Lesson Overview

In this lesson, students investigate what might happen to their scientist or engineer if he or she does not wear a biosuit in their environment. To do so, students conduct an experiment in which they monitor heart rate, breathing rate, blood pressure, skin response, and eye response to cold water. Students take measurements of all five variables prior to dunking their face or hands in cold water for 1 minute. After dunking their face or hands, students take measurements of all five variables again. Students conduct this investigation on each group member and report their results. Students should find that dunking their face or hands in cold water will change the heart rate, breathing rate, blood pressure, and skin temperature. Students may also find differences in the eye response.

When revising their model for the human body reaction to cold water, students should reason that the “cold” message must be sent from the skin to the other organs via a central processing center—the brain. Students should also consider how the various human body systems interact to maintain homeostasis when the human body is exposed to cold water. Finally, students should build on prior knowledge to reason that energy is transferred out of hotter regions or objects into colder ones.

When designing their biosuits, students should understand that they need to help the diver keep warmth, not—as commonly misunderstood at this grade level—keep the cold out. Students should keep this model in mind, along with the model of the human body response, when deciding which materials to use in their biosuits.

Connecting to the Next Generation Science Standards

On Day 3, students make progress toward developing understanding across the following three dimensions:

- **Science and Engineering Practices**: Developing and Using Models, Planning and Carrying out Investigations
- **Crosscutting Concepts**: Cause and Effect

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.
Performance Expectations

This lesson contributes toward building understanding of the following life science and physical science performance expectations:

- **MS-PS3-3.** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
- **MS-LS1-3.** Use argument supported by evidence for how the body is a system of interacting sub-systems composed of groups of cells.
- **MS-LS1-8.** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Specific Connections to Classroom Activity

Students engage in an investigation to determine the physiological responses to putting their face in cold water. Through this investigation, students find out that putting their face in cold water slows the heart rate, slows breathing, and lowers blood pressure. This finding demonstrates that the cold water stimuli somehow travels from the skin to the organs that respond (heart, lungs, and blood vessels). Because the message travels to so many different places, students begin to develop the idea that it must first travel to the brain. Students also consider the ways by which energy (or heat) is transferred from place to place.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>NGSS Element</th>
<th>Connections to Classroom Activity</th>
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</thead>
</table>
| **Science and Engineering Practices** | Developing and Using Models  
- Develop a model to predict and/or describe phenomena.  
- Develop a model to describe unobservable mechanisms.  
Planning and Carrying Out Investigations  
- Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation. | After engaging in the investigation, students develop a revised model demonstrating how the cold water stimuli can cause changes in heart rate, breathing, and blood pressure. Students also consider how the body systems work together to maintain homeostasis. After brainstorming possible investigations, students carry out an investigation to determine the physiological effects of putting their face or hands in cold water. |
| **Disciplinary Core Ideas** | PS3.B: Conservation of Energy and Energy Transfer  
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.  
LS1.A: Structure and Function  
- In multicellular organisms the body is a system of multiple interacting sub-systems. These sub-systems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.  
LS1.D Information Processing  
- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. These signals are then processed in the brain, resulting in immediate behaviors or memories. | After conducting their investigation, students model what happens when they put their face or hands in cold water. Included in this model should be a description of thermal energy transfer. Students conduct an investigation to determine the physiological responses to putting their face or hands in cold water. They find that the cold water stimuli changes heart rate, breathing rate, and blood pressure. Students begin to reason that the "cold" message from their skin travels to the different organs to cause a response. Because the message travels to so many organs, students begin to reason that the message must pass through a central location—the brain. Furthermore, students consider the ways that the different human body systems work together to produce a response. |
Basic Teacher Preparation

In this lesson, students conduct an investigation to measure the physiological response to putting their face or hands in cold water. If possible set up the lab materials prior to the lesson. Each group should have a bucket of cold (ice) water, a stopwatch, and a clear ruler. If available, this lesson can be enhanced by adding a heart rate and blood pressure monitor. If you choose to use a heart rate and blood pressure monitor, plan to introduce students to the use of the technology.

Refer to the Extreme Biosuits Student Handbook ahead of time so you can address any questions students might have. All Day 3 documents can be found on pages 19–23 of the Extreme Biosuits Student Handbook. The documents used in this lesson are:

- Testing the Response to Our Environment (pages 19 and 20)
- Revising Our Model (page 21)
- Reflections—What If Our Scientist or Engineer Does Not Wear a Biosuit? (page 22)
- Defining the Problem and Identifying Solutions (Round 3) (page 23)

To prepare for the whole group discussions, review the Talk Science Primer (see Suggested Teacher Resources for Day 1).

### Required Preparation

<table>
<thead>
<tr>
<th>Required Preparation</th>
<th>Links/Additional Information</th>
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</thead>
<tbody>
<tr>
<td>☐ Gather or purchase the required materials for the lesson</td>
<td>Refer to the Materials List below</td>
</tr>
<tr>
<td>☐ Review suggested teacher preparation resources and the recommended websites</td>
<td>Refer to the Suggested Teacher Resources section at the end of this lesson</td>
</tr>
<tr>
<td>☐ Set up lab stations</td>
<td>Refer to the Materials List below</td>
</tr>
</tbody>
</table>

### Materials List

<table>
<thead>
<tr>
<th>Item</th>
<th>Description/Additional Information</th>
<th>Quantity</th>
<th>Where to Locate/Buy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Biosuits Student Handbook</td>
<td>Given to students on Day 1</td>
<td>1 per student</td>
<td>[Resource Link]</td>
</tr>
<tr>
<td>Bucket of ice water</td>
<td>Use just enough ice to make the water notably colder than the air</td>
<td>1 per group</td>
<td>Available in most schools</td>
</tr>
<tr>
<td>Resource</td>
<td>Description</td>
<td>Quantity</td>
<td>Link</td>
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<tr>
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</tr>
<tr>
<td>Stopwatch</td>
<td>To time heart rate and breathing rate</td>
<td>1 per group</td>
<td>[Resource Link]</td>
</tr>
<tr>
<td>Heart rate and blood</td>
<td>To measure heart rate and blood pressure</td>
<td>1 per group</td>
<td>[Resource Link]</td>
</tr>
<tr>
<td>pressure monitor (Optional)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear ruler (in/cm)</td>
<td>To measure eye response</td>
<td>1 per group</td>
<td>[Resource Link]</td>
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</table>
Day 3: What If Our Scientist or Engineer Does Not Wear a Biosuit?

Introduction (5 minutes)

In the last lesson, students brainstormed ways to test what might happen if their scientist or engineer worked in their environment without a biosuit. In this lesson, students test what will happen to the scientist or engineer by testing the effects of cold water on the body.

Refer students to Testing the Response to Our Environment on pages 19 and 20 in the Extreme Biosuits Student Handbook. Emphasize the idea that the goal of this investigation is to figure out what might happen to the body when it is exposed to cold water. Review the procedures with students.

Investigation: Testing the Response to Our Environment (15 minutes)

Allow students to work in groups to complete the investigation. Be sure students record their data in the data table on page 20 in the Extreme Biosuits Student Handbook.

As students conduct the investigation, circulate to monitor student work and engage students in sense-making discussions. Discussion prompts may include:

- Do you notice any trends in your data?
- Are your results what you expected?
- Why do you think x happened?
- Why do you think x responded one way and y responded a different way?

Whole Group Discussion: Trends in the Data (5 minutes)

After all groups have completed the investigation, engage students in a whole group discussion. Ask students if they noticed any data trends. Students should notice that the heart rate, breathing rate, and blood pressure went down. They should also notice that the skin got cold. Ask students why they think these things happened. Press for students to supply reasoning.

Students might say that the cold water sent a message to the organs to cause them to slow down. Ask students how they think the message got to many different organs at the same time.
Help students develop the idea that the message first needed to pass through the brain, which then sent a message to body parts to tell them to slow down. The evidence for this was that so many body parts slowed down in response to one stimuli. Make sure that all students feel comfortable with this idea before moving on.

Ask students to think about **WHY** heart rate and breathing rate slowed down and why blood pressure dropped when the face was exposed to cold water. Push students to think about the advantages and disadvantages of this response. If students are stuck, encourage them to continue to work with their ideas and make their thinking public.

Many students may have predicted that the heart rate will speed up when the face is placed in cold water. Students might reason that by speeding up the heart rate, the body is trying to warm up. This would be an example of a typical homeostatic mechanism (the body gets cold, so the brain tells the body to do something to warm it up). Students may be very confused as to why the heart slows down. Push students to work with this confusion. You may ask questions such as:

- **In what other cases does our heart slow down?**
- **What happens to the rest of the body when the heart slows down?**
- **How does a slow heart rate relate to our breathing rate?**
- **Can you think of any other animals that regularly put their faces (or bodies) in cold water? Do you think they have the same response? How does that help us think about humans?**

Guide students to the idea that a slower heart rate means that oxygen is being transported around the body at a slower rate. That leads to a slower breathing rate. This translates to the idea that the person could hold their breath for longer periods of time. This is a well-known response in most mammals called the **mammalian diving response**.

The mammalian diving response is advantageous in most cases, so protecting divers from cold water may seem confusing. On one hand, the body responds to cold water by protecting interacting body systems. On the other hand, working in cold water is very difficult for divers! Encourage students to explore these ideas. Eventually, push the idea that even though the human body naturally responds to cold water in ways that protect a diver, divers must be comfortable so they can do their work successfully.

**Extension**

The response tested in this investigation is called the **mammalian diving response**. Scientific American published an article about the mammalian diving response that may be interesting to some students. The article can be found [here](#).
Investigation: Revising our Model (10 minutes)

Once students have started to work with the idea that a slower heart rate may allow a person to hold their breath for a longer period of time but that cold water might prevent a diver from successfully doing their job, have students draft a revised model of the body response to cold water.

Have students read the Revising Our Model directions on page 21 of the Extreme Biosuits Student Handbook. Students should refer to their Draft Model on page 18 in the Extreme Biosuits Student Handbook. The revised model should clearly incorporate evidence from the investigation and science ideas from the discussion. Press students to justify their reasoning for why the message must have traveled to the brain. Also press students to incorporate the idea that all of the body systems work together.

Finally, have students incorporate the idea of thermal energy transfer into their models. Students should model that energy is transferred from hotter regions or objects into colder ones. Students need to understand that they need to help the diver keep warmth in and cold out. Students need this understanding later, when they begin developing their biosuits.

Have students share their models in their small groups and the whole group.

NGSS Key Moment
By revising their models, students are demonstrating their developing understanding of LS1.D. Students should cite evidence for the changes in their models. Comparing the model developed on Day 3 to the model developed on Day 2 will provide insight regarding progress along LS1.D.

NGSS Key Moment
At this point in the modeling process, students need to draw on science understanding developed as part of MS-PS1-4, which addresses the kinetic model of thermal energy transfer.

Mini-Lesson: What If Our Scientist or Engineer Does Not Wear a Biosuit? (10 minutes)

After completing their revised model, have students individually reflect on what they figured out in this investigation. Instruct students to respond to the prompts on page 21 in the Extreme Biosuits Student Handbook. Also have students complete Defining the Problem and Identifying Solutions (Round 3) on page 23. Students should now be able to complete the final column, labeled Challenges, of the chart.
Whole Group Discussion: What If Our Scientist or Engineer Does Not Wear a Biosuit? (Optional) (5 minutes)

Ask students to think about what might happen if scientists and engineers do not wear biosuits when working in extreme conditions. Push students to identify the reasons why the cold water may be dangerous to scientists and engineers working in the field. Ask students to share their ideas about designing biosuits.

NGSS Key Moment

This discussion helps students to further define the design problem. Students should realize that a biosuit must minimize the transfer of thermal energy from the human to the environment. This realization aids in the connection to MS-PS3-3 in the next lesson.

Extension

Ask students to think about why the mammalian diving response is beneficial for most mammals. Help students to think carefully about the response in different situations (such as hunting for food vs. completing a scientific task). Reading this article in the Dartmouth Undergraduate Journal of Science may help with understanding.

Returning to the Driving Question Board (5 minutes)

Reference the lesson question on the DQB, Why are biosuits needed in certain environments? Ask students if they think they made progress in answering the question. Also ask students if they think they made progress in answering any of the other questions on the board. Tell students to record their progress on a sticky note. When students are finished, they should read their sticky notes out loud to the class and post them to the DQB. If students have additional questions, they should add them to the DQB.

Assessment

Several opportunities for formative assessment exist in this lesson:

- Extreme Biosuits Student Handbook entries can be used to monitor student progress during the module.
- Use revised student models (page 21) in comparison to initial student models (page 18) to monitor growth on key learning for this lesson.
- Use What If Our Scientist or Engineer Does Not Wear a Biosuit student reflections on page 22 to get a sense of student thinking.
- Compare all three rounds of Defining the Problem and Identifying Solutions (pages 13, 16, and 23) to observe student growth throughout the module.
• Consider gathering evidence of student progress through small group and whole group discussions.
• Student contributions to the Driving Question Board can also be monitored.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.

Community Connections

Ask students to talk to an adult at home to brainstorm other examples of the mammalian diving response. Encourage students to brainstorm situations in which this response may be beneficial or harmful to mammals.

Suggested Teacher Resources

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<thead>
<tr>
<th>Meeting the Needs of All Learners</th>
<th>Extreme Biosuits Teacher Handbook, Appendix B</th>
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<tbody>
<tr>
<td>Extreme Biosuits Student Handbook</td>
<td>[Resource Link]</td>
</tr>
<tr>
<td>Mammalian diving response</td>
<td>[Web Link]</td>
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<tr>
<td>Mammalian diving reflex</td>
<td>[Web Link]</td>
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<tr>
<td>Conduction: Heat Conduction through Materials</td>
<td>[Web Link]</td>
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<tr>
<td>Molecular Workbench: Heat</td>
<td>[Web Link]</td>
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