Investigation 7
Exercise and Body Systems

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Subject
Life Science

Grade Level
Grades 5-8 (based on middle school benchmarks)

Driving Question
How does the human body change during exercise?

Abstract
Students jog in place and develop questions about how the body is affected by exercise. They learn how to measure pulse, respiration rate, and production of carbon dioxide (using BTB solution). They develop step-by-step research methods to investigate their question, and state a hypothesis about the outcome of their investigation. They carry out their research, collect data, make a graphic representation of the data, and state a detailed conclusion. Research projects are presented to the class and turned into the teacher. Additional questions for further investigation are developed.

Michigan Curriculum Framework Science Benchmarks
http://www.miclimb.net/content/main.html

Constructing New Scientific Knowledge Benchmarks:
I.1.M.1 Generate scientific questions about the world based on observation.
Key concepts: Scientific questions can be answered by gathering and analyzing evidence about the world.
Real-world contexts: Any in the sections on Using Scientific Knowledge.

I.1.M.2 Design and conduct scientific investigations.
Key concepts: The process of scientific investigations—test, fair test, hypothesis, theory, evidence, observations, measurements, data, conclusion. Forms for recording and reporting data—tables, graphs, journals. See C-I.1 m-3 (tools).
Real-world contexts: Any in the sections on Using Scientific Knowledge; also, recognizing differences between observations and inferences; recording observations and measurements of everyday phenomena.

I.1.M.3 Use tools and equipment appropriate to scientific investigations.
Tools: various data collection tools suitable for this level, including computers.
Real-world contexts: Any suggested in Using Scientific Knowledge benchmarks for which students would design and/or conduct investigations.

I.1.M.6 Write and follow procedures in the form of step-by-step instructions, formulas, flow diagrams, and sketches.
Key Concepts: Purpose, procedure, observation, conclusion, data.
Real-world contexts: Listing or creating the directions for completing a task, reporting on investigations.

Reflecting on New Scientific Knowledge Benchmarks:
II.1.M.1 Evaluate the strengths and weaknesses of claims, arguments, or data.
Key concepts: Aspects of arguments, such as data, evidence, sampling, alternate explanation, conclusion; inference, observation.
Real-world contexts: Deciding between alternate explanations or plans for solving problems; evaluating advertising claims or cases made by interest groups; evaluating sources of references.

Using Life Science Knowledge Benchmarks:
Organization of Living Things III.2.M.4 Explain how selected systems and processes work together in animals.
Key concepts: Systems/Processes—digestion, circulation, respiration, endocrine, reproduction, skeletal, muscular, nervous, excretion, transport, growth, repair.
Real-world contexts: Interrelations of body systems during selected activities, such as among skeletal, muscular, circulatory, and respiratory systems during physical exercise.

Big Ideas

As muscles work, they require energy from digested food. Oxygen is required to release food energy. Carbon dioxide is produced during this process, and needs to be exhaled from the body. The digestive, circulatory, and respiratory systems work together during physical exercise to provide increased amounts of digested food and oxygen to the cells and transport carbon dioxide and other wastes out of the body, allowing the muscular system to propel the skeletal system.

Prerequisites For Students

Students should have some familiarity with the layout of the digestive, circulatory and respiratory systems, although they do not need to know the names of all the parts of each system. Some names are important, of course, including lungs, stomach, small intestine, arteries and veins. They also need to understand that every part of the human body is composed of cells, including the muscles.

Estimated Time Needed

Four classes of approximately 50 minutes

Background Information

Organisms get most of their energy from carbon-based compounds (plant and animal parts). This process takes place within every cell, using oxygen and releasing carbon dioxide. Through respiration, an organism brings in oxygen and rids itself of carbon

dioxide. Students may know that burning requires oxygen (this can be demonstrated by snuffing out a candle by placing a glass over it). You may use the analogy that, as oxygen is used to burn wood, paper, or a candle, it is also used to "burn" food in an animal's body. When food is combined with oxygen, carbon dioxide is produced (as it is in burning of wood or paper or natural gas).

Oxygen enters the human body through breathing. It enters the lungs and goes to the alveoli, where the blood flows past and attaches up to four oxygen molecules to each hemoglobin molecule (hemoglobin molecules are found within red blood cells). The circulatory system works to transport this oxygen-rich hemoglobin throughout the body to every cell.

Food is digested in the stomach and small intestine, and the digested molecules (proteins, fats and sugars) are transported by the circulatory system to every cell. Sugars are used for quick release of energy; fats can also be used for the release of energy; proteins are usually used for building new cells. When digested food molecules and oxygen are combined in cells, carbon dioxide is produced. The carbon dioxide must be expelled, and is transported through the blood, into the alveoli and out of the lungs with the expired air.

Students can see how increased respiration creates increased carbon dioxide by using the indicator, bromthymol blue (BTB). The bromthymol blue solution is used to detect the amount of carbon dioxide in the exhaled air. As exhaled air is blown through a straw through BTB solution, carbon dioxide is dissolved in the water creating carbonic acid which lowers the solution's pH. As the pH decreases, the BTB solution changes from blue to green to yellow. The degree and quickness of color change indicates the relative amount of carbon dioxide present in the exhaled air.

This lesson gives each student group a chance to design and do an investigation. Student groups answering different questions related to the body's response to exercise can all use the format given to develop and test their hypotheses in a scientific manner. However, not every question is one that should or can be investigated with an investigation. Part of the role of the teacher in this lesson is to recognize this, and to encourage students to develop questions that can be answered through investigation. To determine whether a student question is worthy of scientific investigation, check the following criteria:

- Does the question involve how something changes when acted on by something else?
- Does finding the answer involve collecting data?
- Is the process something that can be demonstrated in the classroom or on school grounds?

Teacher Page 7-1 gives a sample of how a student group might fill out Student Page 7-1, involving investigation design. Teacher Page 7-2 is an example of a Research Methods page. Teacher Page 7-3 gives an example of the group's Data Collection, and Teacher Page 7-4 is a sample Conclusion. These are meant to be used as examples, not as instructions for any group's investigation.

Materials List
For each student group of 3 or 4
Newsprint
Set of markers or colored pencils
Graph paper
Rulers
Copies of Student Page 7-1 (have extras on hand)

Have available for use:
Stopwatches
BTB solution
Straws

Advance Preparation
BTB can be purchased from most chemical supply companies or you may prepare it yourself by doing the following: Prepare a 0.1% solution by dissolving 0.5 grams of bromthymol blue in 500 ml of water. To this add ammonium hydroxide (NH_4OH) or sodium hydroxide (NaOH), drop by drop, until the solution is a deep blue. Dilute as needed.

Procedure

Part 1: Student Exploration (Day 1)

1. Ask: What happens to your body when you exercise? Allow students to answer this in any way they like.

2. After students have discussed their initial thoughts, focus the discussion on how body functions change during, and immediately after exercise (such as an increased pulse rate and increased breathing rate, and perspiration). Discuss these kinds of changes rather than the long-term benefits of exercise (such as weight loss and cardiac health).

3. Ask students to jog in place and observe changes in their bodies (breathing rate increases, pulse increases, muscles get tired, perspiration, etc.) Have each student describe one change that occurred in their body during exercise.

4. Ask students to generate questions about how their body functions change as they jog. Write all questions on the board while they are jogging.

5. Ask students to discuss what they already know or believe about the immediate effects of exercise on body functions. Ask them *why* they think the body changes in these ways during exercise. Continue to write down any questions that arise during the discussion.

6. Review with students what they already know about the circulatory and digestive systems, without giving away answers to the questions about exercise. Students

probably know that the heart pumps blood to other parts of the body. Tell them that the heart pumps blood to every *cell* in the body. Illustrate this concept by pointing to different parts of the body and describing it as made up of millions and millions of cells, each of which needs blood. (But don't tell them why the cells need blood at this point, since this is part of the investigation.)

Also review what they know about where food travels after it is eaten – from the mouth, through the esophagus, into the stomach, then the small intestine. Some food is digested in the stomach, some in the small intestine. Wastes from the food we eat are passed out of our bodies through our large intestine. Students probably know that we need food for energy, but they should learn more about the details of this through this investigation.

This discussion is important for activating students' prior knowledge and establishing a base of common knowledge from which to build this investigation.

Part 2: Question or Statement

1. Break students into investigation groups.

2. Have each student group choose one question from the class list to investigate.

3. Each group should sharpen its question so that it is "testable." For example, a question such as "How much does exercise raise your heart rate?" is not testable because it is not specific, where something like the following is: "How much does your heart rate change when you jog in place for two minutes?" Testable questions require students to collect specific data.

   Possible questions might include:
   - Does doubling your exercise time double your heart rate?
   - Is there a limit to how high your pulse rate or respiration rate will go?
   - Do you produce more carbon dioxide (when you breathe out) during exercise than when resting?
   - How quickly does your breathing rate go back to normal after you stop exercising?

Part 3: Method for Gathering Data

1. Have each group determine a method for collecting data. The method will depend on the question they pose. Suggested methods are listed below. You can help students understand these methods as needed.

   Heart rate: Groups who are investigating the relationship between heart rate and exercise need to determine a method for measuring heart rate. This is usually accomplished by measuring the pulse. They will need to determine a length of time

for recording the pulse – typically 10 or 15 seconds, then multiply to get the number of beats per minute (10x6 = 60 sec or 15x4 = 60 sec).

Oxygen used: To measure the amount of oxygen inhaled during jogging, students may decide to count breaths. Again, they will need to establish a period of time over which to count.

Carbon dioxide exhaled: One way to measure carbon dioxide is by using BTB solution. When carbon dioxide is blown through BTB, it changes from blue to green or yellow. The amount of time needed to change it depends on the amount of carbon dioxide. Students can blow their breath through a straw and time the color change.

For all methods, students will need to gather data about body conditions prior to exercise as well as after exercise. Help them think about the need to collect data from several students, not just one. Also, if any groups decide to measure body functions for one student that has not exercised and a different student who has exercised, ask them to consider whether differences in body functions between the two students might affect their results. Help them think about "fair tests."

Part 4: Prediction/Hypothesis

1. After groups develop their method, have them make a prediction or hypothesis about the outcome of applying their method to the question. You may need to model one for the entire class. It should be something like: If we jog for two minutes, our breathing rate (the number of breaths we take) will double over what it is when we jog for one minute. Each group will have a different prediction, depending on the question they have chosen to investigate.

   For the groups measuring the increasing in exhaled carbon dioxide, their prediction would involve the difference in time it takes to turn BTB from blue to green or yellow, from *before* exercise to *after* exercise. It might be as simple as "After jogging for 2 minutes, it will take less time to turn BTB from blue to green (or yellow), because we are producing more carbon dioxide." Again, make sure they understand the conditions for a fair test in their investigation.

2. Distribute the Investigation Design student pages. Have students fill in the first six items:
   #1: their question;
   #2: what they already know about how the body reacts during exercise;
   #3: what they will change (they will change their exercise state, from resting to jogging);
   #4: what data they will collect (heart/pulse rate, breathing rate, or carbon dioxide production);
   #5: their prediction or hypothesis; and
   #6: what things they will keep the same during each trial (for example, make sure the

same person's heart rate is checked before and after jogging, rather than checking two people's heart rates at the same time, one who has jogged and one who hasn't, etc.)

Part 5: Research Details

1. Using a page titled "Research Methods," have students write a detailed plan for conducting their investigation. The plan should list every step they intend to take. (A sample Research Methods page is attached, Teacher Page 7-2.) They will need sufficient time to brainstorm different possible approaches to collecting the data. The methods they develop should allow them to find out whether their hypothesis or prediction is correct.

2. Have groups practice the appropriate methods they will use, prior to jogging: measuring their own pulse (beats/minute); measuring their rate of respiration (# breaths/minute); measuring carbon dioxide production rate (how long it takes to turn BTB green or yellow).

3. For any of these measurements, student groups should include in their design that they measure any body function both before and after exercise, in order to have a fair test.

4. Have groups hand in their Research Methods and Student Page 7-1. Review them, looking for things like equipment availability, if there is time to do their research, if it is doable by students this age, and general workability. Check each group's design to make sure it includes a hypothesis and that there is a clear method for recording data. Give guidance as you review the materials, but try not to dictate specific changes. This is best done by asking critical questions such as, "How will you measure that?," and "What things will you keep the same?" Then groups can come up with changes that answer your questions and critiques.

5. **(Day 2)** Return the Research Methods with your comments and let groups re-design or alter their research methods as needed.

Part 6: Data Collection

1. Ask each group to think about the type of data it will collect. Have students develop a data collection form that has room for the information they wish to collect, and some sort of measurement unit for what they will collect. Circulate through the room as students are designing the data collection forms and offer assistance. Often, a simple chart works best. Have them fill in values for the variable that they control, which will usually be the time they start the jogging and the time they will finish it.

   Groups will compile several forms and record-keeping pages in this investigation. They may need a file folder or binder of some kind to manage their papers.

2. Have students do their investigations and collect their data on the data collection forms they have designed.

Part 7: Data Analysis, Use and Communication of Results

1. **(Day 3)** Explain to the class that graphing often makes patterns emerge from the data. Have each group graph their data. Graphing forms may vary, depending on the type of data. Bar graphs and line graphs are probably appropriate for most of the comparisons that students will make.

2. Ask groups to discuss the data and look for patterns. Do their data support their hypothesis? What conclusions can they draw?

   Caution them to draw conclusions from their data that either support their hypothesis or that don't. But ask them not to try to explain what happened in terms of internal body functions that they cannot see. The explanations are *interpretations* of the data that will come next.

   Some interpretations that go beyond conclusions might include:
   - Breathing rate increases during exercise because your body needs oxygen to run.
   - Your lungs produce more carbon dioxide during exercise.
   - Blood flow increases during exercise because the blood moves oxygen to muscle cells.

3. Hold a class discussion to *use* the knowledge they have gained from the investigation to explain what is going on inside their bodies when they exercise. These are the *interpretations of data* discussed above. Pose questions to students such as:
   - Why do you think you need more oxygen when you exercise?
   - What could be going on inside your body that needs more oxygen during exercise?
   - Where could the additional carbon dioxide come from that is exhaled during exercise?
   - Why would your pulse rate increase during exercise? What does your heart do for your body? Why would it have to do more of this during exercise?

   Guide the discussion so that students come to understand that exercise requires more energy than normal; energy is needed specifically by our muscle cells; we get energy from food; energy is released from food when it is combined with oxygen in the cells; carbon dioxide is released by this process. These are not simple extrapolations of the data – they are interpretations that are based on the data. The data is *evidence* that this process takes place in our cells.

4. Have students complete the formal Conclusion Page, Student Page 7-2, based on their data and discussions. Help each group as needed. The questions that comprise the formal conclusion are listed here as well as on the Student Page:
   - What was the purpose of the investigation?

- What did you find out?
- Was the hypothesis supported by the data?
- How does what you found out compare with what other researchers have found out? (i.e., what other groups within the class found out.)
- How can you explain what you found out?
- What else would you like to do with this investigation, and how would you make it better?

5. **(Day 4)** Have each group present its question, hypothesis, research methods, graphic representation of data, and conclusion to the class. Every group member should have a part in the presentation. Presentations should include these parts (write them on the board):
   - The group's question
   - The full hypothesis
   - The research methods
   - The data, presented as graphs, charts, or drawings
   - The conclusion
   - Participation by each group member

6. Have students turn in all Student Pages, the Research Methods, and the graphic representations of data for assessment purposes. If you wish, you may have groups put these together on posterboard as a display that can be set up where others in the school can see it.

Part 8: Guided Questions for Reflection

1. Ask the class to discuss any problems with their research design or data collection that could have kept them from getting good results. Ask how they could correct those problems for future investigations.

2. Ask the class to discuss how the results from different groups supported or did not support each other's work.

3. Have students answer questions individually on Student Page 7-3, then discuss their answers as a group. Questions are listed here with possible student responses. Students should be prepared to answer these questions from the discussion held in Part 7. However, individuals may need teacher support.
   - How does your body act and feel right after heavy exercise? (breathing is faster)
   - What does this tell you about what the body needs in order to exercise? (more oxygen; also, the body needs to get rid of more carbon dioxide)
   - Does exercise affect respiration in ways other than the rate of breathing? (it increases heart rate)
   - What body systems are working together during exercise? What is the role of each? (respiratory system – bringing oxygen into the blood and removing carbon dioxide; circulatory system – moving oxygen from the lungs to all cells and

carbon dioxide from the cells to the lungs; digestive system – providing energy-rich food which can be moved by the circulatory system to all cells)
- Why do bodies need more oxygen during exercise? (oxygen is combined with digested food in each cell to release energy for cell use)
- Where must the carbon dioxide come from that you breathe out? (It must come from each cell as a by-product of the release of energy)
- What are two characteristics of a fair investigation into how body systems work? (1. The same method must be used in all cases. 2. Conclusions must be based on the data collected. Other responses might be acceptable.)

Part 9: Student Questions for Additional Inquiry

1. Ask students to list further questions they have, and how they might determine the answers to these questions.

2. As time permits, let them perform these subsequent investigations.

Assessment

Group assessment can be made by ranking proficiency in each of the parts of the final presentation: the hypothesis, the Investigation Design page, the step-by-step Research Methods, the graphic presentation of the data collected, the conclusion, and, finally, the participation of all members.

Individual assessments can be done by interviewing individual students about their group's project and assessing their understanding of what the group did and why it was done. If desired, you may require each student to fill out their own copy of the Student Pages. If additional individual assessment is desired, students can be asked these questions:
- Explain the changes in a body when exercising.
- How would you investigate one of these changes?

Names_____

Investigation Design

1. What is our question?

2. What do we know? – How does exercise affect (heart rate, oxygen used, carbon dioxide produced)?

3. What will we do? – How will we change things to affect how the body responds?

4. What data will we collect? – How will we measure the response of the body to what we change?

5. What is our hypothesis? – **If** we (#3) _____,

then (#4) _____will change by

_____ .

6. The things we keep the same on purpose are:

Names_____

Conclusion

Answer all of these questions in your conclusion:

1. What was the purpose of the investigation?
2. What did you find out?
3. Was the hypothesis supported by the data?
4. How does what you found out compare with what other researchers have found out?
5. How can you explain what you found out?
6. What else would you like to do with this investigation, and how would you make it better?

Name_____

Thinking About the Data

Answer all of these questions in your conclusion:

1. How does your body act and feel right after heavy exercise?

2. What does this tell you about what the body needs in order to exercise?

3. Does exercise affect respiration in ways other than the rate of breathing?

4. What body systems are working together during exercise? What is the role of each?

5. Why do bodies need more oxygen during exercise?

6. Where must the carbon dioxide come from that you breathe out?

7. What are two characteristics of a fair investigation into how body systems work?

Names (Sample student responses)

Investigation Design

1. What is our question?
   How are heart rates affected by exercise?

2. What do we know?
   We breathe more heavily and feel tired after exercising for awhile.

3. What will we do? – How will we change things to affect how the body responds?
   We will have the person exercise by running back and forth between two chairs in the room.

4. What data will we collect? – How will we measure the response of the body to what we change?
   We will measure the runner's heartbeat before and after exercise, for 15 seconds, by counting their pulse beats. We will do this with 3 different people.

5. What is our hypothesis? If we (#3) change the body's functions by exercising then (#4) the data we collect as heart beats per minute will change by increasing.

6. The things we will keep the same on purpose are:
   The distance between the chairs, the way we take the pulse, measuring the pulse directly after the exercising has stopped, etc.

Research Methods

(Sample student responses)

1. Choose a runner.
2. Set up two chairs at different ends of the room or in the hall.
3. Take the jogger's pulse while she is resting. Take the pulse by counting the number of heartbeats (you can feel these on the wrist) in fifteen seconds and multiply this by four.
4. Have the runner run between the chairs four times and take her pulse again, in the same way.
5. Do this six times in a row.

NOTE: This group used a chart to collect data. In one column, they wrote the number of times the runner ran between the chairs (0, 4, 8, 12, etc.). In the second column, they put the runner's pulse (number of heartbeats per minute). The graphic representation they used was a line graph. Heart rate (beats per minute) was on the Y axis. Number of times the runner ran between chairs was on the X axis.

Names (Sample student responses)

Conclusion

Answer these questions in your conclusion:

1. What was the purpose of the investigation?
2. What did you find out?
3. Was the hypothesis supported by the data?
4. How does what you found out compare with what other researchers have found out?
5. How can you explain what you found out?
6. What else would you like to do with this investigation, and how would you make it better?

Conclusion

The purpose of this investigation was to see how heart rates are affected by exercise. We found that the heart rate was raised more and more as our runner kept exercising. Our hypothesis was: **If** we change the heartbeat by having the person run back and forth between two chairs **then** the heartbeat (pulse) will change by going up as length of exercise time increases. Our hypothesis **was** supported by our data. Other researchers in our class had similar results. We think that the heartbeat goes up because the heart has to get more oxygen to the muscles when they are exercising. But our research does not prove this, it just proves that the heart rate goes up. We think this study should be done with different people acting as runners, to see if different hearts react differently to exercise.