Don't Freeze My Feet!

How does the molecular structure of a molecule affect its melting point?

Summary of Scenario and Segments

In this performance task students will analyze data to determine how molecular structure affects melting point. They will do this with the intention of figuring out why reindeer feet are able to withstand cold temperatures.

In segment 1, students will learn that reindeer feet have a high concentration of oleic acid in their feet as compared to the rest of their legs. After we ask why this is true, we look at the melting points of oleic acid as compared to the melting points of other fatty acids present in reindeer legs. Students use this data to make the connection that, because oleic acid has a low melting point, it is less likely to freeze in cold temperatures, which allows reindeer to retain their mobility.

In segment 2, students ask "What is special about oleic acid that allows it to have a lower melting point as compared to stearic acid and palmitic acid?" To answer this question, students will look at a new data set using CODAP that will allow them to compare the number of double bonds in a molecule and the melting point of a molecule. Using this data, students should come to the conclusion that, as the number of double bonds in a molecule increases, the molecule's melting point decreases.

In segment 3 students will summarize their findings in a scientific poster and be given the opportunity to both receive feedback and give constructive criticism in a controlled environment. After this, they will be able to revise their work and reflect on why scientists organize data in the ways that we do.

Grade(s): High School Chemistry, 9-12 Grade, CA NGSS Integrated Model

Time: 90-120 min total. This performance task can be broken into 3 discrete lesson segments that are approximately 30-40 minutes long each.

Video Overview

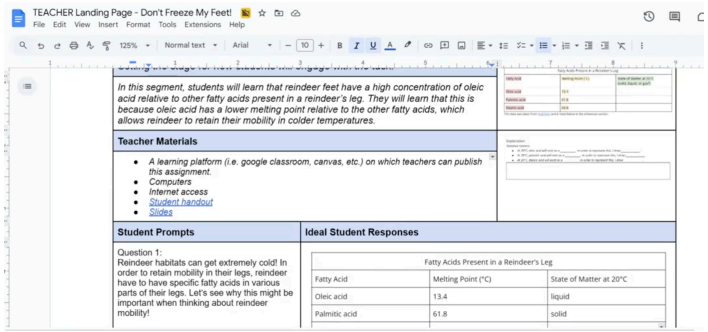


TABLE OF CONTENTS Google Drive Folder		
Teacher Handouts for Segments		
Teacher Handout Segment 1	TH Segment 2	TH Segment 3
Student Handouts for Segments		
Student Handout Segment 1	Student Handout Segment 2	Student Handout Segment 3
Task Implementation Guidance		
How to task is meant to be used	Supporting Diverse Sensemaking: Pre-Requisites and Scaffolds	NGSS Assessment Targets How the task was developed

Task Implementation Context

How the task is meant to be used	**Instructional Purpose** ☐ **Curriculum-Neutral Positioning:** This performance task can be integrated into any curriculum that addresses the intended assessment targets. ☐ **Diagnostic Usage:** Understand students' initial ideas before instruction. ☐ **Formative:** Supports teachers and students with knowing where they are with their learning, where they are headed, and how to support next steps with learning. ☑ **Summative:** Useful to report on student learning across a sequence of instruction. ☐ **Assessment as Learning:** The performance task serves as a learning experience itself. **Timing for Integration into Instruction** ☐ Beginning of Unit ☑ Middle of Unit ☑ End of Unit ☑ Flexible to be used in various ways **Student Configuration for Assessment Moments** ☑ Individual work ☐ Partner work ☑ Small Group work ☐ Whole Class work
Additional guidance from the developers about how the task can be used	*It would be best to use this task after learning about intermolecular forces. Teachers can prepare students by letting them know that they will be using knowledge from their thermodynamics unit (particle diagrams, states of matter, etc.) and combining this with their knowledge of intermolecular forces (melting point, strength of intermolecular forces, etc.) to properly analyze data in an attempt to answer an essential question.*

Description of Phenomenon or Problem

In this performance task, students need to figure out why it is beneficial for reindeer to have such high concentrations of oleic acid in their feet.



NGSS Assessment Target(s)

Which performance expectation(s) is this task associated with?	
HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). • SEP: Developing and using models • CCC: Energy and matter • DCI: Definitions of energy HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles • SEP: Planning and carrying out investigations • CCC: Patterns • DCI: Structure and properties of matter, types of interactions	
Science and Engineering Practices	• Developing and using models • Planning and carrying out investigations
Crosscutting Concepts	• Energy and matter • Patterns
Disciplinary Core Ideas	• Definitions of energy • Structure and properties of matter, types of interactions

Supporting Diverse Sensemaking

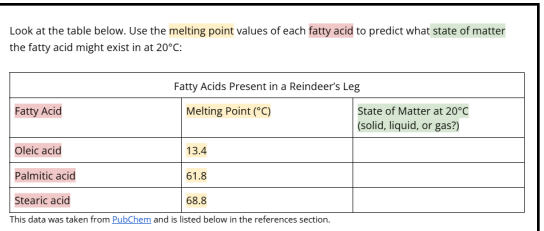
What additional knowledge, skills, and/or information will students need to bring to the performance task that is not being directly assessed? (Prerequisites)
• *How to draw particle diagrams of the 3 states of matter (solids, liquids and gases)* • *How melting point can indicate the strength of a substance's intermolecular forces.*
What design features and scaffolds are included to help remove access barriers and support the variability of students?
• *Inclusion of images/visuals* • *Color coding* • *Sentence starters* • *Video tutorials*

Segment 1: Task Scenario and Prompts and Scoring Guidance

Segment Scenario

Setting the stage for how students will engage with the task.

In this segment, students will learn that reindeer feet have a high concentration of oleic acid relative to other fatty acids present in a reindeer's leg. They will learn that this is because oleic acid has a lower melting point relative to the other fatty acids, which allows reindeer to retain their mobility in colder temperatures.



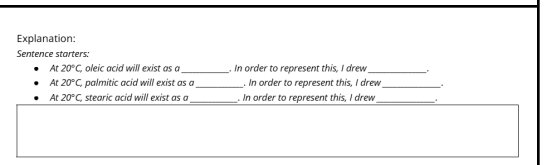
Look at the table below. Use the melting point values of each fatty acid to predict what state of matter the fatty acid might exist in at 20°C:

Fatty Acids Present in a Reindeer's Leg		
Fatty Acid	Melting Point (°C)	State of Matter at 20°C (solid, liquid, or gas?)
Oleic acid	13.4	
Palmitic acid	61.8	
Stearic acid	68.8	

This data was taken from PubChem and is listed below in the references section.

Teacher Materials

- *A learning platform (i.e. google classroom, canvas, etc.) on which teachers can publish this assignment.*
- *Computers*
- *Internet access*
- *Student handout*
- *Slides*



Explanation:

Sentence starters:

- *At 20°C, oleic acid will exist as a _____. In order to represent this, I drew _____.*
- *At 20°C, palmitic acid will exist as a _____. In order to represent this, I drew _____.*
- *At 20°C, stearic acid will exist as a _____. In order to represent this, I drew _____.*

Student Prompts

Question 1:
Reindeer habitats can get extremely cold! In order to retain mobility in their legs, reindeer have to have specific fatty acids in various parts of their legs. Let's see why this might be important when thinking about reindeer mobility!

Look at the table below. Use the melting point values of each fatty acid to predict what state of matter the fatty acid might exist in at 20°C:

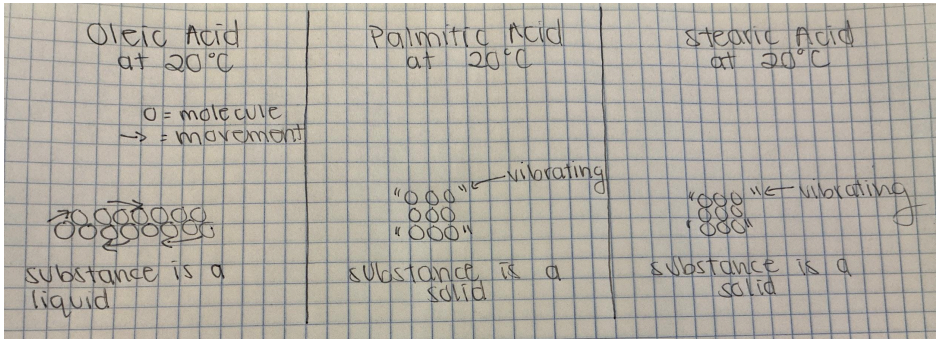
Ideal Student Responses

Fatty Acids Present in a Reindeer's Leg		
Fatty Acid	Melting Point (°C)	State of Matter at 20°C
Oleic acid	13.4	liquid
Palmitic acid	61.8	solid
Stearic acid	68.8	solid

This data was taken from PubChem and is listed below in the references section.

🔴 Potential Sticking Point: Students may need to be reminded of the definition of "melting point" prior to completing this activity.

🟢 Teacher Move: Teachers can say, "Water has a melting point of 0°C. Knowing this, whisper to your neighbor the state of matter water will likely be in at 20°C." If students are getting that, you can then ask, "Ok, what about -40°C?" After they seem to understand this, you can then transfer this knowledge to question 1.

Question 2 Develop a model that answers the question, "What do the particles of each fatty acid look like at 20°C?" Be sure to: ● Use the table of melting points above to help you create your model. Be sure to include appropriate labels. ● Below your model in the box provided, explain why you chose to represent each fatty acid in the ways that you did.	 Notice that, in the ideal model, students represent oleic acid as a liquid while representing palmitic and stearic acid as solids. Students should show how the particles, or molecules of these substances would interact with one another in the model (i.e. are the molecules vibrating? Sliding past each other? etc.). **Ideal Explanation:** At 20°C oleic acid will exist as a liquid, as evidenced by its melting point, which is 13.4°C. Because of this, I've drawn the molecules of this substance sliding past each other with more kinetic energy as compared to palmitic acid and stearic acid. Stearic acid and palmitic acid will both exist as solids at 20°C, as evidenced by their melting points in the table above. Because of this, I've drawn the molecules of this substance tightly packed together and vibrating, with less kinetic energy as compared to oleic acid.
Question 3 How does your model above explain why oleic acid provides greater mobility and flexibility for reindeer feet during cold temperatures?	**Example Student Response**: Because oleic acid does not freeze as easily as the other two acids, it probably helps reindeer to retain their mobility within their feet. This is because, if reindeer feet were to freeze, the reindeer would not be able to move their feet, which means that there should be some cold-resistant molecules within their feet.
Question 4 Use your model to predict what might happen if reindeer feet were primarily composed of stearic acid rather than oleic acid.	**Example Student Response**: If reindeer feet were primarily composed of stearic acid rather than oleic acid, I predict that the reindeer would lose some mobility in their feet in colder temperatures. This is because stearic acid's melting point is 55.4 degrees higher than oleic acid, making it much less resistant to cold temperatures as compared to oleic acid.
Navigation Across Segments	
*At the end of this segment, students should be wondering what makes oleic acid different from palmitic and stearic acid. They should be asking **why** oleic acid has a lower melting point as compared to the other two fatty acids.*	
Scoring Guidance (Rubric)	

Question 1.

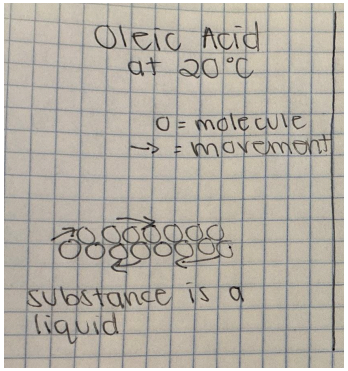
Use the melting point values of each fatty acid to predict what state of matter the fatty acid might exist in at 20°C:

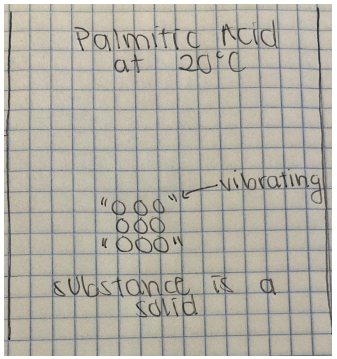
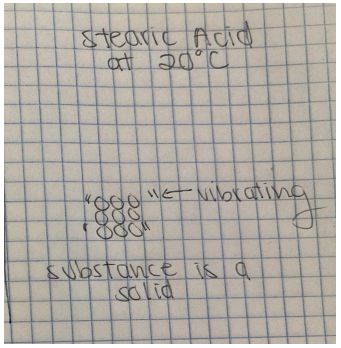
Required Components of Answer	Examples
Accurately states that oleic acid is a liquid at 20°C	State of Matter at 20°C liquid solid solid
Accurately states that palmitic acid is a solid at 20°C	
Accurately states that stearic acid is a solid at 20°C	

Question 2.

Develop a model that answers the question, "What do the particles of each fatty acid look like at 20°C?" Be sure to:

- Use the table of melting points above to help you create your model. Be sure to include appropriate labels.
- Below your model, in the box provided, explain why you chose to represent each fatty acid in the ways that you did.

Required Components of Answer	Examples
Oleic Acid Model: • Students will receive 1 point for drawing particles that represent a liquid (i.e. flowing past each other, appropriate movement drawn, etc.). • Students will receive 1 point for including labels, a legend, or a key that explains the various components of the model.	

Palmitic Acid Model • Students will receive 1 point for drawing particles that represent a solid (i.e. particles should be tightly packed, vibrating, etc.). • Students will receive 1 point for including labels, a legend, or a key that explains the various components of the model.	
Stearic Acid Model • Students will receive 1 point for drawing particles that represent a solid (i.e. particles should be tightly packed, vibrating, etc.). • Students will receive 1 point for including labels, a legend, or a key that explains the various components of the model.	
Explanation: • Students will receive 3 points if they accurately explain how <u>*each*</u> fatty acid's melting point can help them determine what state of matter each substance should be in at 20°C.	*At 20°C oleic acid will exist as a liquid, as evidenced by its melting point, which is 13.4°C. Because of this, I've drawn the molecules of this substance sliding past each other with more kinetic energy as compared to palmitic acid and stearic acid.* *Stearic acid and palmitic acid will both exist as solids at 20°C, as evidenced by their melting points in the table above. Because of this, I've drawn the molecules of this substance tightly packed together and vibrating, with less kinetic energy as compared to oleic acid.*

Question 3.

How does your model above explain why oleic acid provides greater mobility and flexibility for reindeer feet during cold temperatures?

Required Components of Answer	**Examples**
Students state that oleic acid is more likely to be a liquid at colder temperatures.	*Because oleic acid does not freeze as easily as the other two acids, it probably helps reindeer to retain their mobility within their feet. This is because, if reindeer feet were to freeze, the reindeer would not be able to move their feet, which means that there should be some cold-resistant molecules within their feet.*
Students make the connection that, if a reindeer's foot does not freeze and become solid, the reindeer should retain more mobility.	

Question 4.

Use your model to predict what might happen if reindeer feet were primarily composed of stearic acid rather than oleic acid.

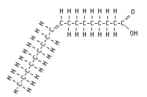
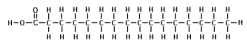
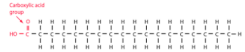
Required Components of Answer	**Examples**
Students should predict that reindeer would lose mobility in their feet.	*If reindeer feet were primarily composed of stearic acid rather than oleic acid, I predict that the reindeer would lose some mobility in their feet in colder temperatures. This is because stearic acid's melting point is 55.4 degrees higher than oleic acid, making it much less resistant to cold temperatures as compared to oleic acid.*

Segment 2: Task Scenario and Prompts and Scoring Guidance

Segment Scenario
Setting the stage for how students will engage with the task.

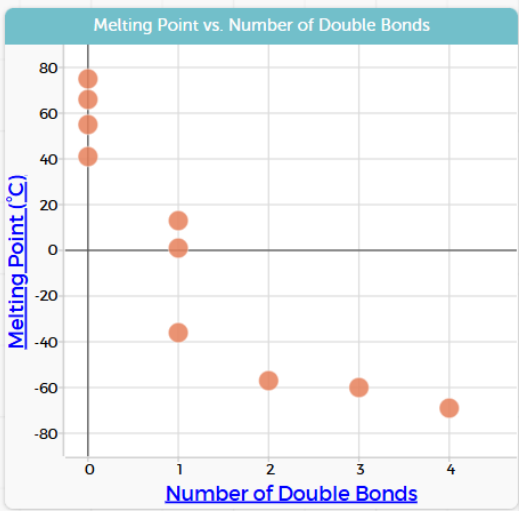
Students now know that oleic acid has a lower melting point, making it the ideal fatty acid for reindeer feet, but they do not know why. In this segment they will attempt to answer the question:

"How does molecular structure affect a molecule's melting point?"

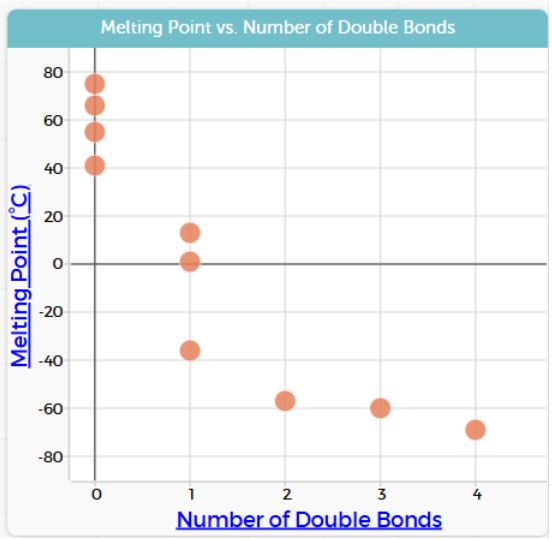
Name of Fatty Acid	Picture of Fatty Acid
Oleic Acid	
Palmitic Acid	
Stearic Acid	

Teacher Materials

- *A learning platform (i.e. google classroom, canvas, etc.) on which teachers can publish this assignment.*
- *Computers*
- *Internet access*
- *Student handout*
- *Slides*



Student Prompts	Ideal Student Responses
We now know that oleic acid helps to keep reindeer feet from freezing in cold temperatures. There MUST be something different about oleic acid that gives it this special property! Our new question we will answer in this segment is, "How does molecular structure affect a molecule's melting point?" To answer this question, we will look at a particular type of phospholipid called phosphatidylcholine, which is a	**Example student response:** Oleic acid has a double bond on its carbon chain that palmitic acid and stearic acid do not have. This causes the molecule to look bent, which might be causing its melting point to be lower as compared to the other two molecules.

big molecule made of two fatty acid chains. It is helpful for us to study this molecule because it is made of fatty acids, which is what we were studying in segment 2!). Question 5 Look at the table below. How does oleic acid differ from the other fatty acids shown below?	
Question 6, Part C: Play with the data and create a graph that represents how the molecular structure of a molecule affects its melting point. Screenshot your graph and insert it in the box below. Be sure to include a title, axis and labels.	🔴 Potential Sticking Point: To help students demystify what they are looking at, it may be helpful to point out that the big scary word, phosphatidylcholine, is not something they need to memorize! It's just a big name for a big molecule. 🟢 Teacher Move: To make this fun, you can offer extra credit to anyone who learns how to spell this word before the next day if you think students will enjoy that! Other suggestions include: • Pronouncing the word all together • Having a class competition to see who can say this "5 times fast the most clearly" **Example student response**:  Although there are many ways to represent the data given to students, it would be ideal for students to place the melting point (the dependent variable) on the y-axis and number of double bonds (the independent variable) on the x-axis. An example is shown above. Notice that in the example the title has been edited to accurately reflect the information being shown. To do this, students simply have to double click on the

	top blue section of the graph. 🔴 Potential Sticking Point: Students may have trouble orienting themselves to the CODAP website. 🟢 Teacher Move: Remember, teachers and students have access to this video to teach them how to use CODAP if necessary! ● In addition to that, a copy of the data has been saved in this spreadsheet for your convenience!
Question 6, Part D: Look at your response to part C. Why does this representation of the data best help you answer the driving question? Remember, our driving question is, **"How does molecular structure affect a molecule's melting point?"**	**Example student response:** I chose to put "melting point" on the y-axis because I know that we are trying to determine if "melting point" is affected by molecular structure. Because of this, I knew I needed to include it in the chart. I also chose to include the number of double bonds on the x-axis because this is what seemed to be causing the melting point to drop.
Question 7, Part A: Look at the graph you've created above. What patterns or trends are present in the data?	**Example student response:** The more double bonds a molecule has, the lower the melting point. For example, all molecules with no double bonds have melting points at or above 40°C. Right when one double bond is added to any molecule, the melting point immediately drops under this value and continues to drop as double bonds are added.
Question 7, Part B: What are the limitations of this data?	**Example student responses:** ● Students may question whether or not the double bonds are cis or trans double bonds. ● Students may also wish to compare oleic acid to another fatty acid rather than this phospholipid. ● Students may wish to know **where** the double bond is present in the fatty acid chain and see if that makes a difference in melting point. ● Students may question why some jumps in melting point vary so greatly. For example, for a phosphatidylcholine molecule with 18 carbons, the addition of a 2nd double bond drops the molecule's melting point by 58 degrees, whereas the addition of a 3rd double bond only drops the molecule's melting point by a mere 3 degrees. 🔴 Potential Sticking Point: students may not understand what the word "limitations" means in this context. 🟢 Teacher Move: Teachers can read this question aloud to the students. Teachers can then ask students to say the word *limitations* outloud. Teachers should then say, "Turn and tell your neighbor what a limitation is." After allowing time for student discussion, the teacher can say, "In this context, a *limitation* is a shortcoming. The question is asking where the data is incomplete. In other words, what other

	questions might you want to have answered to give you a better picture of what's actually going on?"
Question 7, Part C: If a phosphatidylcholine molecule had 16 carbon atoms and 3 double bonds, would you expect its melting point to be above or below 0°C? Explain your answer choice by citing evidence from the graph you've created.	**Example student response:** The melting point of this molecule would certainly be below 0°C as evidenced by the fact that, with only one double bond, the melting point is already at -36°C. With the addition of two new double bonds, the melting point is expected to drop below -36°C.
Question 7, Part D: Based on the data, would the intermolecular forces present between phosphatidylcholine molecules increase or decrease as the number of double bonds increases? Explain your answer.	**Example student response:** Because a substance's melting point decreases as the number of double bonds increases, a substance's intermolecular forces must also be decreasing in strength as the number of double bonds increases in a molecule.
Question 7, Part E: Answer the following question: **What is it about oleic acid's molecular structure that makes it so useful for reindeer and their feet as compared to palmitic and stearic acid?** ● Be sure to use evidence from the data you've analyzed above to support your answer. ● Be sure to use the following terms in your answer: intermolecular forces, melting point, double bonds.	***Teacher tip**: To make grading easier, you can ask students to color code their responses (see scoring guide for an example). **Example student response:** Oleic acid's double bond allows it to have a lower melting point, which allows reindeer to retain their mobility in colder temperatures. The addition of this double bond weakens the intermolecular forces within the molecule, which lowers its melting point. This is exemplified in the graph titled, "Melting Point (0°C) vs. Number of Double Bonds." In this graph all molecules with no double bonds have melting points at or above 40°C. Right when one double bond is added to any molecule, the melting point immediately drops under this value and continues to drop as double bonds are added.

Navigation Across Segments

Students should end this segment feeling confident about the answer to the essential question. We will now prepare them to present on their conclusions in an attempt to give and receive feedback.

Scoring Guidance (Rubric)

Question 5.

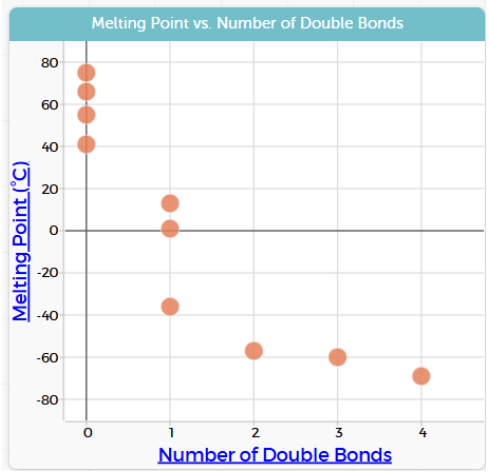
Hypothesis! What do you think is different about oleic acid's molecular structure that allows it to have a lower melting point as compared to the other molecules listed above?

Required Components of Answer	Examples

There are many possible responses. Because this is just a hypothesis, students may list any relevant differences in oleic acid's structure.	*Oleic acid has a double bond on its carbon chain that palmitic acid and stearic acid do not have. This causes the molecule to look bent, which might be causing its melting point to be lower as compared to the other two molecules.*

Question 6 Part C

Play with the data and create a graph that represents how the molecular structure of a molecule affects its melting point. Screenshot your graph and insert it in the box below. Be sure to include a title, axis and labels.

Required Components of Answer	**Examples**
Students included a title that accurately reflects the data shown on the graph.	
Students listed "melting point" as one of the variables on the graph.	

Question 6 Part D

Look at your response to part C. Why does this representation of the data best help you answer the driving question? Remember, our driving question is, "How does molecular structure affect a molecule's melting point?"

Required Components of Answer	**Examples**

Students should give some explanation as to why they chose to compare the two variables shown in their graph.	*I chose to put "melting point" on the y-axis because I know that we are trying to determine if "melting point" is affected by molecular structure. Because of this, I knew I needed to include it in the chart. I also chose to include the number of double bonds on the x-axis because this is what seemed to be causing the melting point to drop.*

Question 7 Part A

Look at the graph you've created above. What patterns or trends are present in the data?

Required Components of Answer	**Examples**
Students should list at least one pattern or trend they notice in their data in order to receive credit.	*The more double bonds a molecule has, the lower the melting point. For example, all molecules with no double bonds have melting points at or above 40°C. Right when one double bond is added to any molecule, the melting point immediately drops under this value and continues to drop as double bonds are added.*

Question 7 Part B

What are the limitations of this data?

Required Components of Answer	**Examples**
Students list at least one way in which the data provided to them is insufficient.	• *Students may question whether or not the double bonds are cis or trans double bonds.* • *Students may also wish to compare oleic acid to another fatty acid rather than this phospholipid.*

	• *Students may wish to know where the double bond is present in the fatty acid chain and see if that makes a difference in melting point.* • *Students may question why some jumps in melting point vary so greatly. For example, for a phosphatidylcholine molecule with 18 carbons, the addition of a 2nd double bond drops the molecule's melting point by 58 degrees, whereas the addition of a 3rd double bond only drops the molecule's melting point by a mere 3 degrees.*

Question 7 Part C

If a phosphatidylcholine molecule had 16 carbon atoms and 3 double bonds, would you expect its melting point to be above or below 0°C? Explain your answer choice by citing evidence from the graph you've created.

Required Components of Answer	**Examples**
Students should state that the melting point of this new molecule should be below 0°C.	*The melting point of this molecule would certainly be below 0°C as evidenced by the fact that, with only one double bond, the melting point is already at -36°C. With the addition of two new double bonds, the melting point is expected to drop below -36°C.*
Students should cite relevant evidence from the graph to support their answer.	

Question 7 Part D

Based on the data, would the intermolecular forces present between phosphatidylcholine molecules increase or decrease as the number of double bonds increases? Explain your answer.

Required Components of Answer	**Examples**
Students should state that, as double bonds increase, melting point decreases.	*Because a substance's melting point decreases as the number of double bonds increases, a substance's intermolecular forces must also be decreasing in strength as the number of double bonds increases in a molecule.*
Students should make the connection that, if a substance's melting point is lower relative to other molecules, its intermolecular forces are weaker.	

Question 7 Part E

Answer the following question: **What is it about oleic acid's molecular structure that makes it so useful for reindeer and their feet as compared to palmitic and stearic acid?** Be sure to use evidence from the data you've analyzed above to support your answer.

a. Be sure to use the following terms in your answer: intermolecular forces, melting point, double bonds.

Required Components of Answer	**Examples**
Students should mention that oleic acid's double bond allows it to have a lower melting point.	Oleic acid's **double bond** allows it to have a lower **melting point,** which allows reindeer to retain their mobility in colder temperatures. The addition of this double bond weakens the **intermolecular forces** within the molecule, which lowers its melting point. This is exemplified in the graph titled, "Melting Point (0°C) vs. Number of Double Bonds." In this graph all molecules with no double bonds have melting points at or above 40°C. Right when one double bond is added to any molecule, the
Students should mention that a lower melting point is advantageous for reindeer feet because it allows them to retain mobility.	
Students should mention that the addition of a double bond weakens the intermolecular forces present within the molecule	

OR Students should mention that a lower melting point is indicative of weaker intermolecular forces.	melting point immediately drops under this value and continues to drop as double bonds are added.
Students should list relevant evidence to support their answer.	

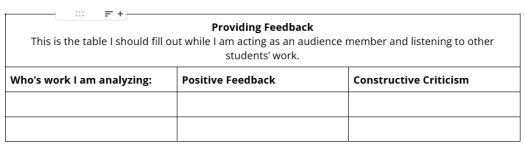
Segment 3: Task Scenario and Prompts and Scoring Guidance

Segment Scenario *Setting the stage for how students will engage with the task.*
In this segment students will summarize their findings in a poster, present to their peers, and give and receive feedback on their work.
Teacher Materials

My Presentation
This is the table I should fill out while I am presenting on my own work.

Who is critiquing me:	Positive Feedback	Constructive Criticism

- *Poster paper*
- *Tape (blue painter's tape is ideal)*
- *Markers*
- *Rulers*
- *Internet access*
- *Student handout*
- *Slides*



Providing Feedback

This is the table I should fill out while I am acting as an audience member and listening to other students' work.

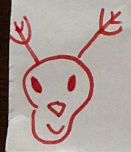
Who's work I am analyzing:	Positive Feedback	Constructive Criticism

Student Prompts	Ideal Student Responses
Question 8 Create a poster that answers the following question, **"What is it about reindeer feet that allows them to stand in the cold snow?"** Your poster should include the following: ● Any background information you feel is necessary for the audience to understand the essential question. ● Your claim, or the answer to your question. ● Evidence to support your claim. ○ This means you should be including a representation of your data ● An explanation as to why your evidence supports your claim.	***Teacher tip:** Question 8 can be done in pairs to save time. **Example student response:**

Essential Question: What is it about Reindeer feet that allows them to stand in the cold snow?

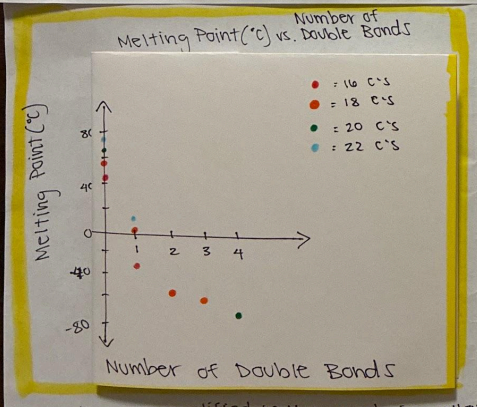
Background:

Reindeer live in extremely cold environments. Because of this, they need to be able to stand in the snow for long periods of time without their feet freezing. In this investigation, reindeer feet are studied to see what allows them to exist in cold temperatures while retaining their mobility.



Claim:

Reindeer feet are unique because they have a high concentration of oleic acid, which is a fatty acid with a particularly low melting point.



Evidence and Justification:

Reindeer are able to survive in low temperatures while retaining mobility in their feet because of the high concentration of oleic acid in their feet. Because of oleic acid's molecular structure, namely the fact that it has a double bond in its carbon chain, it has a low melting point, which helps keep reindeer feet from solidifying in cold temperatures.

The addition of a double bond to a carbon chain lowers the melting point of a molecule, as exemplified in the graph in yellow. Here it is shown that, regardless of the number of carbons in a molecule, the presence of a double bond weakens the intermolecular forces between molecules. This lowers the molecule's melting point, which is what keeps reindeer feet from solidifying in winter months.

Question 9 It is important to understand how to have a productive discussion with other researchers that allows you to give and receive feedback in a professional manner. For the last segment of this activity we will practice doing this! a. Using tape, hang up your poster somewhere in your classroom. b. You will present to two other classmates in the room AND listen to two other classmates in the room. Your teacher will explain how this will work. As you go through this process, fill in the tables below:	***Teacher Tip:** When doing this work, it is helpful to divide the class in half to accomplish this task: 1. First, half the class will present while half of the class acts as audience members. a. I usually half the first presenters hang up their posters somewhere in the room, then I have the audience members find one person they can listen to. This means every presenter is just presenting to one person. b. After the first presentation, students can simply move clockwise around the room to make this transition easier. 2. Once every presenter has presented twice, the class will switch. a. This means presenters will take their posters down (if necessary) and audience members will hang their posters up. b. If you are running this in pairs, notice this setup may change slightly to allow for presentations to be done in pairs. *This method of having students present is helpful for the following reasons: 1. It comes with much lower stakes as compared to whole class presentations. a. Students are only presenting to one other person at a time rather than 36 other students. 2. If properly prepared, it also allows students to lead with a sense of empathy while providing feedback rather than awkwardly stumbling through the activity. a. Teachers who lead this activity commonly say, “Friends don’t let friends fail assignments! Make sure you are actually helping your friends when providing feedback!” b. It is recommended that teachers guide students through the “Peer review session: tips and tricks” document prior to running this activity. It is strongly recommended that you print this for students so that they can annotate this document and carry it with them and they give/receive feedback. **Example student response:** “My Presentation” ● *Positive Feedback: I was told that my background information section was very detailed and thorough.* ● *Constructive Criticism: Someone mentioned that I did not include any justification for the evidence I provided. I need to add that in before submitting the final draft of my poster.* “Providing Feedback” ● *Positive Feedback: Amanda made sure to compare the melting point of the molecules to the number of double bonds in the molecules. This allowed us to more clearly see the relationships between these two variables. Some groups did not do this. Good job Amanda!* ● *Constructive Criticism: I would’ve liked to see Amanda talk more about why a low melting point means that the intermolecular forces are weaker.*

Question 10 When conducting research in an attempt to answer a question, scientists often have an independent variable and a dependent variable. ● An independent variable is the variable that is changed by the scientist OR exists independently of other variables. ● A dependent variable is the variable that is affected by the independent variable. Look at the question we attempted to answer while looking through our data: **How does molecular structure affect a molecule's melting point?** In this question, what would the independent variable be? What would the dependent variable be?	**Example student response:** ● The independent variable = molecular structure, or the number of double bonds present within a molecule ● The dependent variable = melting point
Question 11 When displaying data in a graph, researchers tend to place the independent variable on the x-axis and the dependent variable on the y-axis. Why do you think scientists all choose to display their data in this way? List any potential benefits you can think of.	**Example student response:** ● Example 1: It is important for scientists to do things in the same way every time. When scientists and researchers are consistent, it is easier to comprehend what other scientists and researchers are doing or communicating in their work. ● Example 2: It makes sense to put the independent variable on the x-axis because usually, when time is one of the variables being studied, this goes on the x-axis. This helps us read graphs the same way we read a book!

Navigation Across Segments

Students should end this segment feeling as though they were able to gain and receive feedback from their peers. They should also have had the opportunity to reflect on this process and learn from their mistakes.

Scoring Guidance (Rubric)

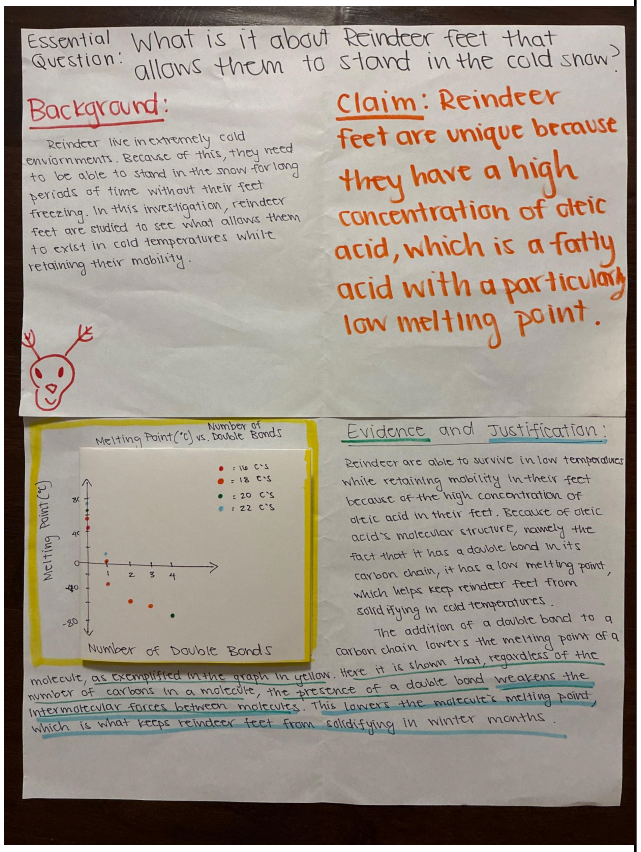
Question 8

Create a poster that answers the following question,

"What is special about reindeer feet that allows them to stand in the cold snow?"

Your poster should include the following:

- Any background information you feel is necessary for the audience to understand the essential question.
- Your claim, or the answer to your question.
- Evidence to support your claim.
    - This means you should be including a representation of your data
- Evidence that supports your claim and justification of that evidence.

Required Components of Answer	**Examples**
Relevant background information should be provided (i.e. what is the essential question about and why is it important?).	
A claim should be written clearly on the poster, meaning the essential question was answered.	
The data was represented somewhere on the poster. Ideally, this would mean that the student included the graph that was created via CODAP.	
The student explained how the data supported the claim.	
The student included justification, meaning the student provided relevant scientific facts that further explained why the data supported the claim. (for this talk about intermolecular forces and its connection to melting point).	

Question 9

You will present to two other classmates in the room AND listen to two other classmates in the room. Your teacher will explain how this will work. As you go through this process, fill in the tables below (see tables on assessment):

First table (pictured below)

My Presentation This is the table I should fill out while I am presenting on my own work.		
Who is critiquing me:	**Positive Feedback**	**Constructive Criticism**

Required Components of Answer	**Examples**
Students should receive half of a point for writing at least one piece of positive feedback that they received for each presentation. *They will do this twice (see the two rows in the table), which means they will receive 1 point total for this column.*	*I was told that my background information section was very detailed and thorough.*
Students should receive half of a point for writing at least one piece of constructive criticism that they received for each presentation. *They will do this twice (see the two rows in the table), which means they will receive 1 point total for this column.*	*Someone mentioned that I did not include any justification for the evidence I provided. I need to add that in before submitting the final draft of my poster.*

Second table (pictured below)

Providing Feedback This is the table I should fill out while I am acting as an audience member and listening to other students' work.		
Who's work I am analyzing:	**Positive Feedback**	**Constructive Criticism**

Required Components of Answer	**Examples**
Students should receive half of a point for writing at least one piece of positive feedback that they gave to another student <u>for each presentation.</u> *They will do this twice (see the two rows in the table), which means they will receive 1 point total for this column.*	*Amanda made sure to compare the melting point of the molecules to the number of double bonds in the molecules. This allowed us to more clearly see the relationships between these two variables. Some groups did not do this. Good job Amanda!*
Students should receive half of a point for writing at least one piece of constructive criticism that they gave to another student <u>for each presentation.</u> *They will do this twice (see the two rows in the table), which means they will receive 1 point total for this column.*	*I would've liked to see Amanda talk more about why a low melting point means that the intermolecular forces are weaker.*

<u>Question 10</u>

Look at the question we attempted to answer while looking through our data: **How does molecular structure affect a molecule's melting point?** In this question, what would the independent variable be?
What would the dependent variable be?

Required Components of Answer	**Examples**
Students correctly stated that molecular structure is the independent variable.	*Molecular structure is what is presumed to affect a molecule's melting point, which means that*

Students correctly stated that melting point is the dependent variable.	*molecular structure is the independent variable and melting point is the dependent variable.*

Question 11

When displaying data in a graph, researchers tend to place the independent variable on the x-axis and the dependent variable on the y-axis. Why do you think scientists all choose to display their data in this way? List any potential benefits you can think of.

Required Components of Answer	**Examples**
Students must list one potential benefit of organizing variables in this way on a graph.	• *It is important for scientists to do things in the same way every time. When scientists and researchers are consistent, it is easier to comprehend what other scientists and researchers are doing or communicating in their work.* • *It makes sense to put the independent variable on the x-axis because usually, when time is one of the variables being studied, this goes on the x-axis. This helps us read graphs the same way we read a book!*

How the Performance Task Was Developed

This performance task comes from the Laboratory of Lipid Biology and Cell Membrane Biophysics in conjunction with a National Science Foundation funded project at UCSD that is designed to support students with their understanding of intermolecular forces, their ability to analyze data, and their communication skills.

Task Name and Version History	Don't Freeze My Feet! Version 2
Task Developer(s)	Hannah Nakamoto
Institution(s)	San Diego Science Project, UC San Diego Budin Lab, UC San Diego
Image and Video Sources	Tapping Santa Claus Office GIF By The Elves!, Retrieved from: https://giphy.com/gifs/everwhatproductions-christmas-snow-3ohs7OgmKPNdUtFmus

Budin I, de Rond T, Chan Y, Chen L, Petzold C, and Keasling JD. Viscous control of cellular respiration by membrane lipid composition. Science 362:1186-1189 (2018).

Winnikoff, J. R., & Budin, I. (2025). Homeocurvature: A new dimension of membrane adaptation to extreme environments. Progress in Lipid Research, 100, 101355. https://doi.org/10.1016/j.plipres.2025.101355

PubChem. (n.d.). Oleic acid. Pubchem.ncbi.nlm.nih.gov. https://pubchem.ncbi.nlm.nih.gov/compound/Oleic-acid#section=Melting-Point

Avanti Research. (2024). Avanti Research. https://avantiresearch.com/tech-support/physical-properties/phase-transition-temps