



# **Burn Baby Burn!**

## **A Lesson on Muscle Fatigue**

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Summer 2006

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**Lesson # 14**

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**Appropriate citation:**

Odom, B. Burn Baby Burn! A Lesson on Muscle Fatigue (APS Archive of Teaching Resources Item #3717). [Online]. Bethesda, MD: American Physiological Society, 2006. <http://www.apsarchive.org/resource.cfm?submissionID=3717>.

**Editor's notes:**

Website URLs listed in this resource were current as of publication, but may now be obsolete. If you know of a replacement URL, please suggest it in the resource's "Comments" section <http://www.apsarchive.org/resource.cfm?submissionID=3717>.

The APS encourages teachers to give students a copy of the "ABC" (Appropriate, Beneficial, Caring) rules for use of animals in the classroom, to discuss the rules, and to ask students to sign the "ABC" rules contract (see References). Also, teachers should have a plan for short term care of the animals (with supporting references for appropriate care guidelines) and for disposal or long-term care of all classroom organisms.

Teachers should carefully review any stimulus or environmental change for an animal being used in experiments or observations before students are allowed to use that stimulus. This is especially important if the stimulus could cause pain or distress to the organism. Teachers may be able to identify a less stressful stimulus for the students to use in their experiment.

Although mammals provide excellent opportunities for observational studies, they require particular care in terms of handling and may cause allergic reactions in some students. The teacher should check local and state guidelines before using mammals in the classroom.

**Disclaimer:**

This activity was created by the author and reviewed by the American Physiological Society. Any interpretations, statements, or conclusions in this publication are those of the author and do not necessarily represent the views of either the American Physiological Society or the funding agencies supporting the professional development program in which the author participated.

<b>PURPOSE</b>	The purpose of the activity is to understand the functions of skeletal muscle and the effects of fatigue on these muscles.
<b>OBJECTIVES</b>	Upon completion of this activity, students will be able to: <ul style="list-style-type: none"><li>• measure work done by muscles.</li><li>• infer how muscle fatigue affects skeletal muscle.</li><li>• understand the conditions and effects of atrophy.</li><li>• develop lab procedures designed to test a hypothesis.</li><li>• collect and analyze data.</li><li>• work within a group to create an experiment to explain findings.</li></ul>
<b>GRADE LEVEL</b>	9 <sup>th</sup> -12 <sup>th</sup> grade
<b>PRIOR KNOWLEDGE</b>	This unit should be used as an introduction of the skeletal and muscular systems. Teacher should review experimental design and hypothesis testing.
<b>TIME REQUIRED</b>	The activity may take two or three 60 minute class periods. The steps should be broken up into class periods based upon time allotted and availability.
<b>INCLUDING ALL STUDENTS</b>	<p>Muscle fatigue affects all students. Students with disabilities are encouraged to focus on smaller muscles including but not limited to index and thumb fingers, frontalis muscles (muscles use to frown) or the nasalis muscle (flaring the nostrils). Using repetition with these muscles will create the fatigue phenomenon as well.</p> <p>There will be clear differences of muscle fatigue between male and female students. The genetic and body composition differences can be explained during the initial lecture. Resources to help explain these differences are included in the Resources and References section.</p> <p>A brief biography of the astronaut used in Assessment Option #4 is also a great way to include diversity in the lesson. This can be accomplished by introducing students to women astronauts or astronauts of different ethnicities. The NASA Astronaut office webpages (see References) contain information about current astronauts as well other careers in the aerospace industry.</p>
<b>QUESTIONS TO ASK ALONG THE WAY</b>	<ul style="list-style-type: none"><li>• What differences do you expect to find between athletes and non-athletes?</li><li>• Is the fatigue sensation just a perception (like fear) or is it a biological reality?</li><li>• Would you expect to find a difference between boys and girls of the same age?</li></ul>

**NATIONAL  
SCIENCE  
EDUCATION  
STANDARDS**

*K-12 Unifying Concepts and Processes*  
Evidence, models, and explanation  
Change, constancy, and measurement

*Grades 9-12*

Science as Inquiry

Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

Life Science

Matter, energy, and organization in living systems

Science and Technology

Understanding about science and technology

Science in Personal and Social Perspectives

Personal and community health

**MATERIALS**

Teachers should provide materials that can be used for resistance.

- resistance bands
- rubber bands
- free weights
- canned foods
- water bottles
- stop watch

***Teacher Tip:*** *Many of these items can be found in your neighborhood dollar stores.*

Group size may vary although group sizes with 4 people or less seem to work best. Groups should be encouraged to select roles for each member: Team leader, Materials manager, Recorder, and Timer.

**SAFETY**

Students should be instructed as to the proper ways of testing muscle fatigue (e.g., not working past the burn, using weights that are adequate for the size of students).

**PROCEDURE**

**I. Engage**

- A. Students will be shown a clip from the movie “Pumping Iron” (1977). Teachers should choose a clip that shows an exaggerated example of the muscular system. Students and teachers will discuss similarities and differences found among men and women in their body shapes and sizes.

**Teacher Tip:** *In the event that “Pumping Iron” cannot be shown, teachers can also ask students to bring in appropriate pictures of body builders found on the Internet or in magazines.*

- B. Students will begin the K-W-L worksheet. What do you know about skeletal muscle fatigue? What do you want to know about skeletal muscle fatigue?

**II. Explore**

Groups will research fatigue by completing an Internet Treasure Hunt worksheet that answers the following questions:

- A. What happens to astronaut muscles in space?
- B. What is the relationship between the motion sickness and muscles as experienced by astronauts in space
- C. What are antigravity muscles? What happens to them in space?
- D. What happens to astronaut muscles once they return to Earth? What are some common complications?

**Teacher Tip:** *Teachers should divide the Internet Treasure Hunts among students. Depending on class size, there may be groups completing the same Internet Treasure Hunts. In the case of 4 students to each group, teachers may assign one Internet Treasure Hunt to each group member the day before the experiment. Students will discuss their findings during the first 10 minutes of class on the following day.*

**III. Extend**

Students will, within their groups, create an experiment to test skeletal muscle fatigue in three different muscles sizes:

- Small (index and thumb fingers)
- Medium (bicep)
- Large (quads)

Students will have a choice to utilize various props provided for by the teacher. Each group will be given the experimental design worksheet (Appendix F) to help guide the groups through the creation of their experimental design. Student must have experimental design approved by instructor before proceeding. Students will then present their findings in a presentation that will include stating the problem, hypothesis, graph, and conclusions.

**Teacher Tip:** *Present a lecture to explain experimental results and clear any misconceptions brought about in-group experimental designs.*

**WHERE TO GO FROM HERE** This lesson can lead directly to the introduction of cardiac and smooth muscles. Students can compare the fatigue of skeletal muscle to that of cardiac muscle and smooth muscle. Where are these types of muscles found? Does the fatigue feel the same? Does it cause permanent damage to the organ(s)?

**ASSESSMENT**

- Completion of the K-W-L worksheet.
- Students can engage in peer evaluation. Students will critique poster of other students using parameters given by teacher on the Peer Evaluation Rubric (see Student section).
- Students can present a presentation (which will include problem, hypothesis, graph, and conclusions) and be critiqued with the Student Presentation Rubric (see Student section).
- Student can complete a multiple choice test reviewing important topics discussed in lecture and lab (see Student section).
- Student can write a letter to a NASA astronaut discussing muscle fatigue and ways astronauts can limit muscle fatigue while in space.

**REFERENCES AND RESOURCES**

1. *Astronaut biographies*  
<http://www.jsc.nasa.gov/Bios/index.html>  
Biographies from the Johnson Space Center at NASA.
2. *Boys growing up*  
[http://www.bbc.co.uk/science/humanbody/body/articles/lifecycle/teenagers/boys\\_growth.shtml](http://www.bbc.co.uk/science/humanbody/body/articles/lifecycle/teenagers/boys_growth.shtml)  
From the British Broadcasting Channel of the United Kingdom on their Science & Nature: Human Body & Mind webpages.
3. *Gender Differences in Endurance Performance and Training*  
<http://home.hia.no/~stephens/gender.htm>  
Contains information about athlete physiology and performance from the Institute for Sport, Agder College, Kristiansand, Norway and Seiler, S.
4. Human Muscular System  
<http://www.anatomy-resources.com/human-anatomy/sh370.htm>  
Anatomy-resources.com provides good pictures for human anatomy K-12 education.
5. *JAXA: Japan Aerospace Exploration Agency*  
[http://iss.sfo.jaxa.jp/med/index\\_e.html#2.3](http://iss.sfo.jaxa.jp/med/index_e.html#2.3)  
Website provides information about the Japanese space program and Space Medicine.
6. *Muscles and Space Missions*  
<http://www.mcgill.ca/reporter/36/09/watt/>  
This article can be found in the McGill Reporter, a campus newspaper at McGill University Montreal, Quebec, Canada.

**REFERENCES  
AND  
RESOURCES**

7. *The Muscular System*  
<http://webschoolsolutions.com/patts/systems/muscles.htm>  
Partners in Assistive Technology Training and Services website provides information about assistive technology related disciplines like physical therapy and occupational therapy.
8. NASA Explores  
[http://www.nasaexplores.com/show2\\_912a.php?id=04-202&gl=912](http://www.nasaexplores.com/show2_912a.php?id=04-202&gl=912)  
This website provides K-12 educational resources on current NASA projects.
9. National Aeronautics and Space Administration (NASA)  
<http://exploration.nasa.gov/articles/issphysiology.html>  
This website provides information about the American space program.
10. RubiStar  
<http://rubistar.4teachers.org>  
A free tool to help teachers create quality rubrics.
11. Seiler, S. (2005). *Basic Skeletal Muscle Physiology*  
<http://home.hia.no/~stephens/musfacts.htm>  
Contains information about athlete physiology and performance from the Institute for Sport, Agder College, Kristiansand, Norway.
12. What happens to muscles in space?  
[http://radarsat.espace.gc.ca/asc/eng/astronauts/osm\\_muscles.asp](http://radarsat.espace.gc.ca/asc/eng/astronauts/osm_muscles.asp)  
The Canadian Space Agency website provides information about their space program.
13. Why do astronauts suffer motion sickness in space?  
<http://www.space.gc.ca/asc/eng/sciences/tre.asp>  
The Canadian Space Agency website provides information about the Torso Rotation Experiment.

### Multiple Choice Test Answers

1. Skeletal muscles work in \_\_\_\_\_ pairs:
  - a. **opposing**
  - b. complementary
  - c. identical
  - d. none of the above
  
2. Myosin and actin are \_\_\_\_\_ that make up fiber units called myofibrils.
  - a. enzymes
  - b. **filaments**
  - c. fibers
  - d. none of the above
  
3. Muscle strength depends on
  - a. The number of times you work out per week.
  - b. The number of fibers in your muscle
  - c. **The thickness of the fibers**
  - d. None of the above
  
4. Past research suggested that muscle fatigue is caused by
  - a. lack of oxygen supplied to your muscles
  - b. build up of carbon dioxide in your blood
  - c. **build up of lactic acid in the body**
  - d. none of the above
  
5. Current research has suggested that lactic acid
  - a. **helps prevent muscle fatigue**
  - b. increases muscle fatigue
  - c. plays no role in muscle fatigue
  - d. none of the above





What I *Know*  
 What I *Want to Know*  
 What I *Learned*

Name \_\_\_\_\_  
 Period \_\_\_\_\_

Topic of Discussion: <b>Skeletal Muscle Fatigue</b>		
What I <i>Know</i> about this topic/question	What I <i>Want</i> to know about this topic/question	What I <i>Learned</i> about this topic/question

**Internet Treasure Hunt**

Name: \_\_\_\_\_ Date: \_\_\_\_\_

This web info search will help you find information about the effects of exercise on the human body. You will be looking at pre-selected web sites to answer each question. It is important to not only find the information at the site, but also to consider who wrote the site, what their purpose is in writing it, and how credible (accurate) you think the information is.

<b>Question 1: What happens to astronaut muscles in space?</b>		
	<b>Site 1</b> <i>What Happens to Muscles in Space?</i> <a href="http://radarsat.espace.gc.ca/asc/eng/astronauts/osm_muscles.asp">http://radarsat.espace.gc.ca/asc/eng/astronauts/osm_muscles.asp</a>	<b>Site 2</b> <i>Saving Muscle in Space</i> <a href="http://www.nasaexplores.com/show2_912a.php?id=04-202&amp;gl=912">http://www.nasaexplores.com/show2_912a.php?id=04-202&amp;gl=912</a>
Who created this web site (organization, etc.)?		
Why did they create it? (check all that apply)	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think the info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
What did you learn?		

**Internet Treasure Hunt**

Name: \_\_\_\_\_ Date: \_\_\_\_\_

This web info search will help you find information about the effects of exercise on the human body. You will be looking at pre-selected web sites to answer each question. It is important to not only find the information at the site, but also to consider who wrote the site, what their purpose is in writing it, and how credible (accurate) you think the information is.

<b>Question 2: What is the relationship between motion sickness and the muscles as experienced by astronauts in space?</b>		
	<b>Site 1</b> <i>Space Medicine</i> <a href="http://iss.sfo.jaxa.jp/med/index_e.html#2.3">http://iss.sfo.jaxa.jp/med/index_e.html#2.3</a>	<b>Site 2</b> <i>Motion Sickness in Space</i> <a href="http://www.space.gc.ca/asc/eng/sciences/tre.asp">http://www.space.gc.ca/asc/eng/sciences/tre.asp</a>
Who created this web site (organization, etc.)?		
Why did they create it? (check all that apply)	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think the info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
What did you learn?		

**Internet Treasure Hunt**

Name: \_\_\_\_\_ Date: \_\_\_\_\_

This web info search will help you find information about the effects of exercise on the human body. You will be looking at pre-selected web sites to answer each question. It is important to not only find the information at the site, but also to consider who wrote the site, what their purpose is in writing it, and how credible (accurate) you think the information is.

<b>Question 3: What are antigravity muscles? What happens to them in space?</b>		
	<b>Site 1</b> <i>What Happens to Muscles in Space?</i> <a href="http://www.space.gc.ca/asc/eng/astronauts/osm_muscles.asp">http://www.space.gc.ca/asc/eng/astronauts/osm_muscles.asp</a>	<b>Site 2</b> <i>Saving Muscle in Space</i> <a href="http://www.nasaexplores.com/show2_912a.php?id=04-202&amp;gl=912">http://www.nasaexplores.com/show2_912a.php?id=04-202&amp;gl=912</a>
Who created this web site (organization, etc.)?		
Why did they create it? (check all that apply)	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think the info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
What did you learn?		

**Internet Treasure Hunt**

Name: \_\_\_\_\_ Date: \_\_\_\_\_

This web info search will help you find information about the effects of exercise on the human body. You will be looking at pre-selected web sites to answer each question. It is important to not only find the information at the site, but also to consider who wrote the site, what their purpose is in writing it, and how credible (accurate) you think the information is.

<b>Question 4: What happens to astronaut muscles once they return to Earth? What are some common complications?</b>		
	<b>Site 1</b> <i>Muscles and Space Missions</i> <a href="http://www.mcgill.ca/reporter/36/09/watt/">http://www.mcgill.ca/reporter/36/09/watt/</a>	<b>Site 2</b> <i>Human Physiology Research and the International Space Station</i> <a href="http://exploration.nasa.gov/articles/issphysiology.html">http://exploration.nasa.gov/articles/issphysiology.html</a>
Who created this web site (organization, etc.)?		
Why did they create it? (check all that apply)	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure	<input type="checkbox"/> To provide factual information <input type="checkbox"/> To influence the reader's opinion <input type="checkbox"/> To sell a product or service <input type="checkbox"/> I'm not sure
How credible (accurate) do you think the info is?	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure	<input type="checkbox"/> Very accurate <input type="checkbox"/> Somewhat accurate <input type="checkbox"/> Not very accurate <input type="checkbox"/> I'm not sure
What did you learn?		

**III. Experimental Design Worksheet** Name: \_\_\_\_\_ Date: \_\_\_\_\_

Lab Partner(s): \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Directions:** Discuss each of the following questions with your group members.

**Hypothesis:** What questions are we asking? What do we think the answers to our questions will be?

**Variables:** What is our independent variable (the variable that we are manipulating)? What is our dependent variable (the variable that we are measuring)?

**Procedure:** How do we plan to manipulate the variables? How many trials will we need? How will we make sure the conditions during each trial are constant?

**Observations:** What type of data are we collecting? Who will be collecting the data? Should we draw a chart for the data collection?

**Conclusion:** Was our hypothesis right? Did we have any errors in our data collecting process? What could we have done differently? Is there another experiment we could do to expand on this topic?

### Student Presentation Rubric

Category	4	3	2	1
<b>Hypothesis Development</b>	Independently developed an hypothesis well substantiated by previous lecture and observation of similar phenomenon	Independently developed an hypothesis somewhat substantiated by lecture and observation of similar phenomenon.	Independently developed an hypothesis somewhat substantiated by lecture or observation of similar phenomenon	Needed adult assistance to develop an hypothesis
<b>Variables</b>	Independently identifies and clearly defined which variables were going to be changed (independent variables) and which were going to be measured (dependent variables).	Independently identified which variables were going to be changed (independent variables) and which were going to be measured (dependent variables). Some feedback was necessary to clearly define the variables.	With adult help identified and clearly defined which variables were going to be changed (independent variables) and which were going to be measured (dependent variables).	Adult help needed to identify and define almost all the variables.
<b>Description of procedure</b>	Procedures were outlined in a step-wise fashion that could be followed by anyone without additional explanations. No adult help was needed to accomplish this.	Procedures were outlined in a step-wise fashion that could be followed by anyone without additional explanations. Some adult help was needed to accomplish this.	Procedures were outlined in a step-wise fashion but had 1 or 2 gaps that require explanation even after adult feedback had been given.	Procedures that were outlined were seriously incomplete or not sequential, even after adult feedback had been given.
<b>Data Collection</b>	Data was summarized, in a way that clearly describes what was discovered	Data was summarized in a way that somewhat described what was discovered.	Adult assistance was needed to clearly summarize what was discovered.	Summary of data was incomplete even when adult assistance was given.
<b>Conclusion/ Summary</b>	Student provided detailed conclusion based on data and related to lecture and hypothesis statement.	Student provided somewhat detailed conclusion based on data and related to lecture and hypothesis statement.	Student provided a conclusion with some reference to data, lecture, and hypothesis statement.	No conclusion was apparent.

*Adapted from Rubistar Science Fair Experiment Rubric <http://rubistar.4teachers.org>*

**Peer Evaluation Rubric**

Category	4	3	2	1
<b>Hypothesis Development</b>	Group developed a hypothesis that is based on what was learned in lecture <u>and</u> what they have observed.	Group developed a hypothesis that is somewhat based on what was learned in lecture <u>and</u> what they have observed.	Group developed a hypothesis that is somewhat based on what was learned in lecture <u>or</u> what they have observed.	Group was unable to develop a hypothesis based on what was learned in lecture <u>or</u> what they have observed.
<b>Variables</b>	Group identifies and clearly defines the variables tested.	Group somewhat identifies and defines the variables tested.	Group did not accurately identify or define all variables tested.	Group did not accurately identify or define the variables tested.
<b>Description of procedure</b>	Procedures were outlined in a step-wise fashion that could be followed by anyone without additional explanations.	Procedures were mostly outlined in a step-wise fashion that could be followed by anyone without additional explanations.	Procedures were somewhat outlined in a step-wise fashion.	Procedures that were outlined were seriously incomplete or not sequential.
<b>Data Collection</b>	Data was summarized, in a way that clearly describes what was discovered.	Data was summarized in a way that somewhat described what was discovered.	Data was somewhat summarized.	Data was not summarized.
<b>Conclusion/ Summary</b>	Student provided detailed conclusion based on data and related to lecture and hypothesis statement.	Student provided somewhat detailed conclusion based on data and related to lecture and hypothesis statement.	Student provided a conclusion with some reference to data, lecture, and hypothesis statement.	No conclusion was given.

Adapted from Rubistar Science Fair Experiment Rubric <http://rubistar.4teachers.org>



**Multiple Choice Test**

Name: \_\_\_\_\_ Date: \_\_\_\_\_

1. Skeletal muscles work in \_\_\_\_\_ pairs:
  - a. opposing
  - b. complementary
  - c. identical
  - d. none of the above
  
2. Myosin and actin are \_\_\_\_\_ that make up fiber units called myofibrils.
  - a. enzymes
  - b. filaments
  - c. fibers
  - d. none of the above
  
3. Muscle strength depends on
  - a. The number of times you work out per week.
  - b. The number of fibers in your muscle
  - c. The thickness of the fibers
  - d. None of the above
  
4. Past research suggested that muscle fatigue is caused by
  - a. lack of oxygen supplied to your muscles
  - b. build up of carbon dioxide in your blood
  - c. build up of lactic acid in the body
  - d. none of the above
  
5. Current research has suggested that lactic acid
  - a. helps prevent muscle fatigue
  - b. increases muscle fatigue
  - c. plays no role in muscle fatigue
  - d. none of the above