosine diphosphate (ADP) and results in the release of energy and a phosphate group. In this way ATP serves as a storage molecule of energy which can be used by the cell. But where does the ATP come from? Cells get their ATP from the controlled chemical breakdown of glucose to form two molecules of pyruvate. This process requires two molecules of ATP but results in the release of four molecules or a net gain of two molecules of ATP. This process is referred to as glycolysis and is illustrated in Figure 1. Once pyruvate is formed, it can be processed in several different ways. Mammalian cells usually process pyruvate by putting it into the tricarboxylic or Kreb's cycle. In the presence of oxygen, oxidative phosphorylation produces more ATP from the byproducts of the Kreb's cycle reactions. This is referred to as aerobic respiration. However when oxygen is limiting, other processes must be used in order to deal with pyruvate. This is done through anaerobic respiration or fermentation and involves the breakdown of pyruvate into simpler compounds. Two of the most important fermentation processes which are used on an industrial scale are ethanol or lactic acid fermentation. This is illustrated in Figure 1.

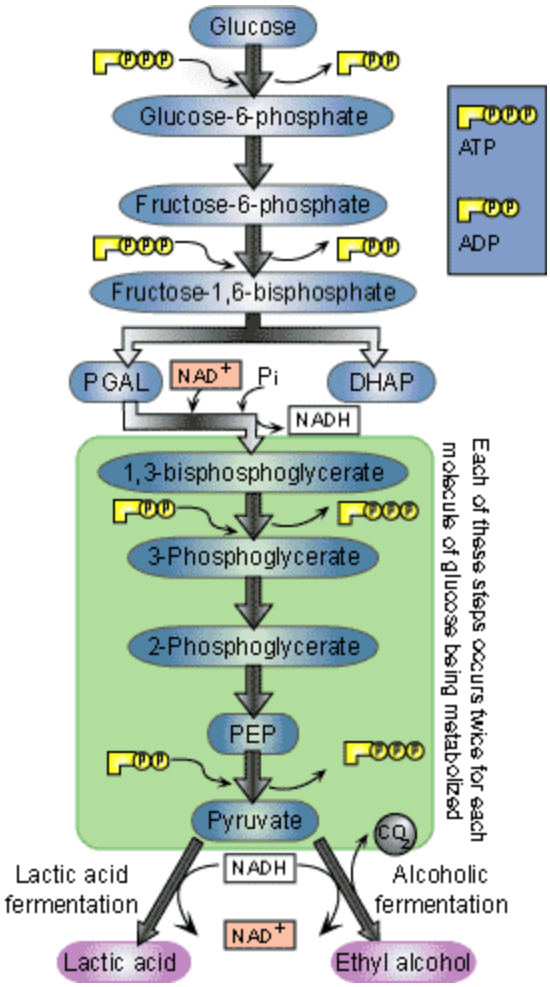


Figure 1. Glycolysis and fermentation.

http://www.scq.ubc.ca/food-microbiology-the-basics-and-the-details-of-cheese-production/

Aerobic Respiration

Unit (Lesson) Overview

Unit Title: Cellular Respiration

Lesson Summary: Students will construct a flap-book as a study resource and will model simplified reactions involved in the stages of aerobic respiration and calculate the total ATP produced during the process.

Subject Area(s) and Grade Levels: Click box(s) of the subject(s) and grade(s) that your Unit targets.

☒ Life Science ☐ Physical Science ☐ Earth Science ☐ 5th ☐ 7th ☒ Biology

Arkansas Framework: http://arkansased.org/education/word/biology_9-12_06.doc

SLE – Student Learning Expectation Details

MC. 3.B.2 Describe and model the conversion of stored energy in organic molecules into usable cellular energy (ATP):

- *glycolysis*
- *citric acid cycle*
- *electron transport chain*

Lesson Specific

Lesson Specific

National Standards: http://www.education-world.com/standards/national/index.shtml

National Standards Details:

NS.9-12.3 Life Science:

Students should develop an understanding of the cell.

Students should develop an understanding of matter, energy, and organization in living systems.

Student Objectives and Procedures: (All 7-E's may not be present in a single lesson)

Objective: The student will:

- Determine the yield of energy carrier molecules produced by glycolysis.
- Identify the energy carrier molecules produced during aerobic respiration.
- Describe the three main stages of aerobic respiration.
- Model reactions of the Krebs cycle.
- Determine the efficiency of aerobic respiration by calculating the total production of ATP.

Focus Question: How do living cells carry out energy releasing reactions?

Prerequisites / Background Information:

Students should be able to distinguish between aerobic and anaerobic respiration, have knowledge of the products and reactants, and have a basic understanding of molecular structures.

Timeline:

Preparation: 30 minutes
Elicit/Engage: 15 minutes
Explore: 2 class periods
Explain: 30 minutes
Cleanup:

Teacher Preparation:

- Prepare copies of all "flap book" inserts selected for use.
- Make colored paper "punches" and place in zipper bags.
- Gather other materials

Materials:

- Plain file folders/one per student
- Glue sticks or rubber cement
- Colored paper dots (made with a paper punch)
- Scissors
- Stapler or transparent tape
- Small zipper baggies
- Textbooks or other sources of information

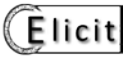
Technology – Hardware: (Click boxes of all equipment needed)

☐ Camera	☒ Computer(s)	☐ Digital Camera
☐ Projection System	☐ Television	☐ VCR
☐ Video Camera	☐ Internet Connection	☐ Other: Go Temp

Technology – Software: (Click boxes of all software needed.)

☐ Database/Spreadsheet	☐ Multimedia	☐ Other: logger lite/pro
☐ Internet Web Browser	☐ Word Processing	

Internet Resources: List Resources Here or at End.

Procedures:	**Teacher's Notes:**
	
• Exercise caution when using scissors.	
	
• Briefly review anaerobic respiration and reinforce the idea that only small amounts of ATP are produced. • Ask students if they think that larger organisms (such as vertebrates) can depend on anaerobic respiration. Small organisms, such as yeast, have lower energy requirements than large vertebrates, i.e. less movement etc.	• Depending on the responses, lead students to the idea that large organisms have large energy requirements. • Tell students that they will examine the cycles involved in aerobic respiration to determine why it is more efficient than anaerobic respiration and why oxygen is necessary.

Engage

- Students will create a "flap book" from a plain file folder. The front cover may be illustrated and additional pockets or charts may be glued to the back.
- As students progress through the lesson they will attach various materials to the folder and complete the activities.

Teachers may choose which materials to include in the booklet or create and substitute their own materials. Encourage the students to use the booklet as a study resource throughout the next few days.

Explore

- Students will complete several exercises related to aerobic respiration.
- After each activity the finished materials will be attached to the inside of the flap book.
  - Paired reading on glycolysis
  - Class review of vocabulary
  - Determine the yield of ATP from glycolysis
  - Write a description of glycolysis
  - Construct a model of the Krebs cycle using colored punch dots
  - Calculate the Yield of ATP
  - Cellular Respiration Concept Map

- The "flap book" inserts are to be constructed as students develop an understanding of glycolysis and aerobic respiration.
- Teachers may want to use this as an on-going activity throughout the examination of respiration, adding materials each day.
- Teachers should review the cycles and ask questions as the diagrams are examined and added to the book.

Explain

- Students will answer the 8 questions and complete the general concept map provided for the flap book.

Elaborate

- Discuss the reasons that the yield of ATP from respiration may vary among organisms.
- Compare and contrast the yield of aerobic respiration to anaerobic respiration.

- Teachers may wish to review additional information on chemiosmosis and electron transport.

Evaluate

Formative Assessment- Student responses to questions as they complete the "flap book".

Extend

Cross-Curricular

- List Information as Applicable with Bullets/Step

Flap Book Construction: Modeling Cellular Respiration

The following instructions describe the construction of the "Flap Book" inserts. Teachers may choose to add or substitute other materials if desired. The inserts may be created independently, by groups of two cooperating students, or with the teacher serving as a guide. As each sheet is completed it can be glued/taped or stapled into the flap book. The completed book can be used as a study resource for summative evaluations.

Teacher Preparation:

- Make copies of the inserts selected for use.
- Select extension activities (if desired) and prepare materials to add to the flap book: phosphorylation, chemiosmosis, electron transport chain.
- One plain file folder is needed for each student flap book.
- Gather the necessary materials for construction of the flap book inserts: Citric Acid Cycle (Krebs) - colored "punch" dots, zipper bags, glue sticks, scissors, stapler/transparent tape.
- Mini-glue dots can be purchased at business supply stores for this activity.

Glycolysis "Pairs Read"

Pair students according to reading ability: below grade level readers with those at grade level (or at grade level/above grade level). Assign the reading roles 'A' and 'B'. Students are to face each other and read the summary of glycolysis aloud one paragraph at a time, stopping to summarize or ask questions. The roles of reading and summarizing are alternated after each paragraph. You may also ask them to highlight familiar terms and circle new terminology.

Suggestions for Post-Reading Activities:

- If the students have difficulty comprehending what they have read, discuss the main points of each paragraph and write their ideas on the board or chart paper.
- Ask students to summarize the process of glycolysis (in their own words) on their foldable flap-book insert.
- Begin a 'Word Wall' and tell students they will select new terms to add to the wall after each flap-book insert is complete. Color code the terms to represent 'prior knowledge' and 'new vocabulary', or place terms in columns to represent 'developing understanding' and 'mastery'. Refer to the Word Wall daily and discuss the vocabulary. As you determine they have mastered new ideas move the terms to the mastery column.
- Give the students colored punch dots and write a color key on the board. Tell them to glue colored dots to the glycolysis chart on their sheet to represent the molecules involved in glycolysis (ATP, NADH, glucose and/or pyruvate).
- Emphasize the investment of ATP required, the pay-off and the final yield (profit) and link these ideas to examples from the students' own experience.

Krebs Cycle Model Construction:

1. Give each group of 2-3 students a zipper bag of colored punch dots.
2. Depending on the colors chosen for each molecule, write a color key on the board for students to refer to.
3. Tell students to glue the dots to the Krebs cycle sheet to represent each molecule. They may refer to the glycolysis sheet for an example of how the black dots could be glued in a straight row to represent glucose and pyruvate molecules.
4. The completed chart, along with the Glycolysis sheet, will be used to do the calculation of ATP. The color-coded dots make it easier for students to count each molecule present on the chart.

Optional Activity – Students may construct larger models of the Krebs cycle on poster board by referring to the flap book inserts. Colored cereals, (Cheerios), beads, pompons or sticky dots could be used to represent each atom/molecule. These may be displayed on the bulletin board.

Materials needed:
For each group: Glue or glue sticks, colored paper dots, The Citric Acid Cycle sheet.

Suggested Colors (if using cereals such as Cheerios or paper punch dots):
Blue/Black: Carbon Purple: NADH Yellow: ATP
Pink/Red: Oxygen Orange: $FADH_2$

Calculating the Yield of ATP from Aerobic Respiration:

After students have completed glycolysis and the citric acid cycle they may use the diagrams to complete the calculation of the number of ATP molecules produced during aerobic respiration.

Modifications:
- Place the students in groups of two.
- Complete the sheet as a whole class assignment with the teacher pointing out where each number would be found on the charts.

Discussion: Note: The production of ATP varies!

- Most of the ATP is generated after electron transport during chemiosmosis. Electrons carried on $FADH_2$ and NADH are used to "phosphorylate" ADP to form ATP.

- The production of 38 ATP during aerobic respiration implies "perfect process", but this number can vary. Glycolysis occurs in the cytoplasm and the NADH must move into the mitochondria where it is used to generate ATP. This movement may reduce the energy the NADH molecules are carrying and therefore decreases the number of ATP they generate during electron transport. Unlike the NADH produced during the Krebs cycle, **each NADH generated during glycolysis may produce only 2 ATP during electron transport (rather than 3 ATP)**. This occurs frequently in organisms and it results in a total yield of 36 ATP molecules generated during respiration. Teachers will find this mentioned in most high school textbooks.

- The production of ATP may be lowered further by leakage of protons through mitochondrial membranes and other factors. Some estimates place the yield between 19-30 molecules.

• Oxygen is the final acceptor of electrons passed through the ETC. With the addition of hydrogen ions water is formed. Without oxygen, respiration would cease.

• Carbon dioxide released during respiration is exhaled from the body.

• Enzymes are required during many steps of glycolysis and the Krebs cycle.

• Glucose and other carbohydrates are not the only molecules that can be metabolized during respiration. Proteins and fats can serve as a source of energy.

Foldable and Assessment Questions:

The "foldable" with questions related to respiration may be attached to the inside flap of the booklet and used for assessment. Students may also refer to textbooks for other information. Blank foldables are provided for teachers who wish to substitute vocabulary terms or other questions.

Cellular Respiration Concept Map:

As a general summative evaluation students may complete the Cellular Respiration Concept Map as a general review. An optional word list is provided, and a key to the suggested answers is included. This may also be attached to the center section of the flap book.

Cellular Respiration and Glycolysis

Student Instructions: You and your partner will do a "Pairs Read". **Student 'A'** will read one paragraph as **student 'B'** listens. Afterward, student 'B' will paraphrase and briefly describe the main points, or will ask Student 'A' to repeat information. Roles are then reversed until the reading is complete.

When you are finished, summarize (in your own words) the most important steps and end products of glycolysis in your "flap book".

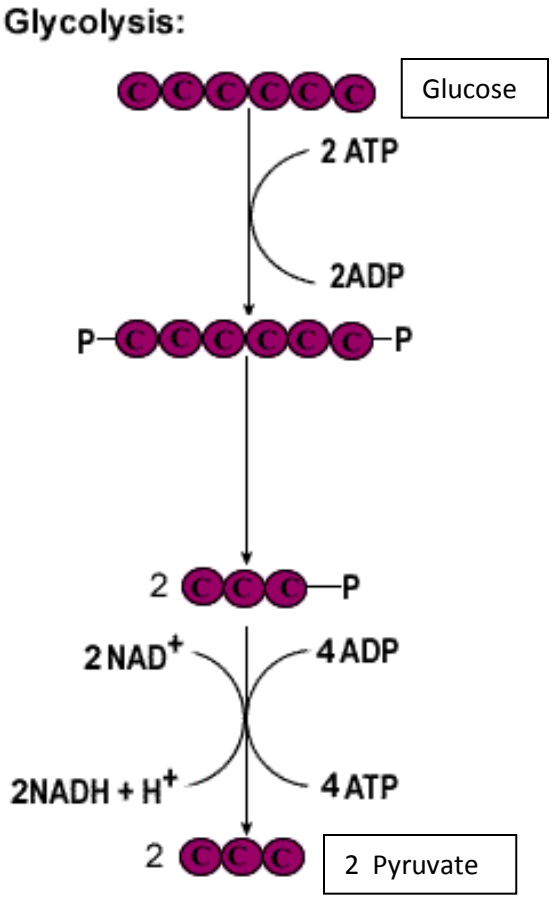
Pairs Read: Cellular Respiration and Glycolysis

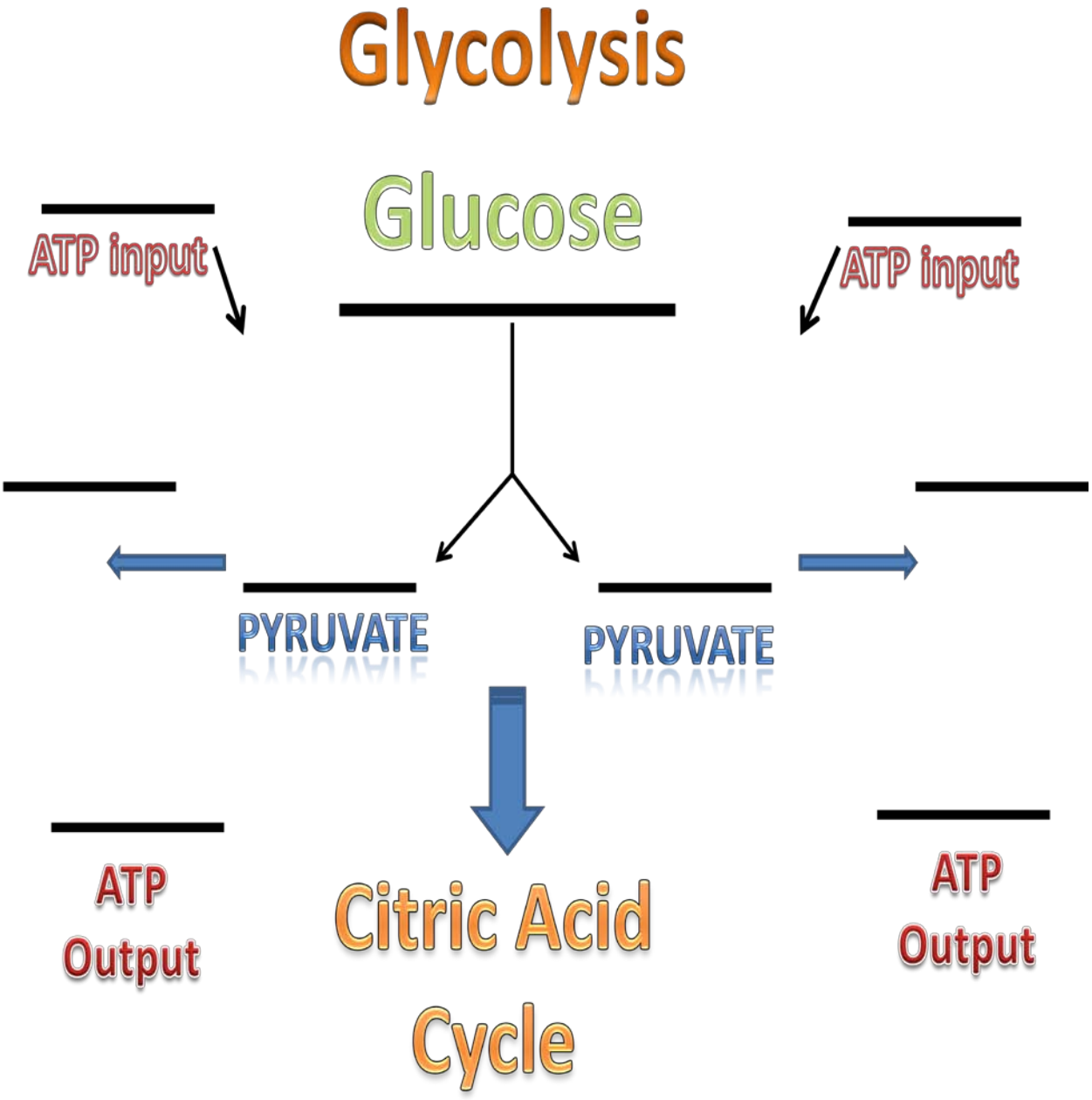
All living things require energy. Just as a radio needs a battery or another source of electricity in order to work, your cells need a source of energy to carry out important tasks. Autotrophs, such as plants, can absorb energy from the sun for use in their cells. Heterotrophs, such as animals, take in foods from which they extract energy. The most efficient way for cells to harvest energy stored in food is through cellular respiration, a biochemical pathway for the production of ATP, or adenosine triphosphate. Cellular respiration occurs in both eukaryotic and prokaryotic cells and has three main stages: glycolysis, the citric acid cycle (Krebs cycle), and electron transport.

Glycolysis literally means "sugar splitting" and that is exactly what happens. During this process, glucose, a six-carbon sugar, is split into two three-carbon sugars. Glycolysis consists of two phases. The first is an energy investment stage during which the cell must actually spend two ATP molecules to begin the process. This investment is repaid when four ATP molecules and two high energy NADH molecules are generated. Also gained, are the two molecules of pyruvate, a three-carbon sugar.

Glycolysis can occur with or without oxygen. In the presence of oxygen, glycolysis is the first stage of aerobic cellular respiration. During the stages of aerobic respiration the two molecules of pyruvate will be broken down to generate more ATP and other energy carriers. Without oxygen, glycolysis proceeds to the process called fermentation.

Examine the glycolysis flow chart on the right.





1. Considering the input and output of ATP, what is the total yield of ATP?

2. What is the total yield of NADH?

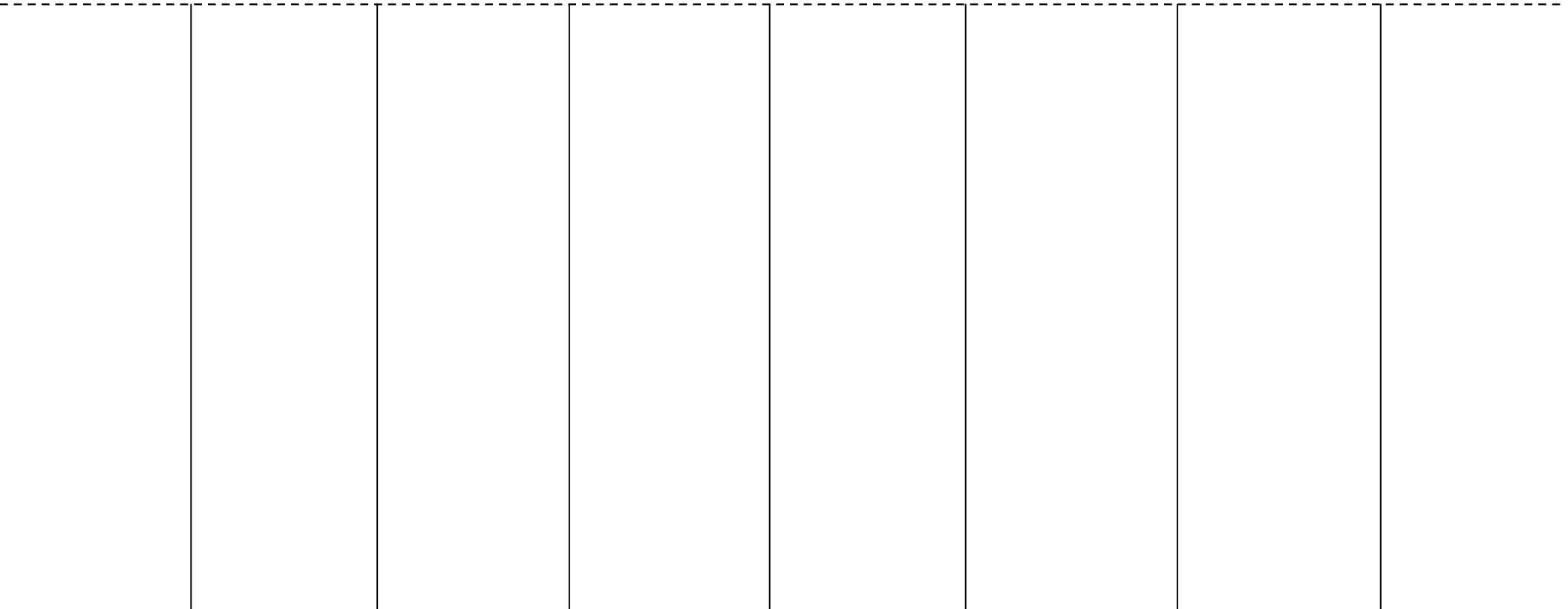
3. What are the final products from Glycolysis that enter the Citric Acid Cycle?

Fold on dotted line.

Cut the solid lines.

Glue this side to the inside of the right flap.

Write questions or vocabulary terms on the outside of each flap, answers on the inside.



Write the overall chemical formula for cellular respiration.
Rewrite the reaction in words.

Where in the cell does glycolysis occur during respiration?
Where does the Citric Acid Cycle occur?

What is the "yield" of ATP from glycolysis?
Explain what this means.

What happens in organisms if oxygen is not present after glycolysis?

Why is oxygen necessary for aerobic respiration?

Distinguish between NADH and $FADH_2$.
What is their role during respiration?

What is the "waste" gas of respiration?
During what stage is it produced?

What is the average number of ATP molecules produced during cellular respiration?
What is the role of ATP in the cell?

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Cut the solid lines.

Glue this side to the inside of the right flap.

Answer the questions on the inside of the flap.

Fold on dotted line.

Cut the solid lines.

Glue this side to the inside of the left flap.

Glycolysis

Citric Acid Cycle (Krebs Cycle)

Electron Transport Chain

Cellular Respiration Concept Map

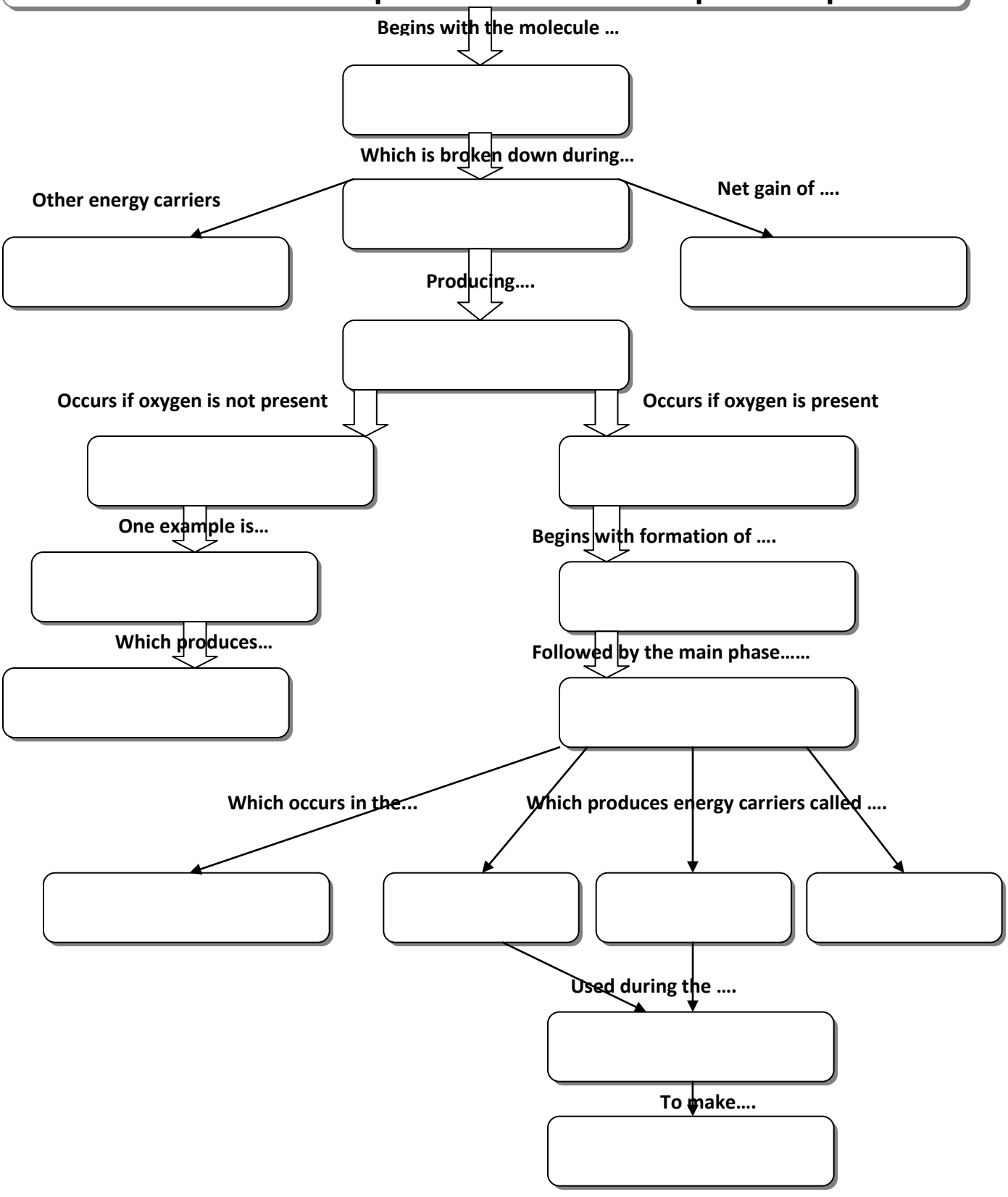
The following concept map may be used to introduce the broad concepts of respiration or as a summative assessment after students have studied respiration. Teachers may choose to provide the word bank or to allow students to fill in the concept map using texts or prior knowledge. **Note: Some terms may be used more than once and not all the terms will be needed to complete the concept map.**

The completed concept map may be added to the "flap-book" as a center page.

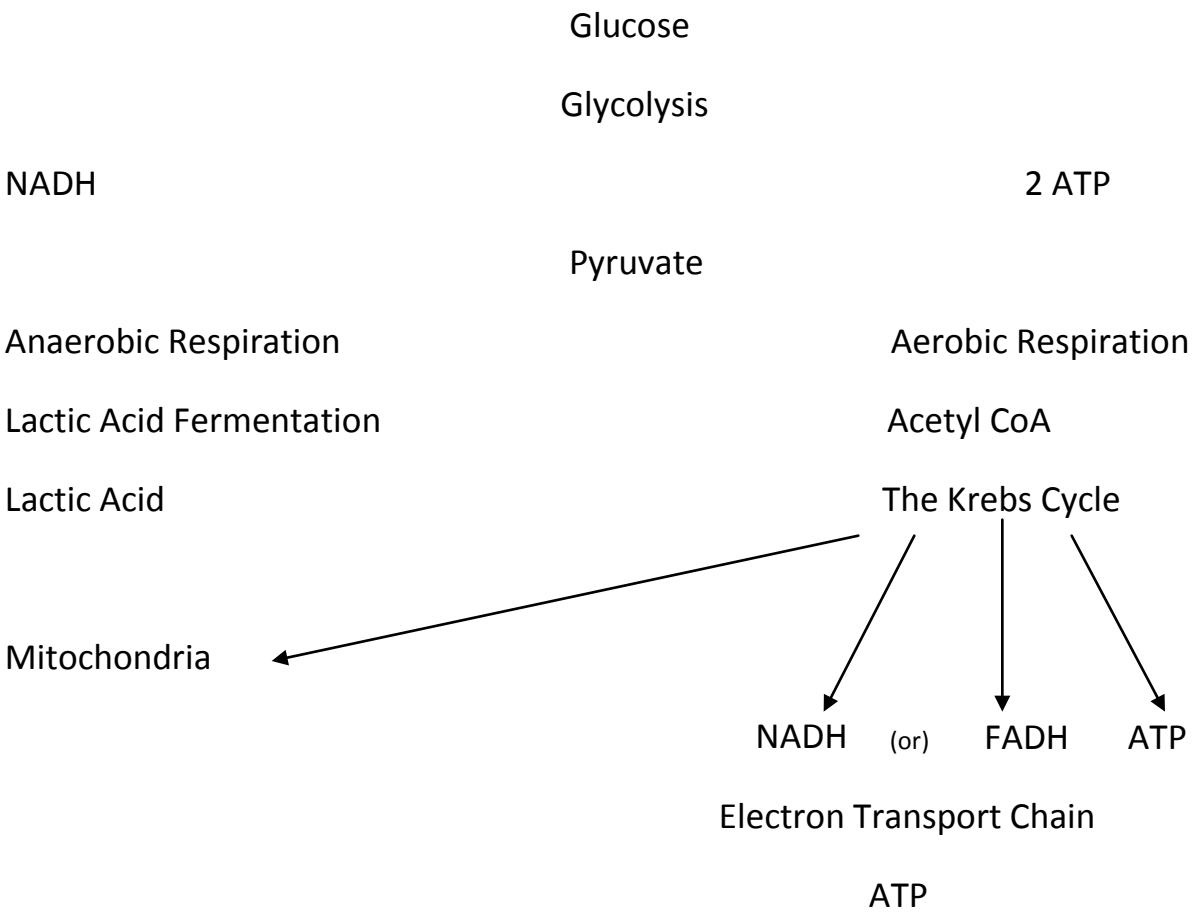
WORD BANK

2 ATP
ATP
NADH
NADH
FADH
Electron transport chain
Anaerobic respiration
Aerobic respiration
Acetyl CoA
Mitochondrion
Cytoplasm
Lactic acid fermentation
Glycolysis
Glucose
Pyruvate (or Pyruvic acid)
Lactic acid
Krebs cycle

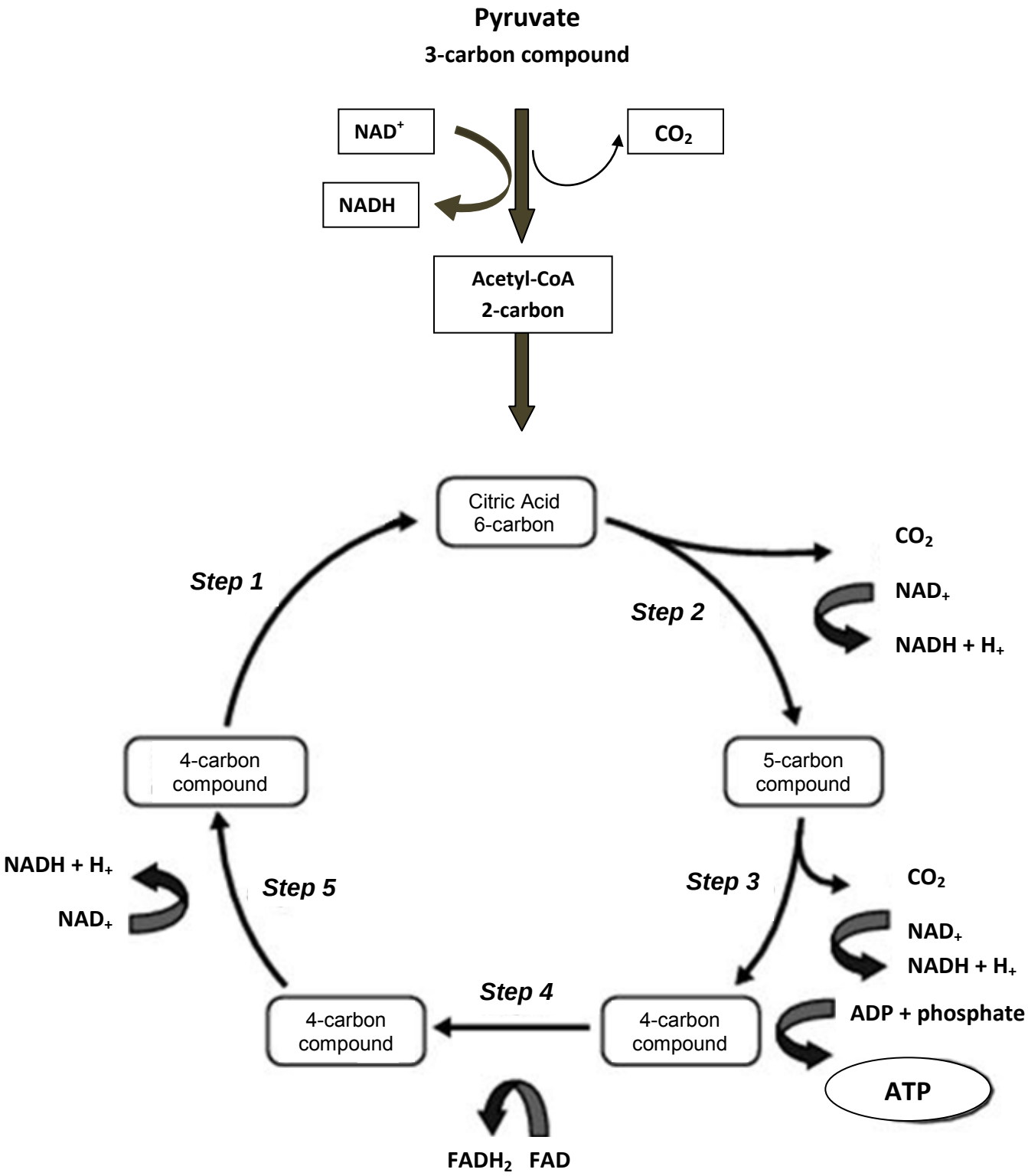
Cellular Respiration Concept Map



Key to Cellular Respiration Concept Map



The Citric Acid Cycle (Krebs Cycle)



Calculating the Yield of ATP from Aerobic Respiration

Fill in the blanks below to indicate:

- **The <u>number</u> of <u>ATP</u> and <u>energy carrier molecules</u> produced during each phase of aerobic respiration.**
- **The <u>total gain of ATP</u> from <u>one glucose molecule</u> at the end of aerobic respiration.**

	ATP	Other Energy Carriers	
Part A-			
Glycolysis- (The breakdown of glucose into two pyruvate molecules.)			
ATP used	-_____Molecules		
ATP produced	+_____Molecules		
NADH produced		=_____Molecules	
Part A Total	**=_____ATP**	**=_____NADH**	

Below List the Energy Rich Molecules Produced from <u>One Pyruvate Molecule!</u>

Part B-			
Acetyl CoA Formation- (from one pyruvate)			
NADH produced		=_____Molecules	
Krebs Cycle-			
ATP produced	=_____Molecules		
NADH produced		=_____Molecules	
$FADH_2$ produced			=_____Molecules
Part B Sub-Total	=_____ATP	=_____NADH	=_____$FADH_2$
Two pyruvate molecules were made during glycolysis and entered the Krebs cycle. →	Multiply the number of each molecule by 2. ↓		
Part B Total	**=_____ATP**	**=_____NADH**	**=_____$FADH_2$**
Add Part A and B	**=_____ATP**	**=_____NADH**	**=_____$FADH_2$**
Part C- Electron Transport	(No Change in Number) ↓	Multiply by 3 Each Molecule produces 3 ATP ↓	Multiply by 2 Each produces 2 ATP. ↓
Add these 3 numbers ⇨	**=_____ATP**	**=_____ATP**	**=_____ATP**
Grand Total of ATP Produced			