Marathon Runner - Student Materials

Unit 1	Biology

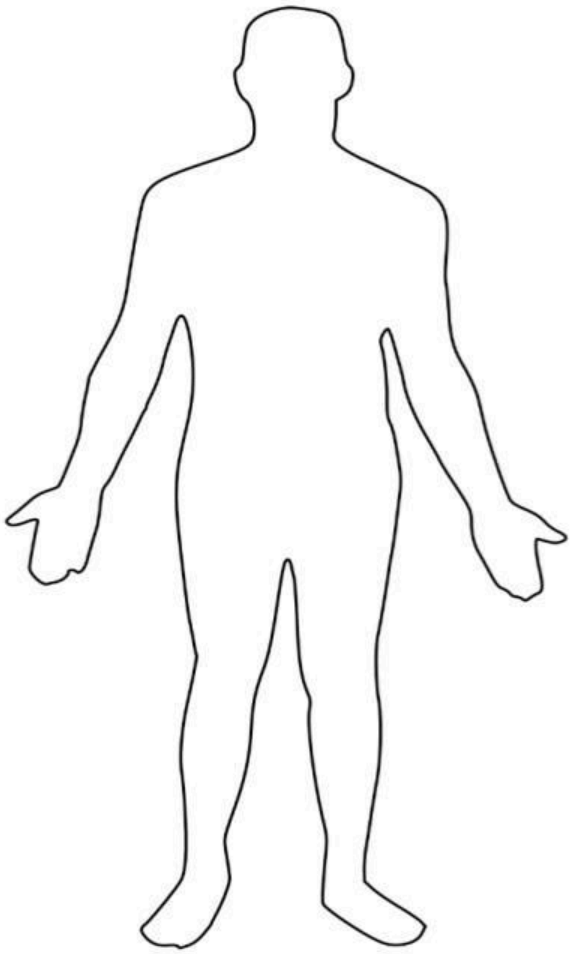
Student Materials Table of Contents

Performance Task Organizer

Unit 1 Marathon Runner	Biology
Student Name:	

Initial Human Body Model

Initial Model → What is happening in the body during extended exercise?

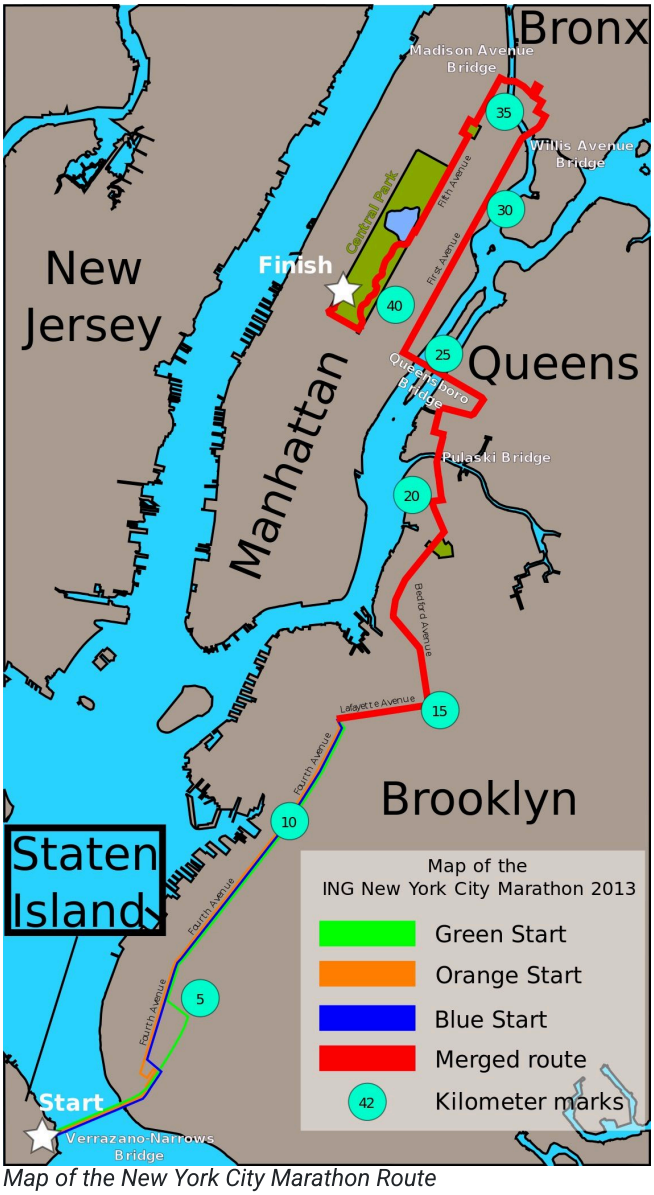


Marathon Runner Collapse

Directions:

1. Silently read the texts provided to you.
2. Circle three details that are most important to the phenomenon being described.
3. Share with your group. Each person should identify the details that he/she circled.
4. Discuss as a group, and determine the overall story. What is the phenomenon?

Marathon Runner Text #1



Map of the New York City Marathon Route

Marathon Runner Text #2
Disoriented Runner in the NYC Marathon

With marathons gaining in popularity, the number of athletes joining these events has ballooned over the last 20 years. In the past, the participants in long races were mostly elite athletes, who undergo special training to prepare for the marathon. These days, many amateur athletes participate in the marathon.

This year, one such amateur athlete -- a 40-year-old woman running a marathon for the first time, runner #0358 -- got very sick and disoriented during the second half of the marathon. She kept running the race, and she even took pictures with her family along the race course, but she later had no memory of running the second half of the race! Runner #0358 went home and then became very ill and disoriented, eventually ending up in a coma.

While the runner did recover after a while, this event concerned the race organizers. What could have happened to her to make her so sick!? Race personnel expect some runners to struggle during a grueling event like the marathon, but they try to set up the event to prevent serious problems. There are medics along the race course, and a medical tent at the finish line.

This year's running of the NYC Marathon was on an unusually hot, humid, and sunny day. The race started at 10:00 AM, but some runners were on the course for 4 or 5 hours. During that time, the temperature got as high as 28°C (about 82°F), and the sun was out all day. Many runners ended up seeking medical care either at a stop along the race course, or at the end of the race. The data in the table (below) are from the assessment of four participants, including the runner who had the most negative outcomes.

Marathon Runner Text #3
Medical Tent Data

Bib number	**0014**	**0358**	**1059**	**1489**
Age/Sex	23 F	40 F	25 M	50 M
Time	1:45:17 (dropped out at mile 15)	6:35:18	3:15:30	4:32:58
Weight (kg)	54	73	63	70
Plasma Sodium (mEq/L)	138	130	145	142
Blood Glucose (mg/dL)	140	120	90	100
Body Temperature (°C)	39	37.5	37	38
Oxygen Saturation (%)	99	98	98	97
Other Symptoms	Dry skin, not sweaty, nausea	Disoriented, unstable gait	Tired, very sweaty	Pain in both feet & ankles

See-Think-Wonder Graphic Organizer

See	Think	Wonder

Marathon Runner Problem

What is the overall story?

Important details our group surfaced (provide at least 5):

1. _____
2. _____
3. _____
4. _____
5. _____

Overall Story (based on group discussion):

Before the race:

_____

_____

_____

_____

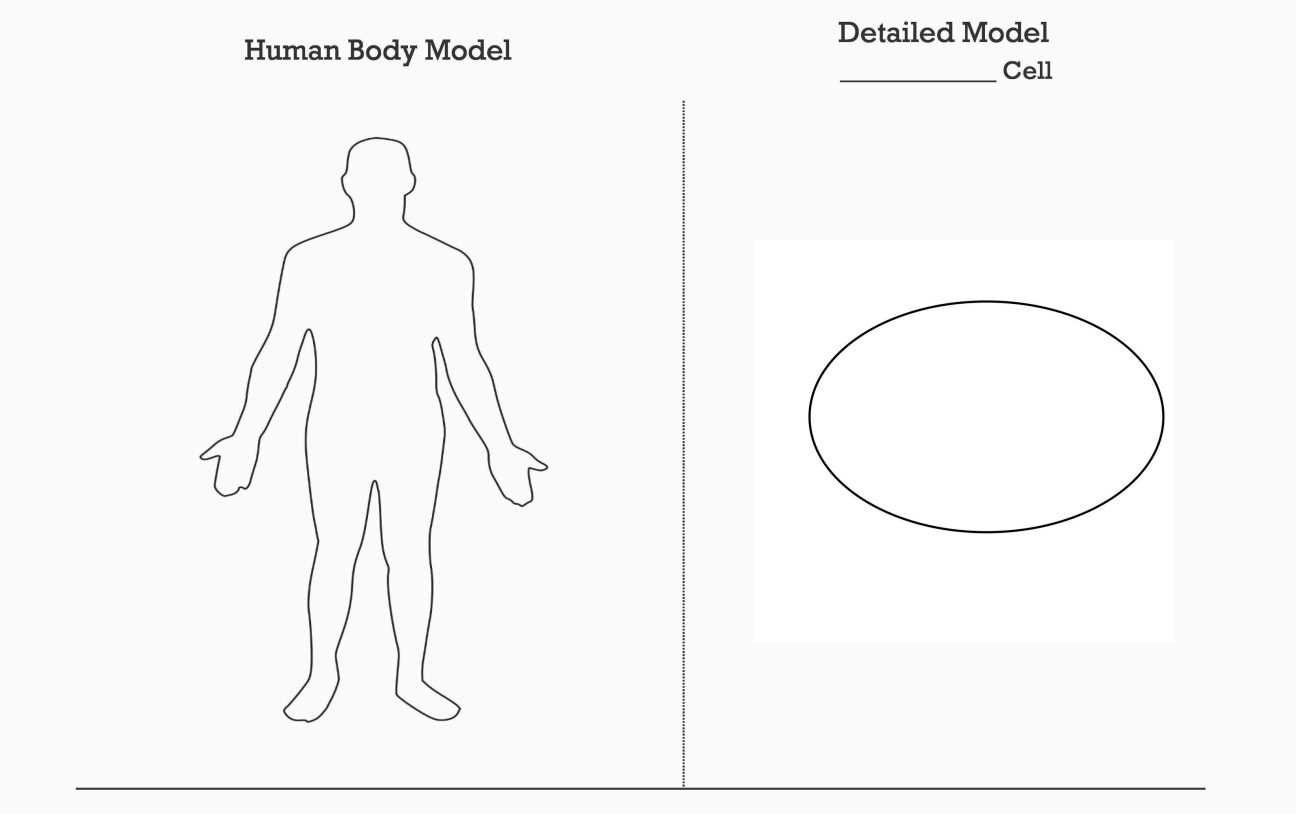
During the race:

After the race:

Gas Exchange & Cellular Respiration Model

Directions:

1. Create a human body model and a cell model to show what happens when a person is properly regulating gas exchange, including the relationship between gas exchange in the body system overall and its cellular subsystem.
2. Draw an arrow from the human body to the detailed model showing what part of the body the zoom in is located.
3. Include these components: O_2, CO_2, ATP, mitochondria, lungs, brain
4. Circle or highlight any parts that could model the sick runner.
5. Select yes, no, or maybe. Write your explanation, providing evidence from this learning cycle for your reasoning. Evidence can come from investigations, data tables, and texts.



Our Driving Question: Did the runner run out of oxygen? (Normal Oxygen Saturation level is _____)

Circle one below:

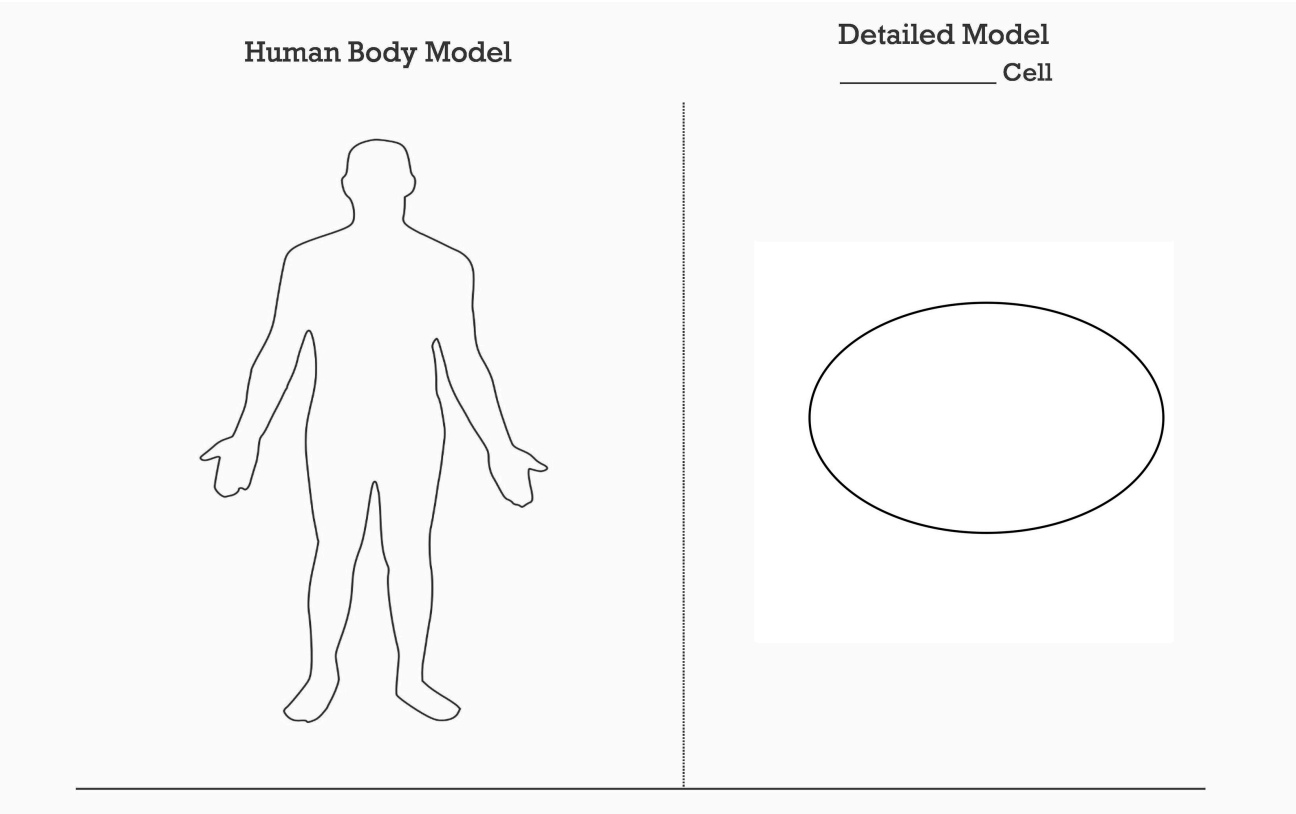
Yes Maybe No

Explanation:

Muscles & Energy Model

Directions:

1. Create a human body model and a cell model to show what happens when a person is maintaining homeostasis, including the relationship between energy transfer in the body system overall and its cellular subsystem.
2. Draw an arrow from the human body to the detailed model showing what part of the body the zoom in is located.
3. Include these components: O_2, CO_2 ATP, mitochondria, glucose, insulin, pancreas
4. Circle or highlight any parts that could model the sick runner.
5. Select yes, no, or maybe. Write your explanation, providing evidence from this learning cycle for your reasoning. Evidence can come from investigations, data tables, and texts.



Our Driving Question: Did the runner run out of energy? (Normal blood glucose level is _____)

Circle one below:

Yes Maybe No

Explanation:

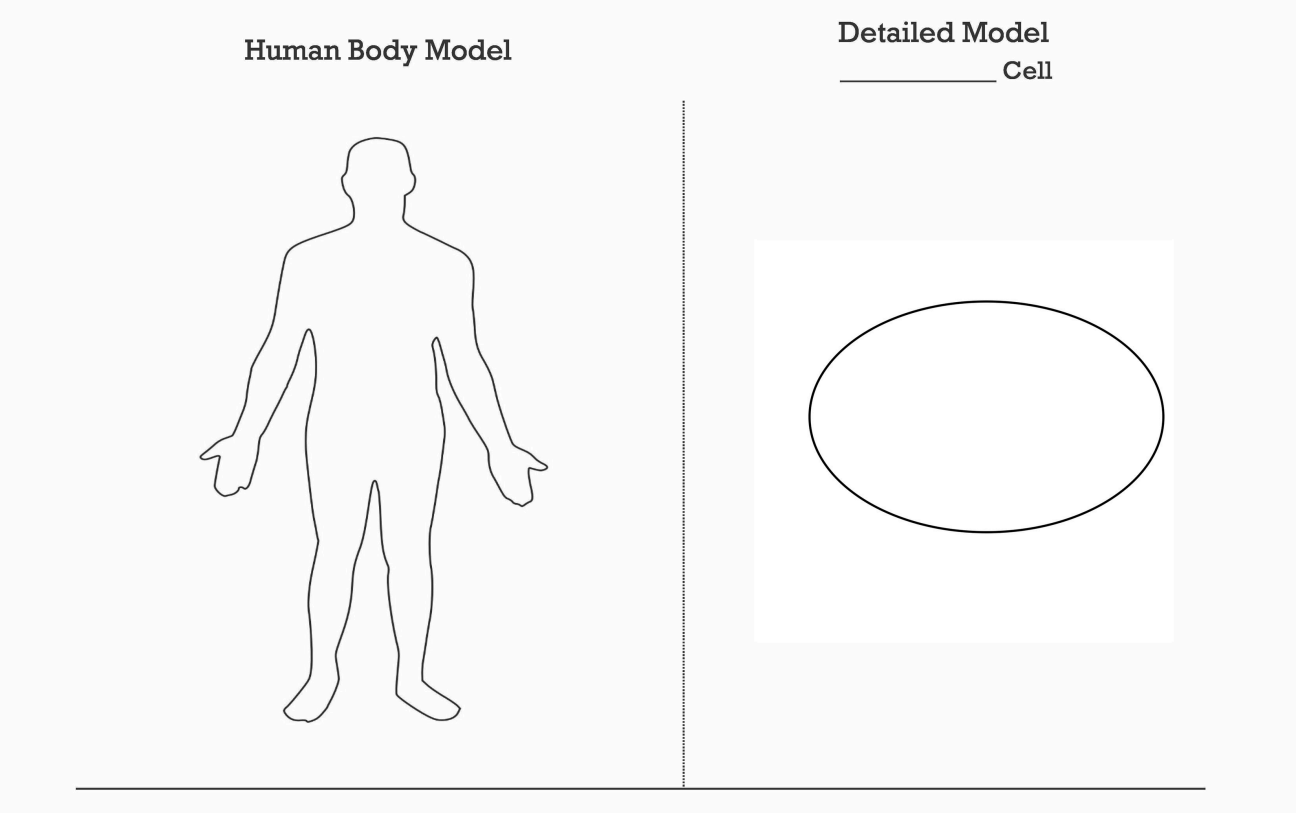
Thermoregulation Model

Directions:

1. Create a human body model and a cell model to show what happens when a person is **maintaining homeostasis,** including the relationship between energy transfer in the body system overall and its cellular subsystem.
2. Draw an arrow from the human body to the detailed model showing what part of the body the zoom in is located.
3. Choose which components are essential for this model:

_____

4. Circle or highlight any parts that could model the sick runner.
5. Select yes, no, or maybe. Write your explanation, providing evidence from this learning cycle for your reasoning. Evidence can come from investigations, data tables, and texts.



Our Driving Question: Did the runner overheat? (Normal body temperature is _____)

Circle one below:

Yes Maybe No

Explanation:

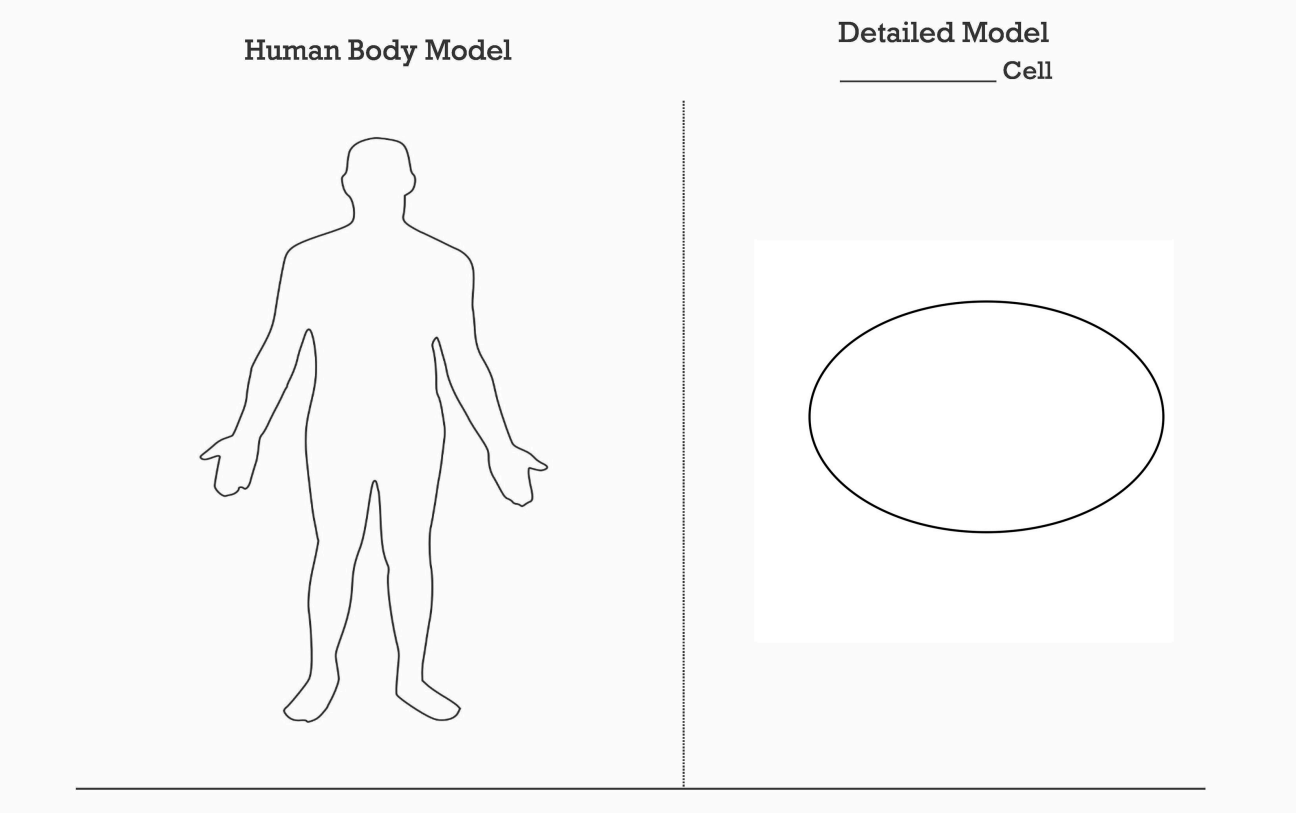
Water Balance Model

Directions:

1. Create a human body model and a cell model to show what happens when a person is maintaining homeostasis, including the relationship between the transportation of materials in the body system overall and its cellular subsystem.
2. Draw an arrow from the human body to the detailed model showing what part of the body the zoom in is located.
3. Include these components:

_____

4. Circle or highlight any parts that could model the sick runner.
5. Select yes, no, or maybe. Write your explanation, providing evidence from this learning cycle for your reasoning. Evidence can come from investigations, data tables, and texts.



Our Driving Question: Did the runner drink too much water? (Normal plasma sodium level is _____)

Circle one below:

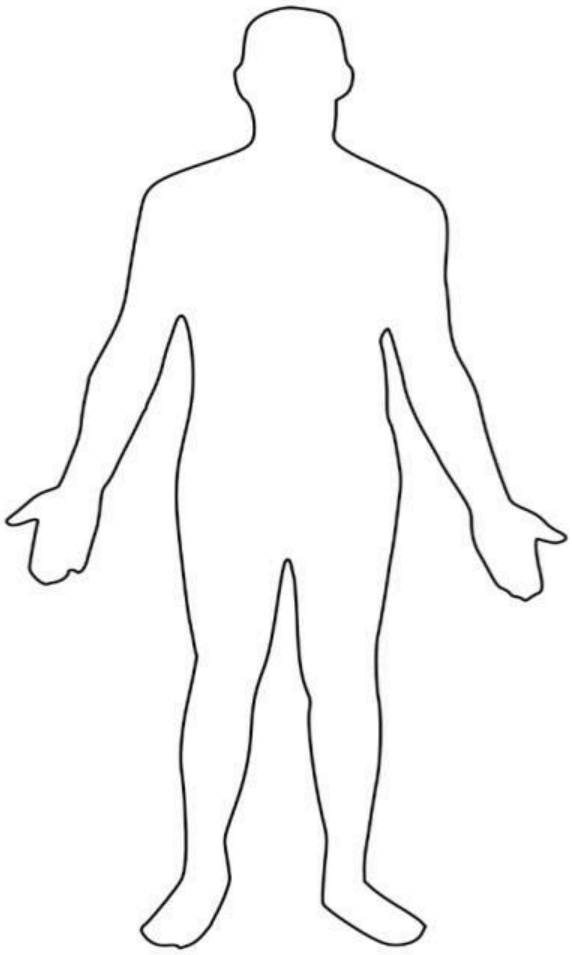
Yes Maybe No

Explanation:

Final Explanatory Model

Directions:

1. Create a human body model that depicts what caused runner #0358 to become very ill and eventually go into a coma.
2. Your model should include multiple body systems, and show a zoomed in view of what is happening in an organ or cell. It can also include a key or short written caption to clarify your model.
3. Write an explanation to describe the visual representation of your model in words. Explain how one other feedback mechanism is being used in the runner to maintain homeostasis. Use appropriate scientific vocabulary and evidence to explain the phenomenon.



Why did one runner become very ill?

Self Evaluation

Directions:

Use all of your resources from the unit (Performance Task Organizer, class notes, handouts) to respond to the following reflection prompts.

Part 1: Developing and Using Scientific Models

1. How would you describe a scientific model? How has your thinking changed since the beginning of the unit?
2. Describe how a peer or activity from the unit changed your thinking on what a scientific model is and how they can be used.
3. What questions do you still have on how to develop or use a scientific model?

Part 2: Final Performance Task Model

1. All models have limitations, discuss the limitations of your model
2. In generating your final model, you made decisions on what to represent and how to represent it. Discuss your decision making process, giving specific examples from your model.
3. How could you improve your final model?

Gas Exchange and Cellular Respiration 5E

Unit 1 Marathon Runner	Biology
Student Name:	

Surfacing Ideas for Experimental Design

Directions: Using the lab protocol and your observations during the experience, brainstorm the following with your lab group:

Things that we know **are the same** between each lab group	Things that **might not be the same** between each lab group	Things that definitely are **not the same** between each lab group
Ways in which we could improve this experimental design:		

Cellular Respiration in Yeast Investigation - Basic Protocol

1. Select a balloon. Inflate and deflate fully one time.
2. Add 1 packet of yeast to a glass bottle or beaker.
3. Add 100 mL warm water to the bottle, using a funnel. Water should feel warm to touch, but not too hot.
4. Swirl to mix the yeast and water.
5. Add the assigned amount of sugar, and swirl again to mix.
6. Immediately after swirling, place the balloon over the mouth of the bottle.
7. Do not disturb the set-up after this point.
8. Measure the rate of respiration.

Cellular Respiration in Yeast Investigation

Directions

- Annotate the introduction section by circling points you think are most important for the purpose of the investigation.
- Complete the following sections to plan out your investigation.

Introduction
Have you ever wondered why bread dough will rise? Bread dough contains yeast, a single-celled organism, that gets its energy from sugar, just like the cells in your body do. Yeast can serve as a model organism that we can use to investigate processes that humans have in common with yeast.

All living things need energy to survive. In this investigation, we will explore how yeast generate ATP to use as an energy source through a process called **cellular respiration**. By varying the amount of sugar we provide yeast, we can uncover more about how the process works, and what materials are needed to complete it.

How can we measure the rate of cellular respiration in yeast? We can measure the output(s) of the process through a few methods:

- Size of a balloon: we can capture the amount of the gas that is produced by measuring the increase in the volume of a balloon.
- Height of foam: when yeast undergoes respiration, bubbles are produced. By measuring the height (volume) of foam, we can estimate how much cellular respiration is taking place.

Planning the Investigation

Research Question

What is your experimental question? What are you trying to figure out?

Hypothesis
Use this format: If I add sugar to a yeast solution, then _____ because _____.

Investigation Design

Individually brainstorm ideas on how to design an investigation that addresses your research question. You can sketch out your ideas or write them down in bullet point format.

In your design, include

- The types of data you will be collecting

- How much data you will collect
- How you will ensure your data is accurate
- Limitations on the type and precision of data that you are able to collect

Consensus
Discuss your ideas with your group. Come to consensus on a design plan.

Variables
Use this table to name the variables in your investigation.

Independent Variable	Dependent Variable	Control Group	Controlled Variable(s)
	1. Size of balloon	Beaker without sugar added.	
	2.		

Materials
Each group will need:
- 3 plastic water bottles or glass Erlenmeyer flasks
- 3 packets yeast
- 3 balloons
- 300mL warm water
- Sugar (the amount will be assigned to each group)
- Measuring tape

Procedure

- Which part of the procedure do you think is going to be the most difficult? Annotate with an arrow that points to the step.
- Which part of the procedure do you think is going to take the most time? Annotate by circling the step's number.

1. Select a balloon and inflate/deflate it 1 time.
2. Add 1 packet of yeast to beaker #1.
3. Add 100 mL warm water to the bottle. [Water should feel warm to touch, but not too hot.]
4. Swirl gently for 5 seconds to mix the yeast and water.
5. Add the appropriate number of packets of sugar, and swirl again to mix.
6. Begin timing NOW. Do not disturb this beaker after this point.
7. Repeat steps 2-4 with beaker #2.
8. ADD sugar to beaker #2 and swirl again to mix.
9. Immediately after swirling, place the second balloon over the mouth of the beaker.
10. Begin timing for the second beaker NOW. Do not disturb this beaker after this point.
11. Repeat steps 2-4 with beaker #3.
12. Measure the size of each balloon after 15 minutes and after 30 minutes. Record your data in Table 1 below. While you are waiting to measure, fill in your qualitative data into Data Table 3.
13. Measure the height of the foam for each beaker after 15 minutes and after 30 minutes. Record your data in Table 2 below. While you are waiting to measure, fill in your qualitative data into Data Table 3.
14. Submit or record your group quantitative data to a class wide data set.
15. Create a graph showing data for both circumference and height of foam, based on the **combined class wide data.**

Table 1: Balloon Circumference

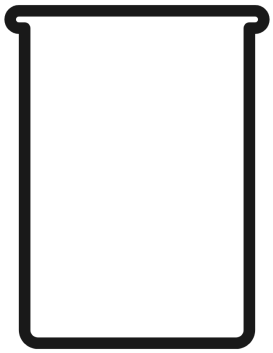
	Circumference of the balloon at 0 minutes	Circumference of the balloon after 15 minutes	Circumference of the balloon after 30 minutes
Beaker 1			
Beaker 2			
Beaker 3			

Table 2: Height of Foam

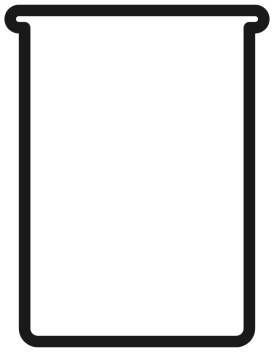
	Height of foam at 0 minutes	Height of foam after 15 minutes	Height of foam after 30 minutes
Beaker 1			
Beaker 2			
Beaker 3			

Qualitative Data
Label the contents and describe what you observe occuring in each beaker.

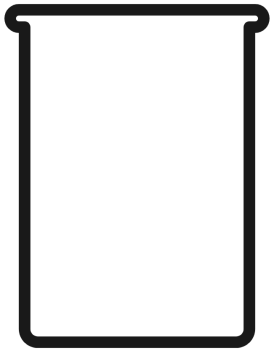
Beaker 1



Beaker 2



Beaker 3



Graph
Use the space below to create a graph.

Effect of Sugar on Respiration in Yeast

Graphing Support - Scaffold

After collecting group data, and finding a class-wide average, work as a group to identify:

The type of graph we think should be used is the:	Bar Graph OR Line Graph
The reason(s) why we think we should use this type of graph is (are):	

Peer Graphing Rubric - to be used after graphing the class wide data

The Grader's Name:	The Grapher's Name:
We Chose a Bar Graph!	
Point Description	Point Received (✓)
Give a point if an appropriate scale is marked, without any breaks in data, on the x-axis.	
Give a point if an appropriate scale is marked, without any breaks in data, on the y-axis.	
Give a point if the independent variable data is plotted correctly (look at the data table to confirm this!)	
Give a point if the dependent variable data is plotted correctly (look at the data table to confirm this!)	
Total Checks GIven:	
Feedback:	

The Grader's Name:	The Grapher's Name:
We Chose a Bar Graph!	
Point Description	Point Received (✓)
Give a point if an appropriate scale is marked, without any breaks in data, on the x-axis.	
Give a point if an appropriate scale is marked, without any breaks in data, on the y-axis.	
Give a point if the independent variable data is plotted correctly (look at the data table to confirm this!)	
Give a point if the dependent variable data is plotted correctly (look at the data table to confirm this!)	
Total Checks GIven:	
Feedback:	

The Grader's Name:	The Grapher's Name:
We Chose a Line Graph!	
Point Description	Point Received (✓)
Give a point if an appropriate scale is marked, without any breaks in data, on the x-axis.	
Give a point if an appropriate scale is marked, without any breaks in data, on the y-axis.	
Give a point if the independent variable data is plotted correctly (look at the data table to confirm this!)	
Give a point if the dependent variable data is plotted correctly (look at the data table to confirm this!)	
Give a point if the data points are circled, and the data points are connected with a straight line.	
Total Checks Given:	
Feedback:	

The Grader's Name:	The Grapher's Name:
We Chose a Line Graph!	
Point Description	Point Received (✓)
Give a point if an appropriate scale is marked, without any breaks in data, on the x-axis.	
Give a point if an appropriate scale is marked, without any breaks in data, on the y-axis.	
Give a point if the independent variable data is plotted correctly (look at the data table to confirm this!)	
Give a point if the dependent variable data is plotted correctly (look at the data table to confirm this!)	
Give a point if the data points are circled, and the data points are connected with a straight line.	
Total Checks Given:	
Feedback:	

Making Sense of Investigation Design

Analysis of Class-Wide Data

See Things I see in the class-wide data collected.	**Think** Ideas that this data makes me think about.	**Wonder**
Prompts to get you started: • Which amount of sugar was associated with the greatest balloon circumference? • The highest foam?	Prompts to get you started: • Which amount of sugar do you think generated the most energy for the yeast? Why? • What are some of the inputs and outputs in our yeast model? • Which of these inputs and outputs can you see? • Which of these inputs and outputs can you not see, but have evidence that they are there?	

Investigation Summary Independent Writing

1. Why did you use a class average of all the data collected to analyze?

2. How might you improve the procedure to generate more accurate data in order to respond to the research question?

3. What were some of the limitations of using yeast as a model organism to study cellular respiration in humans?

4. What else do we need to know about why humans breathe faster when exercising?

5. If you were to repeat this experiment, how would you refine its design to obtain more reliable data?

6. Was your hypothesis supported? Explain your reasoning.

Sentence starters:

- Yes, my hypothesis was supported. The data collected demonstrated that. . . .
- No, my hypothesis was not supported. The data collected demonstrated that. . . .

7. Describe: What did we do in this investigation? Why is this investigation a part of this unit?

8. Explain: What is the phenomenon you observed in this investigation? How does the phenomenon relate to this unit?

9. Analyze: Based on what you observed, what information would be useful in creating an input-output model of the yeast reaction?

Discussion

Talk with your investigation group, and record any new ideas that come up.

Yeast Respiration Investigation Rubric

Student Rubric - Yeast Respiration Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder and respond to the evaluation questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Yeast Respiration Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.
Time Management	Procrastinated, did not use school time or schedule provided to get work completed.	Mostly used time well and completed investigation on time.	Used time well to ensure things get done on time.

Analyzing Blood Oxygen Levels Investigation Rubric

Student Rubric - Analyzing Blood Oxygen Levels Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder and/or respond to the analysis questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Analyzing Blood Oxygen Levels Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.
Time Management	Procrastinated, did not use school time or schedule provided to get work completed.	Mostly used time well and completed investigation on time.	Used time well to ensure things get done on time.

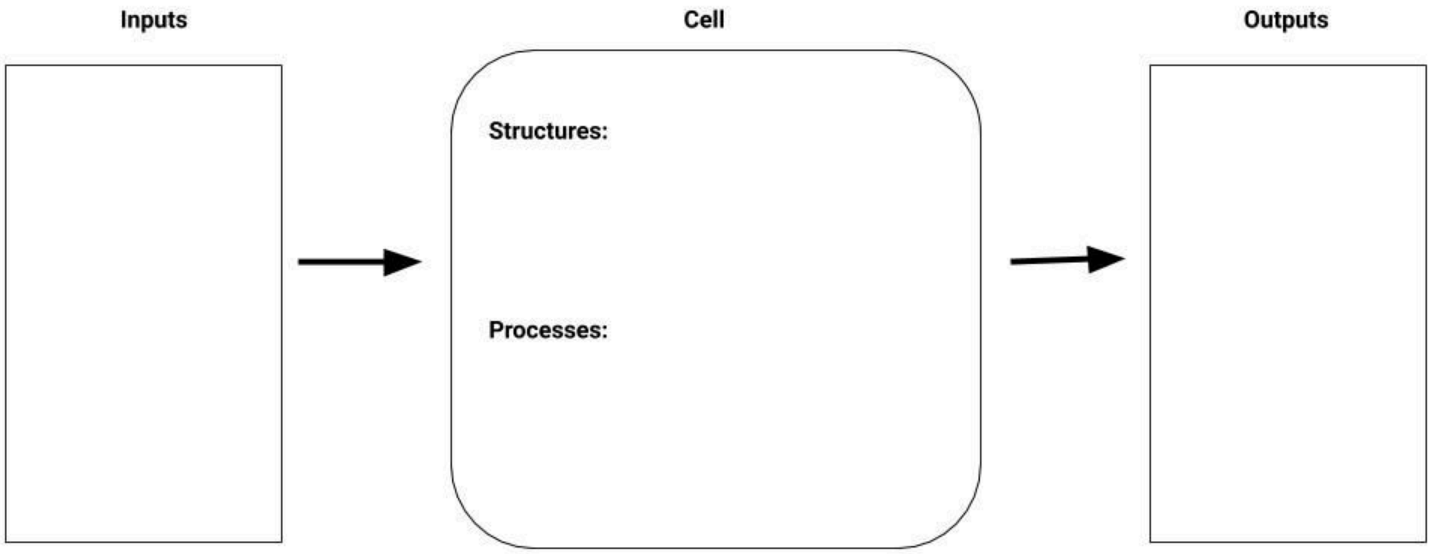
Input-Output Model for Cellular Respiration

How can we represent the process of cellular respiration in a cell?

Directions:

1. Use the space below to develop an input-output model that represents what you learned about cellular respiration from data you collected during the yeast respiration lab.
    a. **Inputs** are anything that we added to the cell (into the bottle)
    b. **Outputs** are anything that came out of the cell as a result of a **process**
    c. **Structures** are parts of the system

2. Share your ideas with your peers in order to develop a class wide model that represents cellular respiration.



Gas exchange input-output model

Cellular Respiration in Yeast Text

Directions: Read and annotate the text, using the following annotations.

✔	Points that confirm your group's model
✖	Points that contradict your group's model
O	Points that help to modify or add to your group's model

Cellular Respiration in Yeast

What Is Yeast?

Have you ever baked fresh bread? It is a simple process in which a baker combines sugar, yeast, water, and flour together to make dough. However, baking bread does take some time. After the ingredients have been combined, the dough needs time to rise. This is where the yeast does its job. **Yeast** is a single-celled **fungus**. Yeast consume the sugar in the dough mixture as their food, producing carbon dioxide as a waste product. The carbon dioxide, a gas, makes the bread rise. When the bread is baked, the gas pockets in the bread give it the fluffy consistency people love.

What Is Cellular Respiration?

Through cellular respiration, cells generate **Adenosine Triphosphate,** known as **ATP**, a molecule that stores chemical energy. When the yeast consume the glucose (a type of sugar) in the dough, they convert the energy in the sugar into ATP, which they use to fuel their own life processes.

Cellular respiration in eukaryotic cells occurs mainly in the **mitochondria.** In prokaryotic cells, it occurs in the cytoplasm. All organisms use cellular respiration to produce ATP. Cells break down ATP to release energy, in order to carry out life processes including growth, movement, making molecules, and transporting molecules.

How is Yeast Like a Human?

Yeast are unicellular (single-celled) single-celled organisms, which means that all of their life functions are carried out in that single cell. Humans are different because we are multicellular, meaning that we are made of multiple cells. Because we have so many cells, they arrange themselves into groups that are specialized by function, so the life functions that we carry out are distributed across different organs and organ systems. For example, every yeast cell needs to "eat" and "breathe," while our human bodies have unique body systems for digestion and ventilation (breathing).

However, even though our bodies as a whole system divide up their life functions using organ systems, those organ systems are made of organs, which are made of cells. Each one of our cells is alive, and must perform the process it needs to stay alive, which includes **cellular respiration.** In the same way as yeast cells, human cells take in glucose and, through respiration, produce ATP molecules to store energy.

Aerobic and Anaerobic Respiration

The yeast start the process of respiration by using available oxygen. This is called **aerobic** cellular respiration. Oxygen and glucose are converted into ATP, releasing the waste products of carbon dioxide and water. Our own cells use this process to extract energy from the food we eat, that is why we exhale carbon dioxide and

water as waste products (just like the yeast!). Next time you hold up a mirror and breathe, you can see the water vapor collecting on the mirror -- this is one of the waste products from generating ATP from glucose.

When the yeast run out of oxygen, they still need to generate ATP, so they switch to **anaerobic** respiration, which does not require oxygen. The cells convert the glucose into ATP, generating carbon dioxide and lactic acid as an output. However, this type of respiration is not as efficient as aerobic, and produces less ATP. Anaerobic respiration happens in human cells as well, often during times of intense exercise.

Sources:
http://study.com/academy/lesson/cellular-respiration-in-yeast.html; https://en.wikipedia.org/wiki/Cellular_respiration

Summary Task

How did the class consensus discussion go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

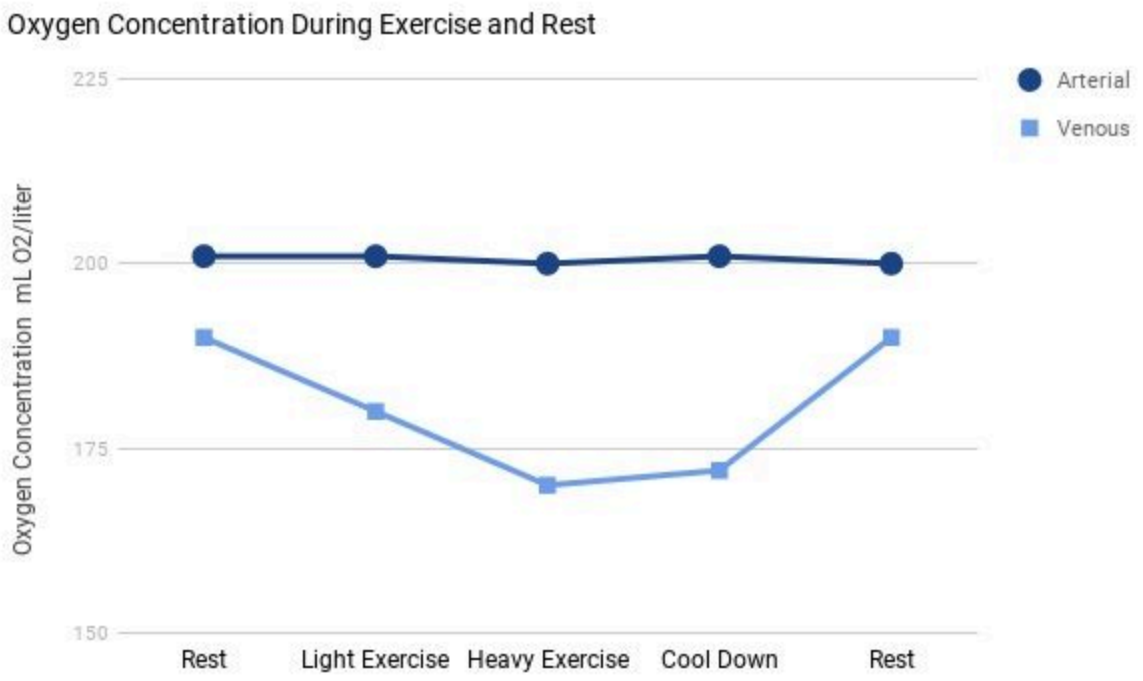
4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today.

Why do people breathe harder or faster when exercising?

Words	Input-Output Model

Blood Oxygen Graphs



Blood oxygen graphs

Arterial blood and venous blood were taken from the same person over time as they rested and exercised.

Arterial blood is taken from arteries. Arterial blood is moving from the lungs and heart, towards the body.

Venous blood is taken from the veins. Venous blood is moving from the body (muscles, organs) towards the heart and lungs.

Blood Oxygen Graphs Three-Level Guide

Directions:

- Annotate the graph, based on the directions in Step 1.
- Use the graph to respond to the prompts in Step 2.
- Use the graph and your knowledge of biology to respond to the prompts in Step 3.

Step 1 - Reading the Lines

1. Read the title. Underline the gas represented in this graph.
2. Find the areas of the graph that represent rest. Box in those areas by drawing a square around those portions of the graph.
3. Find the data point in the graph with highest blood oxygen level, and circle it.
4. Find the data point in the graph with lowest blood oxygen level, and circle it.

Step 2 - Reading between the lines

1. At rest, what is the O_2 concentration in arterial blood?

2. At rest, what is the O_2 concentration in venous blood?

3. Describe the relationship between exercise and the concentration of O_2 in arterial blood.

4. Describe the relationship between exercise and the concentration of O_2 in venous blood.

Step 3 - Reading beyond the lines

1. Describe the difference between the O_2 concentration in arterial blood and the O_2 concentration in venous blood during exercise.

2. During exercise, why is the O_2 concentration in arterial blood different from the O_2 concentration in venous blood?

3. Carbon dioxide (CO_2) concentration is not represented on the graph. Based on your knowledge of biology, predict the relationship between exercise and the concentration of CO_2 in venous blood.

4. What new or unresolved questions do you have about the graph, gas concentrations in the blood, or how the body regulates gas exchange during exercise?

Summary Task

Today we completed a class consensus discussion after looking at a few different sequence charts. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today.

1. How does the body regulate gas exchange?

2. Why do we say that gas exchange is a feedback mechanism?

3. How is gas exchange regulated at the cell, organ, and body system level? Give one example of each.

Cellular level:

Organ level:

Body system level:

4. Cells, organs, and body systems can all be thought of as systems and components of the larger system of the body. Explain how the process of gas exchange links these different levels of systems.

Comparing Gas Exchange Text

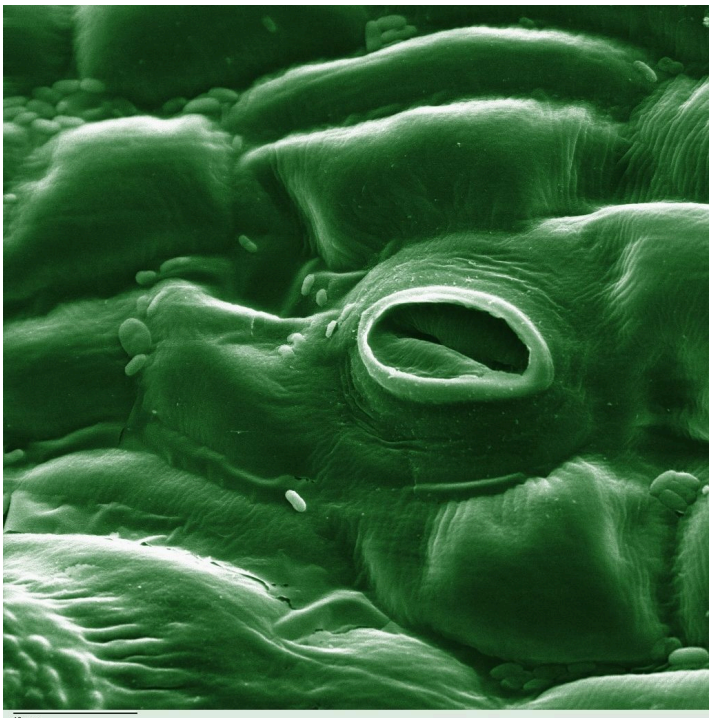
Gas Exchange in Plants

All living organisms continually produce gases during cellular respiration and other metabolic processes. Plants and other organisms are in contact with their environment, and exchange gases with their environment. The gaseous balance in plants is quite complex because plant cells carry out both respiration and photosynthesis.

Plants respire in much the same way as animals; oxygen is used to break down carbohydrates (sugars), and carbon dioxide and water are produced as waste products. The photosynthetic process requires an input of carbon dioxide and water. These two reactants are used to produce carbohydrates, and oxygen is released as a waste product.

Although plants both generate and use oxygen, they generally produce more oxygen than they use. Unlike animals, plants take in and use carbon dioxide, and even though they produce some carbon dioxide during cellular respiration, generally they take in more carbon dioxide than they release, because of photosynthesis.

Gases move into and out of the plants through specialized openings located along the lower surface of the leaf, called stoma. The picture on the left shows an open stoma. Each stoma (or stomate) is surrounded by two specialized structures called guard cells. These two cells are attached together at each end of both cells.



Stoma in tomato plant leaf

When guard cells take up water, the expanding of the cells forces the sides apart and results in the opening of the stomate. The opening of the stoma allows for gas exchange: carbon dioxide enters and oxygen leaves through the process of diffusion.

However, when stomata open to take in carbon dioxide, water vapor is lost, putting plants at risk of drying out. Therefore, plants need to carefully regulate the opening and closing of stoma so that they do not lose too much water while gaining carbon dioxide. Plants do not have a nervous system like humans, but their cells do still respond to stimuli. In this case, there are carbon dioxide sensors inside the guard cells, which tell them when carbon dioxide levels in the leaf are too low, which triggers the stoma to take in water and open. If the plant loses too much water, the guard cells lose water and close the stoma.

Comparing Gas Exchange R-G-S-S

Directions for Read-Generate-Sort-Solve:

1. Read: Read the text about gas exchange (*Comparing Gas Exchange Text*) silently.
2. Generate: On your group's chart paper, generate ideas about how plants use feedback mechanisms to regulate gas exchange.
3. Sort: Have everyone in the group star one idea that they think is most relevant to the question.
4. Solve: As a group, discuss the ideas you deemed most important, and come up with a response to the question.

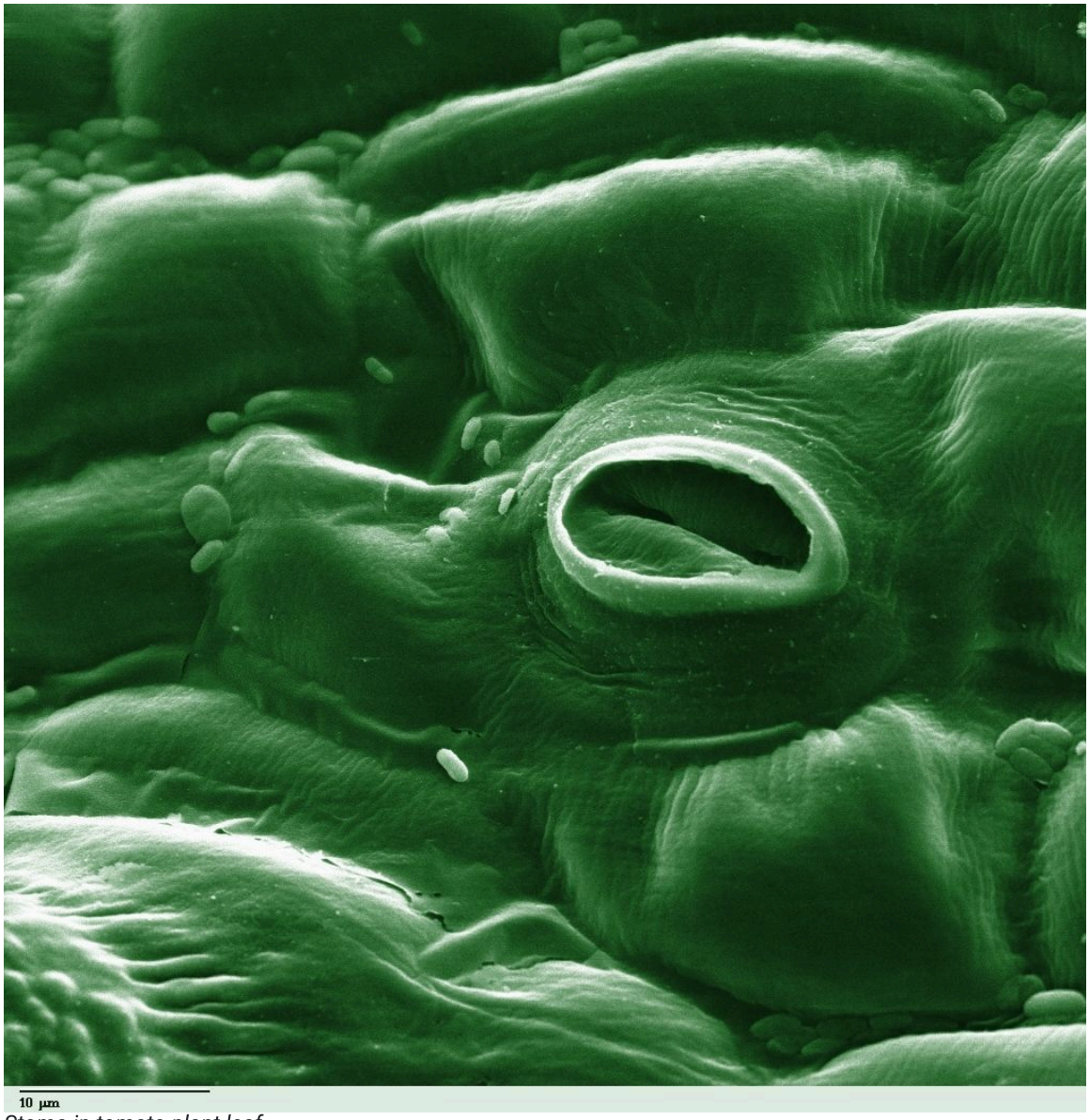
Do all organisms do gas exchange the same way as humans do?
Generate Ideas.

Name:	**Name:**
Name:	**Name:**

Do all organisms do gas exchange the same way as humans do?

After your group discussion, independently construct a model on the diagram of the stomate below showing how plants regulate gas exchange. In your model, be sure to include:

- The gases that are moving into and out of the system
- Which direction the gases are going in
- The stimuli triggering the stomate to open or close
- The mechanism of the stomate opening or closing



Stoma in tomato plant leaf

When you are done with your model, describe how feedback in the guard cells stabilize the balance of gases in the plant leaf while regulating water loss.

Gas Exchange & Cellular Respiration Model Rubric

Component	Developing	Proficient
Model	Shows what is happening within the human body and a specific cell during gas exchange/cellular respiration, but is missing a few of the components below: • Includes O2, CO2, ATP, mitochondria, lungs, and the brain in the model • Includes a cell model • Draws an arrow from the human body model to the detailed cell model • Shows interactions on multiple levels (organ, tissue, cell) The images are somewhat clear and show an attempt at some legends/keys or written captions to clarify the model.	Effectively and accurately shows what is happening within the human body and a specific cell during gas exchange/cellular respiration and includes all of the elements below: • Includes O2, CO2, ATP, mitochondria, lungs, and the brain in the model • Includes an appropriate & detailed cell model • Draws an arrow from the human body model to the detailed cell model • Shows interactions on multiple levels (organ, tissue, cell) The images speak for themselves or contain legends/keys and written captions to clarify the model. Model is aesthetically pleasing. It is neat and easy to understand.
Explanation	Student makes a claim identifying whether the marathon runner ran out of O2 during the race. The claim is weakly supported with evidence from the medical tent data, lab activity, or reading. Reasoning is not provided to support the claim.	Student makes a claim identifying whether the marathon runner ran out of O2 during the race. The claim is supported with relevant and accurate evidence from the medical tent data, lab activity, or reading. Reasoning is provided to support the claim.

Student Self-Score Circle one			**Teacher Score** Circle one		
Model	Developing	Proficient	**Model**	Developing	Proficient
Explanation	Developing	Proficient	**Explanation**	Developing	Proficient
Glow			**Glow**		
Grow			**Grow**		

Muscles & Energy 5E

Unit 1 Marathon Runner	Biology
Student Name:	

Experiencing Muscle Fatigue

Have your muscles ever become tired after exercising? What did that feel like?

We can safely stimulate muscle fatigue by pulling a rubber band apart with our fingers as many times as we can.

Steps:

1. Place one end of the rubber band around your thumb of your right hand and the other on the end of your ring finger on the same hand.
2. To give a good amount of resistance, either double the rubber band or twist it in the middle so that it loops around the fingers.
3. Check the rubber band that will be used for any flaws to prevent the rubber band from breaking.
4. Get a timer (stopwatch, clock, or cell phone).
5. Open your hand as wide as you can and then close it as many times as you can in 1 minute.
6. Count the number of times you were able to open and close it, and write that number below.
7. Without resting, and using the same hand, repeat steps 1-6.

1st attempt	2nd attempt
Number of times _____	Number of times _____

Describing your Experience:

1. On which attempt were you able to open and close your hand the most times?

2. How did your hand feel after the end of the second attempt? How did it feel similar to or different than other times in which your muscles felt tired after exercising?

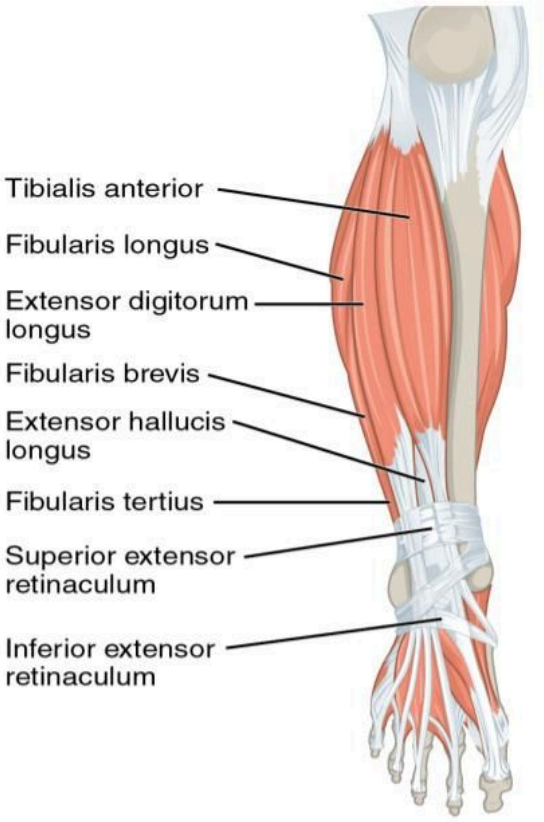
3. Using your input-output model, and prior knowledge, predict a reason for your results.

4. Discuss the limitations of this investigation. How can we learn more about why muscles become tired during exercise?

Muscles at Different Scales

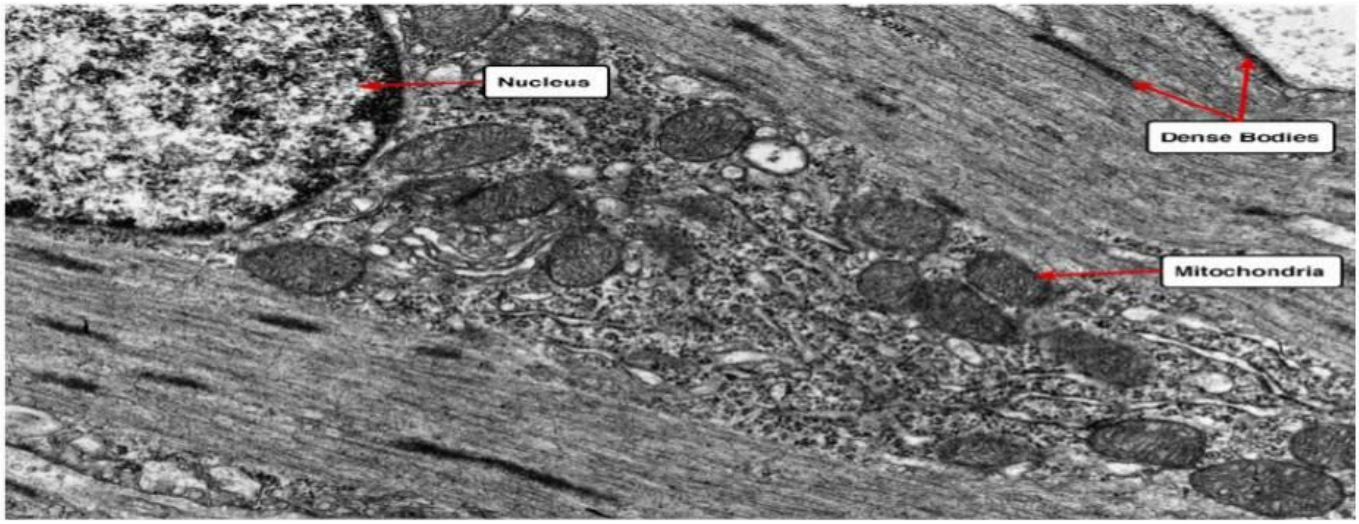
Image 1: Whole Body (System)

Image 2: Organ



Superficial muscles of the right lower leg (anterior view)

Image 3: Cell



Exercise and Cellular Respiration Investigation

Planning the Investigation

Purpose & Research Question
The purpose of this investigation is to figure out why ….

The research question is

Hypothesis
A good hypothesis has this format and punctuation: If _____, then _____ because_____.

If

then

because

Investigation Design
First, individually brainstorm ideas on how to design an appropriate investigation that addresses your research question. You can sketch out your ideas or write them down in bullet point format.

Hint:
Carbon dioxide production can be measured by breathing through a straw into a solution of bromothymol blue (BTB). BTB is an acid indicator; when it reacts with acid it turns from blue to yellow. When carbon dioxide reacts with water, a weak acid (carbonic acid) is formed (see chemical reaction below). The more carbon dioxide you breathe into the BTB solution, the faster it will change color to yellow.

$6CO_2 + 6H_2O \leftrightarrow 6HCO_3^- + 6H^+$

Consensus

Discuss your ideas with your group. Come to consensus on a design plan

Variables

Use this table to name the variables in your investigation.

Independent Variable	Dependent Variable	Control Group	Controlled Variable(s)

Materials

Some suggested materials are provided below. What other materials will you need for this investigation? Take into account the cost and availability of possible materials.

Needed per group:

- bromothymol blue (BTB)
- straw

Data Collection

Use the prompts below to plan how you will collect data in this investigation.

Quantitative Data

- What are you measuring?
- What tool(s) will you use to measure?
- What is the unit(s) of measurement?
- How accurate is your tool / type of measurement?
- What time intervals?
- How many trials?

Qualitative Data

- What observations will you collect?
- How will you collect observations? (checkboxes, written observations, etc)
- What time intervals?

1. How do the data you plan to collect provide evidence towards the research question?
2. What are some possible sources of error in your data collection plan? How can you address these errors?
3. What are the limitations of your data collection plan? How can you address these limitations?

Procedure

Return to your investigation plan and confer with your group. Do you need to make any changes to the plan based on data collection and materials concerns? List out your procedure, step by step.

Data Tables
Use the space below to create the data tables you need for your investigation.

Graphs
Title your graph and use the space below to create a graph.

Analysis of Data

See-Think-Wonder

See Things I see in the class-wide data collected.	Think Ideas that this data makes me think about.	Wonder Questions and wonderings I have about the data.
Prompts to get you started: • *What effect did exercise have on the variables measured?*	Prompts to get you started: • *Based on the variables measured, what is the impact of exercise on the rate of cellular respiration?* • *What impact would increasing exercise have on blood glucose levels?* • *Based on the data collected, what insight do you have on why muscles may become tired during exercise?*	

Conclusion

Was your hypothesis supported? Be sure to explain your reasoning! (Sentence starters: "Yes, my hypothesis was supported. The data collected demonstrated that ….." or "No, my hypothesis was not supported. The data collected demonstrated that …")

Summary

1. Why did we measure multiple variables to investigate exercise and cellular respiration?

2. How might you improve the procedure to generate more accurate data in order to respond to the research question?

3. In this investigation, we exercised for 1-2 minutes at a time. How might our body respond differently when exercising for longer periods of time (like in a marathon)?

4. Based on what you learned in the previous 5E, where does the energy used by muscle cells come from? What inputs were your muscles using, and what outputs were they creating?

5. Based on what we learned in the previous 5E, what role does the brain or nervous system play in maintaining homeostasis during exercise?

5. What did we learn about exercise, cellular respiration, and why muscles may become tired during exercise? What else do we need to learn about to better understand the phenomenon under investigation?

Exercise and Cellular Respiration Investigation Rubric

Student Rubric - Exercise and Cellular Respiration Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to answer all of the analysis questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Exercise and Cellular Respiration Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.
Time Management	Procrastinated, did not use school time or schedule provided to get work completed.	Mostly used time well and completed investigation on time.	Used time well to ensure things get done on time.

Exercise and Cellular Respiration Investigation -Scaffolded

Introduction
This lab will address how exercise (increased muscle activity) affects the rate of cellular respiration. You will measure 3 different indicators of cellular respiration: breathing rate, heart rate,and carbon dioxide production. You will measure these indicators at rest (with no exercise) and after 1 and 2 minutes of exercise. Breathing rate is measured in breaths per minute, heart rate in beats per minute, and the amount of carbon dioxide in exhaled air.

Carbon dioxide production can be measured by breathing through a straw into a solution of bromothymol blue (BTB). BTB is an acid indicator; when it reacts with acid it turns from blue to yellow. When carbon dioxide reacts with water, a weak acid (carbonic acid) is formed (see chemical reaction below). The more carbon dioxide you breathe into the BTB solution, the faster it will change color to yellow.

$6CO_2 + 6H_2O \leftrightarrow 6HCO_3^- + 6H^+$

Purpose & Research Question
The purpose of this investigation is to figure out why ….

The research question is

Hypothesis
A good hypothesis has this format and punctuation: If _____, then _____ because_____.

If

then

because

Materials

Needed per group:

- Beaker/Test tube/cup
- Diluted bromothymol blue solution (BTB)
- Straw
- Stop watch or timer

Procedure

PART A: Resting (no exercise)

Measuring Carbon Dioxide Production:

1. Use a graduated cylinder to measure out 20 mL of tap water and pour it into a small beaker.
2. Use a dropper to add 8 drops of bromothymol blue to make a BTB solution.
3. Using a straw, exhale into the BTB solution. (CAUTION: Do not inhale the solution!)
4. Time how long it takes for the blue solution to turn yellow. Record the time in Table 1.
5. Wash out the beaker and repeat steps 1-4 twice more.
6. Average the results of the 3 trials. Record this in Table 1.

Measuring Breathing Rate:

1. Count the number of breaths (1 breath = inhale + exhale) you take in 1 minute. Record this in Table 2.
2. Repeat this 2 more times.
3. Average the 3 trials to get your average breathing rate. Record this in Table 2.

Measuring Heart Rate:

1. While you calculate your breathing rate, have your partner take your pulse.
2. Count the number of beats in 30 seconds and multiply that number by 2. Record this in Table 3.
3. Repeat this 2 more times.
4. Average the 3 trials to get your average heart rate. Record this in Table 3.

PART B: Increased Muscle Activity (exercise)

1. Exercise for exactly 1 minute by doing jumping jacks.
2. While you are exercising, your partner should get the BTB solution ready as in Part A.
3. After 1 minute of exercise, immediately exhale through the straw into the BTB solution. Time how long it takes for the BTB to turn yellow. Record this in Table 1.
4. Then quickly calculate your breathing and heart rates as you did before. You only need to do this once.
5. Record these values in Tables 2 & 3. Remake your BTB solution.
6. Exercise as you did before, but for 2 continuous minutes.
7. Immediately exhale through the straw into the BTB solution. Time how long it takes for the BTB to turn yellow. Record this in Table 1.
8. Then quickly calculate your breathing and heart rates as you did before. You only need to do this once.
9. Record these values in Tables 2 & 3.
10. If there is time, repeat the entire procedure for your lab partner. If there is no time to repeat the procedure for your partner, record data from 2 OR 3 other subjects in the class to get more data.

Data Tables

Table 1: Carbon Dioxide Production (time it takes BTB to change color)

		Time for BTB to change color (seconds)				
		Student 1	**Student 2**	**Student 3**	**Student 4**	**Average**
Resting	Trial 1					
	Trial 2					
	Trial 3					
	Average					
Exercise Time	1 minute					
	2 minutes					

Table 2: Breathing Rate

		Breathing Rate (breaths/minute)				
		Student 1	**Student 2**	**Student 3**	**Student 4**	**Average**
Resting	Trial 1					
	Trial 2					
	Trial 3					
	Average					
Exercise Time	1 minute					
	2 minutes					

Table 3: Heart Rate

		Heart Rate (beats/minute)				
		Student 1	**Student 2**	**Student 3**	**Student 4**	**Average**
Resting	Trial 1					
	Trial 2					
	Trial 3					
	Average					
Exercise Time	1 minute					
	2 minutes					

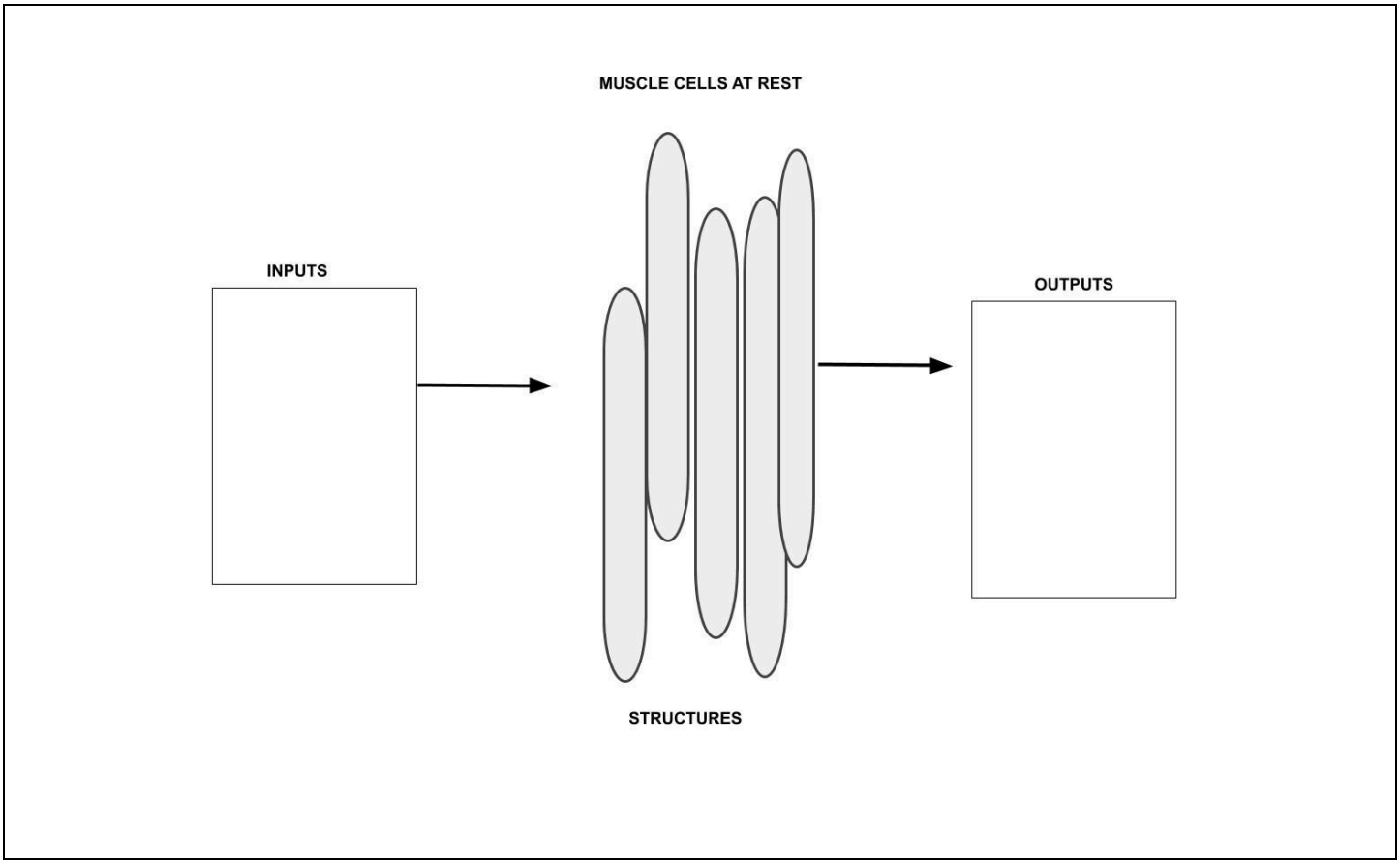
Graphs
Title your graph and use the space below to create a graph.

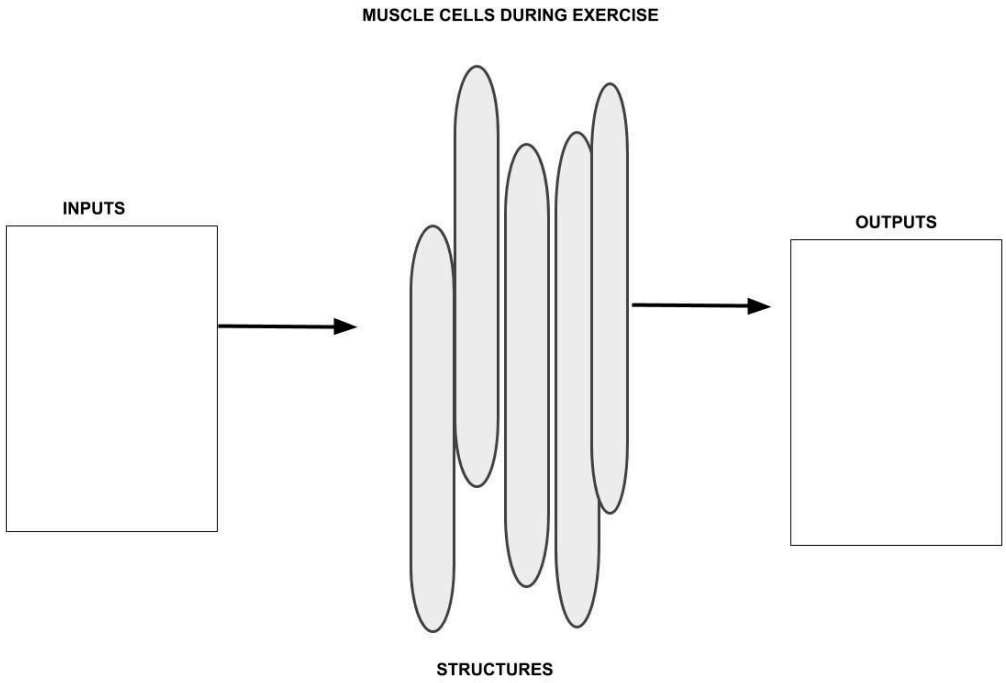
Muscle Cell Input-Output Model

Guiding Question: *Can muscle cells run out of energy?*

Directions:

1. Use the space below to develop an input-output model that represents what you learned about energy and muscle cells, based on the exercise investigation from class.
    a. **Inputs** are anything that we added to the muscle cell.
    b. **Outputs** are anything that come out of the cell as a result of a **process.**
    c. **Structures** are parts of the system.
2. In your model, trace the movement of energy.
3. Share your ideas with your peers in order to develop a class wide model.





Muscle Cell Input-Output Model during exercise

Muscle Fatigue Text

Directions: Read and annotate the text, using the following annotations.

✔	Points that confirm your group's model
✖	Points that contradict your group's model
◌	Points that help to modify or add to your group's model

Why do our muscles get tired when we exercise?

Woman Exercising With Dumbells

Have you ever felt tired during exercise? The more we exercise, the more we are able to do, but even the most fit athletes experience muscle fatigue eventually. Working muscles (like any other cells) require **ATP** (cellular energy) in order to move our body during exercise. Cells use a two steps process to break down and harness the chemical potential energy stored in **glucose** molecules to generate ATP.

Step 1: This first step takes place in the **cytoplasm without using oxygen** (**anaerobic**). Glucose is broken down into lactate and two molecules of ATP are produced. This is a quick process that produces only 2 ATP but in a fast way (during a sprint for example).
Step 2: This second step takes place in the mitochondria with the **use of oxygen (aerobic).** Lactate is further broken down into the mitochondria and 36 molecules of ATP are produced. This is a longer and slower process but produces more energy (during an endurance type of exercise like a marathon).

Muscle fatigue is mainly caused by the byproducts of these and other cell processes used during intense activity to generate ATP. During exercise, muscle cells may use up most of their glucose and other molecules storage, which increases the amount of waste products in the cells. The circulatory and respiratory systems must work faster to clear away the waste products of cellular respiration from the muscle cells, and to bring in new oxygen and glucose. Cellular respiration also releases heat energy, which is carried through the circulatory system to maintain body temperature.

In addition to having more muscle tissue, athletes often have more mitochondria in their muscle cells and more efficient circulatory and respiratory systems in order to meet the demands of extensive exercise. Athletes can produce more energy more efficiently with less waste products.

The energy required for ATP generation comes from glucose in the food that we eat. It may appear that we can never have too much sugar, but excess sugars in the blood cause damage to tissues. Therefore, the body must regulate, or balance, the amount of sugar that is present in the blood.

Summary Task

Think-Talk-Open Exchange + Buzzwords

Starting Position: Write your own response to this prompt. Be prepared to reference your input-output model when talking about your response.

How do muscle cells access what they need to keep producing cell energy?

Discussion: As each person in your group presents, tally the number of times you hear each buzzword.

Buzzwords	Energy	ATP	Bonds	Glucose
Tally marks				

Reflection: After listening to your group-mates, how would you change your original answer?

Summary

Today we did consensus discussions in small groups, using the routine TTOE.

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

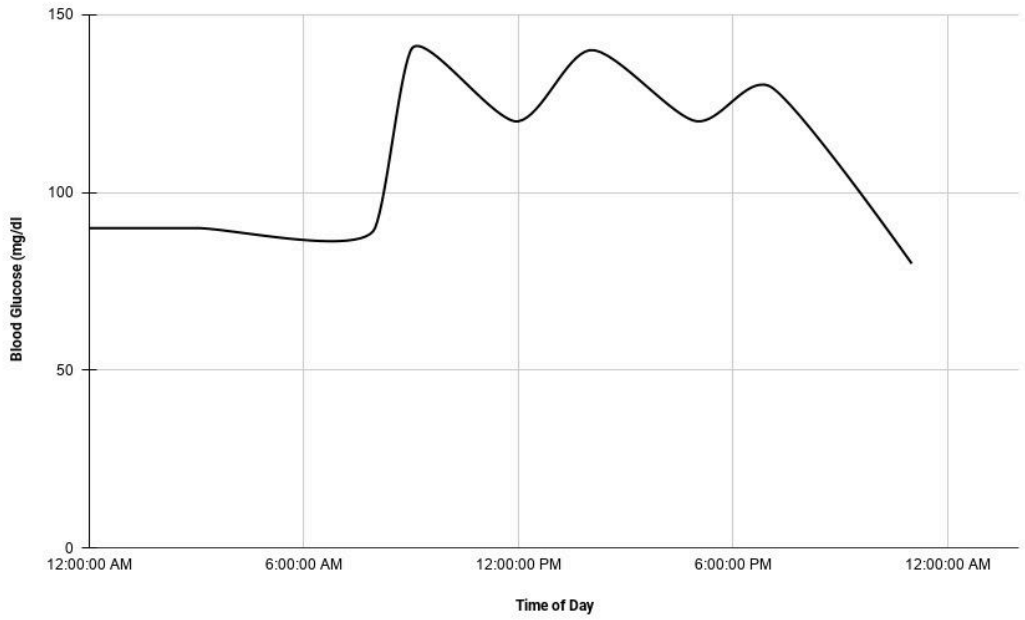
4. What did you learn from this person?

5. One idea that I contributed to my group or my class:

Normal Blood Glucose Graph

Blood glucose levels of a healthy individual over two days

An individual monitored their blood glucose levels over the course of 24 hours. The person ate their breakfast at 7am, their lunch at 12pm, and dinner at 5pm. It might be helpful to to annotate mealtimes on the graph of their blood glucose levels below.



Blood glucose of a healthy individual over 24 hours

See-Think-Wonder Graphic Organizer

See Things I see in the data collected.	**Think** Ideas that this data makes me think about.	**Wonder** Questions and wonderings I have about the data.

Glucose Regulation Investigation

All organisms must keep their internal environments balanced within a set range in order to stay healthy and survive. Maintaining an internal balance, even when external conditions change is called **homeostasis.** One example of something inside of the body that needs to be maintained within certain limits is the amount of sugar (glucose) in the blood, called blood glucose. Too much glucose in the blood can be harmful to cells and tissues, too little and organisms cannot generate enough ATP to fuel their life processes. In this lab, we are going to explore the ways in which the human body maintains healthy levels of blood glucose.

We are investigating how humans regulate blood sugar, so we can figure out what caused the marathon runner to go into a coma. However, as we know that testing or experimentation on humans is difficult. Therefore, we are going to model glucose regulation so we can better understand how we maintain homeostasis in terms of glucose in the blood, and what can go wrong with this process. Using model blood, we are going to simulate what happens in the blood using chemical indicators. The indicators used will change color to demonstrate different amounts of sugar in our model 'blood'. The chart below shows what the color changes mean.

'Blood' color	**What it means**
Royal blue	Blood glucose is too low
Green/teal	Blood glucose is a normal level (homeostasis)
Yellow	Blood glucose is too high

Pre-lab Questions:

1. How might this lab help us understand what happened to the Marathon runner that collapsed?

2) If we are actually interested in understanding glucose regulation in humans, why would we use a model of the system in this lab?

Hypothesis:

- How do you think eating will affect blood glucose (sugar)?

- What do you think an organism can do to decrease the amount of glucose in its blood?

_____

Procedure

1. Get a small clear container with a small amount of simulated blood. This container represents the blood of a healthy organism who has the normal concentration of glucose in its blood.

2. Simulate what happens to blood glucose levels after a meal. Food is broken down into glucose in the digestive system. Use the Glucose dropper to add 5 drops of "Glucose" to the plastic cup. Gently swirl the cup to mix the "Glucose" with the blood. Fill in the chart below.

Color Blood Turns	What this Means	What an Organism Should Do to Maintain Homeostasis

3. After consuming glucose (or food that breaks down into glucose) organisms release insulin. The function of insulin is to open up cell membranes so that glucose can enter the cells to be used in cellular respiration. Add 10 drops of "Insulin" to the beaker. Gently swirl the cup to mix the "Insulin" with the model blood. Fill in the chart below.

Color Blood Turns	What this Means	What an Organism Should do to Maintain Homeostasis

4. Add drops of "Glucose" until you restore homeostasis. After each drop, gently swirl the cup to mix the "Glucose" with the model blood to see if any color change occurs**. Make sure you COUNT EACH DROP!**

    - How many drops of "Glucose" were needed to restore homeostasis? _____
    - What would happen if you gave an organism too much "Glucose"? What would you have to do to restore homeostasis?

    _____

    _____

    _____

    _____

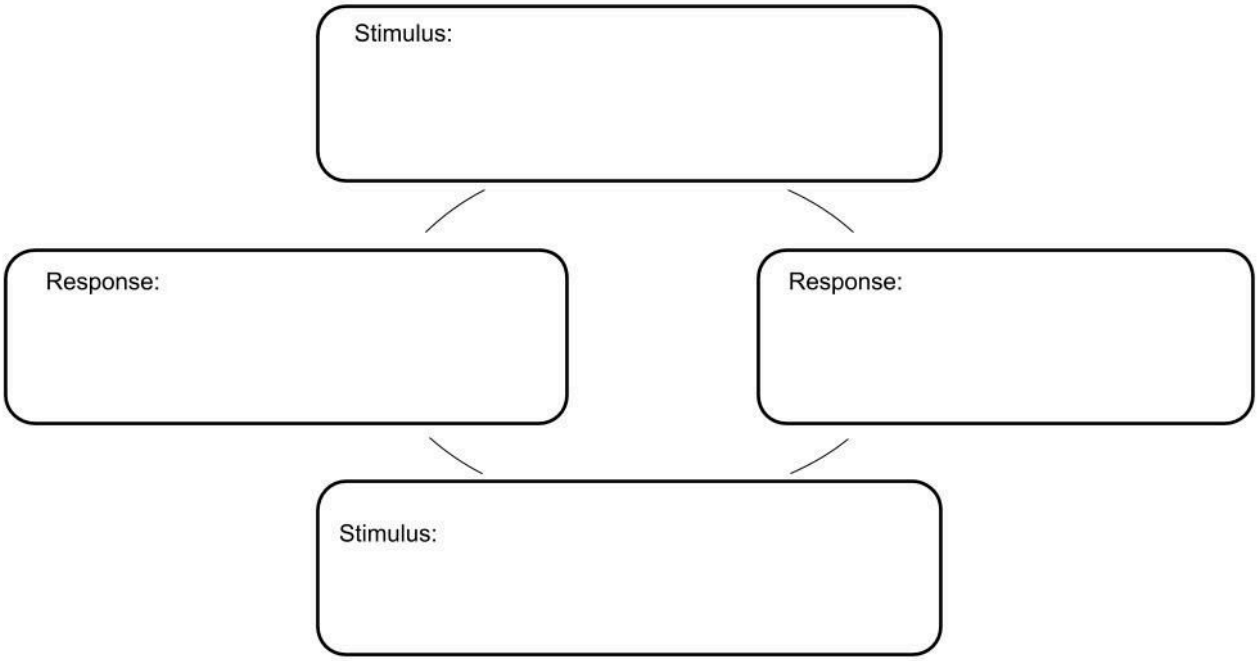
    _____

Analysis Questions

1. What were the two stimuli and two responses in this lab?
   (**Think: What did you see that caused a response, and what was that response?)

Stimulus (what triggered a color change?)	**Response** (what was that color change, and what does it mean?)

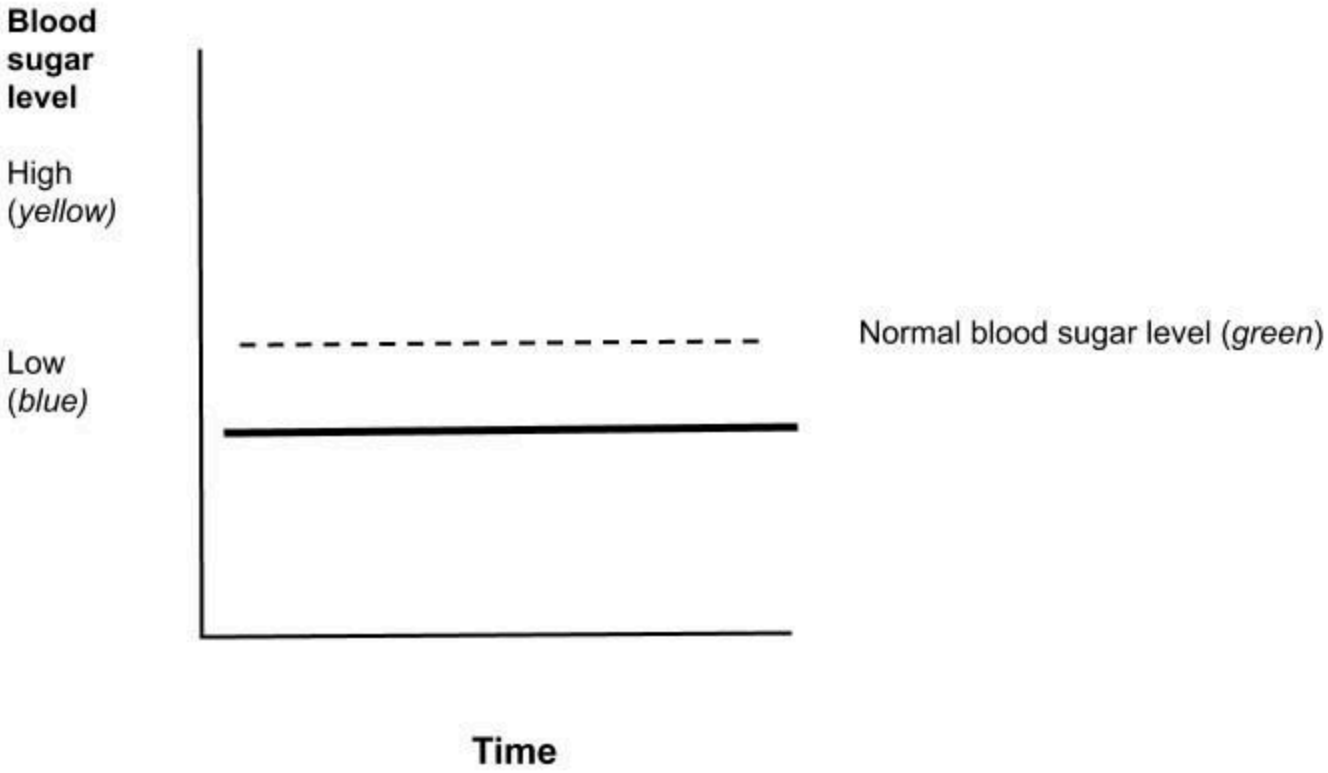
2. Fill in the flowchart below that outlines how blood glucose levels are maintained based on the data you collected.



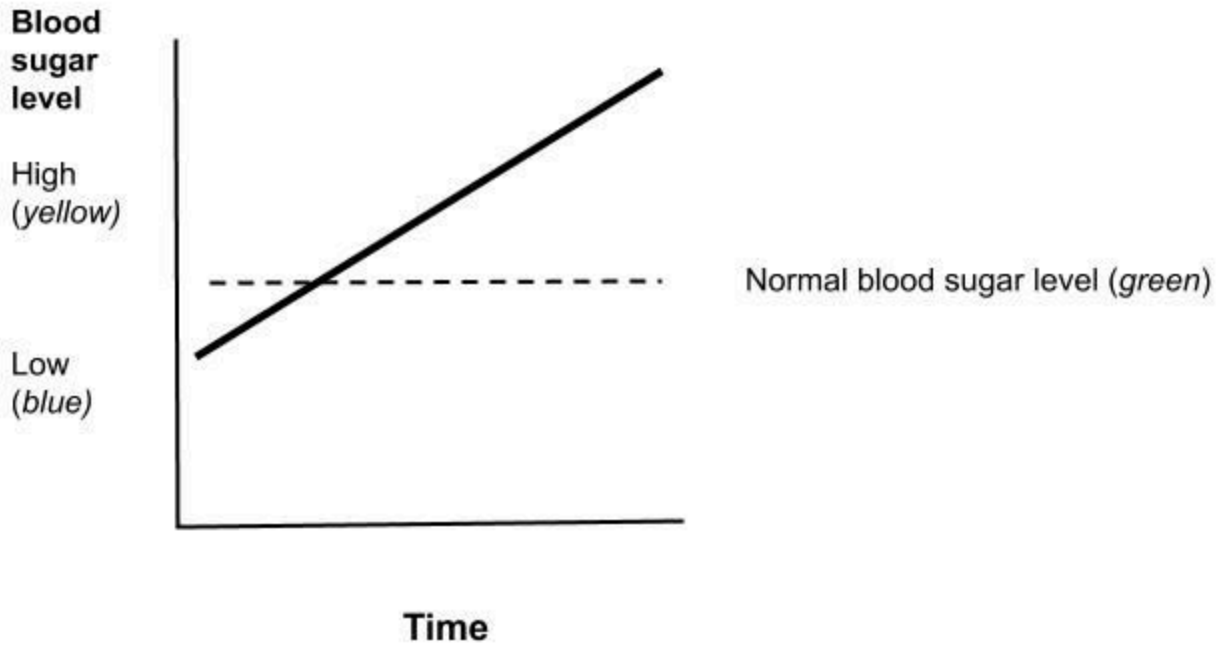
Blood Glucose Feedback Loop Flow Chart

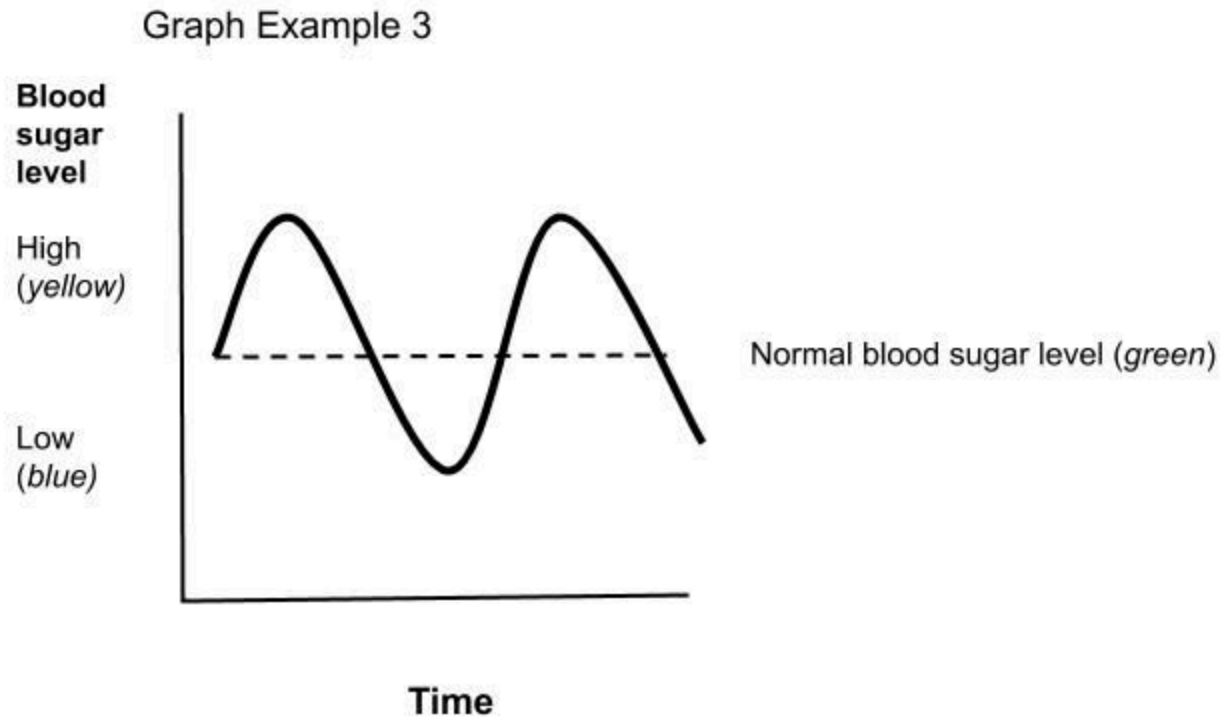
3. Look at each of the following graphs. Choose the one that best represents the data you collected in this lab. On the one that you choose, label where responses would be triggered.

Graph Example 1



Graph Example 2





4. Blood glucose levels are regulated through a **feedback loop**, or feedback mechanism. Based on today's activity and your answers to the questions above, provide a definition of a feedback loop, and explain how it works to maintain blood glucose levels.

Feedback Loop:

5. What do we need to still figure out about how glucose is regulated in the body?

6. What impact do you think exercise has on blood glucose levels and why our muscles become tired during exercise?

Glucose Regulation Investigation Rubric

Student Rubric - Glucose Regulation Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to answer all of the analysis questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Glucose Regulation Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.
Time Management	Procrastinated, did not use school time or schedule provided to get work completed.	Mostly used time well and completed investigation on time.	Used time well to ensure things get done on time.

Summary Task

Today we completed a class consensus discussion after looking at a few different glucose graphs. How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

4. What did you learn from this person?

5. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today.

1. What is a feedback mechanism?

2. Based on the graphical model you created today, describe the relationships between body systems in maintaining blood glucose levels.

3. Describe one feedback mechanism in science and one in everyday life.

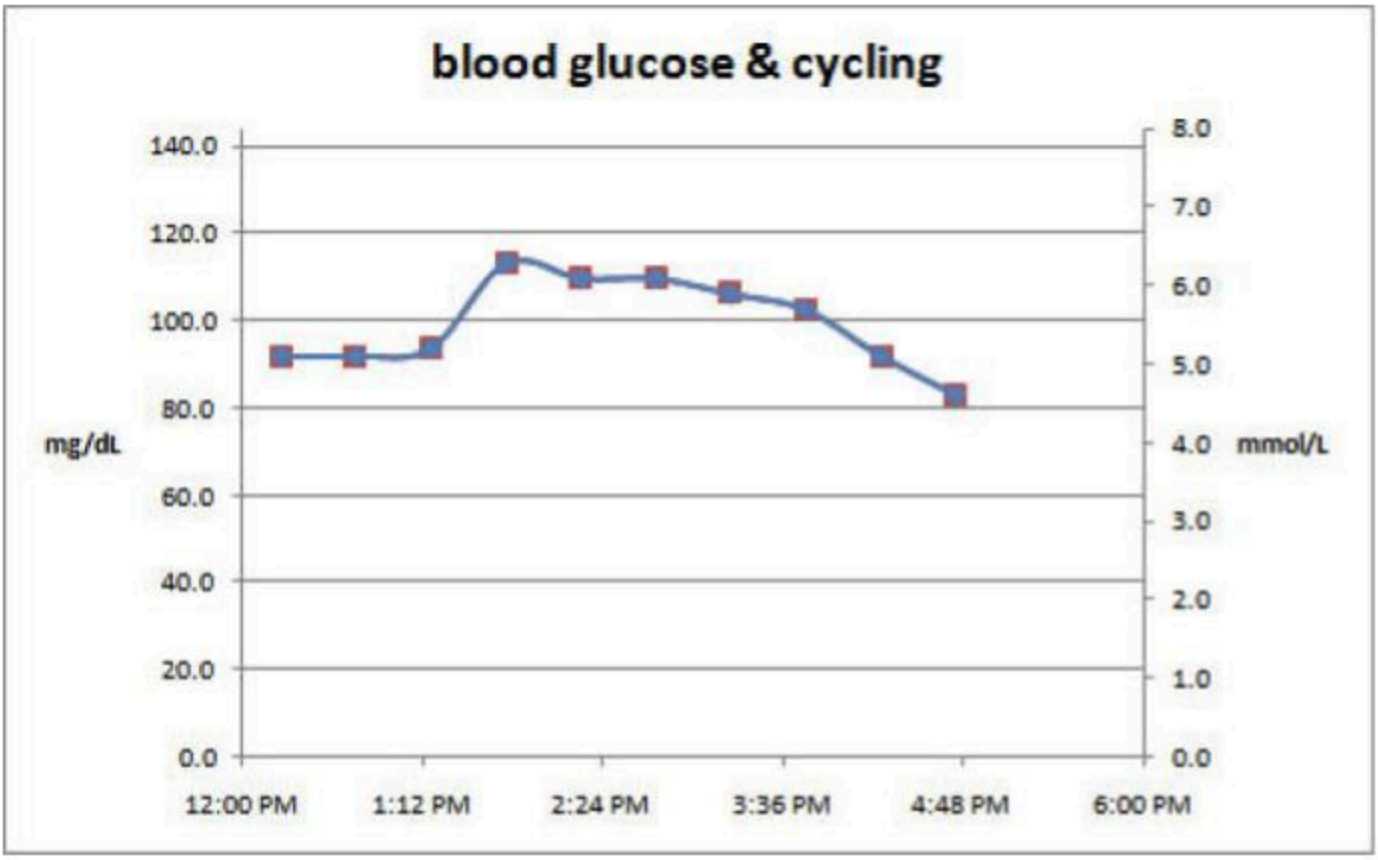
Science:

Everyday life:

4. Why do you think so many processes in the human body are regulated by feedback mechanisms?

Blood Glucose and Exercise

A man decided to track his blood glucose levels over time while cycling. He began his ride a little after 12 pm, and warmed up by cycling at a slow pace. He slowly increased his speed and then continued his ride at a moderate to fast pace until he stopped at about 4:45pm. He did not eat and only drank water during his ride.



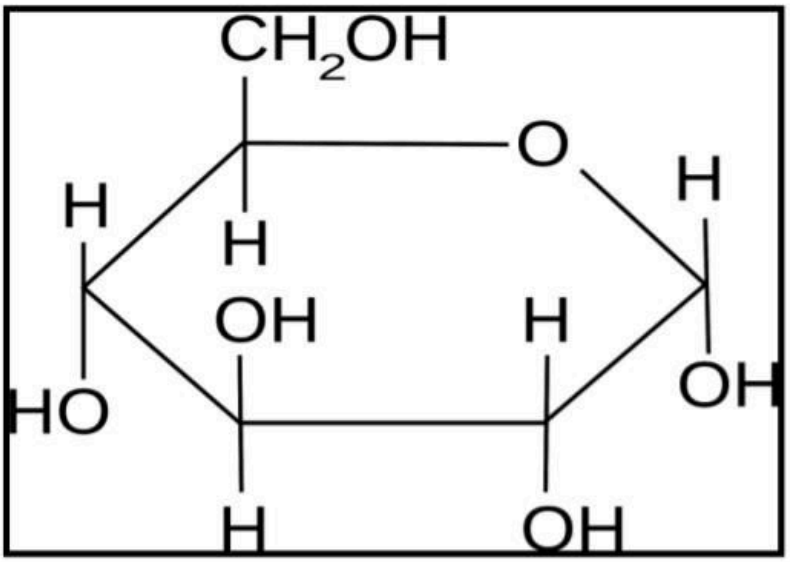
Blood Glucose & Cycling

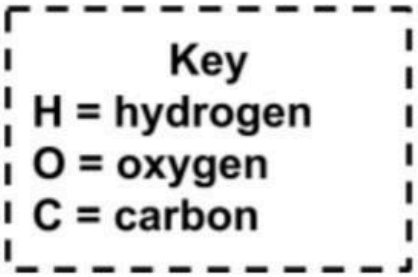
Storage Molecules

During cellular respiration, organisms break down glucose to release energy (generate ATP). Different types of molecules can be broken down into glucose by the digestive system, which is used to generate ATP. The structure of molecules can be represented using letters for the different atoms and lines as bonds between those atoms.

Directions: Using the Venn diagram, compare and contrast three different energy storage molecules that are found in organisms.

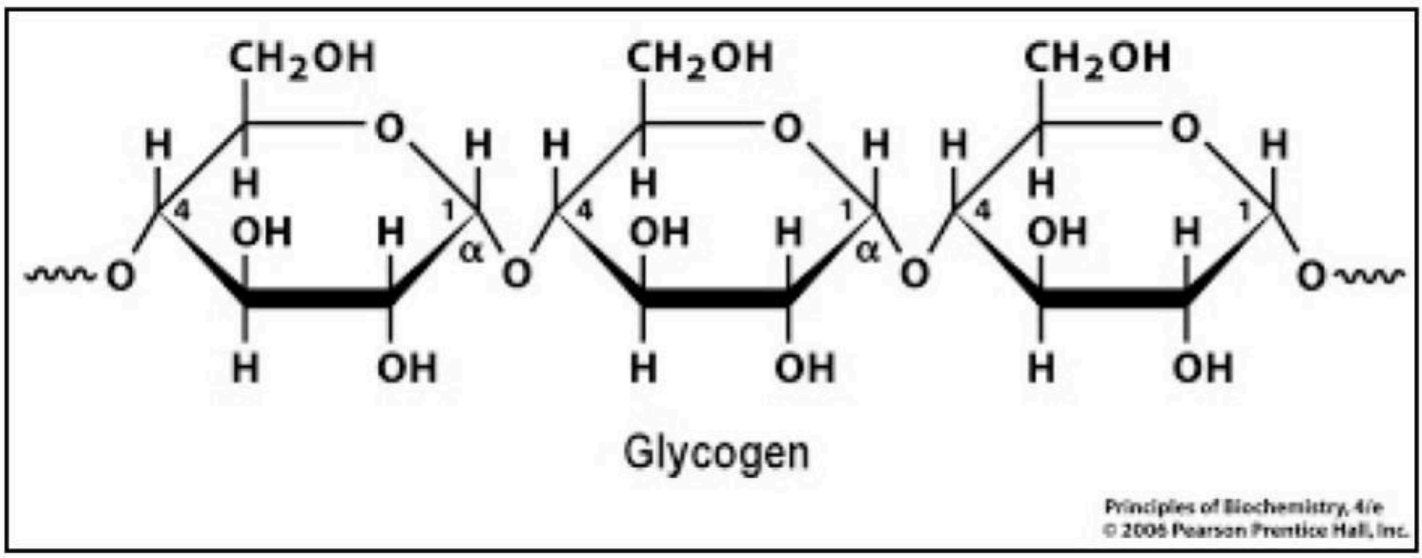
Glucose





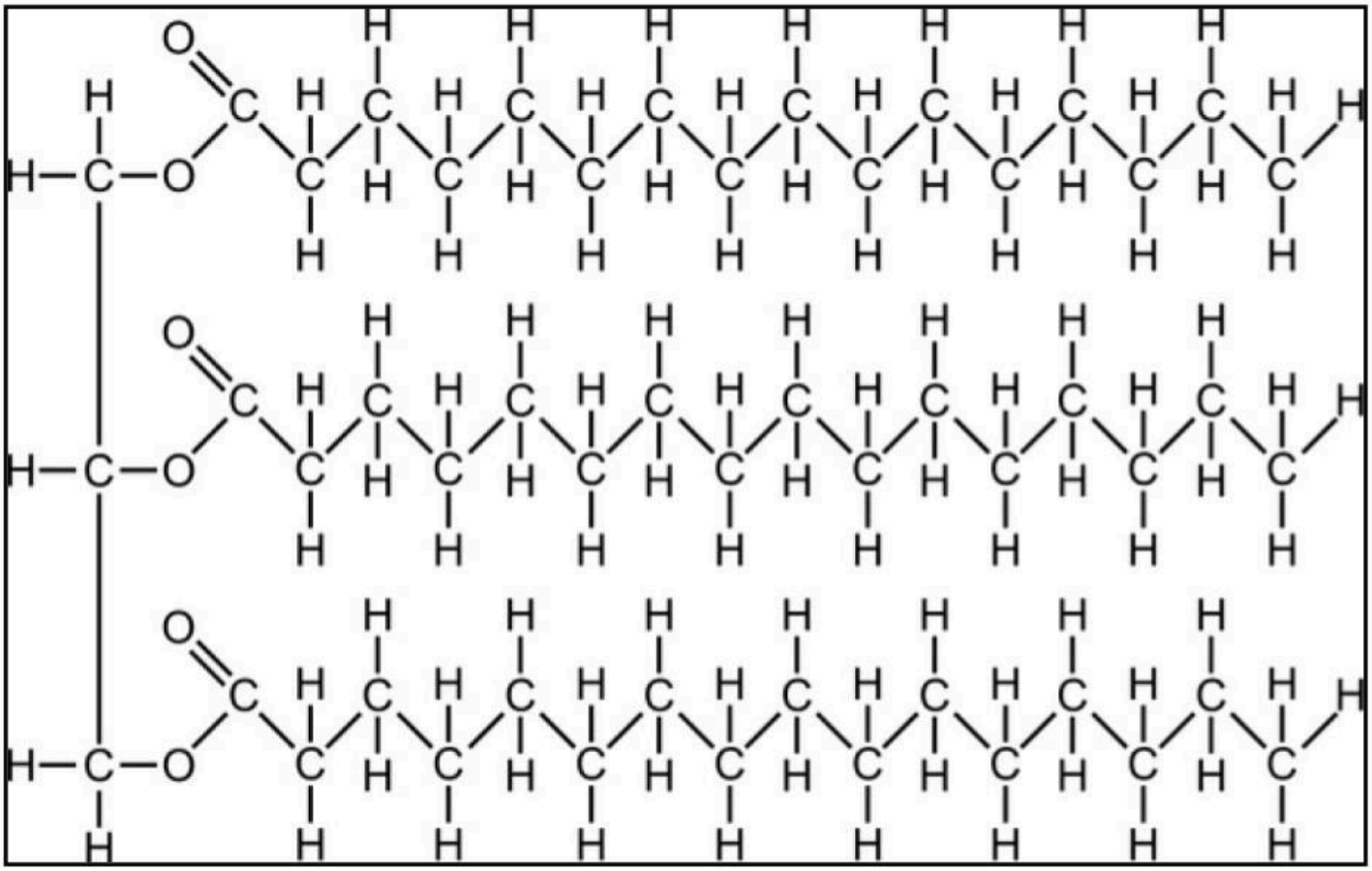
Glucose Molecular Structure

Glycogen



Glycogen Molecular Structure

Triglyceride (Fat)



Trigliceride Molecular Structure

Unique to Glucose	Common in All	Unique to Glycogen
Unique to Lipid (Fat)		

Questions:

1. *Based on your observations, which molecule do you think holds the most energy to fuel cellular respiration? Why?*

2. *Review: Choose one molecule and identify where the 'energy' is held and what constitutes the mass of the molecule. Explain your thinking.*

Experimenting with Fat Loss

Designing an Experiment for Fat Loss

After reading about the cyclist, a student posed the question: How do we know that the cyclist was using fat for energy on his bike ride, and wasn't just using glucose from food he ate in the morning and was still digesting?

That got the student thinking: if I went on a bike ride after eating different meals or different amounts of time before my ride, how would that affect my blood glucose? How would the bike ride change my blood glucose compared to eating those same meals at those same times and then not going on a bike ride?

Your task is to design an experiment that tests one of the questions (or a related question) that the student asked.

Planning the Investigation

Research Question

What is your experimental question? What are you trying to figure out?

Hypothesis
Use this format: If I _____, then _____ because _____.

Investigation Design

Individually brainstorm ideas on how to design an investigation that addresses your research question. You can sketch out your ideas or write them down in bullet point format.

In your design, include

- The types of data you will be collecting
- How much data you will collect
- How you will organize your data
- How you will ensure your data is accurate
- Limitations on the type and precision of data that you are able to collect

Consensus
Discuss your ideas with your group. Come to consensus on a design plan.

Variables
Use this table to name the variables in your investigation.

Independent Variable	Dependent Variable	Control Group	Controlled Variable(s)

Procedure

Write out the complete procedure of your experiment.

Where Does the Fat Go?

This Is Where Your Fat Actually Goes When You Lose Weight

Weight loss happens when you burn more calories for energy than you take in. But after you shed them, *what exactly happens to all those extra pounds of fat*?

When a person loses fat, it might seem like it has evaporated into thin air and well, it kind of has. “Your body's primary source of energy is glucose, which is stored as glycogen in two places: liver and muscles,” explains Tanya Zuckerbrot, a NYC-based registered dietician. “When your body uses up its glycogen stores it turns to fat for fuel. Fat from food is stored in our body as triglycerides, which are made up of atoms.” When we start using that fat for energy, these atoms form into carbon dioxide (CO_2) and water (H_2O), which are breathed out. A small amount of weight is also lost as water in sweat, urine, and tears.

Maria Bella, a nutrition expert, adds that exercise, an activity that increases our breaths per minute and uses large amounts of energy, therefore aids in fat loss. However, the effect of breathing harder during exercise on fat loss is not enormous. Take for example a relatively sedentary 150-pound person who sleeps for eight hours, rests for eight hours, and is active for eight hours: this person will exhale about 1.5 pounds of CO_2 per day. If this same person were to replace an hour of rest with an hour of jogging this would only raise this number by one-third pound of CO_2 a day, equating to about 1/9th of a pound’s worth.

Adapted from: https://www.rd.com/health/diet-weight-loss/where-fat-goes-lose-weight/

Muscles & Energy Model Rubric

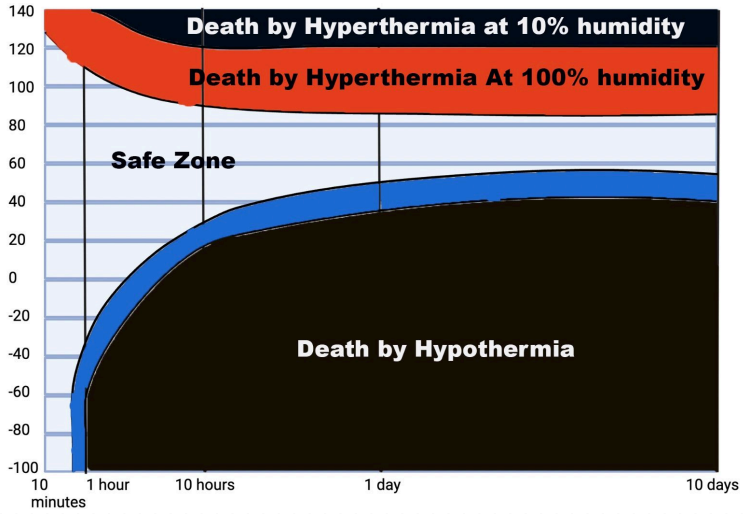
Component	Developing	Proficient
Model	Shows what is happening within the human body and a specific cell with muscles and energy, but is missing a few of the components below: • Includes O_2, CO_2, ATP, mitochondria, glucose, insulin and the pancreas in the model • Includes a detailed cell model • Draws an arrow from the human body model to the detailed cell model • Shows interactions on multiple levels (organ, tissue, cell) The images are somewhat clear and shows an attempt at some legends/keys or written captions to clarify the model.	Effectively and accurately shows what is happening within the human body and a specific cell with muscle and energy and includes all of the elements below: • Includes O_2, CO_2, ATP, mitochondria, glucose, insulin and the pancreas in the model • Includes a detailed cell model • Draws an arrow from the human body model to the detailed cell model • Shows interactions on multiple levels (organ, tissue, cell) The images (for the most part) "speak for themselves." **Or** contains legends/keys and written captions to clarify the model. Model is aesthetically pleasing. It is neat and easy to understand.
Explanation	Student makes a claim identifying whether the marathon runner ran out of energy during the race. The claim is weakly supported with evidence from the medical tent data, lab activity, or reading. Reasoning is not provided to support the claim.	Student makes a claim identifying whether the marathon runner ran out of energy during the race. The claim is supported with relevant/accurate evidence from the medical tent data, lab activity, or reading. Reasoning is provided to support the claim.

Student Self-Score Circle one			**Teacher Score** Circle one		
Model	Developing	Proficient	**Model**	Developing	Proficient
Explanation	Developing	Proficient	**Explanation**	Developing	Proficient
Glow			**Glow**		
Grow			**Grow**		

Human Thermoregulation 5E

Unit 1 Marathon Runner	Biology
Student Name:	

Temperature Extremes



Human Survival During Temperature Extremes

1. Read the title of the graph. Rewrite the meaning of the title in your own words.

2. What is the coldest temperature displayed on the graph, and what does it mean?

3. If someone were exposed to air that was 30°F, how long could they survive?

4. Think back to a time when you were very cold. How did your body respond?

5. Think back to a time when you were very hot. How did your body respond?

6. How does exercise affect a person's ability to survive in cold temperatures? What about hot temperatures?

7. How does the human body tolerate such a wide range of environmental temperatures?

Human Thermoregulation Investigation

Directions

- Annotate the introduction section by circling points you think are most important for the purpose of the investigation.
- Complete the following sections to plan out your investigation.

Introduction

Some students wondered if the marathon runner collapsed because she overheated. In other words, we might wonder if her body was not able to maintain a normal temperature, because she was running and experiencing a temperature change or stress in her environment. It was a warm day, after all! Normal human internal body temperature ranges between about 97.6 to 99.6°F (36.1 to 37.8°C). In this investigation, you will explore the relationship between your *internal body temperature* and the *skin surface temperature* of your hand under different conditions. It will be your task to plan and carry out an investigation to figure out how the human body normally responds to changes in our environment. This will help us figure out what happened to the marathon runner.

How can we measure skin surface temperature and internal body temperature using thermometers? Draw or describe in words below:

Skin surface temperature measurement	Internal body temperature measurement

Humans often experience temperature changes in their environment. For example, people in the Polar Bear Club choose to jump into and swim in very cold water in the winter. People often enjoy relaxing in a hot tub. Hot tubs can be very warm and may have water that reaches up to 100°F (37.8°C).

Members of the Polar Bear Club swimming in icy water

Free-standing outdoor hot tub

Do you think that jumping into cold water will cause the skin surface temperature of the hand to *increase* or *decrease*? Why?

Do you think that jumping into cold water will cause the internal body temperature to *increase* or *decrease*? Why?

Do you think that jumping into warm water will cause the skin surface temperature of the hand to *increase* or *decrease*? Why?

Do you think that jumping into warm water will cause the internal body temperature to *increase* or *decrease*? Why?

Planning the Investigation

Research Question
What is your experimental question? What are you trying to figure out?

Hypothesis
Use this format: If _____, then _____ because _____.

Investigation Design
Individually brainstorm ideas on how to design an investigation that addresses your research question. You can sketch out your ideas or write them down in bullet point format.

Consensus
Discuss your ideas with your group. Come to consensus on a design plan.

Variables
Use this table to name the variables in your investigation.

Independent Variable	Dependent Variable	Control Group	Controlled Variable(s)

Materials
Some suggested materials are provided below. What other materials will you need for this investigation? Take into account the cost and availability of possible materials.

Oral thermometer
Stopwatch or clock
Thermometer probe

Data Collection Plan
Plan the qualitative and quantitative data you will collect, and how you will organize your data.

Quantitative Data

- What are you measuring? How many trials?
- What tool(s) will you use to measure? How accurate is your tool or type of measurement?
- What is the unit(s) of measurement?
- What time intervals?

Qualitative Data

- What observations will you collect?
- How will you collect observations? (checkboxes, written observations, etc)
- What time intervals?

1. How will your data collection provide evidence towards the research question?

2. What are some possible sources of error in your data collection plan? How can you address these errors?

3. What are the limitations of your data collection plan? How can you address these limitations?

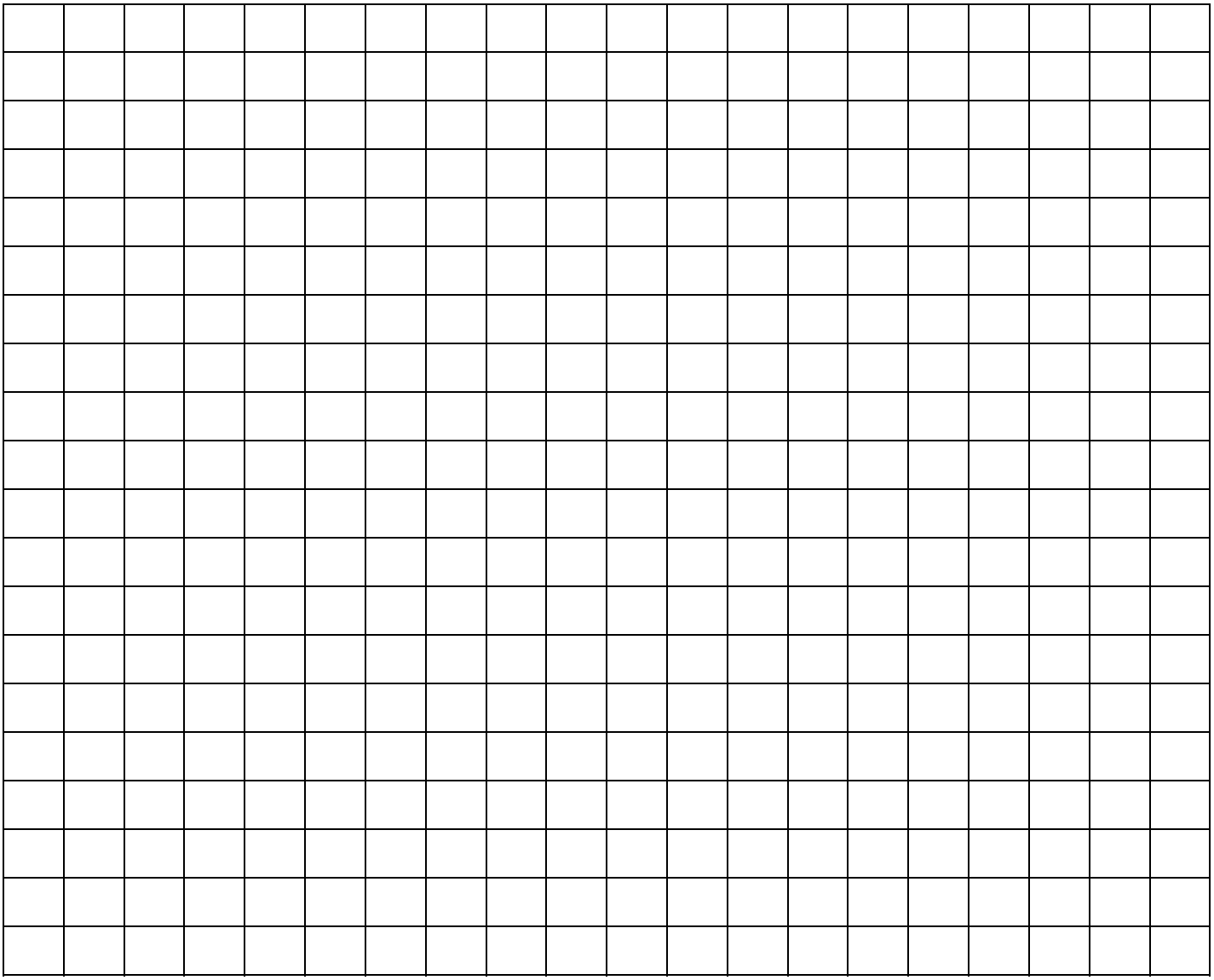
Data Tables

Use the space below to create the data tables you need for your investigation.

Procedure

Discuss your plan with your group. Do you need to make any changes to the plan based on data collection and materials concerns? Write your investigation procedure, step by step.

Graph
Title your graph and use the space below to create a graph.



Investigation Summary

1. What trends or patterns do you observe in your data?

2. What do you think is going on inside the body that explains this trend?

3. Based on carrying out the investigation, and the data you collected, how might you refine or revise the data collection or procedure to address any limitations that surfaced?

4. What else do we need to figure out to understand if the marathon runner collapsed due to overheating?

5. Was your hypothesis supported? Explain your reasoning.

Sentence starters:

- Yes, my hypothesis was supported. The data collected demonstrated that. . . .
- No, my hypothesis was not supported. The data collected demonstrated that. . . .

Thermoregulation Investigation - Scaffolded

Directions

1. Annotate the introduction section by circling points you think are most important for the purpose of the investigation.

2. Complete the following sections to plan out your investigation.

Introduction
Some students wondered if the marathon runner collapsed because she overheated. In other words, we might wonder if her body was not able to maintain a normal temperature, because she was running and experiencing a temperature change or stress in her environment. It was a warm day, after all! Normal human internal body temperature ranges between about 97.6 to 99.6^{o}F (36.1 to 37.8^{o}C). In this investigation, you will explore the relationship between your *internal body temperature* and the *skin surface temperature* of your hand under different conditions. It will be your task to plan and carry out an investigation to figure out how the human body normally responds to changes in our environment. This will help us figure out what happened to the marathon runner.

How can we measure skin surface temperature and internal body temperature using thermometers? Draw or describe in words below:

Skin surface temperature measurement	Internal body temperature measurement

Humans often experience temperature changes in the environment. For example, people in the Polar Bear Club choose to jump into and swim in very cold water in the winter. People often enjoy relaxing in a hot tub. Hot tubs can be very warm and may have water that reaches up to 100^{o}F (37.8^{o}C).


Members of the Polar Bear Club swimming in icy water


Free-standing outdoor hot tub

Do you think that jumping into cold water will cause the skin surface temperature of the hand to *increase* or *decrease*? Why?

Do you think that jumping into cold water will cause the internal body temperature to *increase* or *decrease*? Why?

Do you think that jumping into warm water will cause the skin surface temperature of the hand to *increase* or *decrease*? Why?

Do you think that jumping into warm water will cause the internal body temperature to *increase* or *decrease*? Why?

Planning the Investigation

Research Question
What is your experimental question? What are you trying to figure out?

Does the human body regulate **internal temperature** in response to changes in **external temperature**?

Hypothesis
Use this format: If _____, then _____ because _____.

Variables
Use this table to name the variables in your investigation.

Independent Variable	Dependent Variable	Control Group	Controlled Variable(s)

Materials
These are the materials for each group:

- Oral thermometer
- Beaker of hot water
- Stopwatch, timer, or clock
- Thermometer probe (2)
- Beaker of cold water

Sketch the two types of thermometers we will be using in the lab today in the space below.

Oral Thermometer	Thermometer Probe

Procedure
Which part of the procedure do you think is going to be the most difficult? Annotate with an arrow that points to the step.
Which part of the procedure do you think is going to take the most time? Annotate by circling the step's number.

Part 1: How does dipping my hand in ice water affect my internal temperature and my skin external temperature?

1. Assign roles
    - Directions Reader - Reads all the directions to group
    - Test Subject - Tests their internal temperature and skin temperature
    - Data Collector - Reads the thermometer for each measurement
    - Data Recorder - Records all data in data table for the group to copy
2. Data collector reads the initial ambient temperature (temp of room) using the thermometer probe. Record the temperature here: _____
3. Data collector measures the initial temperature of the *surface of the skin* of the test subject by having them gently grasp the thermometer probe between their thumb and fingers.
4. Record initial skin surface temperature in the group data table below.
5. Measure the test subject's initial internal body (core) temperature using the **oral thermometer.**

6. Record initial internal temperature in the group data table.
7. Fill a cup with water and put a few ice cubes inside. Measure the temperature of the icy water using the thermometer probe and record it here: _____.
8. Test subject should dip their hand into icy water for 30 seconds.
9. Measure and record the test subject's **surface skin temperature** by having them gently grasp the thermometer probe between their thumb and fingers.
10. Record observations about the test subject's response to the icy water (i.e. skin color change, shivering, etc).
11. Measure and record the test subject's internal (core) body temperature using the oral thermometer.

Procedure #2: How does dipping my hand in warm water affect my internal temperature and my skin external temperature?

1. Wait for 2 minutes.
2. Measure and record the test subject's **surface skin temperature** by having them gently grasp the thermometer probe between their thumb and fingers.
3. Measure and record the **temperature of the warm water here:** _____.
4. Immerse the hands of the test subject into warm water for 30 seconds.
5. Measure and record the test subject's surface skin temperature by having them gently grasp the thermometer probe between their thumb and fingers.
6. Record observations about the test subject's response to the hot water (i.e. skin color change, shivering, etc).
7. Measure and record the test subject's internal (core) body temperature using the oral thermometer.
8. Record final ambient temperature (temperature in the room): _____.

Once all of your data has been collected, your data recorder should add your group data to the class data table. Use this data set to create a graph showing temperature *changes* for icy and warm water. Include one line for skin surface temperature and one for core body temperature.

Exposure to Cold Water

	Skin Surface Temperature (^{o}F)	Internal (core) Body Temperature (^{o}F)	Observations
Initial Temp			
After exposure to icy water			
Temperature change (Initial - after icy water)			

Exposure to Warm Water

	Skin Surface Temperature (^{o}F)	Internal (core) Body Temperature (^{o}F)	Observations
Initial Temp			
After exposure to warm water			
Temperature change (Initial - after warm water)			

Graph
Title your graph and use the space below to create a graph.

Investigation Summary

1. What trends or patterns do you observe in your data?

2. What do you think is going on inside the body that explains this trend?

3. Based on carrying out the investigation, and the data you collected, how might you refine or revise the data collection or procedure to address any limitations that surfaced?

4. What else do we need to figure out to understand if the marathon runner collapsed due to overheating?

5. Was your hypothesis supported? Explain your reasoning.

Sentence starters:

- Yes, my hypothesis was supported. The data collected demonstrated that. . . .
- No, my hypothesis was not supported. The data collected demonstrated that. . . .

Making Sense of Thermoregulation

Independent Writing

Describe: What did we do in this investigation? Why is this investigation a part of this unit?

Explain: What is the phenomenon you observed in this investigation? How does the phenomenon relate to this unit?

Discussion

Talk with your investigation group, and record any new ideas that come up.

Human Thermoregulation Investigation Rubric

Student Rubric - Human Thermoregulation Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to answer all of the analysis questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Human Thermoregulation Investigation
How did your partners do in the investigation?

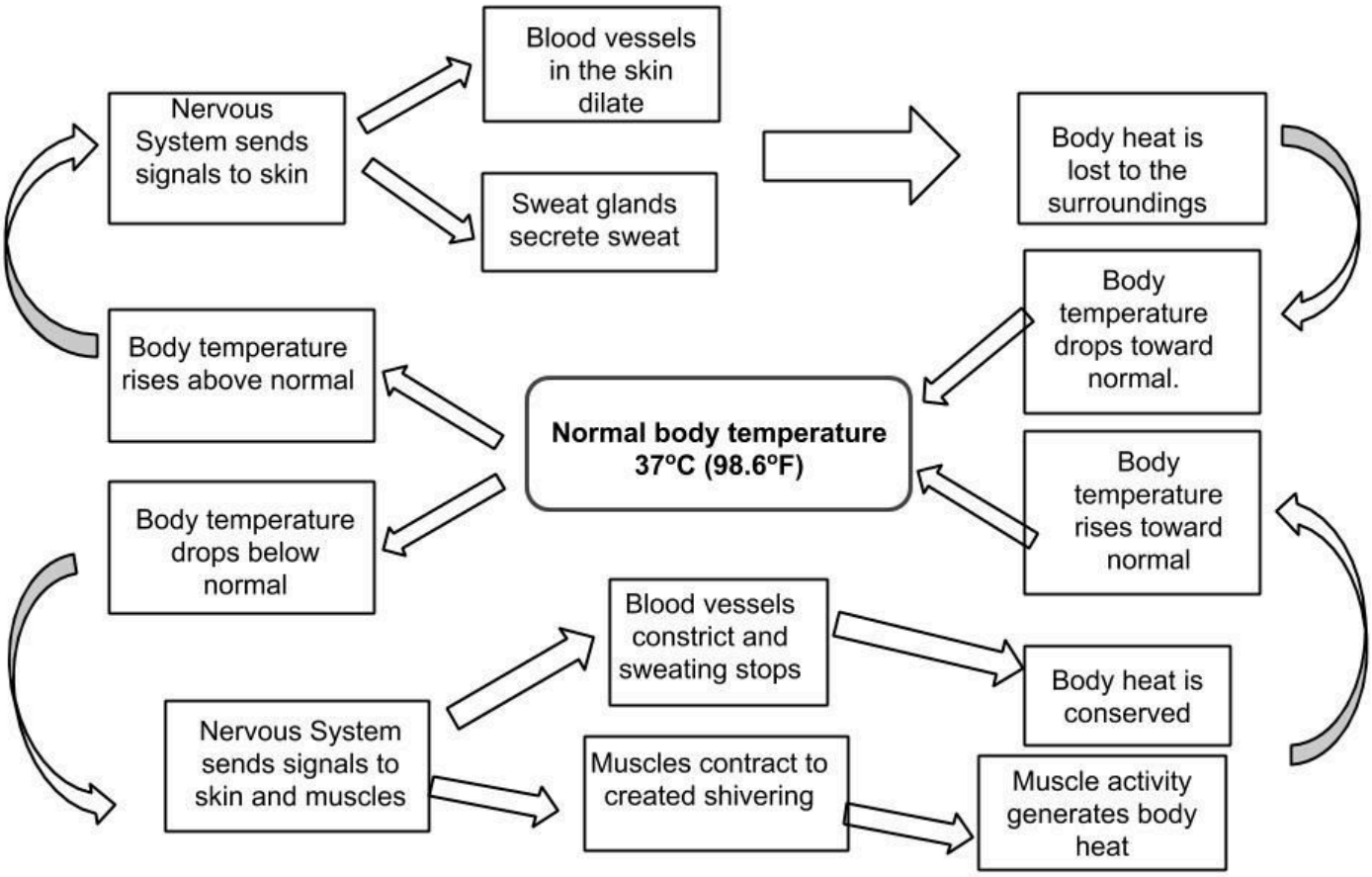
Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.

Time Management	Procrastinated, did not use school time or schedule provided to get work completed.	Mostly used time well and completed investigation on time.	Used time well to ensure things get done on time.

Homeostasis and Thermoregulation in Humans

Directions: Use the three-level guide to annotate and interpret this diagram.



Homeostasis and thermoregulation in humans

Three-Level Guide

Step 1 - Reading the Lines

1. Look at the title. What do you expect to learn from this diagram?

2. Find the *set point* on this diagram. Shade the box with **yellow** pencil.
3. Follow the loop around the top part of the page. Draw a box around each body part.
4. Draw a circle around any actions happening to/by specific body parts.
5. Find an arrow that leads to the human body warming up. Color that arrow **red.**
6. Follow that process, and color with **red** all the arrows that have to do with the body's response to being too warm.

Step 2 - Reading between the Lines

1. Repeat the process described above, but with the set of steps that begins with the body cooling down. Use **blue** to indicate these steps.
2. Circle the area where a process splits into two different processes.
3. Why are there multiple processes happening at once for maintaining body temperature?

Step 3 - Reading beyond the Lines
Discuss with your partner, then write down your answer to each of the following questions.

1. How would this diagram help with understanding the thermoregulation investigation?

2. What information do you think needs to be added or clarified in this diagram?

3. In what situation might you refer to this diagram?

Developing a Scientific Explanation

Directions:

1. Plan your ideas in the Prewriting section.
2. Have a peer review your ideas.
3. In the Drafting section, write a complete scientific explanation in paragraph form.

Prewriting

Research Question
How do changes in temperature at a person's extremities affect the person's core body temperature?

Support for your explanation

Claim based on the evidence What is the answer to your question based on your evidence?	**Evidence** Observations or data that support your claim	**Scientific Reasoning** Why do you think this happened, based on background research?

Peer Review
Have a peer read your work and provide comments on what you plan to write.

Drafting

Scientific Explanation = Claim + Evidence + Science Reasoning

My claim is _____, because _____.

Scientific Explanation (CER) Rubric

Component	Not Evident	Level 1: Beginning	Level 2: Developing	Level 3: Advancing	Level 4: Proficient
Claim	Does not make a claim	Claim does not answer the question (i.e., describe the relationship between the 2 variables)	Claim does answer the question but it is inaccurate.	Claim answers the question, and is accurate, but is incomplete	Claim answers the question, is accurate, and is complete. Completely describes the trend in the relationship between the IV and DV where appropriate.
Evidence	Does not provide evidence	Only provides inappropriate evidence (evidence does not support the claim)	Provides appropriate, but insufficient evidence to support the claim. May include some inappropriate evidence	Provides appropriate and sufficient evidence to support the claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support the claim
Reasoning: Science Concepts	Does not include reasoning	Restates evidence and does not include explanation of science concepts	Includes explanation of science concepts but all are inappropriate concepts that do not link evidence to claim	Includes explanation of some science concepts that link evidence to the claim, but are insufficient (one or more concepts that should have been included are not included) or some are inappropriate	Includes explanation of science concepts that link evidence to the claim (concepts are appropriate), and they are sufficient (no omission of key science concepts) and are clearly stated and accurate.

Reasoning: Logic	Does not include reasoning	Restates evidence or claim and does not include a logic statement that links the evidence to the claim	Attempts to include a logic statement that links the evidence to the claim but does not adequately link the evidence to the claim.	Includes a logic statement that attempts to link the evidence with the claim but needs to be more clearly stated to demonstrate logical reasoning	Includes a logic statement that links the evidence to the claim (including words such as *because* and *therefore*) that clearly demonstrates logical reasoning

Summary Task

How did the class consensus discussion go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today and the models of thermoregulation.

5. How does the body regulate body temperature?

6. Why do we say that thermoregulation is a feedback mechanism?

7. How is body temperature regulated at the tissue or organ, and body system level? Give one example of each, including how information travels between parts of the system to regulate temperature at that level.

Tissue / Organ level:

Body system level:

Homeostasis Model

Humans are masters of long distance running. Given a long enough race, we can outrun horses, antelopes, wolves, and even cheetahs.

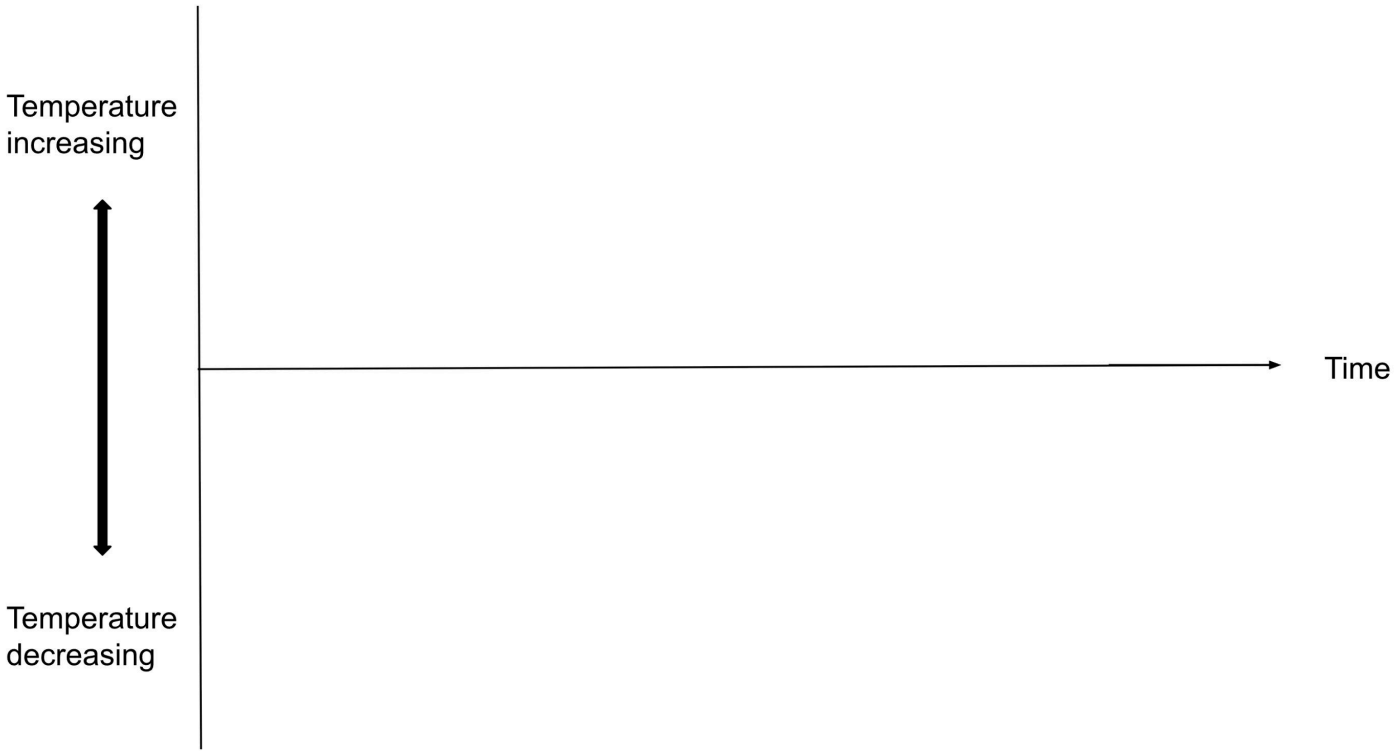
In 2023, on a hot and humid day, a woman named Nicole Teeny, outran a horse. Though horses can sweat, their bodies are more cylindrical than humans', so their sweating surface area is smaller, and their sweating cools their bodies less. Humans have successfully hunted animals like antelopes by outrunning them during persistence hunting; animals like antelopes, cats, and dogs are able to sweat a little bit, but rely more on panting to cool down.

In this activity, you will model how thermoregulation operates in humans in order to understand why differences observed in other animals make them less able to persist in high temperature races.

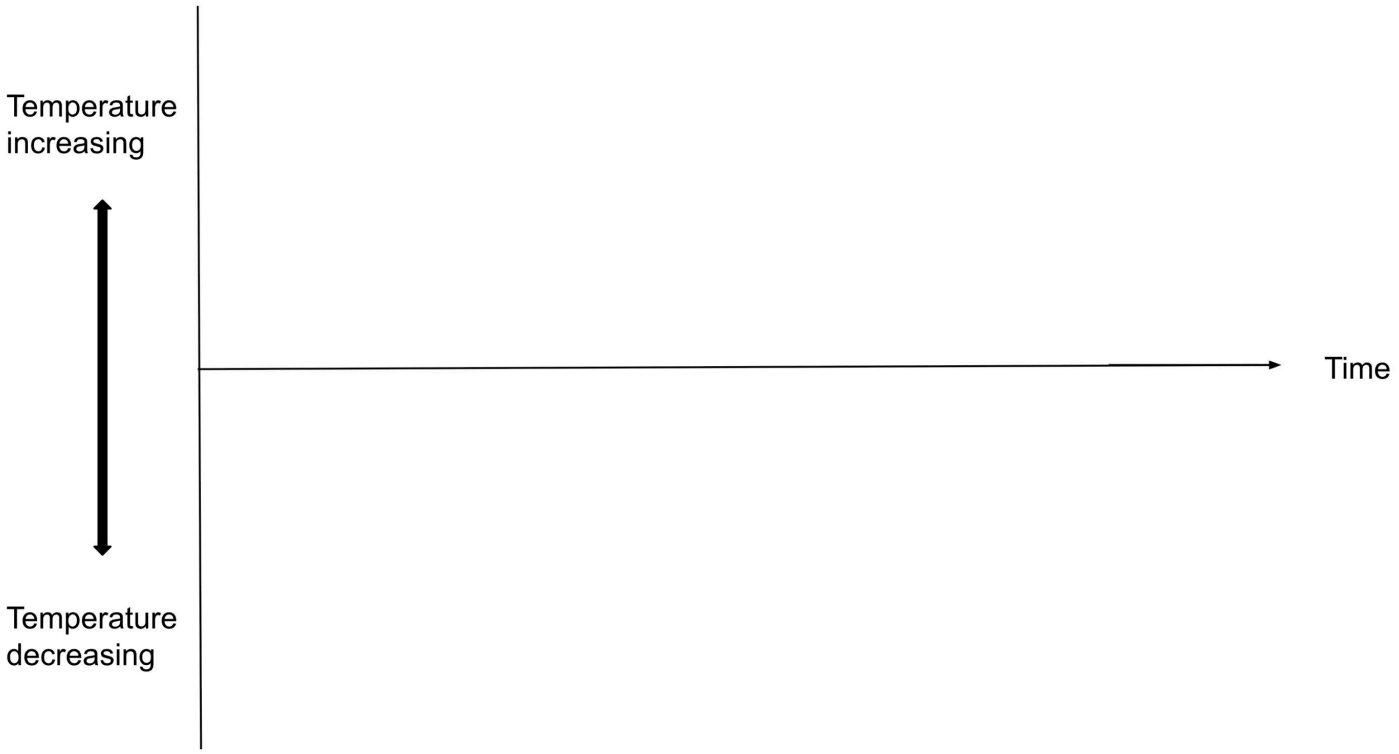
To do so, construct an annotated model of how core body temperature reacts when the body is exposed to the extreme heat or cold. In your model, be sure to include:

- The relative change in body temperature from baseline over time
- The processes responsible for altering body temperature at each moment of change
- The body systems and their components that produce changes in body temperature
- How heat is moving between different systems and parts of the systems as body temperature is regulated

When the body is exposed to heat:



When the body is exposed to cold:



Use your model to answer the following questions:

1. Use your model to describe how information is moving between parts of the system to maintain body temperature.

2. Use your model to describe how heat is moving between parts of the system to maintain body temperature.

3. Consider a situation in which the air surrounding a person is so hot that the heat released through sweating as dilation of the blood vessels has nowhere to go. On your model above, draw a line in another color indicating what would happen to core body temperature in that scenario.

4. Consider a situation in which the air surrounding a person is so cold that the heat from the body is being lost faster than it can be produced through cellular respiration. On your model above, draw a line

in another color indicating what would happen to core body temperature in that scenario.

5. Based on the text above, on your model, identify where thermoregulation in humans is different from thermoregulation in horses, antelopes, cats, and dogs. Explain why this difference allows humans to outrun animals that we usually think of as running faster than us.

Human Thermoregulation Model Rubric

Component	Developing	Proficient
Model	Demonstrates what is happening within the human body and a specific tissue or organ during thermoregulation and includes some of the elements below: • elements your class decided were essential (including but not limited to brain, sweat glands, blood vessels, muscles) • detailed tissue / organ model • an arrow from the human body model to the detailed tissue / organ model • interactions on multiple levels (organ, tissue, body system) The images speak for themselves or contain legends/keys and written captions to clarify the model. Model is aesthetically pleasing. It is neat and easy to understand.	Effectively and accurately shows what is happening within the human body and a specific tissue or organ during thermoregulation and includes all of the elements below: • elements your class decided were essential (including but not limited to brain, sweat glands, blood vessels, muscles) • detailed tissue / organ model • an arrow from the human body model to the detailed tissue / organ model • interactions on multiple levels (organ, tissue, cell) The images are somewhat clear and shows an attempt at some legends/keys or written captions to clarify the model.
Explanation	Student makes a claim identifying whether the marathon runner overheated during the race. The claim is supported with relevant and accurate evidence from the medical tent data, lab activity, or reading. Reasoning is provided to support the claim.	Student makes a claim identifying whether the marathon runner overheated during the race. The claim is weakly supported with evidence from the medical tent data, lab activity, or reading. Reasoning is not provided to support the claim.

Student Self-Score Circle one			**Teacher Score** Circle one		
Model	Developing	Proficient	**Model**	Developing	Proficient
Explanation	Developing	Proficient	**Explanation**	Developing	Proficient
Glow			**Glow**		
Grow			**Grow**		

Notes:

Water Balance 5E

Unit 1 Marathon Runner	Biology
Student Name:	

Osmosis in Onion Cells Investigation

Introduction:
Red onion cells can serve as a simple model to visualize and understand how water moves in and out of cells in response to solutes, such as salt.

Research Question:

Materials per Group:

- ❑ Red onion slices
- ❑ Cover slips
- ❑ Microscope slides
- ❑ Water
- ❑ Scalpel or knife
- ❑ Dropper or pipette
- ❑ Distilled water
- ❑ Colored pencils
- ❑ Salt solution
- ❑ Paper towels

Procedure:

1. Use a scalpel to slice off a small, very thin slice of red onion skin.
2. Prepare a wet mount of the red onion slice by placing it on a slide, and adding a drop of water. Cover with a coverslip.
3. Place the wet mount under the microscope.
4. Draw and label* **one** red onion cell under 10x magnification, in the Figure 1 box below.
5. In order to immerse the cell in salt solution, pull up a dropper of salt solution, using the pipette.
    a. Place a small piece of paper towel on one side of the slide.
    b. Eject the salt solution from the pipette on the opposite side from the paper towel.
    c. The salt water solution should move across the onion cell (under the cover slip) and be absorbed by the paper towel.
6. Draw and label* **one** onion cell that has been immersed in salt solution in the Figure 2 box below.
7. Repeat steps a-c, using distilled water.
8. Draw and label* **one** onion cell that has been immersed in distilled water in the Figure 3 box below.

**Note: for each diagram, label: cell wall, cell membrane, cytoplasm, nucleus, H_2O, salt (NaCl)*

Data:

Figure 1

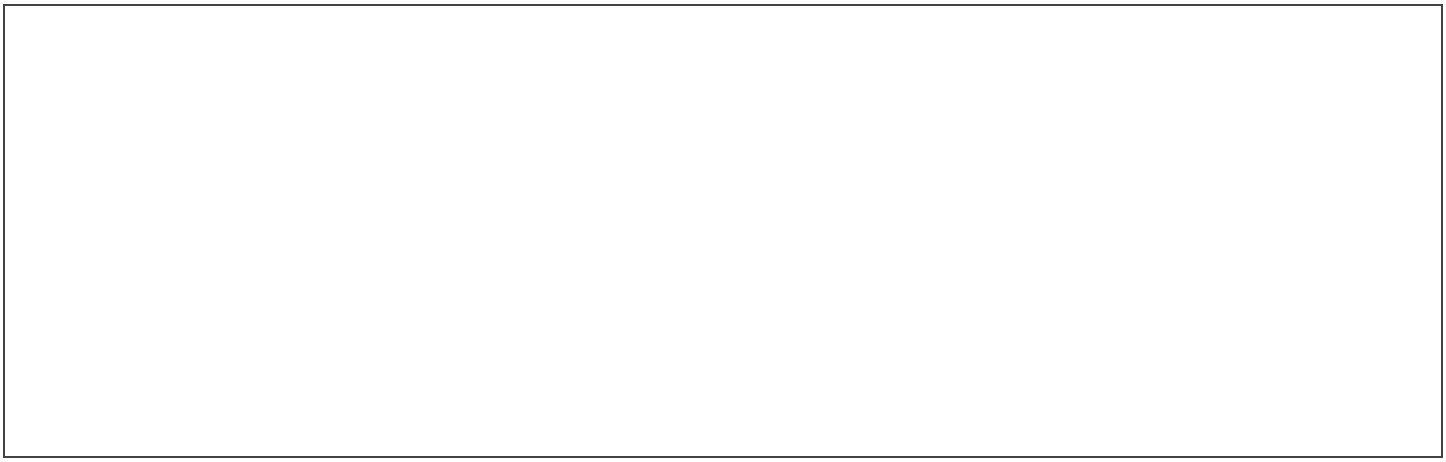


Figure 2

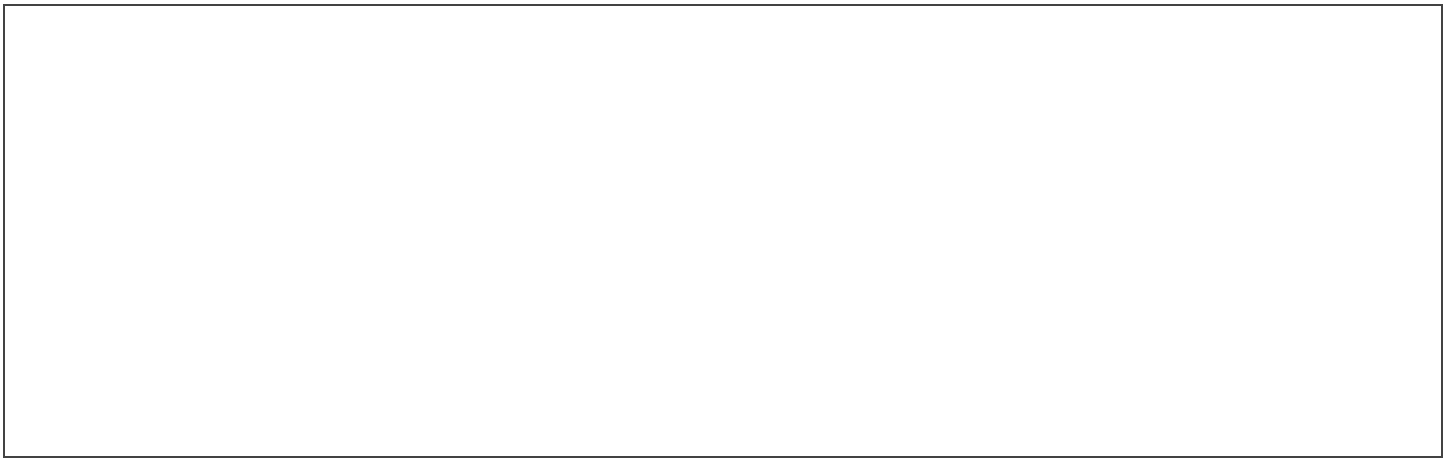
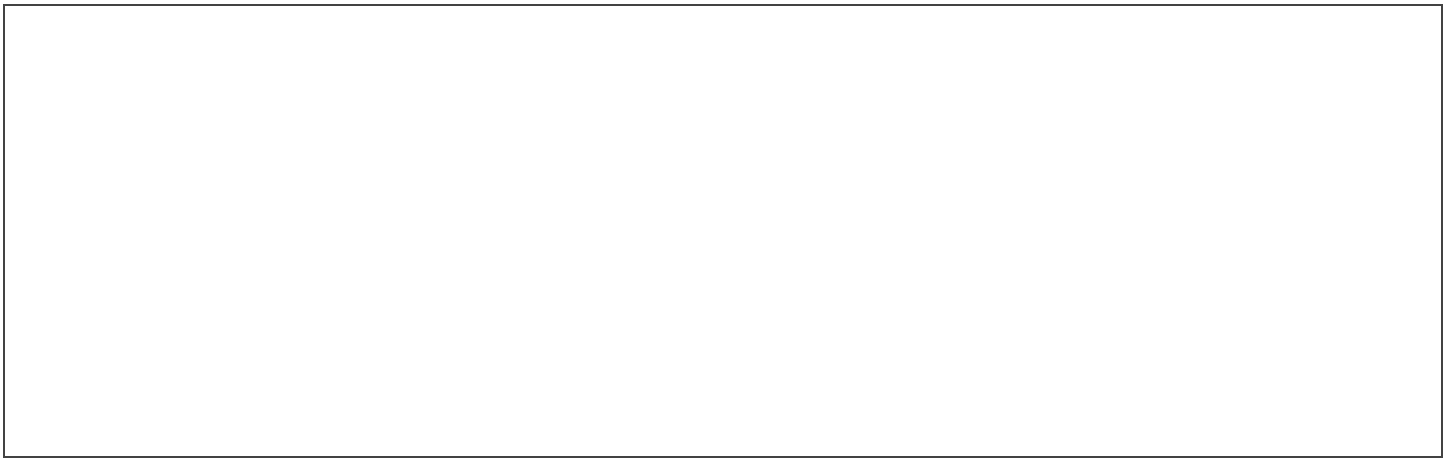


Figure 3



Making Sense of Osmosis in Onion Cells Investigation

Data Analysis:

1. Return to each of the diagrams created in the Osmosis in Onion Cells Investigation. For each, convert them into models of osmosis by:
    a. Identifying where there is a higher concentration of water and of salt (either inside or outside of the cell) and labeling this on the diagram.
    b. Identifying which way the water moved (either into or out of the cell) and representing water movement using a red arrow.

2. Describe what you notice about the water movement. Under which conditions does the water move into the onion cell? Out of the onion cell?

Summary:

1. In this lab, you made observations on how water moved in response to a solute (salt) in onion cells. Based on these observations and the models you created, describe how substances would move into and/or out of the system when a cell is:

    a. Submerged in distilled water (**hypotonic** to the cell)
    b. Submerged in salt solution (**hypertonic** to the cell)
    c. Submerged in a solution that is **isotonic** to the cell

2) What do you still need to figure out to understand how our bodies maintain homeostasis in terms of water and solute balance?

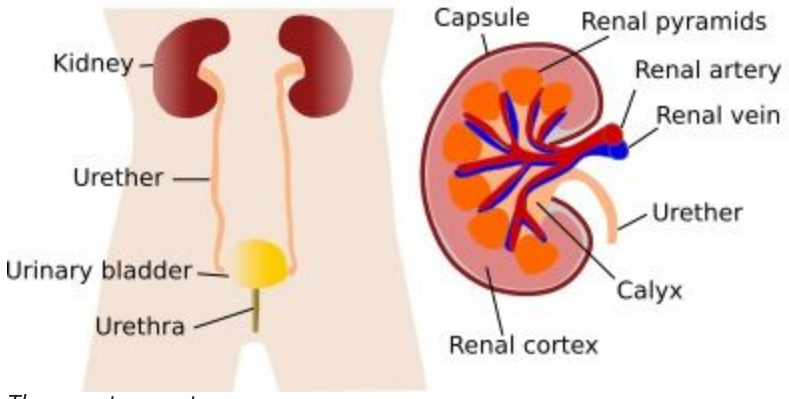
Osmoregulation in the Kidney Investigation

Water Balance

Introduction

Humans can live for weeks without eating, but most people can only survive a few days without drinking water. About 60% of the human body is made up of water, and every cell depends on it to survive and engage in life processes. Water is especially helpful in assisting our body in getting rid of waste products. Our body **excretes** (gets rid of) many waste products through sweat and urine (which contain both water and salts).

The primary organ involved in maintaining water balance, called **osmoregulation**, is the kidney. The kidney has several functions, including filtering out waste products, producing urine, and osmoregulation. All of the blood in our body moves through the kidney. The kidney is a part of the excretory system.



The excretory system

In this investigation, we will consider some data taken from one person exercising on different days. Each day they were given different amounts of water as they exercised for 3 hours at the same intensity level. The exercise was done in a laboratory, so every day the person exercised under the same conditions. The scientists measured the concentration of solute in the blood before entering the kidney (in the **renal artery**), as it left the kidney (in the **renal vein**), and recorded observations of the urine that was produced. **Urea** is a waste product that is created by the liver. It travels in the blood to the kidney and is a component of urine that is excreted from the body.

Guiding Questions:

How do we know when to drink water?
Can we drink too much water?
How does our body regulate water in our bodies?

Additional questions:

Procedure:

1. Use the following data tables to generate observations on how the kidney regulates water and solutes. The prompts below may be helpful as you analyze the data.
2. Choose one of the following situations (no water, medium water, or high water intake) and generate an input-output model that represents what is occurring in the kidney.

Solute concentrations in the blood during exercise after consuming different amounts of water.

Data Table 1: No Water Intake	**Concentration in the Renal Artery**	**Concentration in the Renal Vein**	**Concentration in Urine**
Salts	160 (mmol/L)	130 (mmol/L)	29 (mmol/L)
Glucose	95 (mg/dL)	95 (mg/dL)	0.1 (mg/dL)
Urea	25 (mg/dL)	2 (mg/dL)	25 (mg/dL)
Observations: Urine output is low, urine is dark in color			

Data Table 2: Medium Water Intake	**Concentration in the Renal Artery**	**Concentration in the Renal Vein**	**Concentration in Urine**
Salts	140 (mmol/L)	132 (mmol/L)	12 (mmol/L)
Glucose	102 (mg/dL)	102 (mg/dL)	0 (mg/dL)
Urea	20 (mg/dL)	0 (mg/dL)	20 (mg/dL)
Observations on Urine: Urine output is medium, urine is yellow			

Data Table 3: High Water Intake	**Concentration in the Renal Artery**	**Concentration in the Renal Vein**	**Concentration in Urine**
Salts	130 (mmol/L)	130 (mmol/L)	0.1 (mmol/L)
Glucose	98 (mg/dL)	98 (mg/dL)	0 (mg/dL)
Urea	18 (mg/dL)	1 (mg/dL)	15 (mg/dL)
Observations on Urine: Urine output is high, color is light yellow			

Guiding Prompts:

The following prompts may be helpful as you analyze the data.

1. Which solute(s) (salts, glucose, or urea) stay the same in the blood both in and outside of the kidney regardless of the water intake of the person exercising? Why do you think this is the case?

2. Which solute(s) (salts, glucose, or urea) change in the blood from inside and outside of the kidney when the water intake changes? Why do you think this is the case?

3. Describe the changes in the urine as the person drinks more water during exercise.

Input-Output Model

Choose one of the scenarios above (no water, medium water, or high water intake) and generate a model to represent what is occurring in the kidney.

Making Sense of Osmoregulation in the Kidney Investigation

Investigation Summary Questions:

1) If someone's urine is very dark, explain what is happening in the blood and kidney. Use the terms **concentration**, **solute**, **water,** and **osmosis**.

2) If that same person drinks a liter of water, what do you expect to happen to their urine? Explain your reasoning.

3) Sports drinks contain both water and solutes (salts and electrolytes). What do you predict will move in and out of the kidney when someone drinks a sports drink during exercise? Generate a model of the kidney to represent your thinking. The model should include both what is happening at the cellular level and at the level of the kidney, including how substances move between the cellular and organ levels of the system.

4) What do we need to figure out to better understand how our body balances water and sodium levels in the blood?

Osmoregulation in the Kidney Investigation Rubric

Student Rubric - Osmoregulation in the Kidney Investigation
How did you do in the investigation?

	Student Self-Score Circle one		
I know how this investigation connects to our current unit.	No - I need help.	Almost	Yes
I was able to contribute to the See-Think-Wonder and/or respond to the analysis questions.	No- I need help.	Almost	Yes
I used my time well in this investigation.	No	Mostly	Yes
I plan to come in for extra help to complete parts of the investigation or ask questions.	No		Yes

What other resources could you have used to get more out of this investigation?

- More time
- More resources
- More information
- More help from my partners
- More help from my teacher
- Other:

Partner Rubric - Osmoregulation in the Kidney Investigation
How did your partners do in the investigation?

Directions: Think back to how your partners participated in the lab. For each of the four categories, write your partner's or partners' names in the appropriate box.

	Unsatisfactory	Pretty Good	Excellent
Contributions	Did not participate.	Did the minimum of what was required.	Provided useful ideas when participating in discussion
Working with Others	Rarely listened to others. Disrupted or discouraged others' attempts to participate.	Usually listened to, shared with, and supported the efforts of others.	Listened to, shared with, and supported the efforts of others.
Time Management	Procrastinated, did not use school time or schedule provided to get work completed.	Mostly used time well and completed investigation on time.	Used time well to ensure things get done on time.

Osmoregulation at the System Level Text

Guiding Question: *How does our body osmoregulate during exercise?*

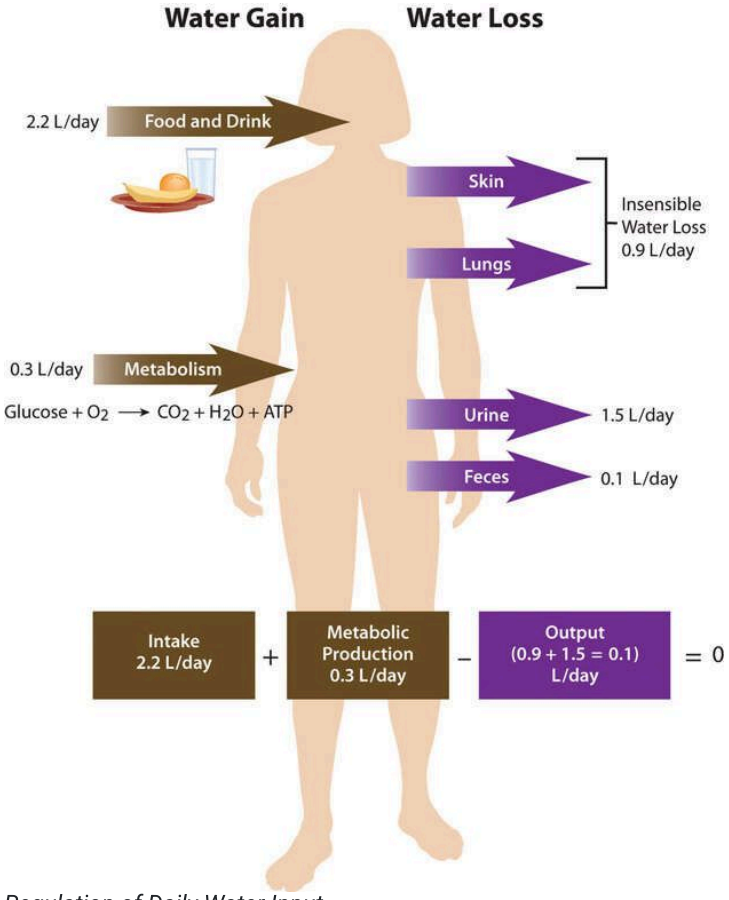
Directions: Read and annotate the text, using the following annotations.

- ✔ Ideas that confirm your group's sequence chart
- ✖ Ideas that contradict your group's sequence chart
- **0** Ideas that help to modify or add to your group's sequence chart

Osmoregulation at the system level

Humans lose about 2.5 liters of water per day through sweating, exhaling water vapor, and urination. This must be balanced with water input. Our tissues produce around 300 milliliters of water per day through metabolic processes. The remainder of water output must be balanced by drinking fluids and eating solid foods that contain water. The average fluid consumption per day is 1.5 liters, and water gained from solid foods approximates 700 milliliters.

Thirst is an osmoregulatory mechanism to increase water input. The thirst mechanism is activated in response to changes in water volume in the blood, but it is even more sensitive to changes in blood solute concentration. The urge to drink results from a complex interplay of hormones, the kidney and the brain. Once the brain detects that there is not enough water (or too much solute) in the blood, we feel 'thirsty' and are stimulated to drink more fluid, until we have a more normal amount of water in our blood.



Regulation of Daily Water Input

At the same time, our blood is moving through the kidney. The kidneys filter about 190 liters of blood and produce (on average) 1.5 liters of urine per day. Urine is mostly water, but it also contains electrolytes and waste products, such as urea. The amount of water filtered from the blood and excreted as urine is dependent on the amount of water in the body, and the electrolyte or solute composition of the blood.

Kidneys have protein sensors that detect blood volume from the pressure, or stretch, in the blood vessels of the kidneys. When blood volume is low, kidney cells detect decreased pressure and secrete enzymes that result in more sodium being pumped into the blood. Water follows sodium into the blood by osmosis, resulting in less water in the urine and restored fluid balance and composition of blood. Additionally, the brain releases antidiuretic hormone that travels to the kidney, where it increases water reabsorption. All of which reduces the volume of urine and makes it more concentrated, therefore conserving water in the body and maintaining normal levels of water and solute in the blood. When blood volume is high, the opposite occurs, resulting in decreased thirst, an increase in urination, and the conservation of solute, such as sodium, in the blood.

Maintaining water balance in our blood is especially important during exercise. When exercising, the body loses water and salts (solute) in our sweat, while still producing urine to rid the body of waste products. Too much water, and not enough solute in the blood, cause cells to swell and burst. Not enough water, and too much solute in the blood, cause cells to lose water and shrink.
Therefore during strenuous exercise, the nervous system, circulatory system, and the excretory systems work together to maintain a delicate balance between water and solute concentrations in the blood.

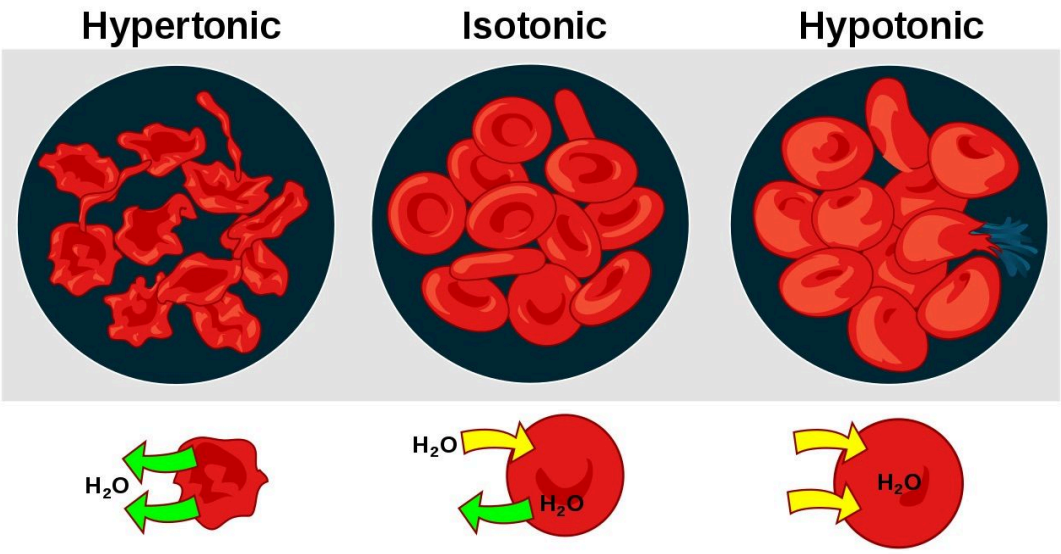
When exercising it is important to stay hydrated. Some athletes consume sports drinks during exercise. Sports drinks can have a wide range of ingredients, including a lot of sugar, vitamins, and even caffeine. However, most sports drinks are primarily water with some dissolved solutes such as salt, sugar, or electrolytes. When sweating excessively, sports drinks may be helpful, as they replenish both water and the salts lost in sweat.

Osmosis in Red Blood Cells Text

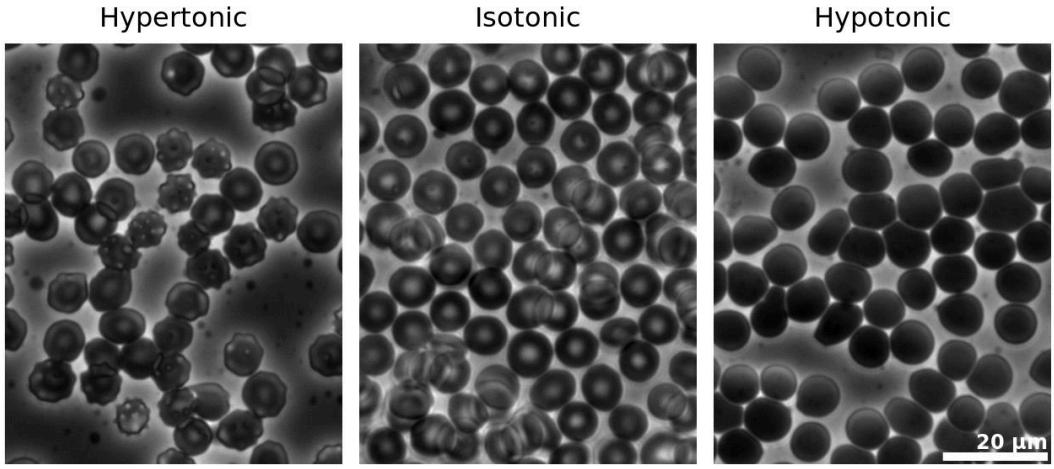
The Importance of Water Balance in Cells

Guiding Question: *How does our body osmoregulate during exercise?*

Osmoregulation is the control of water levels and mineral salts in the blood. Osmoregulation is important at all levels of organization in an organism: cellular, organ, system, and whole body levels. Water levels and mineral salts in the blood are controlled to protect animal cells by stopping too much water from entering or leaving them. The concentration of water and salts is the same inside and outside of the cells. If body cells lose or gain too much water by osmosis, they do not function efficiently.



The osmoregulation of red blood cells in different solute concentrations



Micrographs of red blood cells in diffferent solute concentrations

If the concentration of water is the same inside and out the cells (or *isotonic*), then there is no net movement of water into or out of the cell. The cells remain in their normal state. If the water concentration is too high outside of the cell (*hypotonic*) then water enters the cell by osmosis. If too much water enters, the cell will

burst. If the water concentration is too low outside compared to the inside of the cells (*hypertonic*), water leaves the cells by osmosis. This causes cells to shrivel.

Summary Task

How did the class consensus discussion go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today.

1. How does the body regulate water and salt balance (or osmoregulate)?

2. Why do we say that osmoregulation is a feedback mechanism?

3. How are water and salts regulated at the cell, organ, and body system level? Give one example of each.

Cellular level

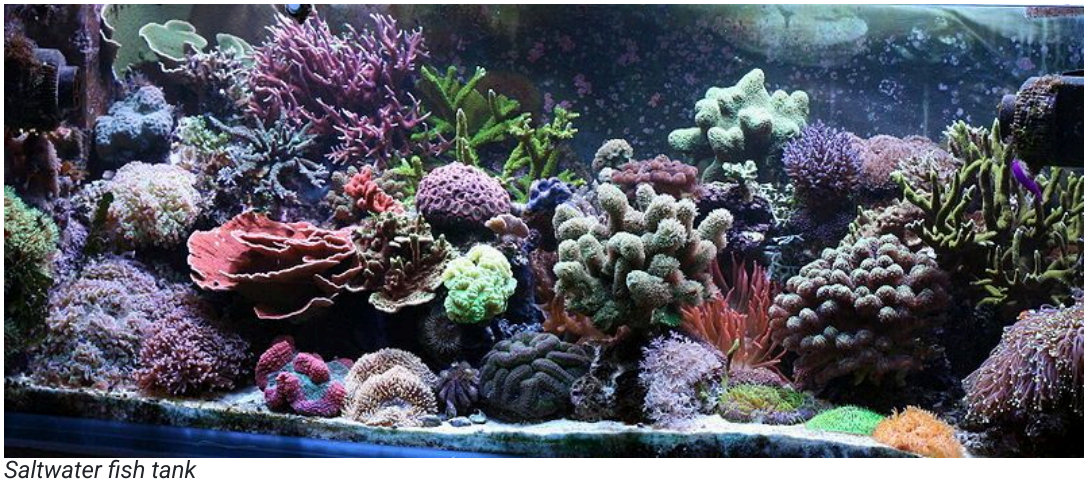
Organ level:

Body system level:

4. Draw a model indicating how water and salts are regulated across the body as a whole by illustrating how salt and water moves between the different scales of the body (cells, organs, and body systems).

Goldfish Scenario

Can Goldfish Live in Saltwater Aquariums?



Saltwater fish tank

For your birthday, your grandparents gave you a beautiful saltwater aquarium. It is an entire ecosystem, hosting a vast array of colorful fish, plants, and even simple animals called sponges. The water in the aquarium is as salty as seawater, and the organisms that live in it are adapted to living in a high saline environment.

Your best friend decides that you need more fish for your aquarium and buys you a brightly colored goldfish. You aren't sure, but you have heard that goldfish are freshwater fish and don't live in the ocean like the rest of the fish in your aquarium. You tell your best friend that you are nervous about putting the goldfish in the aquarium. She is understandably upset and thinks that you don't like her gift. She argues that the goldfish looks a lot like the other fish already in your aquarium, and the water in your aquarium looks just like the water at the pet store that it was already living in.

Goldfish

Directions

You will need to make a decision on whether or not you will add the goldfish to your aquarium, using evidence from the investigations in this 5E sequence and your background knowledge of biology. In order to provide a rationale for your decision to your friend, you will generate a clear model of what you think will happen if you put the goldfish in the saltwater aquarium.

Step 1: Read the and annotate the text provided.

- Look for evidence that will inform your decision
- Use evidence to provide a rationale for your decision that includes how feedback mechanisms allow goldfish to normally maintain internal water balance, and how changing the salinity of its environment will impact its ability to maintain homeostasis.

Step 2: Develop and use a model to represent your rationale to your friend.

- Evaluate the models that are familiar to you.
- Suggest criteria for the model you will create.
- Sketch out or describe your explanatory model, using evidence from your previous investigations and the text.

Evidence from investigations and the text:

Evaluate Models

Use this table to describe the positive characteristics of each type of model. Think about what was useful in helping you understand the concept.

Onion Cell	Kidney Model	Input-Output	Other _____

Use this table to describe the limitations of each type of model. Think about what was useful in helping you understand the concept. Think about what might have been missing or lacking from each model. What could have been there that would have made it even more clear?

Onion Cell	Kidney Model	Input-Output	Other _____

Explanatory Model
Sketch out or describe your explanatory model, using evidence from your previous investigations and the text. Include the criteria you are considering for the model.

Osmoregulation in Fish

Because of their environment, osmoregulation in fish presents specific challenges. Fish have adaptations that enable them to respond to conditions in their environment, including changes in salinity. Fish that live in different salinities (fresh or saltwater) experience different types of challenges in maintaining homeostasis. Just like in humans, multiple body systems interact in fish in order to maintain water balance.

Freshwater fish

Problems:

- These fish are *hypertonic* to their surroundings. This means their blood has a lower water concentration, or a higher concentration of dissolved substances than the surrounding fresh water.
- As fresh water passes through the mouth and over the gill membranes, water molecules diffuse from the fresh water into the blood by osmosis.
- These fish must produce a very large volume of urine to balance this large intake of water.
- This large volume of urine carries salt with it, and the salt has to be replaced.

Solutions:

- To produce a large volume of urine the fish must remove a large volume of water from the blood by having a high rate of filtration into the kidney tubules.
- This is done by having a kidney with many large glomeruli, capillary networks from which fluid is filtered at the start of the kidney tubules.
- Salt replacement is solved by chloride secretory cells in the gills, which actively transport salts from the surrounding water into the blood.

Saltwater fish

Problems:

- These fish are *hypotonic* to their surroundings. This means their blood has a higher water concentration than the surrounding sea water.
- As sea water passes through the mouth and over the gill membranes, water molecules diffuse out of the blood into the sea water by osmosis.
- These fish must replace the water which they constantly lose by osmosis
- They can also only afford to produce a very small volume of urine.
- Drinking sea water brings a large quantity of salt into the blood and this has to be removed.

Solutions:

- To replace the water they lose, saltwater fish drink sea water.
- To produce a small volume of urine they must have a low rate of filtration of water into the kidney tubules.
- This is done by having a kidney with relatively few small glomeruli.
- Salt is removed by chloride secretory cells in the gills, which actively transport salts from the blood into the surrounding water.

Water Balance Model Rubric

Water Balance Model Rubric

Component	Developing	Proficient
Model	Demonstrates what is happening within the human body and a specific cell/organ during water balance and includes some of the elements below: • Includes the elements your class decided were essential (including but not limited to: water, salt, kidneys, blood vessels). • a detailed cell model • an arrow from the human body model to the detailed cell model • interactions on multiple levels (organ, tissue, cell) The images are somewhat clear and shows an attempt at some legends/keys or written captions to clarify the model.	Effectively and accurately demonstrates what is happening within the human body and a specific cell/organ during water balance and includes all of the elements below • Includes the elements your class decided were essential (including but not limited to: water, salt, kidneys, blood vessels) • a detailed cell model • an arrow from the human body model to the detailed cell model • interactions on multiple levels (organ, tissue, cell) The images speak for themselves or contain legends/keys and written captions to clarify the model. Model is aesthetically pleasing. It is neat and easy to understand.
Explanation	Student makes a claim identifying whether the marathon runner drank too much water during the race. The claim is weakly supported with evidence from the medical tent data, lab activity, or reading. Reasoning is not provided to support the claim.	Student makes a claim identifying whether the marathon runner drank too much water during the race. The claim is supported with relevant and accurate evidence from the medical tent data, lab activity, or reading. Reasoning is provided to support the claim.

Scoring Table

Student Self-Score Circle one			**Teacher Score** Circle one		
Model	Developing	Proficient	**Model**	Developing	Proficient
Explanation	Developing	Proficient	**Explanation**	Developing	Proficient
Glow			**Glow**		
Grow			**Grow**		

Breaking News: Death by Water

Drop of water

A woman in her late twenties was found dead in her home, the cause of death: drinking too much water. This young woman decided to enter a radio contest to see how much water one could drink without going to the bathroom in order to win a video-game console for her kids. Unaware of the consequences, she kept drinking more and more water at the radio station. Later at work, she started complaining of a massive headache and headed home. By that time it was too late to reverse the damage and she soon passed away.

This young woman suffered from *hyponatremia,* where the increase of water consumption in combination with little to no urination created a condition of low sodium levels in the bloodstream. Drinking games like these and other underlying medical conditions, create the conditions where the normal homeostasis mechanisms to regulate sodium-water balance are interrupted. The elderly are also commonly at risk, making up the majority of U.S. hyponatremia hospitalizations. Medical professionals importantly urge hyponatremia sufferers to never raise sodium levels too fast as this could cause further injury. It is suggested to return the sodium-water balance at a slow rate so as to not overwhelm the bodily systems.

<u>Zooming in on Hyponatremia</u>

In order to understand what happened in the case of hyponatremia in this young woman, we must first understand the normal state. The kidney system (or hypothalamic-renal feedback loop) normally maintains water-sodium balance within a narrow homeostatic range. When the cell receptors, called osmoreceptors respond to elevated sodium levels in body fluids, the posterior pituitary glands are signaled to secrete *antidiuretic hormone (ADH)*. ADH then enters the bloodstream and thirst is activated, essentially a message from the body to increase fluid intake. Then, the kidneys return enough solute-free water from the fluid in the kidney tubules to dilute the sodium levels back to normal. In the case of this young woman, the normal functioning of the kidney system was interrupted by the rapid increase in solute-free water intake. The kidneys could not keep up with the processing of water and the feedback loop malfunctioned so that ADH was always "turned on".