How do people build muscles if they are not eating muscle proteins?

High School     •     Discipline: LS     •     Time: One 50-minute class period

Lesson Level Performance Expectation:
• Ask questions to clarify and refine a model to explain how the proteins we eat result in the proteins that are found in the body.

What Students Will Figure Out
• Proteins have many functions, and all living things need protein to maintain homeostasis, so even foods we consider to be carbohydrates, like wheat and other grains, have proteins.
• Students have many questions they need to answer about how what we eat is related to what our body is made of.

Lesson Snapshot:
High school students, as scientists, encounter a puzzling phenomenon: professional athletes with muscular bodies who are vegan. Students investigate the diets of these athletes to answer this question: How do people build muscles if they are not eating muscle protein? Students figure out that much of the food we eat contains proteins. Even things we consider to be carbohydrates, like wheat and other grains, have proteins, so even if we are not eating certain kinds of proteins, we do consume other proteins.
### Phenomenon:

**Some people who do not eat meat have large muscles.**

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
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<tbody>
<tr>
<td>Asking Questions and Defining Problems • Ask questions to clarify and refine a model, an explanation, or an engineering problem.</td>
<td>LS1.C: Organization for Matter and Energy Flow in Organisms • As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (HS-LS1-6) (HS-LS1-7)</td>
<td>Cause and Effect • Cause-and-effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller-scale mechanisms within the system.</td>
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This lesson could be one in a series of lessons building toward the following:

**HS-LS1-1.** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]

**HS-LS1-2.** Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. [Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.] [Assessment Boundary: Assessment does not include interactions and functions at the molecular or chemical reaction level.]

**HS-LS3-1.** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

### Materials

<table>
<thead>
<tr>
<th>Student Materials</th>
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<tr>
<td>Per Student • Protein Structure and Function Table • Athletes’ daily menus • Proteins Necessary for Human Growth and Homeostasis</td>
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<table>
<thead>
<tr>
<th>Teacher Materials</th>
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<tr>
<td>Several pieces of chart paper and chart markers or another space to record student ideas publicly</td>
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<table>
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<th>Optional Teacher Resources</th>
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### Lesson Preparation

- Designate an area of your classroom where all students can easily see, and post your chart paper there. This is where you will record information the class shares, as well as construct the class consensus model.—
Experience the Phenomenon

What Students are Doing:

In this section, students confront the idea that people who do not consume muscle proteins (from eating meat) are still able to build large muscles.

Teacher Guidance

1. Introduce the idea of a healthy, muscular athlete.

Project Slide 2. Ask students to think about who comes to mind when they hear the word athlete. Ask students to consider why they thought of that person.

Surface the idea that humans have a variety of body types, and athletes are able to get large or defined muscles by using them in ways that stresses them. Facilitate a discussion about what other things—aside from working out—could help support a body to have muscles.

Suggested Prompts

- When people exercise and push their muscles hard, the muscles need to repair themselves, which eventually makes them grow. What else is important to allow your muscles to grow?

Listen For

- People need to have protein in their diet to build and repair muscles.

Additional Guidance: Facilitating discussion about performance-enhancing drugs and other supplements

Students may express the idea of steroids or performance-enhancing drugs; if that happens, you can mention the fact that professional athletes are tested for drugs often. (For example, Serena Williams, one of the athletes who will be introduced on the next resource, has been tested twice as often as other top American players. Mentioning this may distract students from absorbing the key ideas of this discussion efficiently; however, if students are highly interested in this topic, have students add any questions they have to the Driving Questions Board so those questions may be revisited later.)

Other students may bring up supplements (such as protein shakes or bars). If that is the case, tell them that we will still be able to explore those ideas, and students will see in later steps that some athletes have listed them as part of their daily menu. However, you should attempt to ask clarifying questions that return students to thinking about whole food items. The idea here is to uncover what students know about how diet relates to the human body, and to share ideas so everyone comes away with the understanding that it is important to eat protein, leading students to focus on the protein sources that must be a part of their diet for the next step.

2. Ask students to make some predictions about what kinds of foods an athlete might eat.

Give students some time in the alone zone, then ask students to share their ideas with their elbow partner before sharing them with the rest of the class. The purpose of this discussion is to identify protein sources in an athlete’s diet, and how many protein sources we typically think about are animal-based.

Suggested Prompts

- Since we just agreed it is important for people to have protein in their diet to build healthy muscles, what kinds of foods do you think an athlete would have on a given day?
- Where do those foods come from?
- When we eat steak or chicken, what exactly are we eating?
- Do you think it is important to eat muscle proteins to be able to make big muscles?
How do people build muscles if they are not eating muscle proteins?

Listen For

• chicken, steak, burgers, eggs
• Chicken and steak are muscles from different animals; eggs also come from animals.
• We’re not sure if you have to eat muscle proteins to get muscles, but it makes sense.

3. Students examine the diets of several athletes.

Hand out Daily Menus of Selected Elite Athletes, which gives a typical daily menu for several athletes paired with photos of the athletes. Ask students to highlight the protein sources in each athlete’s diet and record any noticings and wonderings about the daily menus. Next, they should share those ideas in small groups. After groups have shared, the class will come together to share any patterns they have noticed and questions they may have.

Suggested Prompts

• What did you discover about what these athletes consume?
• Were you surprised at what you found?
• Do you think some of these other foods listed also have protein in them?
• What questions do you have about this?

Listen For

• Some of them didn’t eat any meat or eggs or dairy products.
• How can some of them get such big muscles without eating protein from muscles?
• Do other foods have protein? Or is all of the protein coming from some kind of supplement?
• What is different about the proteins in meat and those in a supplement?

4. Ask students to share any experiences they have with people who have a vegetarian or vegan diet.

Focus on the idea that many of these athletes did not have any meat or animal products in their diet. Ask students if they know any people who don’t eat meat, and to share what those people do include in their diet. Give them a moment to think individually, then have them share their ideas with the class.

Listen For

• I know someone who is a vegetarian, but they still eat eggs and drink milk.
• Some people don’t eat certain types of meat, but they do eat other types. (They might eat chicken or fish, but not red meat.)
• I know someone who doesn’t eat anything from an animal. They eat a lot of nuts and peanut butter and different kinds of beans.
Investigate the Phenomenon

What Students Are Doing
In this section, students investigate many different proteins to find out that proteins have many functions in our bodies. They are found in other places as well, not just in muscles.

Teacher Guidance

5. Create a list of all of the things students consider to be protein.
Summarize the last discussion by asking the class if they agree that they might need to know a bit more about proteins. Ask students to turn and talk with an elbow partner to list all of the things they can think of that they consider to be proteins. Return to share ideas as a whole class, and make a list of these items and put the list in a place where all students can see it. Ask students if they think they have a complete list, and what they could do to learn more about the different kinds of proteins.

Sample items students may list
• Eggs
• Fish
• Beef
• Chicken
• Tofu
• Protein drinks/supplements

Suggested Prompts
• Do you think we have listed all of the possible different proteins there are?
• What kind of investigation could we do that might help us determine if we are on the right track?
• Does this list tell us everything we want to know about the proteins?
• If we look at our list, we can see that some of these proteins are what we eat, but it looks like we also have an enzyme on our list. Do you think proteins have other functions?

Listen For
• We could research different proteins to find out how many different kinds there are.
• We could find out what other kinds of functions proteins have.

6. Students investigate a table that lists and describes several proteins.
Give each student a copy of Protein Structure and Function Table. Allow students time to record their noticings and wonderings. Move students into small groups to share, then bring them together as a whole group to have a Building Understanding Discussion.

Suggested Prompts
• What did you notice about the proteins included in this table?
• Did the proteins we listed as a class appear on the table? How might the proteins on the table be connected to those we listed?
• Did you see any similarities among any of the proteins on the list? Any differences?
• What other patterns did you notice?
• What questions did this table raise for you?
How do people build muscles if they are not eating muscle proteins?

Some questions students may have and some things students might notice

- There are a lot more kinds of proteins than we thought.
- We didn’t see very many of the proteins we listed (like chicken or eggs) on the table, but some of the proteins on the table are part of those proteins (ovalbumin in the egg, and there are different proteins that make up muscles).
- Some proteins have similar functions.
- There were lots of different protein shapes.
- We wonder how proteins get these different shapes, and why the shapes are so different.
- We wonder if our muscles are the same as cow or chicken muscles since they are made of the same kinds of proteins.
- Do we need to eat muscle proteins to build muscles? If not, how will we get those proteins if we don’t eat them?
- How can people who don’t eat meat get proteins to build muscle?

7. Students use the protein chart to identify proteins that people are eating.

Give students time in their small group to identify proteins from Protein Structure and Function Table that people might consume, and ask them to compare their list with Proteins Necessary for Human Growth and Homeostasis. Have students return to share findings with the whole class. Then ask students to revisit Athletes’ daily menus to identify any other items in their diet that could be considered protein sources.

**Suggested Prompts**

- What proteins did you find on the chart that are directly connected to things people eat?
- Did you see any connections between those proteins you identified as some that we might eat and the proteins people need?

**Explain the Phenomenon**

**What Students Are Doing**

Students attempt to explain how the proteins they eat contribute to the muscles that are part of their bodies. They compare models for similarities and differences, then identify questions they need to answer to be able to explain this phenomenon.

**Teacher Guidance**

8. Ask students to create an initial model that shows how protein in the food we eat results in muscles on our bodies.

Students work in the alone zone to develop a model that explains how the proteins in the food we eat can give us the proteins in our bodies, such as those needed to develop muscles. Give each student a copy of the Initial Model Template, and allow them 5 minutes to develop an initial model.

**Additional Guidance: Developing an Initial Model to Surface Background Knowledge and Identify Gaps in Understanding**

For students who may struggle, encourage them to use the materials they have looked at so far to help them focus on things they know, and have them start there.

**Suggested Prompts**

- What do we know for sure about what is in the different foods we eat?
- What do you know about what proteins our body needs?
- Would eating more or less protein cause the body to have more or less muscle? How could you show that?
- Are the proteins in the food connected to the proteins in our body?
How do people build muscles if they are not eating muscle proteins? 

For more information about developing an initial model, consult the Developing an Initial Model section of the Protein and Muscles Playlist Front Matter. For an example of how students might represent what they know, consult the Protein and Muscles Playlist Model Tracker.

9. Students share models in small groups and create a list of similarities and differences.

Use the Talking Sticks Protocol to give each student 30 seconds to share and explain what their model is showing. Give students another minute to record a list of similarities and differences among all models that were shared. Once the small groups have developed a list of similarities and differences, bring the class together and create a public list of some common similarities and differences in student models.

Additional Guidance: Talking Sticks Protocol

Directions for the Talking Sticks Protocol can be found in the Protein and Muscles Playlist Front Matter.

10. Develop a Driving Questions Board (DQB)

Can our models or the information we learned about where we find proteins help us understand how our bodies use the proteins we eat to make new and different proteins? Focus on whether they were able to explain if more or less protein in a person’s diet would lead to more or less protein in their body. Ask students to write down any questions they would need to answer to be able to explain how this happens.

Listen For

• It’s hard to explain because not all of the proteins we eat are the proteins we need in our bodies, and we also need some proteins that we don’t think we eat.

Acknowledge that students have learned that there are a lot of different proteins in the food we eat, and our bodies need many different proteins—including those in muscles—to function, but we can’t explain how they are connected. Ask students if after developing their models, they have any new questions about how the protein we eat helps us make the proteins we need. Say, “Let’s try to capture some of the questions we have about what is happening in these phenomena.”

Give students time to generate their own questions. Encourage them to generate multiple questions, but tell students that they will be sharing their questions one at a time.

Say, “It is important that we hear everybody’s questions, and we might find that we have questions similar to some of our classmates’ questions. We are going to create a Driving Question Board to help us group and organize our questions so they can help guide our investigations.”

• Have individual students read their questions aloud to the class.
• Have each student post their question to the DQB.
• Ask students if they have related questions; if so, allow them to share how each question is related, and post it near the others to create a grouping.
• Choose another student to share their question.

Sample Student Questions

• What are the differences between proteins we eat and proteins our body makes?
• What happens to the proteins we eat?
• How does our body make proteins?
• Do the proteins we eat become the proteins in our body?
• Why do all of the proteins have different shapes?

Additional Guidance: Driving Question Board

For more information about developing a Driving Question Board, consult the Driving Question Board section of the Protein and Muscles Playlist Front Matter.
11. Classroom Discussion and Grouping

Acknowledge that a lot of great questions have been asked, and some of them seem to be related. Take some time to organize and label the questions into at least two categories: questions related to what is happening with the proteins we eat, and questions related to how our body makes the proteins we need.

After organizing the questions, facilitate a discussion to ask students which of these questions should be answered first. Surface the idea that it is hard to really think about making proteins if we don’t know much about what they are, and ask students if they have any ideas for how they might start to investigate that.

Sample student ideas for investigation

• We could zoom in on a protein to see what it is made of.
• We could learn about how people digest protein.
• We could compare what is in different proteins.
• We could watch videos or read about what scientists know about proteins.

Tell students their ideas for investigation will be discussed more during the next class.