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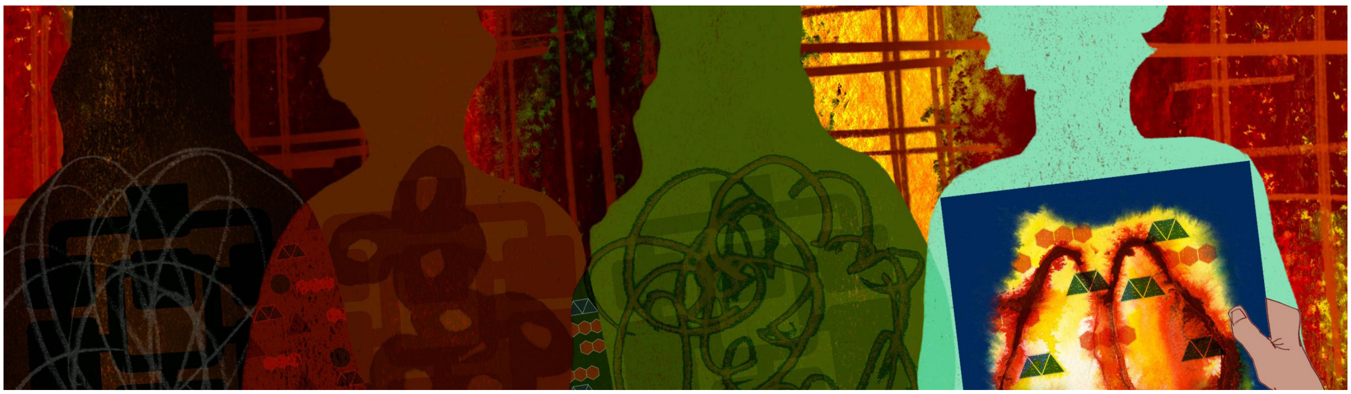

Metabolism:

Making the Diagnosis

Investigation Notebook with Article Compilation

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Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

Amplify.
55 Washington Street, Suite 800
Brooklyn, NY 11201
1-800-823-1969
www.amplify.com

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Metabolism:

Making the Diagnosis

Investigation Notebook

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Chapter 3: Cellular Respiration

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.
2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.
3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.
4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.
5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.
6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.
7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.
8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.
9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.
10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.
11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

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Metabolism: Making the Diagnosis
Unit Overview

Welcome, medical students! You will be put to work right away to figure out what the trillions of cells in the body need in order to keep a human body healthy and able to function. Right from the start, you will be assigned a patient, Elisa, who is not feeling well; it will be your job, after you learn more about how the body works, to diagnose what is wrong with your patient. Along the way, we will use the *Metabolism* Simulation to help you get to know what all the cells and systems of your body need to function and how the body works. Finally, we will also ask you to understand how a professional athlete's body works so well that he or she can do things that most people cannot do.

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Chapter 1: Molecules Needed by the Cells
Chapter Overview

Welcome to medical school! Soon you’ll meet your first patient, Elisa. In order to help diagnose her condition, you are going to become an expert on metabolism—all the things that occur inside our bodies to keep them functioning. Along with your fellow medical students, you will be learning about the human body just as medical professionals do: through investigating, reading, writing, and discussing. With your new knowledge, you will be ready to explain what is going wrong inside Elisa’s body that is causing her to feel tired all the time.

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Lesson 1.2: Welcome to Medical School

Welcome to your first day of medical training! Today, you'll meet a patient, Elisa, and discuss what might be causing her symptoms. To get started working toward a diagnosis, you'll use the *Metabolism* Simulation to explore what happens inside a human body.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 1 Question

- Why does Elisa feel tired all the time?

Vocabulary

- cells
- claim
- metabolism

Digital Tools

- *Metabolism* Simulation (Healthy Body)

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Warm-Up

Why do you think your new patient, Elisa, is feeling tired all the time? Explain your ideas.

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Introducing the *Metabolism* Simulation

Part 1

1. Launch the *Metabolism* Simulation.
2. Select HEALTHY BODY from the menu.
3. Select OBSERVE.
4. Explore with your partner.
5. Think about these questions:
   - How does the Simulation work?
   - What do you notice?

Part 2

Keep observing the *Metabolism* Simulation, but now focus on this question:

- What happens to the food and air that enter this healthy Simulation body?

Part 3

Consider the following question as you observe:

- Which molecules are entering the cell?

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Homework: Testing Diets in the Sim

In this homework, you will experiment with different diets in the Simulation to see how the diet affects the number of molecules getting to the cells.

1. Launch the *Metabolism* Simulation.
2. Select HEALTHY BODY and then select TEST.
3. Plan at least three different tests of the diet for the healthy body. Record your plans in the Diet Plan tables below.
4. Run your tests and record your results: the number of molecules absorbed by the cells.

How to Use Test Mode:

- Set up a pre-planned diet by pressing on items under Add Food Source. Then, press play and observe the Simulation. The diet you selected is fed to the body automatically, and the test runs until the timer reaches 200. During the test, you can observe the Sim in the Live View or switch to the Graph View. In the Graph View, you can see the final results for Total Molecules Absorbed by Cells, which is the data you will record below.
- **Note:** With some diets, your Simulation body will run out of energy before you reach 200 seconds. You'll need to reset and try a new diet.

Healthy Body Diet Tests

Diet Plan #1

Food	Number of servings
corn	
fish	
sandwich	

Results of Diet Plan #1

Molecule	Number of molecules absorbed by cells
glucose	
amino acids	
oxygen	

Diet Plan #2

Food	Number of servings
corn	
fish	
sandwich	

Results of Diet Plan #2

Molecule	Number of molecules absorbed by cells
glucose	
amino acids	
oxygen	

Diet Plan #3

Food	Number of servings
corn	
fish	
sandwich	

Results of Diet Plan #3

Molecule	Number of molecules absorbed by cells
glucose	
amino acids	
oxygen	

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Lesson 1.3: Evaluating Initial Claims About Elisa

What's going on with Elisa? Could it be something happening in her cells? Today, you will learn more about the molecules that cells need to function in a healthy body. Cells are everywhere in your body and make up most of your living tissue—for example, your heart, lungs, skin, and muscles are all made of different types of cells. When your cells don't get the molecules they need, you can feel sick and tired, as Elisa does. Today, you will also get new evidence about Elisa—the results from food and sleep journals she kept. You'll evaluate this evidence and decide whether it supports any of our possible claims.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 1 Question

- Why does Elisa feel tired all the time?

Key Concept

- A functioning human body has molecules from food (glucose and amino acids) and molecules from air (oxygen) in its cells.

Vocabulary

- cells
- claim
- evidence
- glucose
- metabolism
- molecules
- oxygen

Digital Tools

- *Metabolism* Modeling Tool activities: 1.3 Warm-Up and 1.3 Molecules in a Cell
- *Metabolism* Sorting Tool activity: 1.3 Evaluating Evidence
- Scale Tool

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Warm-Up

Launch the *Metabolism* Modeling Tool activity: 1.3 Warm-Up.

- The *Metabolism* Modeling Tool is a tool you will use often to show your thinking about how the human body works.
- Spend the next few minutes trying out different things in the Modeling Tool to get familiar with how it works.
- Try moving the molecules around the body to show your ideas about what happens inside a human body.
- When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: ______________________________

Goal: Explore the Modeling Tool.

Do:

- Try moving the molecules around the body to show your ideas about what happens inside a human body.

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Reading "Molecules Cells Need"

1. Read the article "Molecules Cells Need." Add annotations as you read.
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Read the article a second time, focusing on the questions your teacher wrote on the board.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Modeling Molecules in a Healthy Cell

1. Launch the *Metabolism* Modeling Tool activity: 1.3 Molecules in a Cell.
2. Use the information from the article you have just read to model the molecules you think should be in the functioning cells of a healthy body.
3. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: ______________________________

Goal: Show which molecules should be in the functioning cells of a healthy body.

Do:

- Add molecules to the cell.

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Evaluating New Evidence About Elisa

Part 1

Work with your partner to decide which card offers higher quality evidence, based on how much evidence was collected.

- Be prepared to explain your evaluation.

Evidence Card A

John observed his 14-year-old brother's sleep for one night. His brother slept for 10 hours. Based on this, John concluded that all 14-year-olds need 10 hours of sleep a night.

Evidence Card B

Scientists observed the sleep of 2,000 healthy 14-year-olds every night for a month. The average number of hours the 14-year-olds slept was 9.4 hours. Based on this, the scientists concluded that 14-year-olds need about 9 hours of sleep a night.

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Evaluating New Evidence About Elisa (continued)

Part 2

Launch the *Metabolism* Sorting Tool activity: 1.3 Evaluating Evidence.

1. With your partner, examine the evidence cards and consider where these cards would be placed on the Evidence Gradient.
2. Discuss if there are any low-quality pieces of evidence that should be eliminated.
3. Decide whether this evidence supports or contradicts any of the possible claims about Elisa.
4. When you have finished sorting the evidence, press HAND IN. If you worked with a partner, write his or her name here: ______________________

Claims

Elisa is feeling tired:

- because she isn't getting enough sleep.
- because she is not eating enough food or not eating the right foods.
- because she has a medical condition.

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Evaluating Claims About Elisa

Healthy Sleep Comparison

Average Teenage Sleep Patterns	Elisa's Sleep Pattern
Many scientific studies of teenagers show that most healthy teenagers get between 8 and 10 hours of sleep each night.	Elisa's sleep journal shows that she is getting about 9 hours of sleep every night.

Healthy Eating Comparison

Average Teenage Eating Habits	Elisa's Eating Habits
A scientific study done on 1,000 healthy 14-year-olds found that they ate between 5 and 8 servings of starch per day and between 1 and 4 servings of protein per day.	Elisa's food journal shows that she ate between 6 and 8 servings of food that contained starch every day. She ate between 2 and 4 servings of food that contained protein every day.

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Name: ________________________ Date: ________________

Homework: Exploring the Relative Scale of Molecules

Molecules, even though they are very tiny, can be different sizes. Below is a list of some of the molecules that are in the *Metabolism* Simulation.

glucose molecule

starch molecule

protein molecule

carbon dioxide molecule

water molecule

amino acid molecule

oxygen molecule

1. In the space below, list the molecules in order from smallest to largest. It is okay if you aren't sure.

Smallest

____

____

____

____

____

____

____

Largest

2. Do you think these molecules are larger or smaller than a cell in the human body? Explain your answer.

____

____

____

3. Explore the Scale Tool if you want to learn more about these different-sized molecules that can be found in the human body.

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Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why your patient, Elisa, could be feeling so tired?

1. I understand what molecules Elisa's cells need and where they come from.

   ☐ yes

   ☐ not yet

Explain your answer choice above.

____

____

2. I understand how those molecules get to the cells in Elisa's body.

   ☐ yes

   ☐ not yet

Explain your answer choice above.

____

____

3. I understand how the cells use those molecules to release energy for Elisa's body to function.

   ☐ yes

   ☐ not yet

Explain your answer choice above.

____

____

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Homework: Check Your Understanding (continued)

4. What do you still wonder about Elisa's condition or how her body gets what it needs to function?

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Chapter 2: Body Systems
Chapter Overview

In Chapter 1, you learned about the molecules that need to get to Elisa's cells. But how do the molecules get to the cells? In Chapter 2 you'll investigate how different systems of the body work together to get the cells what they need. You will also investigate what happens when body systems fail.

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Lesson 2.1: Exploring the Classroom Body Systems Model

Today, you'll be playing a role in a classroom-sized model of the human body. You'll get to be one of the body systems that takes in molecules from food and air and delivers them to cells, or you might get to be a cell that needs molecules. Either way, this experience will help you learn more about how a healthy body works so that you can figure out what might be going wrong with the systems in Elisa's body.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 2 Question

- What is happening in Elisa's body that could be preventing molecules from getting to her cells?

Vocabulary

- amino acids
- circulatory system
- digestive system
- glucose
- oxygen
- respiratory system

Digital Tools

- *Metabolism* Simulation (Healthy Body)

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Warm-Up

1. Launch the *Metabolism* Simulation.
2. Select HEALTHY BODY.
3. Select OBSERVE.
4. Focus on *just* oxygen by selecting the other molecules at the bottom of the screen to hide them.
5. Observe how oxygen moves through different parts of the body. Then, answer the question below.

What do you notice about the path oxygen molecules take inside the *Metabolism* Simulation of a healthy body? Describe in detail.

____

____

____

____

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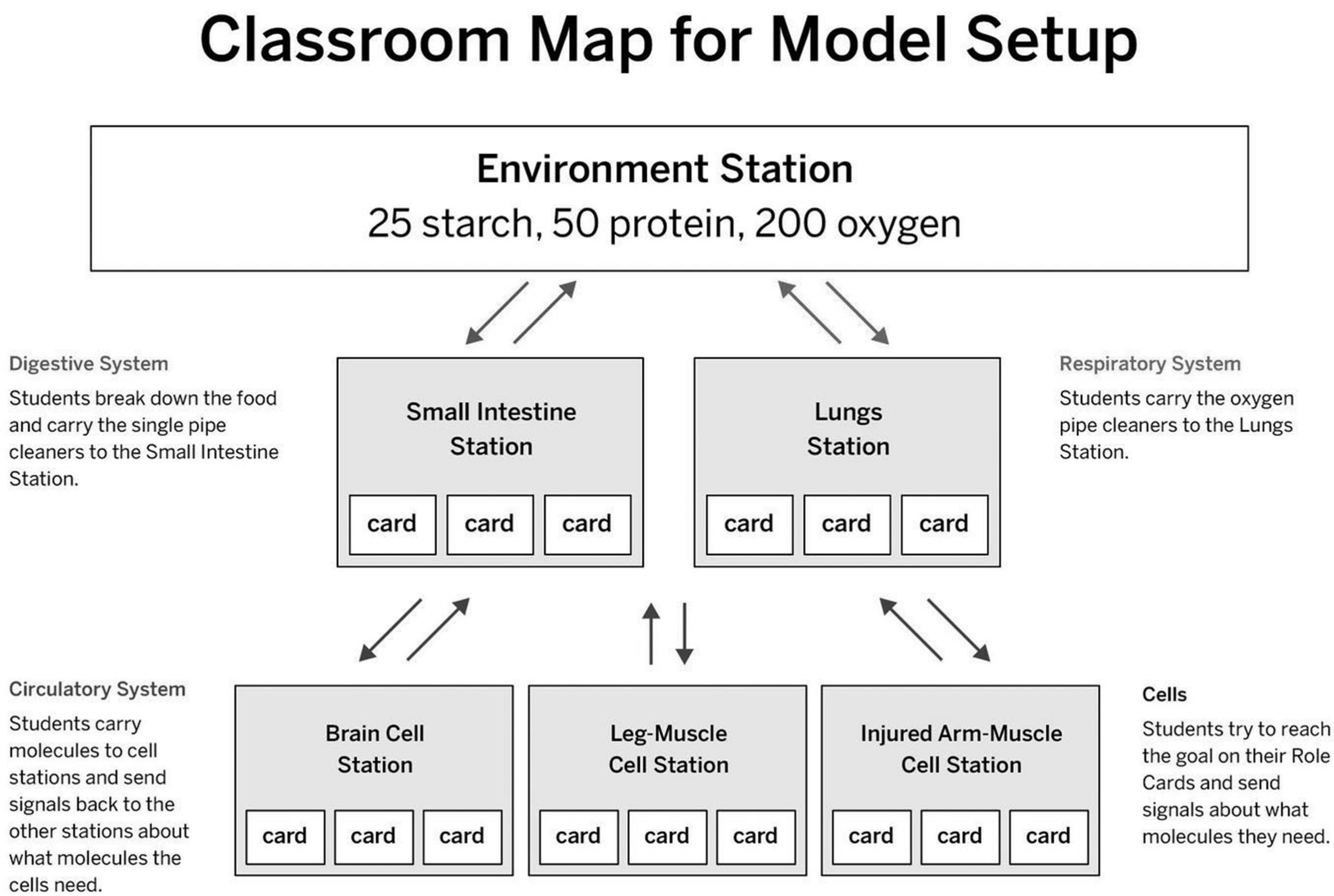
Name: ______________________ Date: ______________

Classroom Body Systems Model

Part 1: Running the Model



Part 2: Discussing the Model

Discuss your answers to the questions below with your group. Make sure each person in your group has a turn to share.

- What did you do in your role in the Classroom Body Systems Model?
- What did you learn about this body system or the cells in the body from participating in this model?

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Homework: Making Observations in the Sim

Make observations about how the different body systems work in the *Metabolism* Sim. Record your observations and answer the questions below.

1. Launch the *Metabolism* Simulation, select HEALTHY BODY, and select OBSERVE.
2. Feed the body sandwiches (which provide a mix of molecule types).
3. Focus on what happens to starch in the digestive system. Turn off all the molecules except for starch and glucose. What do you observe?

____

____

4. Now repeat your observation, but this time turn off all the molecules except for protein and amino acids. What do you observe?

____

____

5. Finally, turn off all the molecules except for oxygen. What do you observe?

____

____

6. Which molecules from food and air end up in the cells in the body? (circle all that apply)

   starch   amino acids   oxygen   glucose   fiber   protein

7. Match each body system to what it does by drawing a line between the system (in the left column) and what it does (in the right column).

circulatory system	breaks down large molecules into smaller molecules
digestive system	takes in oxygen molecules from the environment
respiratory system	delivers molecules to cells in the body

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Homework: Making Observations in the Sim (continued)

8. What questions do you still have about how molecules from food and air get to the cells in the body?

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Lesson 2.2: Patient Stories: Problems with Body Systems

Elisa's medical team thinks there are a few different medical conditions that might explain her symptoms. You will be working in a four-person group to learn as much as you can about each condition so that in a few days you can help make a diagnosis. Today, you'll begin to become an expert on one of four conditions—either anemia, asthma, diabetes, or pancreas injury—by reading an article. Each of these conditions can make it difficult for the body's systems to provide molecules the cells need.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 2 Question

- What is happening in Elisa's body that could be preventing molecules from getting to her cells?

Key Concepts

- Cells can only use molecules that are small enough to enter a cell.
- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.

Vocabulary

- glucose
- metabolism
- oxygen
- system

Digital Tools

- *Metabolism* Modeling Tool activity: 2.2 Warm-Up
- *Metabolism* Simulation (Anemia, Asthma, Diabetes, and Pancreas Injury)

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Name: ______________________________ Date: ________________

Warm-Up

1. Launch the *Metabolism* Modeling Tool activity: 2.2 Warm-Up.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: ______________________________

Goal: Model your ideas about how molecules from food and air get to the cells in the body.

Do:

- Add molecules along the path they take in the body until they reach the cell. Use only as many molecules as you need to show the path.
- A number 1 has been added to the starch molecule to show where this molecule starts its path through the body. Add a number 2 where you think the molecule goes next. Continue to add numbers until the molecules reach the cell.
- If a molecule breaks down into smaller molecules, use an arrow to represent this process.
- If you have time, show the path molecules from air take through the body to reach the cell.

Tips:

- A starch molecule has been placed in the mouth because starch is in food.

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Reading *Patient Stories*

1. Choose an article from the article set *Patient Stories: Problems with Body Systems*. Read and annotate the article.
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Homework: Using the Sim to Observe a Condition

1. Launch the *Metabolism* Sim.
2. Choose the condition you read about below, and then select OBSERVE.
3. Feed and observe the body.
4. Record your observations and questions.

Condition: (circle one)

anemia   asthma   diabetes   pancreas injury

Observations in the Simulation of this condition:

____

____

____

____

Questions I have about this condition:

____

____

____

____

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Lesson 2.3: Learning More About a Condition

What exactly happens in the body of a person with asthma, anemia, diabetes, or a pancreas injury? Today, you'll show your ideas about this by creating a model of the condition you read about, using the *Metabolism* Modeling Tool. You'll get the information you need to make your model by rereading the *Patient Stories* article you read in the previous lesson. Your model will help your group make a diagnosis.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 2 Question

- What is happening in Elisa's body that could be preventing molecules from getting to her cells?

Key Concepts

- Cells can only use molecules that are small enough to enter a cell.
- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.
- In a functioning human body, body systems work together to deliver glucose, oxygen, and amino acid molecules to the cells in the body.
- Systems can work together to form a larger more complex system.

Vocabulary

- circulatory system
- digestive system
- glucose
- metabolism
- molecules
- oxygen
- respiratory system
- system

Digital Tools

- *Metabolism* Modeling Tool activity: 2.3 Model a Condition
- *Metabolism* Simulation (Anemia, Asthma, Diabetes, and Pancreas Injury)

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Name: ______________________________ Date: ________________

Warm-Up

Answer the question below. Then, explain why your answer is the best one.

Why can't a starch molecule enter a cell right after a person eats a meal with starchy foods in it? (check one)

- ☐ Because a starch molecule only stays in the digestive system and never leaves it to go into other systems.
- ☐ Because a starch molecule is too large to fit into a cell and needs to first be broken down into smaller glucose molecules in the digestive system.
- ☐ Because starch molecules first need to enter the respiratory system before they can get into cells.

Why is your answer the best one?

____

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____

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Name: ________________________________ Date: ________________

Second Read of *Patient Stories* Articles

Reread the article from the *Patient Stories* article set about the condition you read about in the last lesson. Answer the following questions about this condition.

1. Which condition did you read about? (circle one)

   anemia asthma diabetes injury to the pancreas

2. Which body system or systems are affected by this condition? (circle all that apply)

   digestive respiratory circulatory

3. Which molecules are affected by this condition? (circle all that apply)

   oxygen glucose amino acids

4. Describe what is going wrong in the body of a person with this condition that is preventing the right molecules from getting to the body's cells.

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Name: ______________________________ Date: ____________________

Modeling a Condition

1. Launch the *Metabolism* Modeling Tool activity: 2.3 Model a Condition.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: ______________________________

Goal: Change this model of a healthy body to show what happens in a body with a medical condition.

Do:

- Add molecules to or remove molecules from her healthy body to show how her body would change if she had the condition you read about (asthma, anemia, pancreas injury, or diabetes).

Tips:

- This model is of a healthy person's body.
- Her body is taking in the molecules she needs and delivering them to her cells.
- Remember to look back at the article to check if your model fits with what you read about the condition.

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Comparing Models to the Sim

1. Launch the *Metabolism* Sim.
2. Select the condition you read about (asthma, anemia, diabetes, or pancreas injury), and then select OBSERVE.
3. Feed and observe the body.
4. Explain what you observed in the Sim and how it fits with your model or doesn't fit with your model.

____

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Homework: Ideas About Elisa's Condition

1. Do you think Elisa might have the condition you read about? Why or why not? (Make sure to identify the condition in your response.)

2. What further evidence do we need to diagnose Elisa?

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Homework: Reading “Meet a Scientist Who Grows New Cells”

Did you know scientists can grow new cells? To learn more about a scientist who is studying how to solve medical problems by growing new cells, read and annotate the “Meet a Scientist Who Grows New Cells” article. Then, answer the question below.

What is one interesting thing you learned from this article?

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Lesson 2.4: Conducting Sim Tests

In this lesson, you will deepen your understanding of how medical conditions affect the human body. To do this, you will use the *Metabolism* Sim to conduct tests that will reveal how healthy bodies are different from bodies with medical conditions. You will work with a partner to discuss the data you collect from the Sim.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 2 Question

- What is happening in Elisa's body that could be preventing molecules from getting to her cells?

Key Concepts

- Cells can only use molecules that are small enough to enter a cell.
- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.
- In a functioning human body, body systems work together to deliver glucose, oxygen, and amino acid molecules to the cells in the body.
- Systems can work together to form a larger more complex system.

Vocabulary

- circulatory system
- digestive system
- glucose
- metabolism
- molecules
- oxygen
- respiratory system
- system

Digital Tools

- *Metabolism* Simulation (Healthy Body, Anemia, Asthma, Diabetes, and Pancreas Injury)
- *Metabolism* Modeling Tool activity: 2.4 Homework

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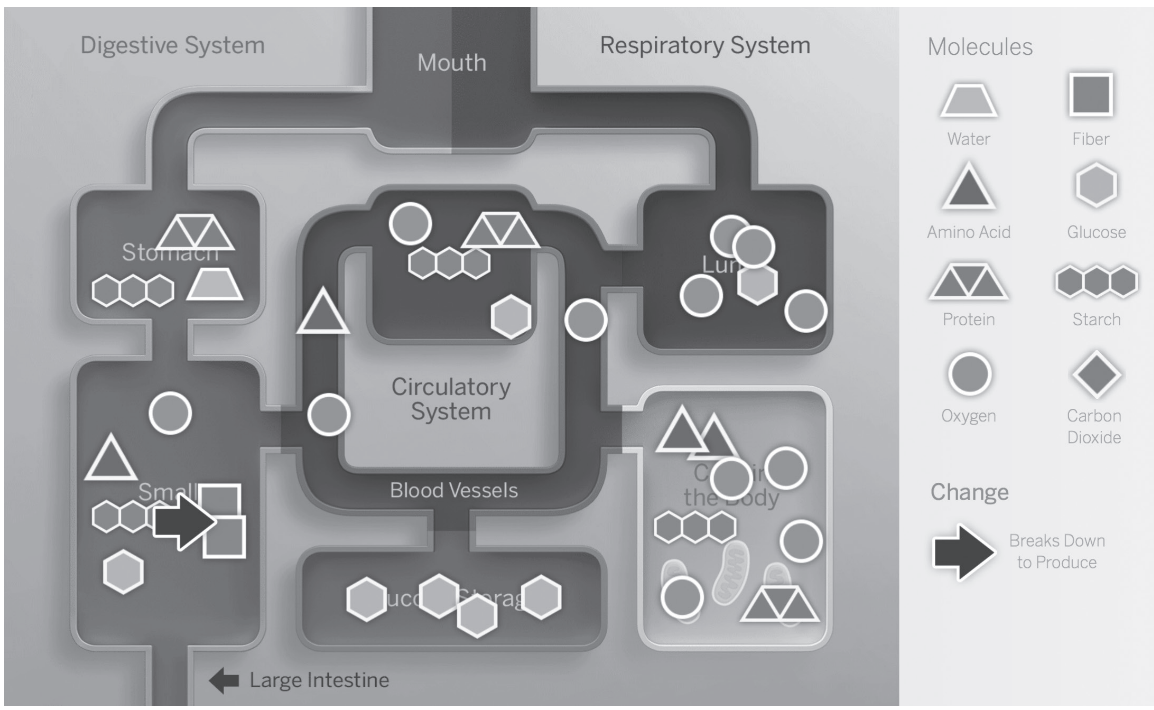
Name: ______________________________ Date: ____________________

Warm-Up

An intern at the hospital created this model to show what happens to the molecules in a healthy person's body after they eat and breathe. The model has some very big mistakes. Add annotations to the image to explain to the intern what is inaccurate about the model.

These sentence starters can help you:

- This molecule would not be found in this body system because . . .
- This molecule would not be found in the cells in the body because . . .



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Name: ______________________________ Date: ________________

Making Comparisons with the Sim

Part 1: Making Predictions

Predict what you will see in the Simulation of the body with the condition you studied. Circle your answers below.

The medical condition that I am learning about is (**anemia** / **asthma** / **diabetes** / **pancreas injury**).

It affects this/these molecule(s) that the human body needs to function: (**oxygen** / **glucose** / **glucose and amino acids**).

In the cells of a body with this condition, I would expect to see (**fewer** / **more**) (**oxygen** / **glucose** / **glucose and amino acids**) molecules than in a healthy body.

Why do you expect to see this in the Simulation? Explain your ideas.

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Name: ______________________________ Date: ______________

Making Comparisons with the Sim (continued)

Part 2: Testing a Healthy Body

Launch the *Metabolism* Simulation.

1. Select HEALTHY BODY, select TEST, and then feed the Healthy Body: two corn, two fish, and two sandwiches.
2. Set the activity level to Walk.
3. Press play to begin the test and switch to Graph View to see the results. (Hint: You can make the tests faster by changing the speed of the Simulation.)
4. Record the results in the data table.
5. Repeat the test and record the results in the Trial 2 column of the table. Record any additional observations in the space below the table.

Data for Healthy Body

	Trial 1	Trial 2
Total glucose molecules absorbed by cells		
Total amino acid molecules absorbed by cells		
Total oxygen molecules absorbed by cells		
Oxygen molecules taken in per breath		

Observations

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Name: ______________________ Date: ______________

Making Comparisons with the Sim (continued)

Part 3: Testing a Body with a Condition

Launch the *Metabolism* Simulation.

1. Select the body with the condition you read about, select TEST, and then feed the body with a condition: two corn, two fish, and two sandwiches.
2. Set the activity level to Walk.
3. Press play to begin the test and switch to Graph View to see the results. (Hint: You can make the tests faster by changing the speed of the Simulation.)
4. Record the results in the data table.
5. Repeat the test and record the results in the Trial 2 column of the table. Record any additional observations in the space below the table.

The medical condition I tested was: ______________________

Data for Body with a Medical Condition

	Trial 1	**Trial 2**
Total glucose molecules absorbed by cells		
Total amino acid molecules absorbed by cells		
Total oxygen molecules absorbed by cells		
Oxygen molecules taken in per breath		

Observations

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Name: ______________________ Date: ______________

Making Comparisons with the Sim (continued)

Part 4: Comparing Your Results

1. Review your data and observations for the healthy body and the body with a condition. How are these two bodies different? Record your ideas below.

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2. Use your data tables and your recorded observations to discuss these questions with your partner:
   - How were the healthy body results different from the results for the body with a condition? Was this what you predicted?
   - Why do you think the body with a condition was different from the healthy body? Explain your understanding of this medical condition to your partner.

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Name: ____________________ Date: ____________

Word Relationships: Discussing Conditions

1. Work with your partner to create a sentence that answers each question, using one or more of the vocabulary words. Every word must be used at least once.
2. After you have discussed, record your sentences below.

Note: Work on either the asthma and anemia questions OR the diabetes and pancreas injury questions, not both.

Word Bank

oxygen	circulatory system	starch
respiratory system	cells	digestive system

Asthma and anemia questions	Diabetes and pancreas injury questions
1. What happens to oxygen in the body of a healthy person?	1. What happens to glucose in the body of a healthy person?
2. What happens to oxygen in the body of a person with anemia?	2. What happens to glucose in the body of a person with diabetes?
3. What happens to oxygen in the body of a person with asthma?	3. What happens to glucose in the body of a person with a pancreas injury?
4. What happens to glucose in the body of a healthy person?	4. What happens to oxygen in the body of a healthy person?

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Name: ______________________ Date: ______________

Homework: Revising Inaccurate Models in the Modeling Tool

1. Launch the *Metabolism* Modeling Tool activity: 2.4 Homework.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: ______________________
3. Then, answer the question below.

Goal: Change this incorrect model so that it correctly shows what happens after a healthy person eats and breathes.

Do:

- Add and remove molecules from the different body systems so that the model accurately represents a healthy body.

Tips:

- Remember this model has some very big mistakes.

Which molecules do cells need to get from outside the body in order to function properly? (check one)

- ☐ water, oxygen, and carbon dioxide
- ☐ glucose, amino acids, and oxygen
- ☐ starch, protein, and fiber
- ☐ glucose, water, and protein

Explain what you changed about the model and why.

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Name: ______________________ Date: ______________

Lesson 2.6: Playing Guess My Model

Even medical students have fun sometimes, right? Today, you will play a game using the *Metabolism* Modeling Tool. You will work with a partner, and each of you will make a model of something that can happen inside the human body. You won't know what your partner is modeling. Then, you will try to figure out what your partner modeled. This game will help you review important ideas and apply everything you've learned so far about how the human body gets molecules to its cells.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 2 Question

- What is happening in Elisa's body that could be preventing molecules from getting to her cells?

Key Concepts

- A functioning human body has molecules from food (glucose and amino acids) and molecules from air (oxygen) in its cells.
- Cells can only use molecules that are small enough to enter a cell.
- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.
- In a functioning human body, body systems work together to deliver glucose, oxygen, and amino acid molecules to the cells in the body.
- A problem with a body system can result in fewer oxygen, glucose, and/or amino acid molecules getting to the body's cells.
- Systems can work together to form a larger more complex system.

Vocabulary

- amino acids
- circulatory system
- digestive system
- glucose
- metabolism
- molecules
- oxygen
- protein
- respiratory system
- starch
- system

Digital Tools

- *Metabolism* Modeling Tool activities: 2.6 Green Group, 2.6 Blue Group, 2.6 Purple Group

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Name: ______________________ Date: ______________

Warm-Up

In your Digital Resources, find and read the background information for your group.

- For example, if you are in the Purple Group, you will read the background information labeled "Purple Group." This will help prepare you for the game we are going to play today.

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Name: ______________________ Date: ______________

Playing the Guess My Model Game

Launch the *Metabolism* Modeling Tool activity for your group, and then follow the instructions below to play the Guess My Model Game.

Guess My Model Game Instructions

1. Each partner gets an envelope with a set of cards.
2. Each partner shuffles their set of cards and turns them face down.
3. Each partner chooses a card from their pile. (Do not let your partner see your card.)
4. Reread the Background Information for the scenario on the card you chose.
5. Using the Modeling Tool, make a model of the scenario.
6. The first partner guesses first: use the Key and Background Information to decide which scenario you think your partner modeled.
7. Give feedback and revise the model with your partner, if needed.
8. Switch roles: the second partner guesses the first partner's model.
9. Play another round: each partner draws a new card.

Which group are you in (circle one)?

Green Group | Blue Group | Purple Group

What is one scenario that you modeled? ______________________

Describe what you showed in your model.

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Reflecting on the Guess My Model Game

- Were there any scenarios that you had a hard time modeling?
- What did you learn from the game?
- Do you have any more questions about body systems?

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Name: ______________________ Date: ______________

Homework: Reading *Systems of the Human Body*

You have learned a lot about the circulatory, digestive, and respiratory systems. From the *Systems of the Human Body* article set, choose one of the other systems to read about and answer the questions below.

I read the article: (check one)

- ☐ "The Nervous System"
- ☐ "The Excretory System"
- ☐ "The Musculoskeletal System"
- ☐ "The Reproductive System"

1. What does this system do?

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2. What are the important parts of this system?

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Name: ______________________________ Date: ______________

Lesson 2.7: Diagnosing Elisa

Today, you will finally diagnose Elisa! You'll share your expertise with your group, explaining the condition you investigated and how it could affect Elisa's body systems. Then, you'll receive Elisa's test results and compare them to the Sim tests you did earlier. Together, your group will consider the possible claims about why Elisa is tired and decide on a diagnosis that is supported by all the available evidence. You'll craft a written argument supporting this diagnosis. This will help Elisa get the treatment she needs.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 2 Question

- What is happening in Elisa's body that could be preventing molecules from getting to her cells?

Key Concepts

- Cells can only use molecules that are small enough to enter a cell.
- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.
- In a functioning human body, body systems work together to deliver glucose, oxygen, and amino acid molecules to the cells in the body.
- A problem with a body system can result in fewer oxygen, glucose, and/or amino acid molecules getting to the body's cells.
- Systems can work together to form a larger more complex system.

Vocabulary

- circulatory system
- diagnosis
- digestive system
- evidence
- glucose
- molecules
- oxygen
- respiratory system
- system

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Name: ______________________ Date: ______________

Warm-Up

Read the message below. Then, answer the questions below the message.

To: Medical Students
From: Dr. Walker, MD
Subject: Elisa Rodriguez

Today is an exciting day; you will get Elisa's test results and work together to use all the available evidence to make a diagnosis.

Remember, our hospital medical team started you out with four possible claims about Elisa's condition:

- Elisa is feeling tired because she has diabetes.
- Elisa is feeling tired because she has anemia.
- Elisa is feeling tired because she has an injury to her pancreas.
- Elisa is feeling tired because she has asthma.

1. Which condition are you investigating? (circle one)

anemia asthma diabetes injury to the pancreas

2. Which body system would have a problem if Elisa has the medical condition you've been investigating? (circle all that apply)

respiratory system circulatory system digestive system

3. Which molecule that cells need is affected by the medical condition you've been investigating? (circle all that apply)

amino acids glucose oxygen water

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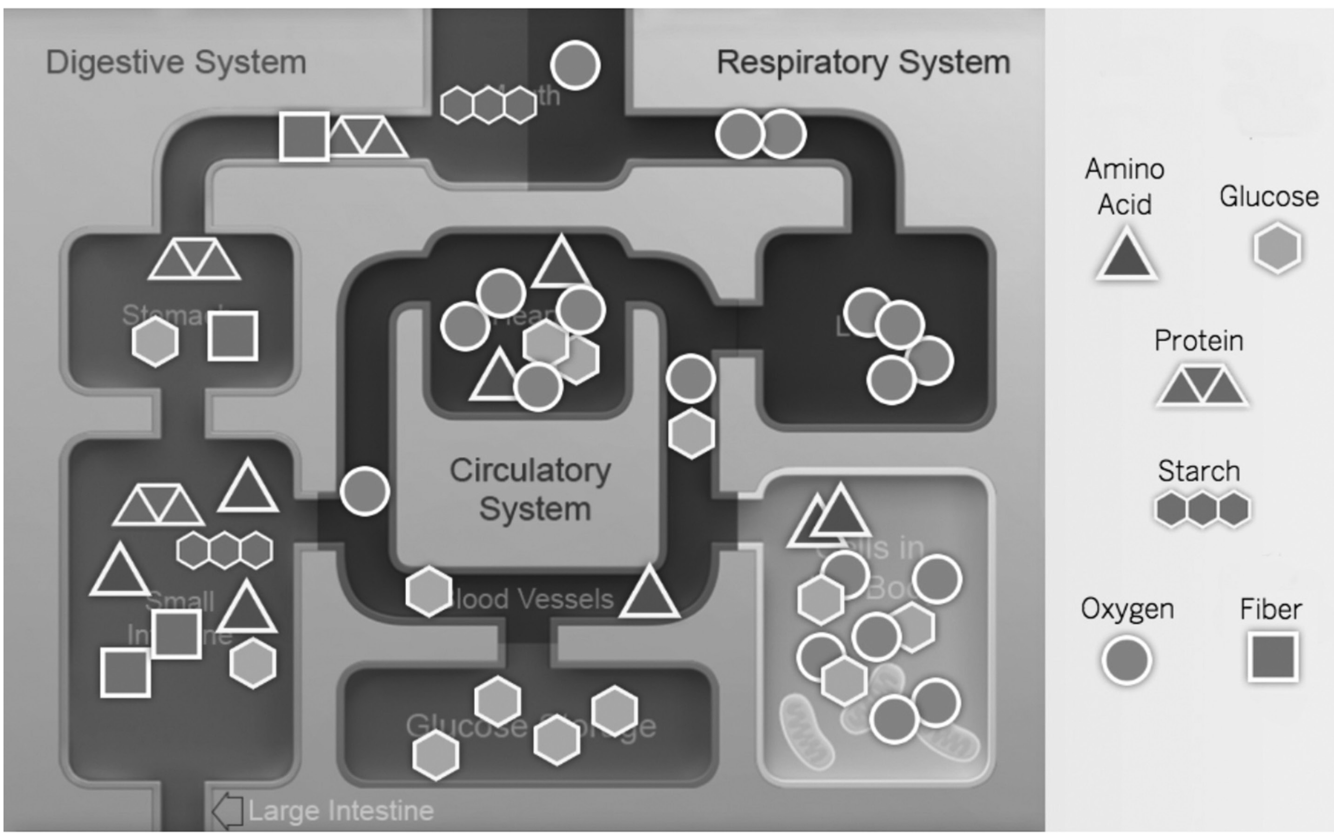
Name: ______________________________ Date: ______________

Analyzing Elisa's Test Results

Part 1: Using the Diagram to Explain Medical Conditions

Take turns explaining your medical conditions, using the diagram and these sentence starters:

- The medical condition I investigated was . . .
- This medical condition affects the body's ability to get the molecules . . .
- This medical condition works like this . . .
    - (Explain how the molecules move through the body system(s) when someone has this condition, and how or why the number of molecules that get to the cells changes because of the condition.)
- If Elisa has this condition, I would expect to see in her test results . . .



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Analyzing Elisa's Test Results (continued)

Part 2: Comparing Test Results to Data from the Sim

1. Work with your partner to compare Elisa's test results (in the table below) to your experiments with the Sim:
   - One partner stays on this notebook page, and the other partner turns back to the Data for Healthy Body and the Data for Body with the Medical Condition from Lesson 2.4 (on pages 39–40).
   - Compare Elisa's test results below to the Healthy Body and the Body with a Condition results. Does the evidence support the claim that Elisa has this condition?
2. Switch and compare to the other condition.
3. Discuss your evidence with your group and agree on a diagnosis.

Elisa's Test Results

	Test result
Total glucose molecules absorbed by cells	19
Total amino acid molecules absorbed by cells	54
Total oxygen molecules absorbed by cells	273
Oxygen molecules taken in per breath	25

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Name: ______________________________ Date: ______________________

Writing an Argument to Support a Diagnosis

You and your group are presenting a diagnosis for Elisa. Each of you will be responsible for explaining why Elisa does or does not have one of the four conditions.

1. First, you will explain how a healthy body functions.
2. Then, you will write an argument in which you explain what happens in the body of someone who has the condition you investigated and support your claim that Elisa does or does not have that condition.

Part 1: Explaining a Healthy Body

Elisa feels tired because she has a condition that affects whether the right molecules are getting to her cells. If her body were functioning correctly, this is what would happen with oxygen:

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If her body were functioning correctly, this is what would happen with starch/glucose:

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Name: ______________________________ Date: ________________

Writing an Argument to Support a Diagnosis (continued)

Part 2: Diagnosis

For each claim below, circle **supported** or **not supported**.

Elisa is feeling tired because she has diabetes.	**supported** / **not supported** by the evidence
Elisa is feeling tired because she has anemia.	**supported** / **not supported** by the evidence
Elisa is feeling tired because she has an injury to her pancreas.	**supported** / **not supported** by the evidence
Elisa is feeling tired because she has asthma.	**supported** / **not supported** by the evidence

Now explain your diagnosis.

- Start your argument by writing something like this:

"My group believes that Elisa has/does not have _____. I think that she does/does not have the _____ condition because . . ."

- Then, explain how molecules move through the body when someone has the condition you investigated, and compare that to Elisa's test results.

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Name: ______________________________ Date: ________________

Homework: Revising Your Argument

1. Read your argument on page 54 and evaluate how well you did each of the following items listed below.
2. Then, revise your argument to make it more convincing. Use the space below if needed.

I stated my claim clearly. (circle one)

Definitely! Sort of Not really Not at all

I included evidence to support the claim. (circle one)

Definitely! Sort of Not really Not at all

I made my reasoning clear by explaining how the evidence supports the claim. (circle one)

Definitely! Sort of Not really Not at all

(If you need more space to revise your argument, use the lines below.)

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Name: ________________________________ Date: ________________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the question below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why your patient, Elisa, could be feeling so tired?

1. I understand what molecules Elisa's cells need and where they come from.

   ☐ yes

   ☐ not yet

Explain your answer choice above.

____

____

2. I understand how those molecules get to the cells in Elisa's body.

   ☐ yes

   ☐ not yet

Explain your answer choice above.

____

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3. I understand how the cells use those molecules to release energy for Elisa's body to function.

   ☐ yes

   ☐ not yet

Explain your answer choice above.

____

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Name: ______________________________ Date: ____________________

Homework: Check Your Understanding (continued)

4. What do you still wonder about Elisa's condition or how her body gets what it needs to function?

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Name: ______________________________ Date: ________________

Chapter 3: Cellular Respiration
Chapter Overview

Congratulations on your successful diagnosis! However, your work isn't done yet: You still need to be able to explain *why* Elisa's condition had such an effect on her energy levels. And once you can explain that, you can use what you've learned about metabolism to help explain how elite athletes are able to perform so much better than average people.

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Name: ____________________ Date: ____________

Lesson 3.1: Learning About Energy Release in the Body

You already know that the cells in your body need three molecules that come from food and air: glucose, amino acids, and oxygen. But what exactly happens with these molecules once they are in the cells in the body? In this lesson, you will begin to investigate which molecules cells need to release the energy the body needs to function. Determining which molecules release energy for the body will enable you to explain why your patient with a medical condition, Elisa, felt so tired.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 3 Question

- How do molecules in the cells of the body release energy?

Vocabulary

- amino acid
- circulatory system
- digestive system
- energy
- glucose
- metabolism
- molecules
- oxygen
- respiratory system

Digital Tools

- *Metabolism* Simulation (Healthy Body)

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Name: ______________________ Date: ______________

Warm-Up

In Chapter 2, you received Elisa's test results, and you compared those results to your Sim test results for a healthy body.

The data table below shows Elisa's test results and test results from a healthy body. Use the data to answer the questions below the table.

Molecules absorbed by the cells in the body	Healthy body	Elisa's body
Glucose	44	18
Amino acids	37	52
Oxygen	300	270

1. Compared to the cells in a healthy body, Elisa's cells are getting far fewer ______________ molecules.

   a. amino acid

   b. oxygen

   c. glucose

2. How do you think getting fewer of these molecules to her cells contributed to Elisa's tiredness? Explain your ideas.

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Name: ______________________ Date: ______________

Considering Claims About Energy Release

Which molecules do cells need to release energy? Select the claim you think is most accurate.

- ☐ **Claim 1:** Cells need glucose to release energy.
- ☐ **Claim 2:** Cells need amino acids to release energy.
- ☐ **Claim 3:** Cells need oxygen to release energy
- ☐ **Claim 4:** Cells need glucose AND amino acids to release energy.
- ☐ **Claim 5:** Cells need glucose AND oxygen to release energy.
- ☐ **Claim 6:** Cells need ALL THREE types of molecules to release energy.

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Name: ______________________ Date: ______________

Gathering Evidence from Heart and Breath Rates

Heart and Breath Rate Activity

1. **Observe breath rate.** Put a finger just under your nose to feel the gas leaving the body when breathed out.
2. **Observe heart rate.** Place two fingers gently on your neck just under your jaw (or on your wrist). Move your fingers around until you can feel a steady beat. Each beat you feel is a pulse of blood from one pump of the heart.
3. **Exercise for one minute.** Wait for the teacher's signal to begin. Run in place, lifting your knees as high as you can and stepping as fast as you can. Be careful not to bump into anyone or anything. Stop at the teacher's signal.
4. **Observe breath rate and heart rate again.** As soon as you stop exercising, observe your breath rate and heart rate as you did before.
5. **Discuss your observations with your partner.** How did your breath change after one minute of exercise? How did your heart rate change after one minute of exercise?

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Name: ______________________________ Date: ________________

Gathering Evidence from the Sim

Which molecules do cells need to release energy?

1. Gather evidence to answer this question by running three tests in the Sim. You will be measuring **the length of time a healthy body can jog** under three conditions: without glucose, without amino acids, and without oxygen.

2. For each test:
   - Launch the *Metabolism* Simulation, select HEALTHY BODY, and then select OBSERVE.
   - Pause the Sim and set the activity level to Jog.
   - For the "without oxygen" test, also press STOP for the breath.
   - Press Play and then feed the body as directed in the data table for that condition.
   - Immediately switch to Graph View and wait for the activity level to drop from Jog to Walk.
   - Pause the Sim and record the length of time the body stayed at Jog.

3. For each test, do two trials. Compare the results of your tests to the control test in the first row of the table to decide if removing that molecule affects energy release. Discuss your ideas with your partner.

Molecule observation test	**Trial 1: length of time jogging**	**Trial 2: length of time jogging**
Control test: with glucose, amino acids, and oxygen (breath on, feed 1 fish and 1 corn)	100–132 time units	100–132 time units
Test A: without glucose (breath on, feed 1 fish)		
Test B: without amino acids (breath on, feed 1 corn)		
Test C: without oxygen (STOP breath, feed 1 fish and 1 corn)		

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Name: ______________________________ Date: ________________

Revising Claims

Which molecules do cells need to release energy?

1. Discuss with your partner the evidence you collected today, and then select the claim you now think is most accurate.
   - ☐ **Claim 1:** Cells need glucose to release energy.
   - ☐ **Claim 2:** Cells need amino acids to release energy.
   - ☐ **Claim 3:** Cells need oxygen to release energy
   - ☐ **Claim 4:** Cells need glucose AND amino acids to release energy.
   - ☐ **Claim 5:** Cells need glucose AND oxygen to release energy.
   - ☐ **Claim 6:** Cells need ALL THREE types of molecules to release energy.

2. Explain how the evidence supports this claim.

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Name: ____________________ Date: ____________

Homework: Running Tests, Using the Sim

Run tests to compare two different activity levels in the Healthy Body of the *Metabolism* Simulation.

1. Select HEALTHY BODY and select TEST.
2. Food Queue: 6 corn.
3. Do two trials for each activity level (Rest and Jog).
4. Record your results in the data table, and then answer the questions on the next page.

Activity level	**Glucose molecules absorbed by the cells**	**Oxygen molecules absorbed by the cells**	**Observations**
Rest, Trial 1			
Rest, Trial 2			
Jog, Trial 1			
Jog, Trial 2			

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Name: ______________________________ Date: ______________

Homework: Running Tests, Using the Sim (continued)

What differences do you notice between what happens in the Rest activity level and what happens in the Jog activity level?

Why do you think these different activity levels produced different results?

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Name: ______________________________ Date: ____________________

Lesson 3.2: Exploring Chemical Reactions

What exactly happens with glucose and oxygen in your cells, and what does it have to do with energy? Today, you'll be doing a hands-on activity that is an example of molecules releasing energy in a process called a chemical reaction. Then, through reading an article and exploring the Sim, you will compare that process to what happens in the cells of the body.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 3 Question

- How do molecules in the cells of the body release energy?

Key Concepts

- In order to release energy, cells need both glucose and oxygen molecules.

Vocabulary

- cells
- cellular respiration
- energy
- glucose
- metabolism
- molecules
- oxygen
- respiratory system

Digital Tools

- *Metabolism* Simulation (Healthy Body)

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Name: ______________________________ Date: ____________________

Warm-Up

1. If a patient has a medical condition that causes his cells to absorb fewer than normal __________ molecules, this patient would likely feel very tired. (check one)

   - ☐ oxygen
   - ☐ fiber
   - ☐ starch
   - ☐ protein

2. Explain your reasoning.

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Name: ______________________________ Date: ____________________

Observing a Chemical Reaction

CHEMICAL WARNING

The *Metabolism* kit contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision.

Chemicals used in this activity are:
- phenol red
- calcium chloride
- baking soda

Safety Note: Using Chemicals

Do not taste or touch the substances in the investigation, do smell substances as a chemist does, and do mix substances only when you are told to do so. Use safety goggles and gloves as necessary. Calcium chloride and phenol red present irritation risks. Wash exposed areas when finished. If calcium chloride, phenol red, or a mixture of substances gets on skin or clothes, rinse the substance off with water. If a substance gets in eyes, rinse the affected eye(s) with water for 15 minutes.

What Happens When These Substances Combine?

Instructions: Each group member should perform one of the first four steps below. Decide among your group members who will perform each step.

1. Measure 10 mL of phenol red solution from the squeeze bottle into the graduated cylinder.
2. Carefully open the bag with the powders.
3. Pour the phenol red solution from the graduated cylinder into the bag.
4. Get as much air as possible out of the bag before sealing it. With your hands on the outside of the bag, gently mix the substances together.
5. Each group member should touch the bag.
6. What do you notice? Make sure each group member shares their observations.

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Name: ______________________ Date: ______________

Observing Cellular Respiration in the Sim

1. Launch the *Metabolism* Sim. Select HEALTHY BODY, and then select OBSERVE. Feed the body as needed.
2. Slow down the Sim to x0.5 speed and observe closely what happens in the cell by pressing the yellow box (Cells in the Body) and then pressing the magnifying glass.
3. Observe what happens BEFORE and AFTER the chemical reaction, then answer the questions below.

Describe what happens in the cell before the chemical reaction.

Describe what happens after the chemical reaction. What evidence did you see of energy release?

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Name: ______________________________ Date: ____________________

Reflecting on Cellular Respiration

Discuss the following reflection questions with your partner. Take turns reading and answering the questions.

- Partner A: What molecules are needed for cellular respiration to happen?
- Partner B: What are the outputs of cellular respiration?
- Partner A: How was the chemical reaction we observed similar to what happens in the mitochondria in your cells?
- Partner B: How does what you learned today help explain why Elisa felt tired?

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Name: ________________________________ Date: ____________________

Homework: Exploring Cellular Respiration

1. Watch the video called *The Story of Sanctorius*, which is in your Digital Resources for Lesson 3.2. This video tells the story of one of the first scientists to study cellular respiration.
2. Use what you've learned today about cellular respiration to answer the question below. Use these words in your response:
   - oxygen
   - glucose
   - cellular respiration
   - energy
   - cells

Because of her diabetes, Elisa had lower numbers of glucose molecules getting to her cells. Why did this cause her to feel so tired?

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Lesson 3.3: Cellular Respiration, Growth, and Repair

You know that glucose and oxygen are needed for cellular respiration, which releases energy—but what exactly does the body do with that energy? And, what about those amino acids, anyway? To investigate these questions, you will observe the *Metabolism* Simulation, complete a short reading, and model your ideas about how healthy cells in the body function. This will help you understand more about how Elisa's body could be affected by her medical condition.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 3 Question

- How do molecules in the cells of the body release energy?

Key Concepts

- In order to release energy, cells need both glucose and oxygen molecules.
- Inside the cell, the atoms that make up glucose and oxygen can be rearranged to make different molecules. This chemical reaction is called cellular respiration and releases energy.

Vocabulary

- amino acid
- cell
- cellular respiration
- energy
- glucose
- metabolism
- molecules
- oxygen
- protein

Digital Tools

- *Metabolism* Simulation (Healthy Body)
- *Metabolism* Modeling Tool activity: 3.3 Model a Cell

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Warm-Up

Use the *Metabolism* Simulation to observe what happens with amino acid molecules inside a cell of a healthy body.

1. Select HEALTHY BODY and then select OBSERVE.
2. Feed the body three sandwiches.
3. Zoom in to see what is happening inside the cell by pressing the yellow box (Cells in the Body) and then pressing the magnifying glass.
4. Observe closely and then answer the questions.

What did you notice happening with the amino acid molecules in the cell?

____

____

In the cell, amino acid molecules combine to form ____________________. (check one)

- ☐ fiber molecules
- ☐ protein molecules
- ☐ water molecules
- ☐ starch molecules

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Reading "Growth and Repair"

Read and annotate the "Growth and Repair" article. After you read, discuss the following questions with your partner.

- What surprised you about this article?
- How are amino acid molecules used in cellular growth and repair?
- How are glucose and oxygen molecules used in cellular growth and repair?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Modeling Cellular Growth and Repair

1. Launch the *Metabolism* Modeling Tool activity: 3.3 Model a Cell.

2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: ______________________________

Goal: Show how energy is released to make growth and repair occur in a healthy, functioning cell.

Do:

- Add molecules and use the arrow and energy symbol to represent changes that result in energy release.

What does your model show about how energy is released to make growth and repair occur in a healthy, functioning cell?

____

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Name: ____________________ Date: ____________

Writing About Elisa

1. Elisa's diabetes causes her to have lower than normal numbers of glucose molecules in her cells. You already wrote about how this makes her tired.
2. Now, write an explanation that answers the question, *How could Elisa's diabetes also affect her body's ability to grow and repair cells?*
3. Use the following sentence to start your explanation, or use a sentence of your own.
   - *Diabetes could affect how well Elisa's cells can grow and repair themselves.*

Word Bank

glucose	amino acid
oxygen	protein
cellular respiration	energy

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Homework: Reading "The Big Climb"

Read and annotate the "The Big Climb: A Story in Large and Small Scale" article. Then, choose an example from the article that shows what is happening to the rock climbers' bodies at the large scale. Describe what is happening to rock climbers' body systems and cells at the small scale.

Find a part of the article that describes signals that are sent within Diego's body. Where does the signal come from, and how does it cause Diego to feel or react?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Lesson 3.4: "Blood Doping: Messing with Metabolism to Win Races"

Energy is constantly being released in your cells, even when you're just sitting around and thinking—so imagine what must be happening in the cells of an elite athlete during a competition! Today, you will read about a controversial and illegal procedure called blood doping, which some athletes have used to increase their cellular respiration and enhance their athletic performance. Understanding how this process works will help you deepen your understanding of metabolism.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 3 Question

- How do molecules in the cells of the body release energy?

Key Concepts

- In order to release energy, cells need both glucose and oxygen molecules.
- Inside the cell, the atoms that make up glucose and oxygen can be rearranged to make different molecules. This chemical reaction is called cellular respiration and releases energy.
- Cells can grow and repair themselves by combining amino acid molecules to form larger protein molecules. This growth and repair requires energy release from cellular respiration.

Vocabulary

- blood doping
- cellular respiration
- circulatory system
- energy
- glucose
- metabolism
- oxygen

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Name: ______________________ Date: ______________

Warm-Up

Read the message from Dr. Walker. Then, answer the questions below the message.

To: Medical Students
From: Dr. Walker
Subject: Elisa Rodriguez

Thank you for wrapping up the diagnosis of Elisa. Thanks to your careful investigation, we've been able to get started with a course of treatment that should have Elisa feeling more energetic soon.

We have a new assignment for you now. We want you to learn about the metabolism of athletes—not just any athletes, but world-class athletes that train for many hours every day. Energy release in the cells is very important to these athletes. To start your thinking about the energy needs of these athletes, please answer the following questions with your best ideas.

1. In order to maintain a high level of performance, what types of foods do you think an athlete should eat right before a race? (check one)

   ☐ foods high in fiber

   ☐ foods high in protein

   ☐ foods high in starch

2. Explain your reasoning.

____

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3. The energy released in cellular respiration helps an athlete perform. How do you think an athlete might be able to increase cellular respiration?

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Name: ______________________ Date: ______________

Reading "Blood Doping"

1. Read and annotate the article “Blood Doping: Messing with Metabolism to Win Races.”
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Rate how successful you were at using Active Reading skills by responding to the following statement:

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

- ☐ Never
- ☐ Almost never
- ☐ Sometimes
- ☐ Frequently/often
- ☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

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Homework: Reading *Odd Organisms and How They Get the Molecules They Need*

You have learned a lot about body systems in humans, but how are other organisms similar and different? From the *Odd Organisms and How They Get the Molecules They Need* article set, choose one organism to read about and answer the questions below.

I read about the (check one)

- ☐ blue whale
- ☐ grasshopper
- ☐ sea sponge
- ☐ trout
- ☐ water bear

1. Compared to a human, what is **different** about how this organism gets molecules from food and air?

____

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2. Compared to a human, what is **similar** about how this organism gets molecules from food and air?

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Name: ______________________________ Date: ____________________

Lesson 3.5: Modeling Cellular Respiration in an Athlete's Body

Highly-trained athletes' bodies perform differently than non-athletes' bodies. For example, an athlete will most likely be able to run faster and farther than a normal healthy person. Is there something different about the ways athletes take in oxygen or how cellular respiration happens in their cells? And what about blood doping—how does it give athletes an edge when they are already some of the most physically fit people in the world? Today, you will compare the bodies of normal healthy people, athletes, and athletes who are blood doping to see how and why their cellular respiration rates and oxygen levels differ. You will run Sim tests, create models in the Modeling Tool, and read, in order to analyze these different bodies.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 3 Question

- How do molecules in the cells of the body release energy?

Key Concepts

- In order to release energy, cells need both glucose and oxygen molecules.
- Inside the cell, the atoms that make up glucose and oxygen can be rearranged to make different molecules. This chemical reaction is called cellular respiration and releases energy.
- Cells can grow and repair themselves by combining amino acid molecules to form larger protein molecules. This growth and repair requires energy release from cellular respiration.

Vocabulary

- blood doping
- cellular respiration
- circulatory system
- energy
- glucose
- metabolism
- oxygen

Digital Tools

- *Metabolism* Simulation (Healthy Body)
- *Metabolism* Modeling Tool activity: 3.5 Model an Athlete

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Warm-Up

In the next activity, you will consider how a normal healthy body is different from an athlete's body. Make a prediction of how you think they are different and explain your reasoning.

1. Oxygen molecules taken in per breath: The athlete's result will be __________ the normal healthy body's result.

   - ☐ higher than
   - ☐ lower than
   - ☐ the same as

Explain your reasoning.

____

____

2. Oxygen molecules absorbed by cells: The athlete's result will be __________ the normal healthy body's result.

   - ☐ higher than
   - ☐ lower than
   - ☐ the same as

Explain your reasoning.

____

____

3. Highest cellular respiration level: The athlete's result will be __________ the normal healthy body's result.

   - ☐ higher than
   - ☐ lower than
   - ☐ the same as

Explain your reasoning.

____

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Name: ______________________ Date: ______________

Comparing a Healthy Body to an Athlete’s Body

This data represents tests from a simulation similar to the one we’ve been using. This simulation represents the body of an athlete.

Talk to your partner and discuss how metabolism in an athlete’s body is different from that in a normal healthy body.

	Healthy body	**Athlete**
Oxygen molecules taken in per breath	25 molecules	45 molecules
Oxygen molecules absorbed by cells	270 molecules	350 molecules
Maximum cellular respiration level during test	8	12

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Modeling an Athlete's Body

1. Launch the *Metabolism* Modeling Tool activity: 3.5 Model an Athlete. The starting model represents the molecules in a healthy body, when exercising.
2. When your model is complete, press HAND IN. If you worked with a partner, write his or her name here: ______________________________

Goal: Show what is happening in an athlete's body during exercise.

Do:

- Change this model of the starch, glucose, and oxygen molecules in a healthy body during exercise to model what happens in an athlete's body during exercise.

Tips:

- Refer to your data table to identify the differences between the healthy body and the athlete's body.
- Note: You'll be revising and handing in this model later in this lesson.

In the space below, describe how your model is different from the Healthy Body Model.

____

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Second Read of “Blood Doping”

Part 1

1. Reread the sections called “What Is Blood Doping?” and “How Blood Doping Works in the Body" to better understand what happens to the molecules, especially oxygen, in an athlete’s body and in a blood-doping athlete’s body.
2. Number the steps below from 1–3 to indicate what an athlete does when she blood dopes.

   ______ She chills the blood and stores it.

   ______ She puts the blood back into her body just before a competition.

   ______ She removes the blood from her body.

3. Reread the first paragraph in the section "How Blood Doping Works in the Body" and highlight the following:
   - the sentences that describe how oxygen gets into the blood and then to the cells in a normal healthy body
   - in a different color, the sentences that describe how blood doping affects the circulatory system’s ability to carry oxygen

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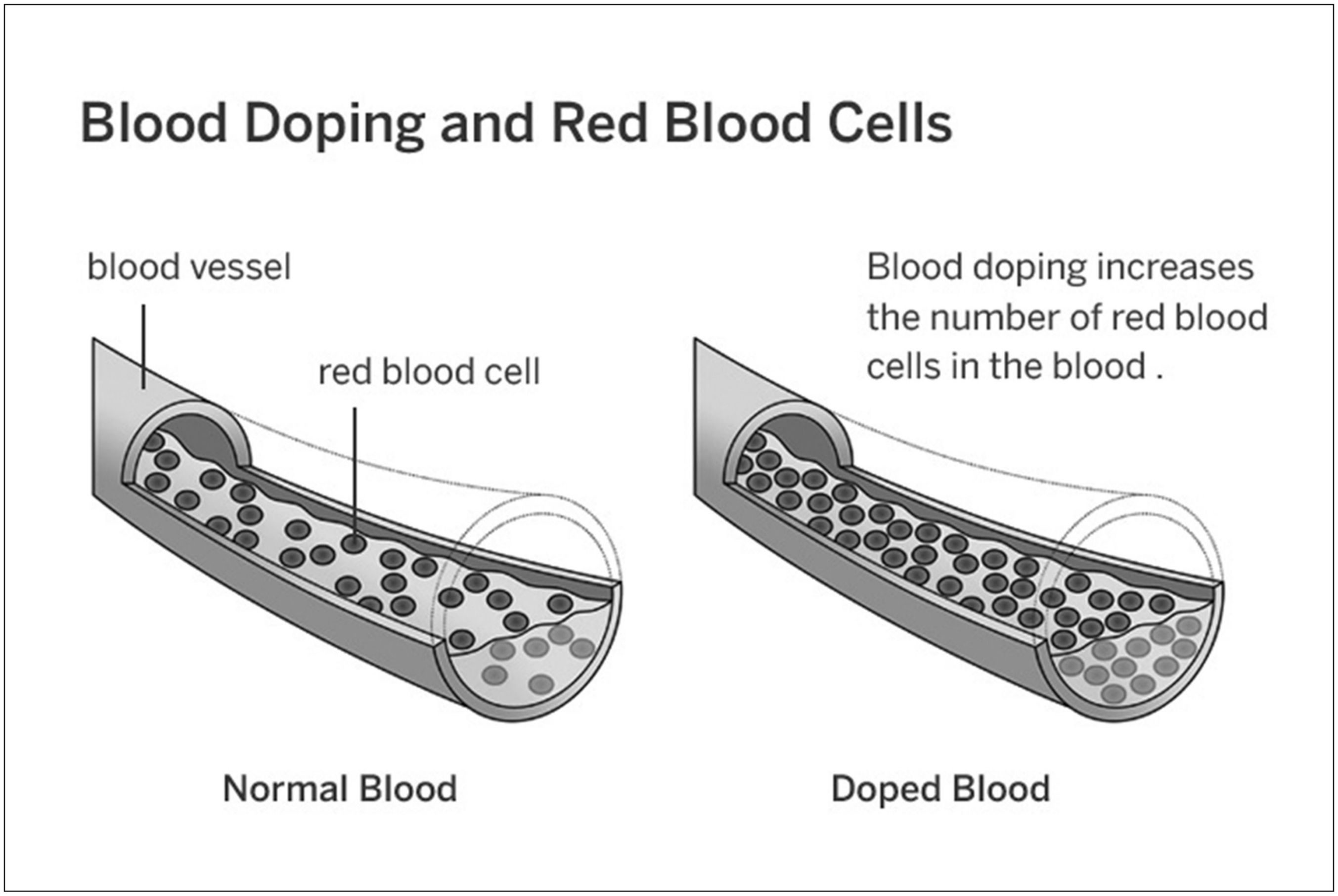
Second Read of "Blood Doping" (continued)

Part 2

Look at the diagram "Blood Doping and Red Blood Cells" from the article and answer the question.



Explain what the diagram shows about how doped blood is different from normal blood.

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Second Read of “Blood Doping” (continued)

Part 3

Use what you read to make predictions about an athlete who is blood doping. If needed, look at the "Blood Doping" article for evidence to support your predictions.

1. How would the amount of oxygen in the circulatory system be different in an athlete who is blood doping, compared to a normal athlete?

____

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2. How would the amount of oxygen absorbed by the cells be different in an athlete who is blood doping, compared to a normal athlete?

____

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Modeling an Athlete Who Is Blood Doping

1. Go back to the *Metabolism* Modeling Tool activity: 3.5 Model an Athlete, where you made a model of an athlete's body during exercise.
2. Based on your predictions (on page 89) about the athlete who is blood doping, change your model in order to represent what a blood-doping athlete's body would look like during the same activity.
3. When your model is complete, press HAND IN. If you worked with a partner, write his or her name

   here: ____

Explain how your model of a blood-doping athlete's body is different from your model of an athlete's body.

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Name: ______________________________ Date: ______________

Homework: Getting a High Cellular Respiration Rate in the Sim

Try to get the highest cellular respiration rate possible in the Sim. Note: You can see the cellular respiration level in the yellow meter in Live View, and as the yellow line and yellow number in Graph View.

1. Plan your strategy! Record your ideas about how to achieve the maximum level of cellular respiration.

____

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2. Launch the *Metabolism* Simulation and complete your mission.
3. Record your observations below. Be sure to describe the highest cellular respiration level reached and how you achieved this level.

____

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Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the question below.

Scientists investigate in order to figure things out. Are you getting closer to figuring out why your patient, Elisa, could be feeling so tired?

1. I understand what molecules Elisa's cells need and where they come from.

- ☐ yes
- ☐ not yet

Explain your answer choice above.

____

____

2. I understand how those molecules get to the cells in Elisa's body.

- ☐ yes
- ☐ not yet

Explain your answer choice above.

____

____

3. I understand how the cells use those molecules to release energy for Elisa's body to function.

- ☐ yes
- ☐ not yet

Explain your answer choice above.

____

____

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Homework: Check Your Understanding (continued)

4. What do you still wonder about Elisa's condition or how her body gets what it needs to function?

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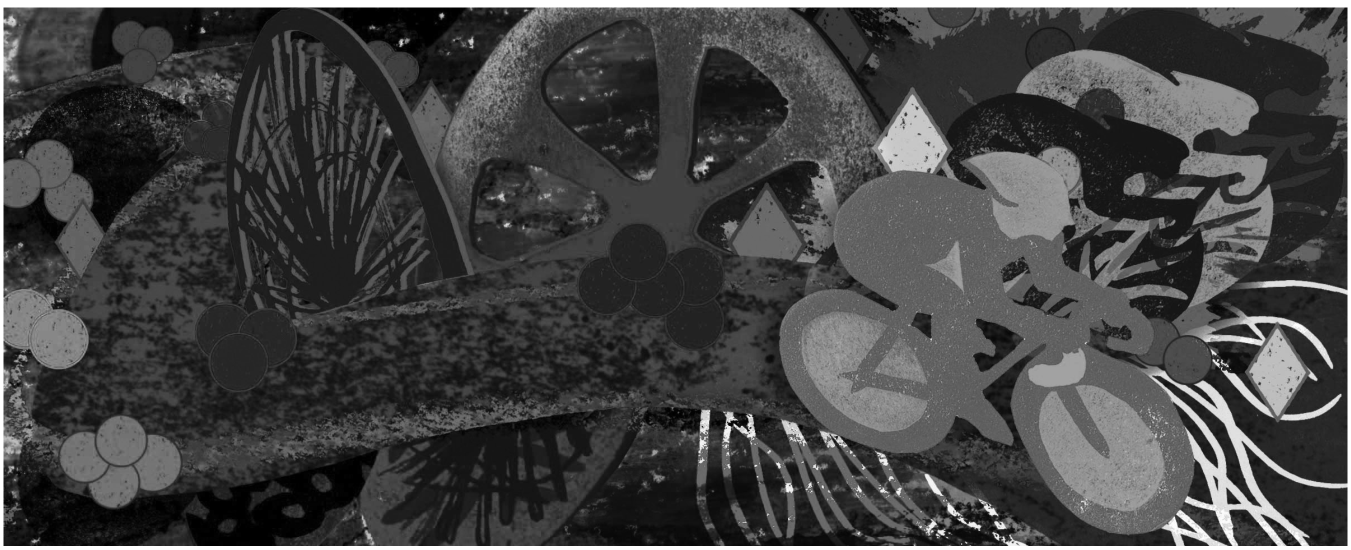
Name: ______________________ Date: ______________

Chapter 4: Metabolism and Athletic Performance
Chapter Overview

In this final chapter, you'll use what you've learned about metabolism to solve a new problem. A champion athlete is suspected of increasing his cellular respiration through illegal methods. Analyze the evidence to decide for yourself what the best explanation is for his improved performance.



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Name: ______________________________ Date: ____________________

Lesson 4.1: Going for Gold: A Cycling Champion's Story

Today, you will learn about a professional racing cyclist who placed 35th in a competitive race and then won a similar race the following year. Some officials think that this athlete's dramatic improvement might have been due to illegal blood doping. Others believe that his improvement could have been caused by changes he made to his diet or the way he trained. In the next two lessons, you will examine evidence and decide for yourself what you think he did to improve his performance so drastically in one year.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 4 Question

- How did the athlete increase his cellular respiration and improve his performance?

Key Concepts

- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.
- In a functioning human body, body systems work together to deliver glucose, oxygen, and amino acid molecules to the cells in the body.
- In order to release energy, cells need both glucose and oxygen molecules.
- Inside the cell, the atoms that make up glucose and oxygen can be rearranged to make different molecules. This chemical reaction is called cellular respiration and releases energy.
- Systems can work together to form a larger more complex system.

Vocabulary

- cellular respiration
- energy
- glucose
- metabolism
- molecules
- oxygen

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Warm-Up

Soon you will watch a video about an athlete whose improved performance has led some to suspect him of blood doping. Think back to what you learned about the blood doping process. What do you remember about how blood doping works and how it could affect cellular respiration?

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Introducing the Science Seminar Sequence

Elite athlete Jordan Jones finished 35th in a competitive bike race last year and finished first in a similar race this year.

How did he increase his cellular respiration and improve his performance?

- **Claim 1:** Jordan Jones increased his cellular respiration and improved his performance by blood doping.
- **Claim 2:** Jordan Jones increased his cellular respiration and improved his performance by changing his pre-race meal.
- **Claim 3:** Jordan Jones increased his cellular respiration and improved his performance by training at a higher altitude.

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Blood Doping and High-Altitude Training

1. Focus on the sections "Catching Blood Dopers" and "An Alternative to Blood Doping" in the "Blood Doping: Messing with Metabolism to Win Races" article.
2. Then, answer the questions below.

How do doctors use the age of red blood cells to decide whether or not someone was blood doping?

____

____

How do doctors use hemoglobin levels to decide whether or not someone was blood doping?

____

____

At high altitude there is __________ oxygen in the air than at lower altitudes, such as sea level.

- ☐ more
- ☐ less
- ☐ the same amount of

How can high-altitude training help athletes get more oxygen to their cells?

____

____

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Evaluating Example Evidence

Review the following two examples of evidence and claims, and then answer the question below.

Example A: A person ate a ham sandwich and ran a race. She finished in first place.

Claim: The ham sandwich was the reason she won, and she should eat ham sandwiches before all her races.

Example B: A person ate different meals before 20 races that he ran. For ten races, he ate spaghetti before the race and finished in either first, second, or third place. For the other ten races, he ate fried chicken and finished in second place once, but finished in sixth or seventh place in the rest of the races.

Claim: Spaghetti helped his performance, and he should eat spaghetti before all his races.

Which claim is based on higher-quality evidence?

- ☐ example A
- ☐ example B

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Evaluating Evidence Cards

Scientists evaluate the quality of evidence when they are building a scientific argument. Evidence is higher quality when it is based on more data because there can be more confidence in the patterns seen in the data.

1. With your partner, discuss each evidence card and use the Evidence Gradient to rate whether the evidence is high quality, medium quality, or low quality. For each piece of evidence, ask yourself the following question: *Does this provide enough data to establish a pattern?*
2. We will discuss as a class how you evaluated the evidence. After the class discussion, review the evidence cards you rated as low quality. If you feel they are not of high enough quality to include in your argument, put them in a discard pile.
3. Once you have decided which evidence cards to keep, place your cards in your own envelope and write your name on the envelope. Your partner should do the same.

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Name: ____________________ Date: ____________

Lesson 4.2: Analyzing Evidence

Today you will get more evidence about Jordan Jones. You will use this evidence to think about the claims that were made about his improved performance. Did Jordan really use blood doping to improve his performance so greatly? Or, did high-altitude training help his performance? Maybe it was the pre-race meal that he had? It will be up to you to consider the evidence and decide what Jordan Jones did to make such an amazing leap from 35th to 1st place in just one year!

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 4 Question

- How did the athlete increase his cellular respiration and improve his performance?

Key Concepts

- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.
- In a functioning human body, body systems work together to deliver glucose, oxygen, and amino acid molecules to the cells in the body.
- In order to release energy, cells need both glucose and oxygen molecules.
- Inside the cell, the atoms that make up glucose and oxygen can be rearranged to make different molecules. This chemical reaction is called cellular respiration and releases energy.
- Systems can work together to form a larger more complex system.

Vocabulary

- cellular respiration
- energy
- glucose
- molecules
- claim
- evidence
- metabolism
- oxygen

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Name: ____________________ Date: ____________

Warm-Up

Officials working for the National Biking Association have made different claims about how Jordan Jones won the American Cycling Classic this year. Right now, which claim do you think is the strongest?

- ☐ **Claim 1:** Jordan Jones increased his cellular respiration and improved his performance by blood doping.
- ☐ **Claim 2:** Jordan Jones increased his cellular respiration and improved his performance by changing his pre-race meal.
- ☐ **Claim 3**: Jordan Jones increased his cellular respiration and improved his performance by training at a higher altitude.

Why do you think that claim is the strongest?

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Name: ______________________________ Date: ______________

Examining and Discussing Evidence About Jordan Jones's Race

Part 1: Reading and Annotating Evidence Cards

1. Set the three claim cards aside for now.
2. Read each evidence card carefully and annotate as needed.
3. At the bottom of each card, write one sentence to explain how this evidence connects to one or more of the claims about how Jordan Jones improved his performance.
4. Combine these cards with the evidence cards you evaluated in the last lesson.

Part 2: Discussing and Sorting Evidence

1. Place the three claim cards in a row on your desk.
2. With your partner, choose one evidence card at a time to focus on. Before you place each card under a claim, discuss your thinking with your partner.
3. Place each evidence card under the claim you think it best supports. Repeat this process until you've sorted all your cards. (Note: Do not sort Card O yet; set that card aside for now.)

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Compare Jordan Jones' Pre-race Meals

1. Re-read Card N.
2. Read and annotate Card O
3. Discuss what Card O tells you about Card N with a partner.

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Name: ______________________________ Date: ______________

Lesson 4.3: The Science Seminar

Did Jordan Jones engage in blood doping? In the Science Seminar today, you and your classmates will be doing most of the talking as you discuss the evidence and try to arrive at the best explanation for Jordan Jones's improved performance. By the end of the lesson, you'll be ready to write a convincing scientific argument.

Unit Question

- How do the trillions of cells in the human body get what they need to function, and what do the cells do with the things they absorb?

Chapter 4 Question

- How did the athlete increase his cellular respiration and improve his performance?

Key Concepts

- The respiratory system brings in oxygen molecules from the air. These oxygen molecules are already small enough to fit into cells.
- The digestive system brings in food and breaks it down into smaller molecules, such as glucose and amino acids, that can fit into cells.
- The circulatory system transports glucose, oxygen, and amino acid molecules to every cell in the body.
- In a functioning human body, body systems work together to deliver glucose, oxygen, and amino acid molecules to the cells in the body.
- In order to release energy, cells need both glucose and oxygen molecules.
- Inside the cell, the atoms that make up glucose and oxygen can be rearranged to make different molecules. This chemical reaction is called cellular respiration and releases energy.
- Systems can work together to form a larger more complex system.

Vocabulary

- cellular respiration
- claim
- energy
- evidence
- glucose
- metabolism
- molecules
- oxygen

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Name: ____________________ Date: ____________

Warm-Up

Read the message from Dr. Walker and answer the question below.

To: Medical Students
From: Dr. Walker
Subject: Jordan Jones

After reviewing Jordan Jones's pre-race meals, along with the evidence from Card N, we don't believe the changes in his meals could explain his improved performance. The difference in the amount of starch between the two meals wasn't enough to have a dramatic effect on his body's ability to release energy through cellular respiration.

Therefore, we want you to focus on the two other claims the National Biking Association asked us to investigate:

Claim 1: Jordan Jones increased his cellular respiration and improved his performance by blood doping.

Claim 3: Jordan Jones increased his cellular respiration and improved his performance by training at a higher altitude.

Do you agree with Dr. Walker and his colleagues that the changes to Jordan Jones's meal could not explain his improved performance? Why or why not?

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Name: ______________________ Date: ______________

Preparing for the Science Seminar

Instructions for Preparing Argument Organizers for Claims 1 and 3

1. Review the evidence that you already connected to Claim 1. Choose the most important evidence cards to support this claim.
2. Glue these evidence cards onto the Argument Organizer under the claim.
3. Clip any other evidence cards that support the claim to the back of the Argument Organizer.
4. Repeat steps 1–3 for Claim 3 to make your second Argument Organizer.
5. If time allows, write notes about the evidence cards in the extra space on each Argument Organizer.

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Name: ______________________________ Date: ________________

Participating in the Science Seminar

Science Seminar Expectations

Students are expected to:

- run the conversation.
- use evidence to support ideas.
- explain their thinking.
- listen to one another.
- respond to one another.
- be open to changing their minds.

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Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the Seminar	Check marks
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of the evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

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Homework: Writing a Final Argument

Over the last few days, you and your classmates thought about arguments that could be made to answer this question:

How did the athlete increase his cellular respiration and improve his performance?

You have considered three claims.

- **Claim 1:** Jordan Jones increased his cellular respiration and improved his performance by blood doping.
- **Claim 2:** Jordan Jones increased his cellular respiration and improved his performance by changing his pre-race meal.
- **Claim 3:** Jordan Jones increased his cellular respiration and improved his performance by training at a higher altitude.

Your final written argument about Jordan Jones has three parts:

- **Part 1:** Writing an argument to support Claim 1 or Claim 3.
- **Part 2:** Explaining why the other claim is not as strong.
- **Part 3:** Explaining why Claim 2 is not supported.

Scientific Argument Sentence Starters

Describing evidence:	**Describing how evidence supports a claim:**
The evidence that supports my claim is . . .	If ______, then . . .
My first piece of evidence is . . .	This is important because . . .
Another piece of evidence is . . .	Since . . .
This evidence shows . . .	Based on the evidence, I conclude that . . .

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Name: ______________________________ Date: ________________

Homework: Writing a Final Argument (continued)

Part 1: Use the Science Seminar Evidence Cards, along with any other evidence from the unit you think is important, to support the claim that you think is strongest based on all the evidence that was available to you.

Write the claim you chose first, then complete the argument. In order to be convincing to someone who reads it, your argument should explain:

- what cellular respiration is;
- what blood doping or training at a higher altitude does to increase cellular respiration; and
- why you think your claim is the best explanation for Jordan Jones's improved performance.

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Part 2: Use the Science Seminar Evidence Cards to explain why you think the other claim (Claim 1 or Claim 3) is not as strong.

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Name: ______________________ Date: ______________

Homework: Writing a Final Argument (continued)

Part 3: Write an argument against Claim 2.

We do know that diet can affect cellular respiration and performance, even if it doesn't explain why Jordan Jones performed better in his race. In order to explain why Claim 2 is not supported, write an argument that includes:

- how starch/glucose are involved in cellular respiration;
- how a diet high in starch could help an athlete perform well; and
- why the evidence does not support the claim that Jordan Jones's change in diet resulted in his improved performance.

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Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that scientists can be more or less certain of their claims depending on the evidence they have. ☐ yes ☐ not yet (check one and explain your answer choice)

2. What are the most important things you have learned in this unit?

3. What questions do you still have?

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Metabolism Glossary

amino acids: molecules that are the building blocks of proteins

aminoácidos: moléculas que son los componentes fundamentales de las proteínas

carbon dioxide: a molecule made of carbon and oxygen atoms

dióxido de carbono: una molécula hecha de átomos de carbono y oxígeno

cellular respiration: the chemical reaction between oxygen and glucose that releases energy into cells
respiración celular: la reacción química entre oxígeno y glucosa que libera energía en las células

chemical reaction: a process in which atoms rearrange to form new substances

reacción química: un proceso en el que los átomos se reorganizan para formar nuevas sustancias

circulatory system: the body system that transports molecules to and from all cells of the body

sistema circulatorio: el sistema que transporta moléculas desde y hacia todas las células del cuerpo

claim: a proposed answer to a question about the natural world

afirmación: una respuesta propuesta a una pregunta sobre el mundo natural

digestive system: the body system that takes in food and breaks it down

sistema digestivo: el sistema del cuerpo que toma alimento por dentro y lo desintegra

energy: the ability to make things move or change

energía: la capacidad de hacer que las cosas se muevan o cambien

evidence: information about the natural world that is used to support or go against (refute) a claim

evidencia: información sobre el mundo natural que se utiliza para respaldar o rechazar (refutar) una afirmación

glucose: a molecule that organisms can use to release energy, and that is made of carbon, hydrogen, and oxygen atoms

glucosa: una molécula que los organismos pueden usar para liberar energía y que está hecha de átomos de carbono, hidrógeno y oxígeno

metabolism: the body's use of molecules for energy and growth

metabolismo: el uso de moléculas por el cuerpo para obtener energía y crecer

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Metabolism Glossary (continued)

molecule: a group of atoms joined together in a particular way

molécula: un grupo de átomos unidos de una manera particular

oxygen: a molecule that organisms get from the air or water around them and use to release energy

oxígeno: una molécula que los organismos obtienen del aire o del agua a su alrededor y que se utiliza para liberar energía

proteins: a category of large molecules that perform important functions inside living things

proteínas: una categoría de moléculas grandes que desempeñan funciones importantes dentro de los seres vivientes

reasoning: the process of making clear how your evidence supports your claim

razonamiento: el proceso de aclarar cómo tu evidencia respalda tu afirmación

respiratory system: the body system that takes in oxygen and releases carbon dioxide

sistema respiratorio: el sistema del cuerpo que toma dentro oxígeno y libera dióxido de carbono

scientific argument: a claim supported by evidence

argumento científico: una afirmación respaldada por evidencia

starch: a type of energy storage molecule made of many glucose molecules connected together

almidón: un tipo de molécula de almacenamiento de energía hecha de muchas moléculas de glucosa unidas

system: a set of interacting parts forming a complex whole

sistema: un conjunto de partes que interactúan formando un todo complejo

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Lawrence Hall of Science:
Program Directors: Jacqueline Barber and P. David Pearson
Curriculum Director, Grades K–1: Alison K. Billman
Curriculum Director, Grades 2–5: Jennifer Tilson
Curriculum Director, Grades 6–8: Suzanna Loper
Assessment and Analytics Director: Eric Greenwald
Learning Progressions and Coherence Lead: Lauren Mayumi Brodsky
Operations and Project Director: Cameron Kate Yahr
Student Apps Director: Ari Krakowski
Student Content Director: Ashley Chase

Leadership Team: Jonathan Curley, Ania Driscoll-Lind, Andrew Falk, Megan Goss, Ryan Montgomery, Padraig Nash, Kathryn Chong Quigley, Carissa Romano, Elizabeth Shafer, Traci K. Shields, Jane Strohm

***Metabolism**: Making the Diagnosis* **Unit Team:**

Maria Alvarelos
Stacy Au-yang
Elizabeth Ball
Candice Bradley
Lisa Damerel
Mason E. Hanson
Nadja Lazansky
Deirdre MacMillan
Helen O. Min
Christina Morales
Patrice Scinta
Elizabeth Shafer
Sara R. Walkup

Amplify:

Irene Chan
Samuel Crane
Shira Kronzon
Charvi Magdaong
Thomas Maher
Rick Martin
Matt Reed
Eve Silberman
Steven Zavari

Metabolism:

Making the Diagnosis

Article Compilation

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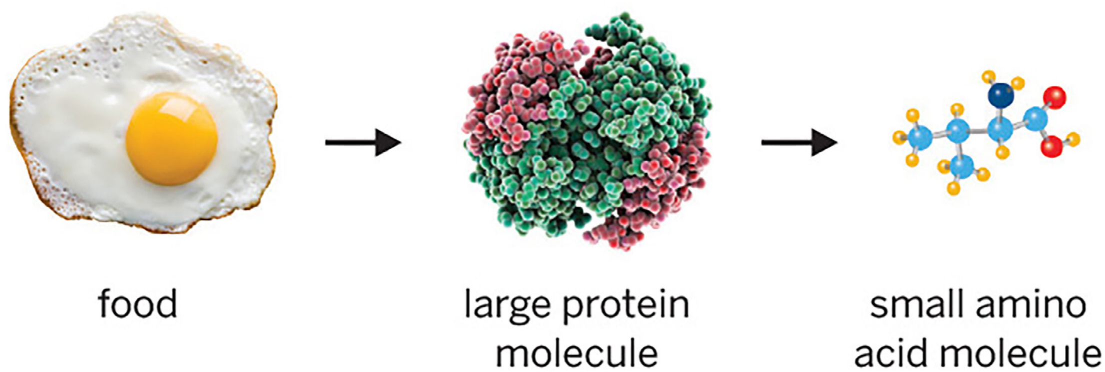
Molecules Cells Need

When your body is healthy, it runs so smoothly that you probably don't even notice it: without thinking about it, you can get up in the morning, breathe, laugh, dance, grow, fight off diseases, and live your life! But what makes a body healthy, and how does it stay that way? In a healthy body, all the systems work together to make sure every cell gets the molecules it needs: oxygen, glucose, and amino acids. Metabolism is the body's use of these molecules for energy and growth.

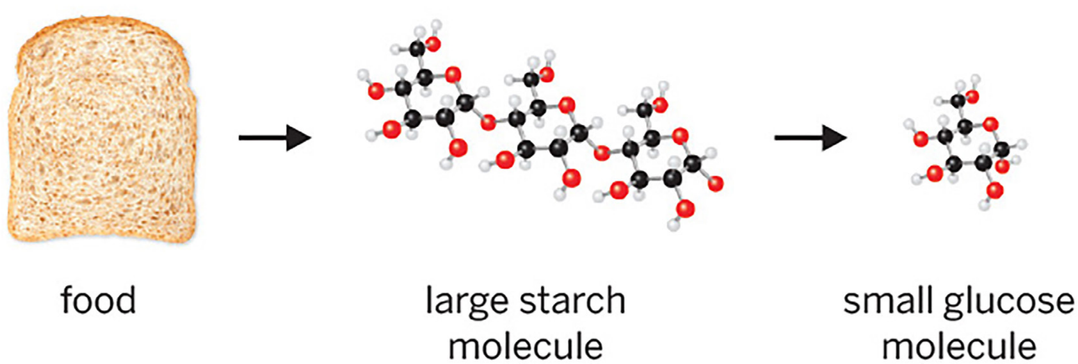
We need to breathe in oxygen molecules from the air around us to keep our bodies alive. Our bodies get other important molecules, such as amino acids and glucose, from the food we eat.

Amino acid molecules are the building blocks of proteins, and we get them from protein-rich foods like beans, meat, and eggs. We get glucose molecules mainly by breaking down foods that contain starch, such as fruits, vegetables, and grains.

The oxygen, glucose, and amino acid molecules you get from air and food are the fuel your body needs to function every day. Without these molecules, your cells can't do what they need to do to keep your body healthy. Many medical conditions cause problems because they can keep these molecules from reaching your cells consistently.



Many foods, such as eggs, contain protein. Large protein molecules are made up of smaller molecules called amino acids.



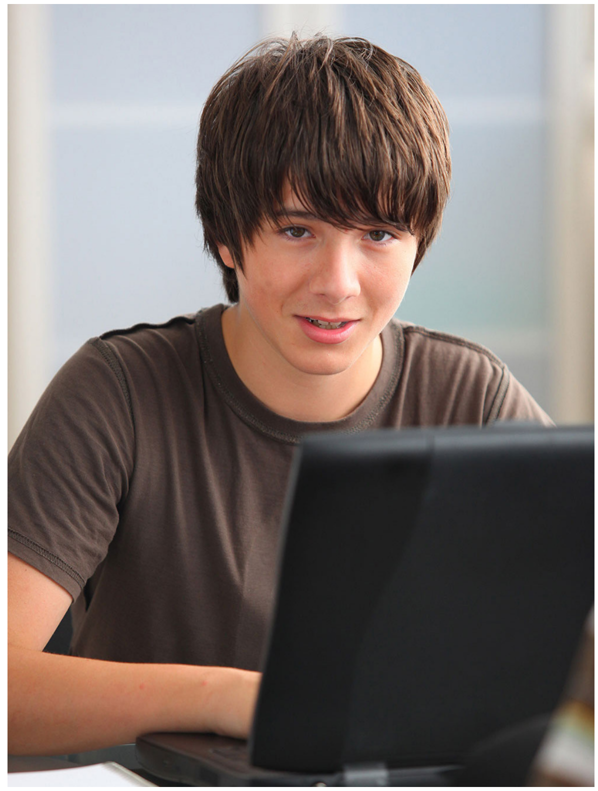
Many foods, such as bread, contain starch. Large starch molecules are made up of smaller molecules called glucose.

Molecules Cells Need © The Regents of the University of California. All rights reserved. Image credit: Science Source

Patient Stories: Problems with Body Systems

With every breath and every bite of food, the human body takes in millions of molecules. These molecules are so small that they can't be seen under a common microscope, but the body can't live without them. How can something so tiny be so important to the health of the whole body? When everything works properly, the body gets certain molecules from food and from the air. The molecules enter the cells of the body and provide everything the cells need to be healthy. Healthy cells make up healthy organs, and healthy organs work together in systems to keep the body breathing, moving, thinking, and releasing energy. The relationship between molecules and health isn't just a cool idea: tiny molecules can actually make a person feel better or worse!

Sometimes people get sick because their cells aren't getting the molecules they need. When this happens, we say the person has a medical condition. Doctors often look for medical conditions when a patient's symptoms don't seem to be caused by something like bacteria or a virus. In many cases, people can manage medical conditions by taking medicine to make sure their bodies get the molecules they need. Read the following story to find out about a person whose body systems didn't provide his cells with everything they need.



Anemia can make patients feel very tired.

Anemia: Red Blood Cell Shortage

My Story

A few months ago, I was feeling tired all the time. I tried taking it easy and getting extra sleep, but that didn't help. I even started feeling like I was going to faint sometimes. My dad took me to the doctor, and she tested my blood. She said my red blood cell count was lower than normal, and the amount of oxygen in my blood was also lower than normal. Based on the blood test, the doctor gave me a diagnosis: anemia. I asked the doctor about anemia—I wanted to know what it was and how I got it! She said anemia means having fewer red blood cells than a healthy person does.

Anemia: Red Blood Cell Shortage © The Regents of the University of California. All rights reserved. Image Credit: Shutterstock

How Anemia Affected My Body

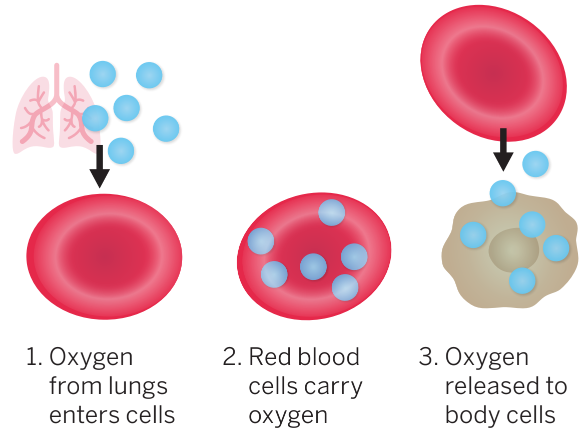
With each breath, oxygen molecules go into our lungs, which are part of the respiratory system. The oxygen molecules move from the lungs through tiny structures called alveoli (al-VEE-oh-lie) and into the circulatory system. The circulatory system is filled with red blood cells, and these red blood cells quickly pick up the oxygen from the lungs and move it all around the body. Through this process, oxygen molecules are delivered to cells all over the body. Cells need oxygen to function well.

My anemia was affecting my red blood cells. Even though my respiratory system was taking in plenty of oxygen, I didn't have enough red blood cells to carry the oxygen around in my circulatory system. Because I had fewer red blood cells to carry oxygen, there was less oxygen in my circulatory system. Because of this, my cells were not getting as much oxygen as a healthy person's cells. My cells were not getting enough oxygen, so they were not doing well—and neither was I!

The doctor said my anemia was probably caused by not getting enough iron in the food I was eating. Not getting enough iron is the most common cause of anemia. Your body needs iron to make red blood cells: if your body doesn't have enough iron, it won't have enough red blood cells.

How I Stay Healthy

The doctor must have been right about the iron, because as soon as I started taking iron pills, I started feeling more energetic. Now I feel fine! I don't need to take iron pills anymore, because I'm making sure to eat plenty of beans, meat, and greens like spinach—those are all foods with lots of iron in them. With these changes, I have plenty of energy.



Oxygen molecules pass from the lungs into the blood, where they are picked up by red blood cells. The red blood cells carry the oxygen to body cells, which can use it to release energy.

Eating plenty of iron-rich foods can help cure and prevent anemia.

Anemia: Red Blood Cell Shortage © The Regents of the University of California. All rights reserved. Image Credit: (b) Shutterstock

Patient Stories: Problems with Body Systems

With every breath and every bite of food, the human body takes in millions of molecules. These molecules are so small that they can't be seen under a common microscope, but the body can't live without them. How can something so tiny be so important to the health of the whole body? When everything works properly, the body gets certain molecules from food and from the air. The molecules enter the cells of the body and provide everything the cells need to be healthy. Healthy cells make up healthy organs, and healthy organs work together in systems to keep the body breathing, moving, thinking, and releasing energy. The relationship between molecules and health isn't just a cool idea: tiny molecules can actually make a person feel better or worse!

Sometimes people get sick because their cells aren't getting the molecules they need. When this happens, we say the person has a medical condition. Doctors often look for medical conditions when a patient's symptoms don't seem to be caused by something like bacteria or a virus. In many cases, people can manage medical conditions by taking medicine to make sure their bodies get the molecules they need. Read the following story to find out about a person whose body systems didn't provide her cells with everything they need.

Asthma is a condition that makes it difficult to breathe.

Asthma: Struggling to Breathe

My Story

I found out I have asthma. I would sometimes have trouble breathing, especially when I exercised during PE class. If I ran home from the bus stop, I would have trouble catching my breath afterward. It felt like my chest was tightening up, and it was hard to breathe. I would make a noise when I was trying to breathe, and my mom told me that was called wheezing.

I went to the doctor and she listened to my lungs, did some other tests, and asked me a lot of questions about when I have a hard time breathing. She said I have asthma. This diagnosis means that if something like exercise or dust irritates my lungs, the tubes inside my lungs swell up. When the tubes swell, they get narrow and not as much air can get through. That can make it hard to breathe.

Asthma: Struggling to Breathe © The Regents of the University of California. All rights reserved. Image Credit: Shutterstock

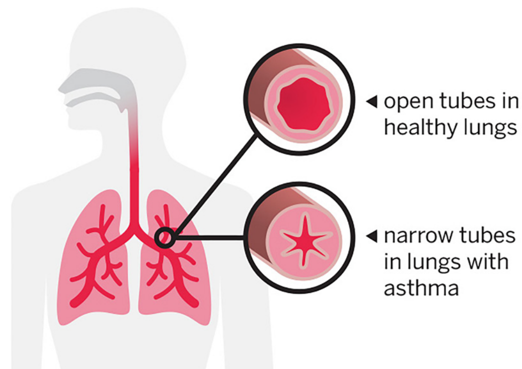
How Asthma Affects My Body

The doctor explained that asthma affects more than just your breathing. She said that when you breathe in, you pull oxygen molecules from the air into your respiratory system. In your respiratory system, the oxygen moves through smaller and smaller tubes deep into your lungs. Inside the lungs are tiny structures called alveoli (al-VEE-oh-lie). In the alveoli, oxygen molecules move from the respiratory system into the blood of the circulatory system. Your blood carries those oxygen molecules throughout your circulatory system, delivering oxygen to all the cells of your body.

Because of asthma, the tiny tubes in my lungs were squeezing shut, and I wasn't getting as many oxygen molecules into my respiratory system as a healthy person would. Because there was less oxygen in my respiratory system, there was less oxygen moving into the blood in my circulatory system. With too little oxygen in my blood, not enough oxygen was getting to my cells. Cells need oxygen! Without oxygen, cells can't do any of the things they need to do for the body to function. I wasn't doing well because my cells weren't doing well.

How I Stay Healthy

The doctor gave me an inhaler to help me breathe when I have an asthma attack. The inhaler stops the tubes in my lungs from swelling, keeping the tubes wide and letting me breathe in more oxygen. The doctor also told me to be careful of certain things, like lots of dust. For instance, the playing fields at my school can get really dusty. When that happens, I should try not to play sports outside. I still participate in PE class, but I tell the teacher when I need to use my inhaler or take a short break. Now I know what causes my asthma attacks and how to take care of myself so they don't happen as often.



Asthma causes the tubes in the lungs to close up, so that air cannot pass through.

People with asthma can use inhalers to keep the tubes in their lungs open.

Asthma: Struggling to Breathe © The Regents of the University of California. All rights reserved. Image Credit: Shutterstock

Patient Stories: Problems with Body Systems

With every breath and every bite of food, the human body takes in millions of molecules. These molecules are so small that they can't be seen under a common microscope, but the body can't live without them. How can something so tiny be so important to the health of the whole body? When everything works properly, the body gets certain molecules from food and from the air. The molecules enter the cells of the body and provide everything the cells need to be healthy. Healthy cells make up healthy organs, and healthy organs work together in systems to keep the body breathing, moving, thinking, and releasing energy. The relationship between molecules and health isn't just a cool idea: tiny molecules can actually make a person feel better or worse!

Sometimes people get sick because their cells aren't getting the molecules they need. When this happens, we say the person has a medical condition. Doctors often look for medical conditions when a patient's symptoms don't seem to be caused by something like bacteria or a virus. In many cases, people can manage medical conditions by taking medicine to make sure their bodies get the molecules they need. Read the following story to find out about a person whose body systems didn't provide her cells with everything they need.

Diabetes prevents the cells in the body from getting the glucose they need.

Diabetes: Glucose Locked Out

My Story

I was diagnosed with type I diabetes when I was five years old. You may have heard of the phrase "blood sugar." When people talk about blood sugar they really mean blood glucose. Glucose is a kind of molecule that cells need in order to release energy, and all people have glucose in their blood. If you have diabetes, your level of blood glucose can get too high.

Diabetes: Glucose Locked Out © The Regents of the University of California. All rights reserved. Image Credit: © iStock.com/MarkHatfield

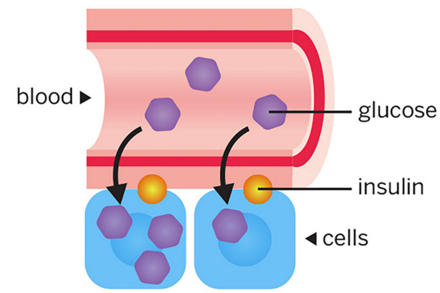
Where does that glucose come from? When you eat starch and other carbohydrates, your digestive system breaks them down into glucose. Then the glucose moves into your blood, and your circulatory system carries it throughout your body. If you don't have diabetes, that glucose moves from your circulatory system into all of your cells. For a person with diabetes, it's not that simple.

How Diabetes Affects My Body

Glucose doesn't just go into your cells automatically. Cells are actually very picky about which molecules are allowed to cross the cell membrane and enter the cell. In order to get glucose into a cell, the cell membrane needs to be unlocked. A molecule called insulin acts like a key to unlock the cell membrane and let glucose inside. Insulin is a protein molecule made in special cells and released into the blood of the circulatory system, which carries the insulin to every cell in the body. People with diabetes have trouble making insulin. Since I have diabetes, my body is not making enough insulin.

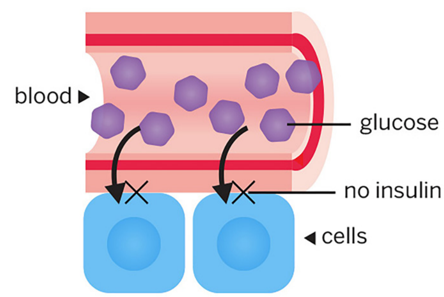
Without insulin, glucose is locked out of my cells. The glucose molecules can't get through the cell membranes—they just get stuck in my circulatory system. When that happens, the amount of glucose in my blood gets higher than normal. More important, my cells don't get as much glucose as they need. Other molecules can get into my cells just fine, but not glucose. When my cells aren't getting enough glucose, they can't function—and that can become very dangerous!

No Diabetes



In a person without diabetes, insulin allows glucose to enter the cell, where it can be used to release energy.

Diabetes



In a person with diabetes, there's no insulin to "unlock" the cells and allow glucose to go in. Because the glucose cannot leave the blood, there is too much glucose in the blood.

Diabetes: Glucose Locked Out © The Regents of the University of California. All rights reserved.

People with diabetes must test the levels of glucose in their blood.

How I Stay Healthy

To keep myself healthy, I've learned how to control the amount of glucose in my blood. I measure my blood glucose several times a day, and use the test results to decide what to eat and when. I also take a kind of insulin that is made in a lab. When I take insulin, my circulatory system carries the insulin to all the cells in my body. The insulin unlocks my cell membranes so that glucose molecules can move from my circulatory system into my cells. That way, my blood glucose doesn't get too high, my cells get enough glucose, and I stay healthy.

Diabetes: Glucose Locked Out © The Regents of the University of California. All rights reserved. Image Credit: © iStock.com/MarkHatfield

Patient Stories: Problems with Body Systems

With every breath and every bite of food, the human body takes in millions of molecules. These molecules are so small that they can't be seen under a common microscope, but the body can't live without them. How can something so tiny be so important to the health of the whole body? When everything works properly, the body gets certain molecules from food and from the air. The molecules enter the cells of the body and provide everything the cells need to be healthy. Healthy cells make up healthy organs, and healthy organs work together in systems to keep the body breathing, moving, thinking, and releasing energy. The relationship between molecules and health isn't just a cool idea: tiny molecules can actually make a person feel better or worse!

Sometimes people get sick because their cells aren't getting the molecules they need. When this happens, we say the person has a medical condition. Doctors often look for medical conditions when a patient's symptoms don't seem to be caused by something like bacteria or a virus. In many cases, people can manage medical conditions by taking medicine to make sure their bodies get the molecules they need. Read the following story to find out about a person whose body systems didn't provide his cells with everything they need.

An injury to the pancreas keeps the body from digesting food properly.

Injury to the Pancreas: Trouble Digesting

My Story

When I was a little kid, I got hit by a car when I was riding my bike. Luckily I was wearing my helmet, so I survived. Still, I was pretty badly injured where the car ran into my body. I had to go to the hospital and have some operations. I seemed fine for a long time after that, but then I started to get sick. It felt like I wasn't digesting my food right. My insides usually hurt after I ate, and I had diarrhea. I also felt tired a lot.

My parents took me to see the doctor. After a bunch of tests, the doctor said that my pancreas must have been injured in the bike accident. He said I have chronic pancreatitis, which means that my injured pancreas isn't

Injury to the Pancreas: Trouble Digesting © The Regents of the University of California. All rights reserved. Image Credit: Shutterstock

working as well as it should. I'd never even heard of a pancreas! The doctor explained that it's a small but important organ that's part of the digestive system. He said injury to the pancreas is a really unusual diagnosis, and that may be why no one figured it out earlier.

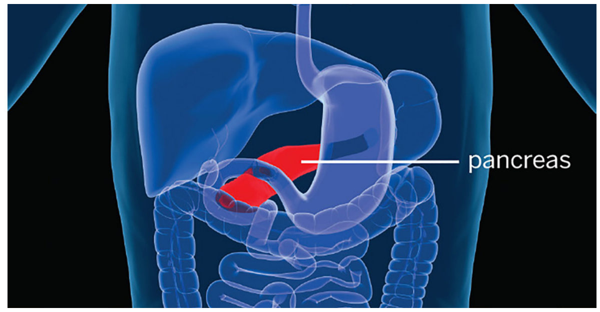
How My Pancreas Injury Affects My Body

The pancreas is part of the digestive system and makes lots of digestive enzymes. These enzymes help break down food into smaller molecules, like glucose and amino acids, that are tiny enough to pass from the digestive system into the circulatory system. Because my pancreas was damaged, it wasn't making as many digestive enzymes as a healthy pancreas would.

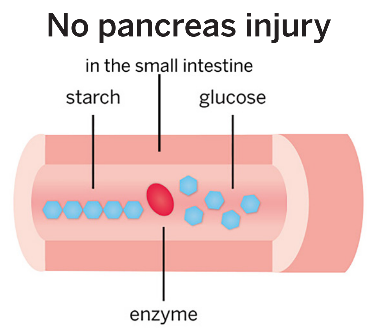
Without enough enzymes, my body was having trouble digesting food—that's what was making me feel sick. Most of the food wasn't breaking down into molecules like glucose and amino acids, so not as many of those molecules were entering my circulatory system as they would in a healthy body. The undigested starches and proteins were just moving right through my digestive system and leaving my body as waste. My cells weren't getting as many glucose molecules as they needed, which was making me feel tired all the time.

How I Stay Healthy

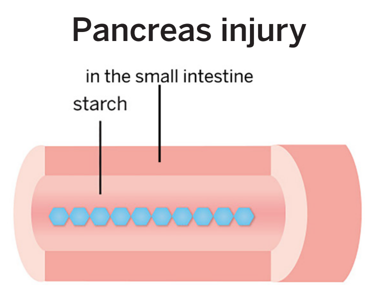
The good news is that scientists have figured out how to make most of the enzymes that a healthy body needs. To stay healthy, I've been taking medicines with enzymes in them, and they are helping my body digest food much better. Now my cells are getting all the molecules they need. I still have a damaged pancreas, but I'm feeling much better.



The pancreas is an organ located underneath the liver and near the stomach.



The pancreas makes enzymes that break down food into smaller molecules.



Without the enzymes made by the pancreas, starch molecules aren't broken down into glucose molecules.

Medicines with enzymes in them can help people with pancreas injuries stay healthy.

Injury to the Pancreas: Trouble Digesting © The Regents of the University of California. All rights reserved. Image Credit: (t) © iStock.com/Raycat

Meet a Scientist Who Grows New Cells

When parts of the body get old or injured, they sometimes stop working the way they should—and cause pain, sickness, or worse. In many cases, doctors can help patients by replacing a part or a whole organ with a machine or a mechanical version, like an artificial heart or a knee joint made from plastic and metal. But what if scientists could grow brand-new organs and use them instead of the mechanical versions? Dr. Grace O'Connell, a researcher at the University of California, Berkeley, is trying to do just that.

O'Connell and the students in her lab study the soft tissues in the spine—specifically the squishy discs of tissue between the vertebrae, or bones, of the spine. Because these discs are between the vertebrae, they're called intervertebral discs. The discs act like cushions between the vertebrae, allowing the spine to bend and keeping the vertebrae from touching. The discs in the spine sometimes begin to wear out with age, or squeeze out from between the vertebrae, so they don't offer as much cushioning. That's a sore spot: vertebrae rubbing together or discs putting pressure on the spinal nerves can cause back pain. In most cases, doctors don't replace discs when they wear out; instead, they remove the worn-out or injured disc and glue the vertebrae above and below it together, forming one longer bone. The glued bone doesn't cause as much pain, but it's also less flexible than two vertebrae with a healthy disc between them.

Dr. Grace O'Connell is working to grow new tissue for spinal discs, which could help people with back problems.

The discs between vertebrae (shown here in white) allow the spine to bend and keep the vertebrae from touching or rubbing against nerves in the spine.

Meet a Scientist Who Grows New Cells © The Regents of the University of California. All rights reserved. Image Credit: (b) Shutterstock

O'Connell hopes to change the way doctors treat damaged or worn-out discs. Instead of gluing the vertebrae together, she hopes to grow brand-new disc tissue to replace old or injured discs! Her lab has two main goals: to study healthy intervertebral discs and to grow new intervertebral disc tissue that behaves just like healthy discs.

Because tissues are made of cells, O'Connell is really working with cells. She begins with a small sample of disc cells and encourages them to reproduce and form new disc tissue. To make the tissue perform exactly like healthy disc tissue, O'Connell and her students look at the cells and how they behave. "The cells create the tissue, which gives the joint its function," she says. "So we look at the way the whole disc works, but we also keep in mind that the cells are really responsible, and we look at how the cells are changing things." Some of the cells O'Connell and her students study come from human medical patients: "Patients sign a release that says they're willing to donate their cells to science, and we get to grow their cells," she says. But sometimes O'Connell and her students study cells that aren't human—and they come from the butcher down the street!

"We get the oxtails," she says. "If they're fresh, the cells are still living, and we can use them."

Growing up near Philadelphia, O'Connell wanted to fly and design airplanes. She even took flying lessons in high school! In college, she studied aeronautical engineering—the study of engineering for flight—but decided to use her engineering knowledge to help people with health problems instead, and studied the way engineering relates to the body. Along the way, she says, "I studied math. Lots of math." She still hopes to earn her pilot's license someday.

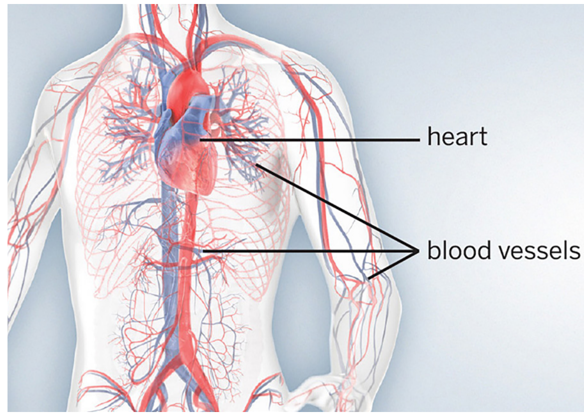
Today, she enjoys the challenges of trying to grow new disc tissue from just a few cells—even when her work doesn't go as planned. "One of the biggest challenges of this kind of research is that the cells don't always do what you want them to," she says. "But sometimes that leads to new questions and new learning." In fact, she says one of the hardest parts of the job is finding out that there are some things nobody knows. "You're told 'this is how things are,' when this really isn't how things are in reality. There's a lot that nobody knows, and you have to find out. It's challenging, but it's very exciting when you do learn something that nobody else knew before."

The scientists at Dr. O'Connell's lab grow new cells in dishes of cell culture medium, which helps support cellular growth.

Meet a Scientist Who Grows New Cells © The Regents of the University of California. All rights reserved. Image Credit: Getty Images

Systems of the Human Body: The Circulatory System

When blood travels through the body, bringing important molecules to cells that need them, it doesn't just flow anywhere and everywhere. Blood flows through a complex system that takes it where it's needed. The circulatory system is made up of blood vessels that extend throughout the body, the blood that moves through the blood vessels, and the heart. It's called the circulatory system because the blood circulates—flows around and around. Blood circulates through the blood vessels to and from the heart and every cell, organ, and system in the entire body. The circulatory system connects the cells to the other body systems, transporting molecules between those systems and the cells. Without the circulatory system, cells could not get what they need from the respiratory system or the digestive system.

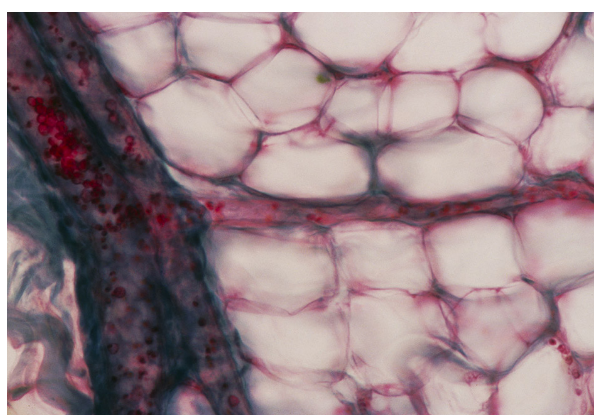


The circulatory system includes the heart, blood vessels, and the blood itself. It transports molecules to and from body cells.

This photo was taken through a powerful microscope. It shows tiny blood vessels branching out in all directions to reach every body cell.

Transporting Molecules to and from Body Cells

Your body cells need certain molecules—oxygen, glucose, and amino acids—in order to function. These molecules are carried in the blood, which is part of the circulatory system. As the heart pumps, it moves the blood through blood vessels that become narrower and narrower and branch out in all directions. These blood vessels extend to every part of your body, bringing blood to every tiny cell. The blood delivers molecules like oxygen, glucose, and amino acids to the cells. Blood also carries away molecules that the cells don't need, like carbon dioxide.



This microscope photo shows body cells and the tiny blood vessels that carry molecules to and from those cells.

Systems of the Human Body: The Circulatory System © The Regents of the University of California. All rights reserved. Image Credit: (m, b) Science Source

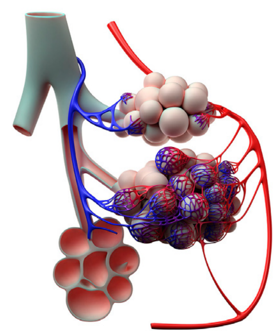
Red Blood Cells Carry Oxygen

Blood is liquid, but it is partly made up of cells—mostly red blood cells. The red blood cells transport oxygen throughout the body, delivering the oxygen to all the other cells in the body. A special protein called hemoglobin (HEE-moe-globe-in) gives red blood cells their ability to pick up oxygen. Red blood cells contain lots of hemoglobin. Hemoglobin is reddish in color, which is why red blood cells (and blood) look red!

Taken through a microscope, this photo shows red blood cells moving through tiny capillaries in single file. Red blood cells carry oxygen to the rest of the body cells.

Picking Up Oxygen in the Respiratory System

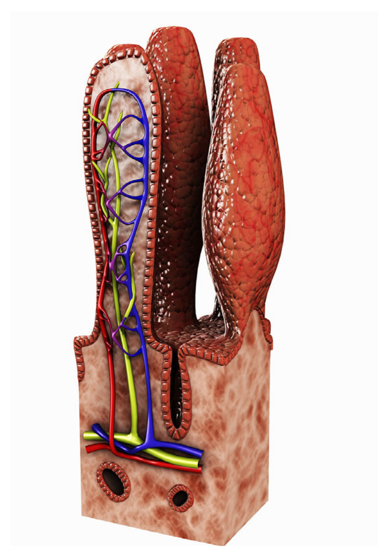
Your circulatory system gets its oxygen from your respiratory system. These body systems connect inside your lungs, at the tiny air sacs called alveoli (al-VEE-oh-lie). It's in your alveoli that the oxygen you breathe moves from your lungs to your blood. The alveoli are surrounded by tiny blood vessels called capillaries, which have very thin walls and are so narrow that red blood cells have to move through them in a single-file line! As you breathe in, your alveoli fill with air. Oxygen from the air passes through your alveoli and enters your capillaries. As red blood cells move through your capillaries, they pick up the oxygen. At the same time, carbon dioxide leaves your blood and goes through your alveoli into your lungs, where you breathe it out.



This diagram gives a cutaway view of the alveoli.

Picking Up Glucose and Amino Acids in the Digestive System

Your digestive system breaks down food into molecules that your cells can use—but it's your circulatory system that actually has to get the molecules to the cells. The circulatory system and the digestive system meet at the walls of your small intestine, where the circulatory system picks up molecules like glucose and amino acids from digested food. This happens in the villi (VILL-eye), tiny finger-like parts that stick out from the walls of the small intestine. Inside the villi, there are capillaries. Glucose



Villi are tiny finger-like parts that line the small intestine. This cross-section diagram shows the tiny blood vessels called capillaries inside the villi. In the villi, molecules pass from the digestive system into the circulatory system.

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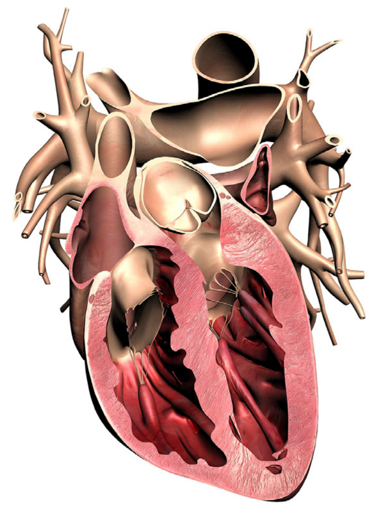
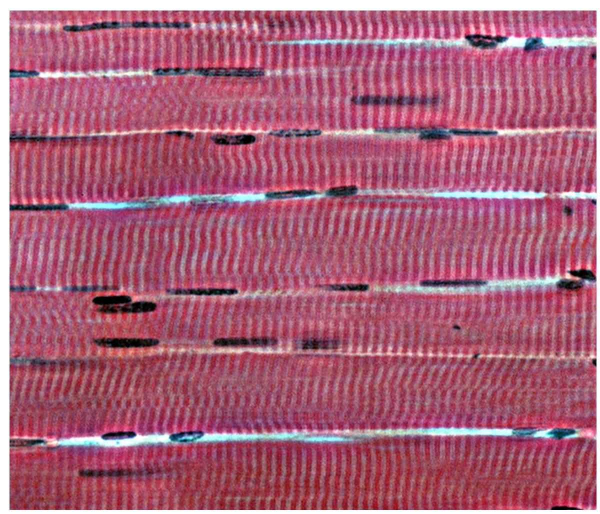
and amino acids pass through the villi and enter the blood in the capillaries. These molecules flow with the blood through blood vessels that branch out to reach every body cell.

The Role of the Heart

Your heart pumps blood through blood vessels all around your body so that your blood can reach every cell. Your heart is made of muscle tissue—a type of muscle that is similar to the muscles in your arms and legs. Of all the muscles in your body, your heart does the most physical work. This is because your heart beats all the time—about 100,000 times each day! Your heart rate (how fast your heart beats) changes depending on what you are doing. On average, the human heart beats about 60 to 100 times every minute. When you exercise, your heart beats faster to deliver molecules to your cells faster. Your exercising heart rate might be twice as fast as your resting heart rate.



An artist created this cross-section image of a heart to show the spaces inside. Blood enters the spaces, and the heart squeezes to pump the blood out into blood vessels.



This microscope photo shows muscle cells from a human heart. The heart is the hardest-working muscle in the body.

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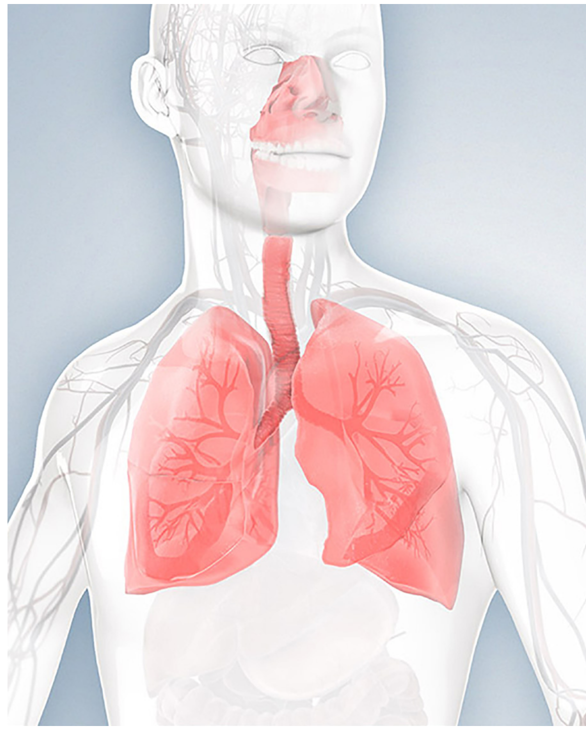
Systems of the Human Body: The Respiratory System

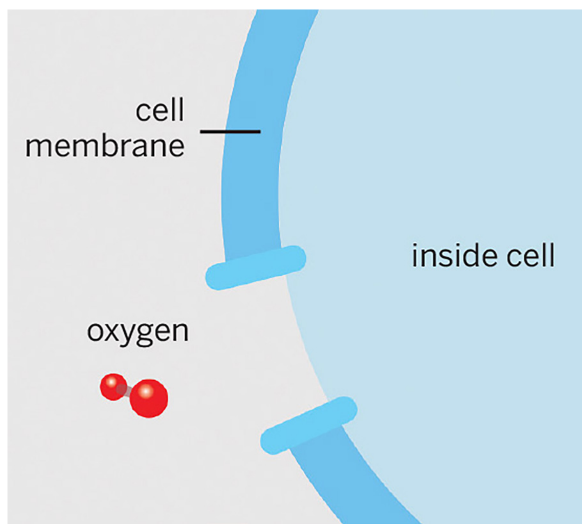
To *respire* means to breathe—the respiratory system is the body system involved in breathing. This body system includes the lungs, the trachea (TRAY-kee-a) (also called the windpipe), and the nose and mouth. Through breathing, the respiratory system brings oxygen into the body and moves carbon dioxide out.



The respiratory system includes the lungs. As you breathe, this system brings oxygen into your body.

Oxygen in, Carbon Dioxide Out

When you breathe, you take in air that contains molecules of oxygen. The air moves through your trachea, which branches into many narrower tubes inside the tissue of your lungs. These tubes continue branching in all directions, becoming narrower and narrower, until they end in millions of tiny air sacs called alveoli (al-VEE-oh-lie). With each breath, oxygen molecules enter the alveoli—but they don't stay there long. The oxygen molecules are small enough to pass through the walls of the alveoli, entering tiny blood vessels that surround these air sacs. At the same time, carbon dioxide molecules are moving in the other direction, out of the blood and into the alveoli. You release this carbon dioxide when you breathe out.



Oxygen molecules are small enough to enter a cell.

Systems of the Human Body: The Respiratory System © The Regents of the University of California. All rights reserved. Image Credits: (t) Shutterstock; (b) Science Source

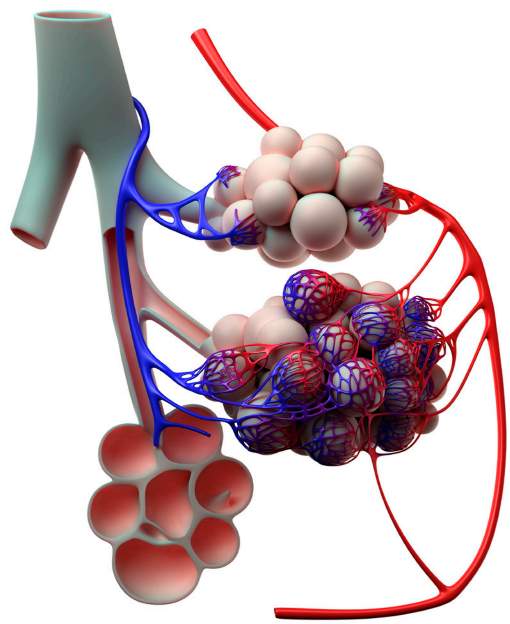
Connecting to the Circulatory System

The respiratory system brings in oxygen molecules that cells need, but those molecules can't get to the cells without the circulatory system. As oxygen molecules pass through the walls of the alveoli and into the blood vessels on the other side, they enter the blood. From there, the blood circulates throughout the body, carrying the oxygen molecules to every body cell. The alveoli are also where carbon dioxide molecules leave the blood and enter the lungs to be released.

Breathing

You take one full breath in and out about 12 to 20 times every minute when you are resting. Nerve cells inside the blood vessels in your neck and chest keep track of the levels of carbon dioxide and oxygen in your blood. When the amount of carbon dioxide gets too high or the amount of oxygen gets too low, the nerve cells in these blood vessels can tell. They send signals to your brain that cause you to breathe faster so that you breathe out the carbon dioxide and bring in fresh oxygen. When you are exercising, your cells need more oxygen and produce more carbon dioxide. Because of this, you breathe faster when you exercise.

An artist created this illustration of the tiny air sacs in your lungs called alveoli. The alveoli are surrounded by blood vessels, shown here in red and blue.



This diagram shows a cutaway view of the alveoli. Oxygen is breathed into the alveoli, where it's passed into the blood vessels leading away from the lungs. Carbon dioxide arrives at the alveoli in the blood vessels and moves into the alveoli so it can be breathed out.

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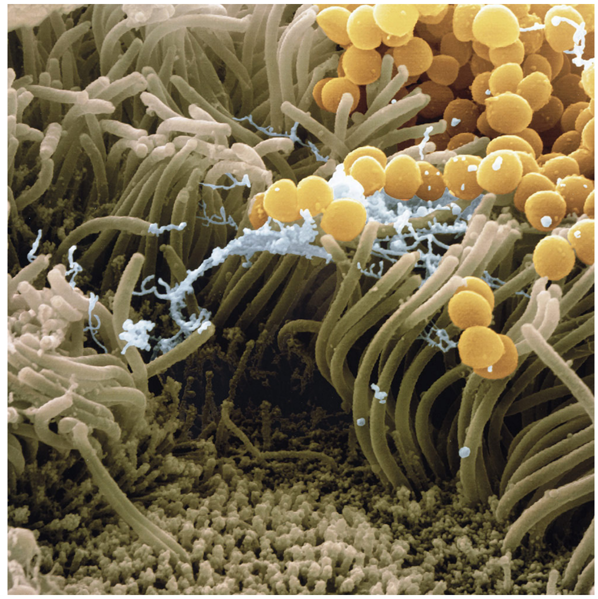
Filtering Out Harmful Particles

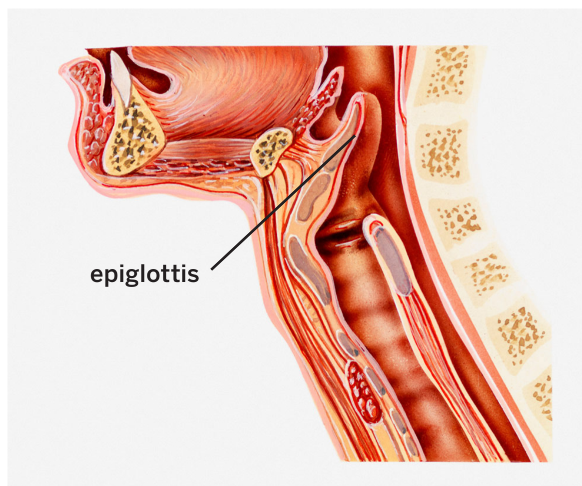
Oxygen isn't the only thing in the air you breathe: dust, pollen, pollution, bacteria, and other small particles are all floating around in the air. These particles can be harmful, and they enter the respiratory system with every breath. The respiratory system has parts that act like filters to keep harmful particles out of the lungs while still letting oxygen in. This filtering is possible because oxygen molecules are so small—they can fit through spaces that larger particles can't. Filtering begins in the nose, where nose hairs and mucus work together to trap large particles and keep them out of the lungs. Smaller particles are filtered by structures called cilia (SILL-ee-ah), which look like tiny hairs lining the walls of your respiratory system. The cilia sway back and forth to trap harmful particles and push them up to the nose, where they can be blown out.

Keeping Food Out of the Respiratory System

You take in both food and air through your mouth, so how does air end up in your respiratory system and food in your digestive system? A small flap of tissue called the epiglottis (epp-ih-GLOT-iss) keeps everything going in the right direction. The epiglottis is open while you breathe, but it closes when you swallow to cover your trachea and keep food out. If food accidentally enters your trachea, it can stop air from flowing—that's called choking. A person who is choking can't breathe because the trachea is blocked. Whatever is blocking the trachea has to be removed or the person may not be able to get enough oxygen to survive.



The gray hair-like things in this photo are microscopic structures called cilia, which line the respiratory system. The cilia are trapping harmful bacteria (shown in yellow), keeping these bacteria out of the lungs.



The epiglottis closes when you swallow to keep food out of your respiratory system. If food accidentally enters the respiratory system, it can lead to choking.

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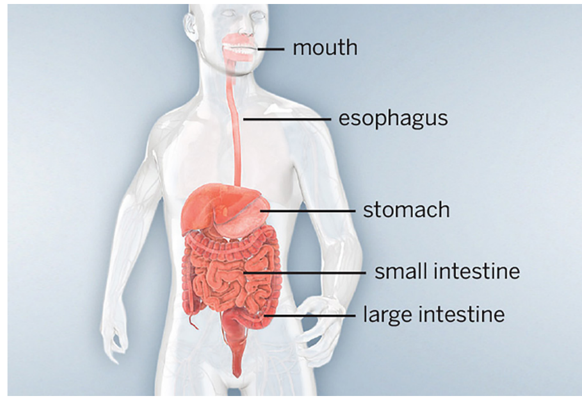
Systems of the Human Body: The Digestive System

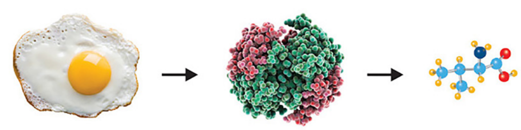


The human digestive system breaks food down into molecules that cells can use.

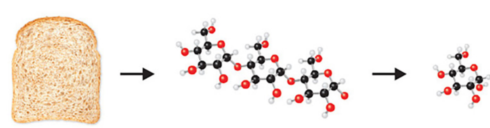
The digestive system includes the mouth, stomach, intestines, and other digestive organs. The function of the digestive system may seem obvious: it digests, or breaks down, food. But what does that really mean? It's not enough to grind food into tiny bits by chewing it. It's not even enough to break the food down into molecules. To get food into a form that cells can use, the digestive system actually has to change the food through chemical reactions, breaking larger molecules into smaller molecules.

Breaking Food Down Into Molecules That Cells Can Use

Foods are made of large molecules, such as proteins and starch. Before cells can use them, those large molecules need to be broken down into smaller molecules like amino acids and glucose. This kind of breakdown can only happen through chemical reactions. The body produces digestive enzymes that help those reactions happen faster. In the stomach, digestive enzymes speed up the chemical reactions that break down protein molecules into amino acid molecules. Other digestive enzymes help to break down starch molecules into smaller glucose molecules through chemical reactions in the mouth and small intestine.



Many foods, such as eggs, are made of large protein molecules. The digestive system breaks down protein molecules into small amino acids that cells can use.



Many foods, such as bread, are made of large molecules called starch. The digestive system breaks down starch molecules into small glucose molecules that cells can use.

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Absorbing Molecules from Food

The small intestine is a very long, winding tube—about 20 feet long in the average adult! The entire length of the small intestine is lined with tiny, finger-like parts called villi (VILL-eye), which help the body absorb molecules like glucose and amino acids. These molecules are small enough to pass through the villi so they can be absorbed into the blood.

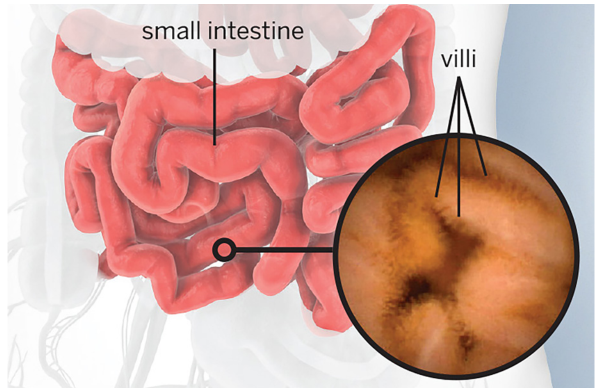
Connecting to the Circulatory System

Glucose and amino acids can't get from the digestive system to the cells without the help of the circulatory system. The digestive and circulatory systems connect at the small intestine, in the tiny, finger-like villi. Inside the villi are microscopic blood vessels called capillaries. Glucose and amino acid molecules pass through the villi and enter the blood in the capillaries. Then these molecules flow with the blood through blood vessels that branch out to reach every body cell.

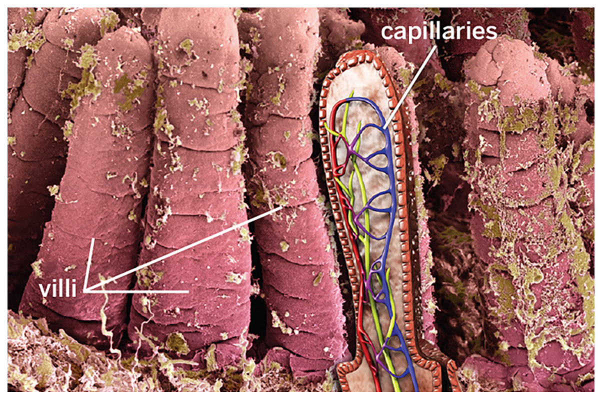
The Path of Food Through the Digestive System

Digestion actually begins in your mouth, as soon as you take a bite! The saliva in your mouth contains digestive enzymes that start breaking down starch molecules while you chew.

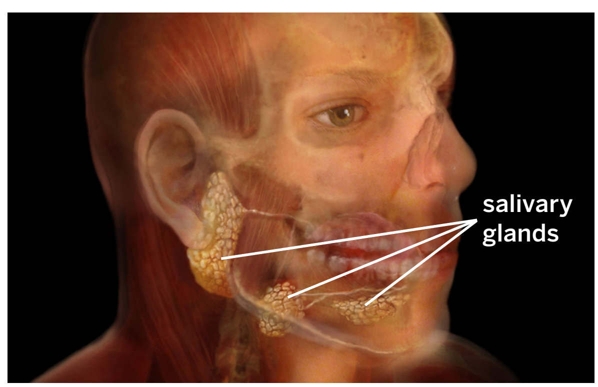
When you swallow, the food travels down a tube called the esophagus to your stomach, where more digestive enzymes break down proteins into amino acids. Your stomach also contains acid, which helps the digestive enzymes work. Food moves from your stomach into your small intestine, where digestive enzymes break down all the starch molecules into glucose. The glucose and amino acid molecules pass through the walls of your small intestine and are absorbed into your blood.



This photo shows a close-up view of the tiny villi that line the walls of the long, winding small intestine. The villi help the body absorb molecules like glucose and amino acids.



Villi are the tiny finger-like parts that line the small intestine. This cross-section diagram shows the microscopic blood vessels called capillaries inside the villi. In the villi, molecules pass from the digestive system into the circulatory system.



Digestion begins in your mouth, with saliva. An artist created this illustration to show where the glands that produce saliva are, hidden inside your head.

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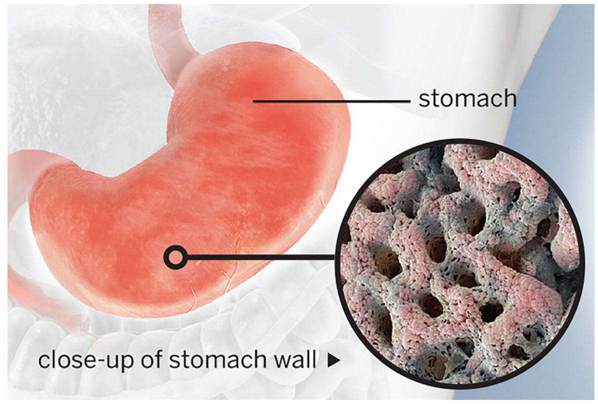
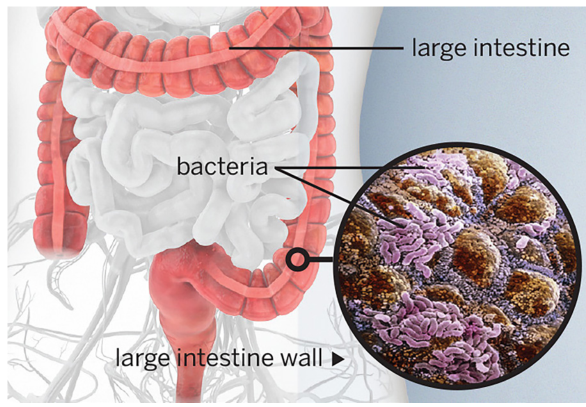
What happens to fiber and other parts of food that the body can't break down into molecules that are small enough to enter cells? These undigested parts of foods move on to the large intestine. In the large intestine, water is absorbed along with vitamins and minerals. Finally, the remaining part leaves the body as waste.

Bacteria in the Digestive System

Your intestines are home to thousands of different kinds of bacteria, but these bacteria don't make you sick. Instead, they actually help your body by making vitamins and breaking down food that your body couldn't digest on its own.



The walls of your stomach are covered with tiny holes. These holes release enzymes and acid that work together to break down the foods you eat.



This photo of the large intestine wall was taken through a powerful microscope. It shows tiny bacteria that live inside the large intestine. Most of these bacteria actually help the body stay healthy.

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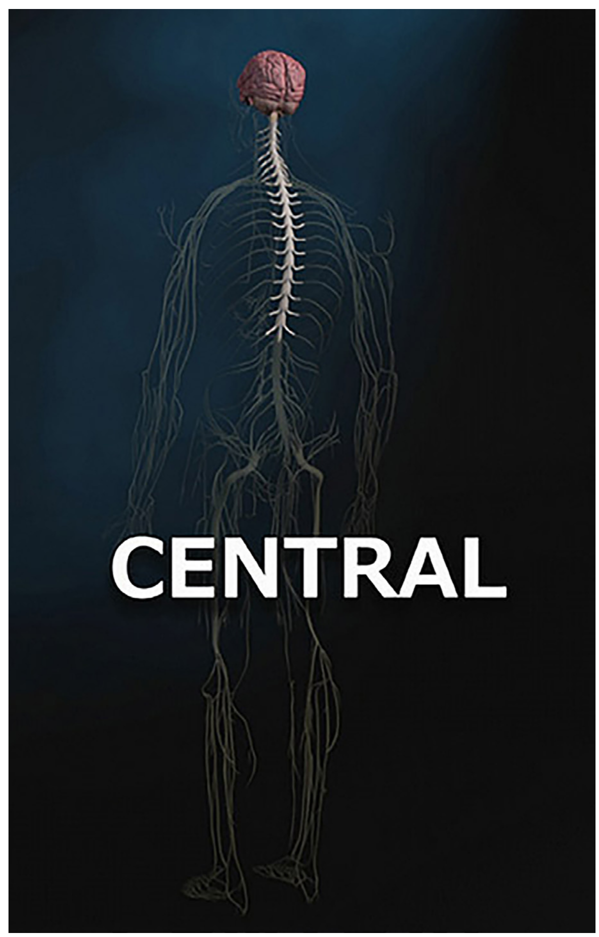
Nerve cells have bodies, like other cells, but they also have axons and dendrites to carry electrical impulses around the body.

Systems of the Human Body: The Nervous System



The central nervous system is formed by the brain and spinal cord.

Imagine you get a paper cut. Ouch! That hurts! But how do you know it hurts? For that, you can thank your nervous system: it carries information from your body to your brain, and from your brain to the rest of your body. When the parts of your nervous system work together, your brain knows what's happening in your body, your body can carry out your brain's orders . . . and you can feel that paper cuts really sting!

Information travels through the body in the form of electrical impulses, or tiny bursts of electricity. The nervous system carries electrical impulses across networks of nerve cells, or neurons, that go to every part of

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the body. This system has two sections: the central nervous system and the peripheral nervous system.

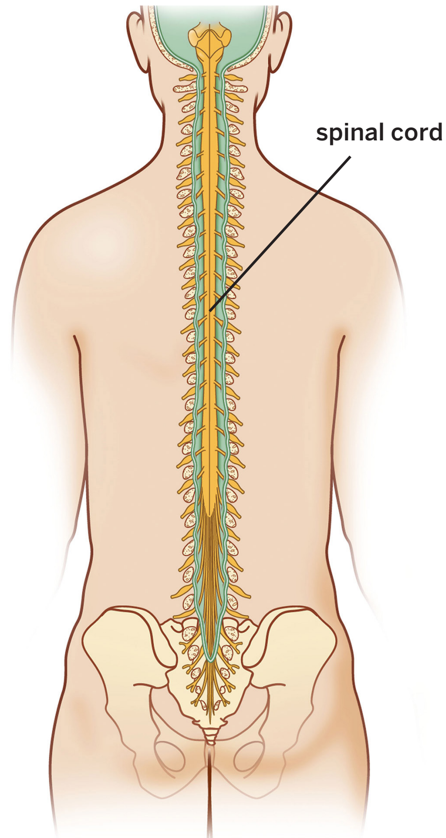
Central Nervous System

The central nervous system (CNS) is the command center of the body, formed by the brain and spinal cord.

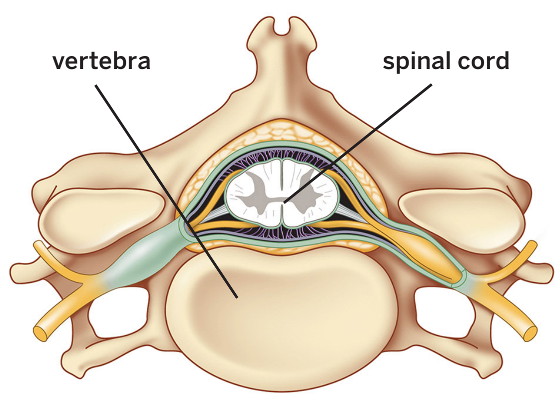
Your brain is in charge of everything you do: moving, breathing, forming and storing memories, thinking, feeling, and thousands of other tiny tasks that make you who you are. Your brain constantly receives information from your body, decides how to react, and sends orders down your spinal cord for your body to carry out. Your brain is made of a kind of tissue called gray matter, and contains about 86 billion neurons. Each of those neurons makes connections with as many as 10,000 other neurons. That's a lot of connections in your brain!

The spinal cord is a thick cord made of nerve cells that reaches from the brain down the spine, and it carries electrical impulses to and from the brain. The spinal cord is also in charge of a few basic tasks on its own—mostly small movements you don't even think about.

The CNS is very important to who you are, how you perceive the world, and how you react to your environment. Because it's so important, the body protects it well! Both the brain and the spinal cord are surrounded by a tough, leathery layer of tissue and then by a layer of bone. The brain is protected by the skull, and the spinal cord is protected by the bones of the spine.



The spinal cord runs from the base of the brain down the back, where it branches into other nerves that carry electrical impulses to the lower half of the body.



The spinal cord is surrounded by the vertebrae, or bones of the spine. The word *vertebrae* is the plural of the word *vertebra*.

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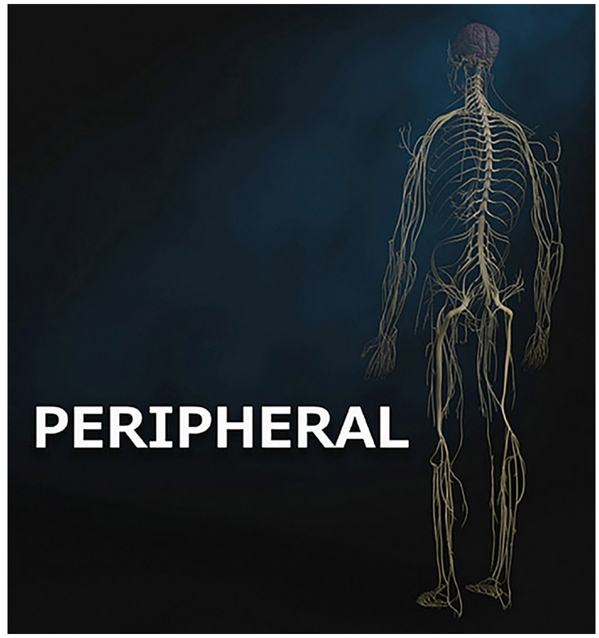
Peripheral Nervous System

The CNS is the biggest and smartest part of the nervous system, but it doesn't reach to parts of the body that are far from the brain. Instead, the CNS works with the peripheral nervous system (PNS) to carry information to and from the outer parts of the body. The PNS is made of nerves that branch out from the spinal cord to every part of the body, from the internal organs to the fingertips.

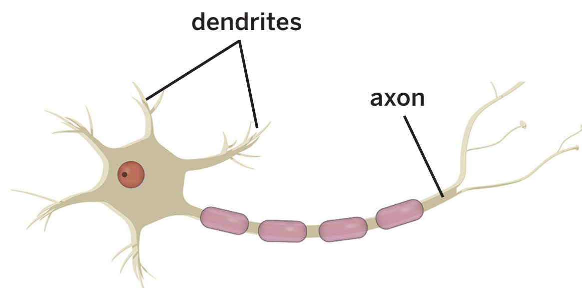


The peripheral nervous system is made up of all the nerves in the body except the nerves in the spinal cord.

Nerve Cells

The parts of the nervous system are made of nerve cells, or neurons. Neurons have some things in common with other body cells: each one has a nucleus, a cell membrane, and the same organelles as other cells in the body, and they use glucose and oxygen to get energy. But neurons are different from other body cells, too. They have extra parts that help them fulfill their purpose of carrying electrical impulses around the body.

Neurons look like regular cells with little arms and long tails. Each one has a body that holds its organelles, plus some short branched "arms" on one end and a long "tail" on the other. The "arms" are called dendrites, and they bring electrical impulses into the body of the neuron. The "tail" is called an axon, and it passes electrical impulses away from the body of the neuron. Neurons are all different sizes: some are very, very tiny, but the longest axon in the body reaches from the spinal cord all the way to the big toe!



Neurons have "arms" called dendrites and "tails" called axons.

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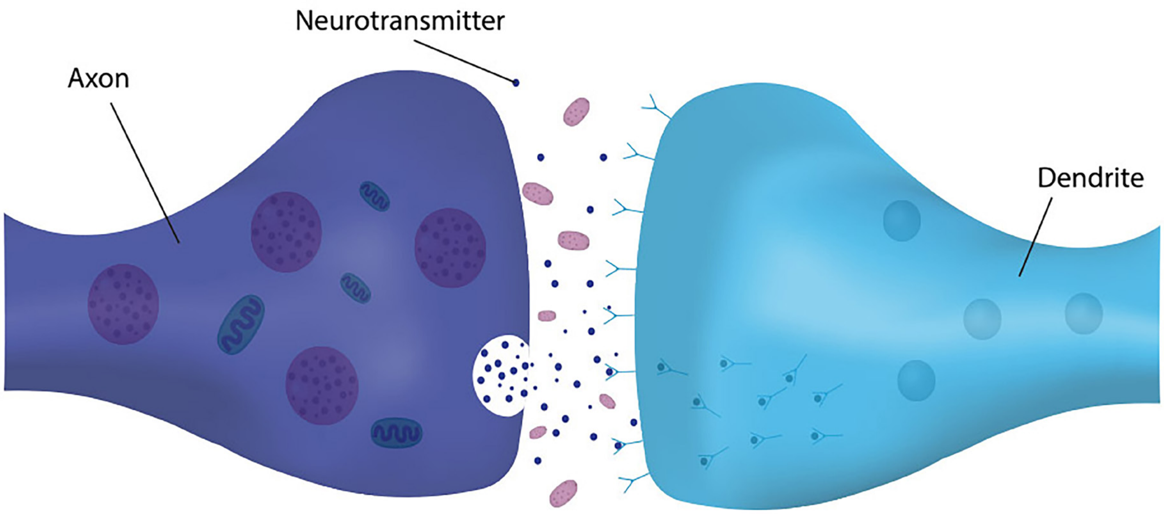
Synapse



The gap between two neurons is called a synapse.

Whenever an electrical impulse travels through the body, it travels along a chain of neurons. But neurons aren't actually connected to each other; there's a tiny gap called a synapse between each axon and the dendrite of the next neuron. So how does the impulse get from neuron to neuron? Chemicals called neurotransmitters are released by the end of the axon and sail across the synapse, and the electrical impulse hitches a ride across with them. When the impulse hits the dendrite of the next neuron, the whole process starts over. Electrical impulses in the body can travel this way as fast as 250 miles per hour!

Neurons are sometimes classified by the direction in which they send information: Sensory neurons take information from sense organs like the skin, tongue, nose, and ears and pass it toward the central nervous system (CNS). Motor neurons take information from the CNS and pass it to muscles and organs so that the body knows what to do.

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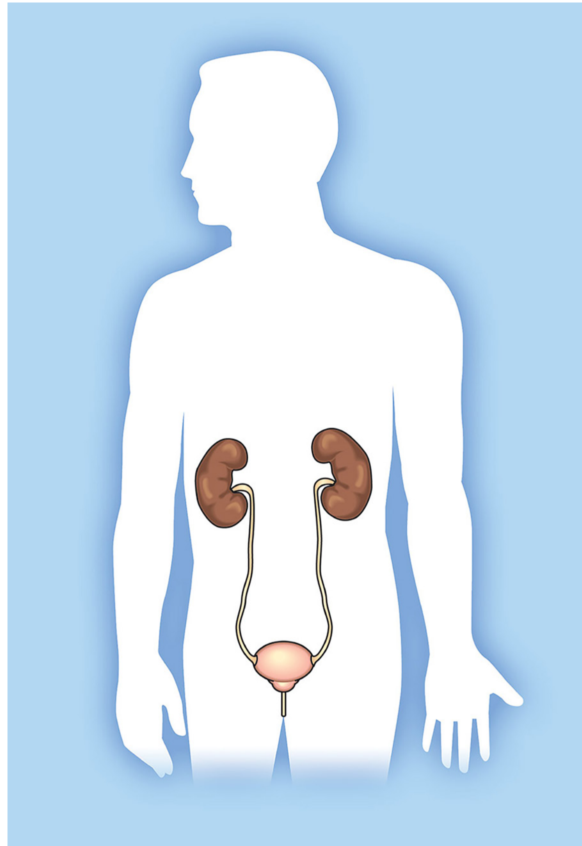
Systems of the Human Body: The Excretory System



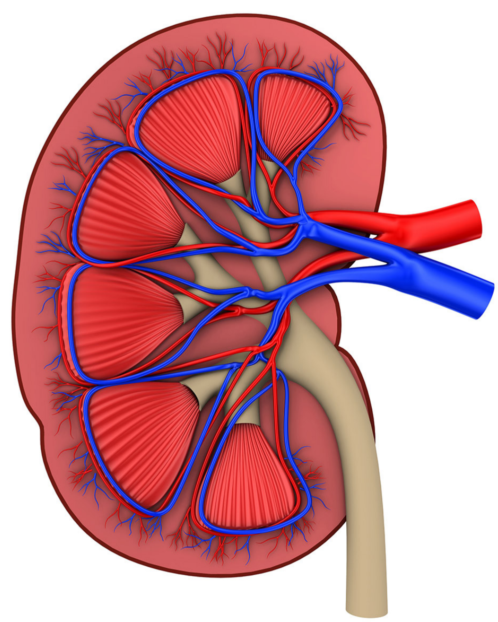
The excretory system removes waste from the body.

Your body can't use everything that goes into it. You take in food so that your body gets the molecules it needs, but some of the substances you take in are either harmful or simply not something your body can use. If these substances begin to build up, you can get sick. That's where your excretory system comes in: it breaks down waste and moves it out of your body.

The excretory system is made up of three main organs: the kidneys, the bladder, and the skin. Other organs that are part of other body systems, like the liver, large intestine, and lungs, also help move waste out of the body—but the kidneys, bladder, and skin are the main organs of the excretory system.

Cleaning the Blood

The kidneys are a pair of bean-shaped organs tucked just underneath the rib cage, one on each side of the spine. Their job is to clean the blood and prepare waste substances to leave the body. Once during every trip through the circulatory system, every drop of blood in the body flows through large blood vessels into the kidneys, where it passes through tiny filters called nephrons (NEF-rons). The nephrons strain out all kinds of substances the blood has picked up on its trip around the circulatory system. Once it's been filtered, the clean blood gets pumped out to keep circulating, and the waste substances are mixed with water to make urine and sent away on their journey out of the body. The tissue of the kidneys works hard: as



The kidneys play a major role in the excretory system. Their job is to clean the blood.

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much as one quarter of the blood in the human body is passing through them at any given time. The average human has about 5 liters of blood, and the kidneys can filter about 150 liters of blood per day—which means every drop of your blood passes through your kidneys as many as 30 times per day.

Collecting Waste

When urine leaves one of the kidneys, it travels through a long tube called the ureter and into the bladder, where it is stored until it can leave the body. The bladder's only job in the body is to collect urine and keep it from building up too much. The bladder is elastic—it stretches when Systemit begins to get full, which signals the nerves in the bladder wall to tell the brain that the bladder needs to be emptied. That's how you know you need to use the bathroom! The average human produces one to two liters of urine every day.

Sweating It Out

The third organ in the excretory system is the largest organ in the human body, and it might be one you don't expect: the skin! In glands under the surface of the skin, waste substances like toxins and extra salts are mixed with water to make sweat, which is then pushed out of pores, or tiny holes in the skin. The salts your body is getting rid of are the reason your skin tastes salty when you sweat.

The kidneys can develop kidney stones, which are hard chunks of minerals. Kidney stones aren't usually dangerous, but passing them through the excretory system can be painful.

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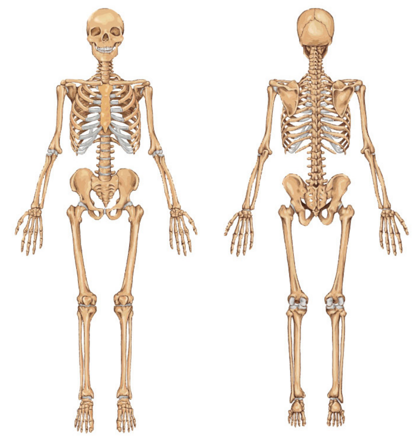
Systems of the Human Body: The Musculoskeletal System

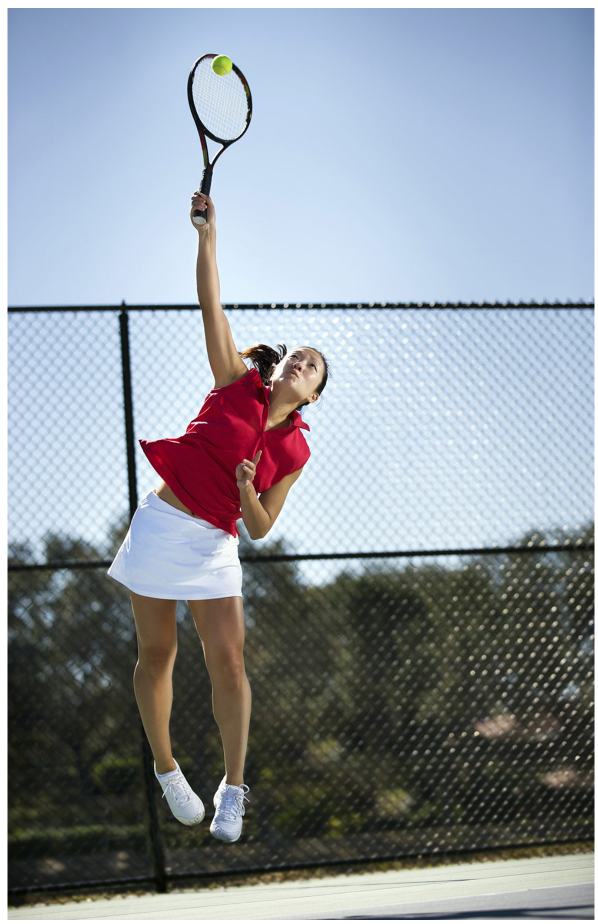
What would you do without muscles and bones? Not much. Your musculoskeletal system, which is made of bones, muscles, cartilage, and connective tissues, supports your whole body. Without these parts, you'd just be a pile of soft tissue, unable to move.



The adult human skeleton is usually made up of 206 bones, and gives structure to the body.

Holding the Body Up

The skeleton is the hard frame of bones that gives the body structure and protects some of the most important organs, like the heart, lungs, and brain. Humans are born with about 300 bones, but some of those bones fuse during childhood, so most adults have 206 bones to hold their bodies up and keep their organs safe. Bones do more than help support your body, though. They also store minerals, fats, and other things the body needs and produce the red blood cells that make the blood so good at transporting oxygen.



The musculoskeletal system allows people to stay upright and move around.

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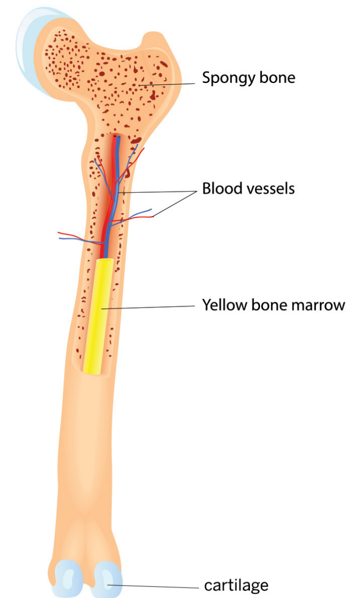
Bones are efficient storage spaces in the body. The outer surfaces of bones are hard, but the insides aren't: either they're made of soft, spongy bone tissue, or they're hollow and filled with a substance called bone marrow. Bone marrow comes in two types that perform two different jobs. Red marrow makes red blood cells, while yellow marrow stores fat that the body can use for energy if it needs to. Even the hard tissue that covers the outside of bones isn't just a tough layer to protect the bone tissue. It's also storage for calcium and other minerals that the body can use if it isn't getting enough minerals from food.

Keeping the Body Flexible

Some parts of your skeleton aren't actually made of bone. These are parts that need to be tough but flexible. Since bones don't bend, that's where cartilage comes in. Cartilage is a material that gives your skeleton a little bit of flexibility. The tip of your nose and most of your ears are made of cartilage, which is why they can bend and bounce back into place. Some of your ribs have cartilage on them, so that your rib cage can move, expand, and contract as you breathe and move around. Cartilage is slippery, so it's also found in joints, helping bones move past each other smoothly. In fact, joint pain is often caused when the cartilage in a joint gets worn down with time. Without cartilage to keep the bones sliding past each other, the joint can't move smoothly.

Bone Structure



Bones have hard tissue on the outside, but are spongy or hollow on the inside.

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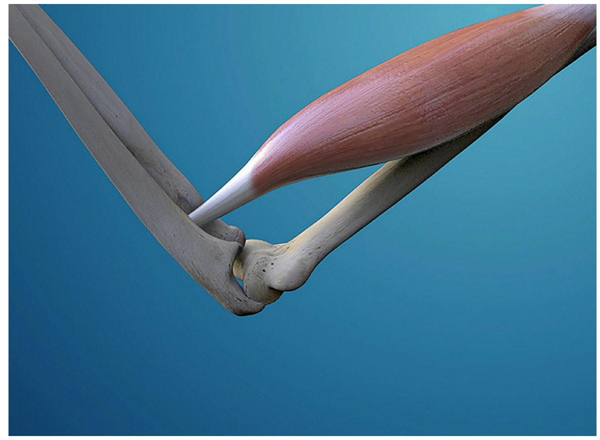
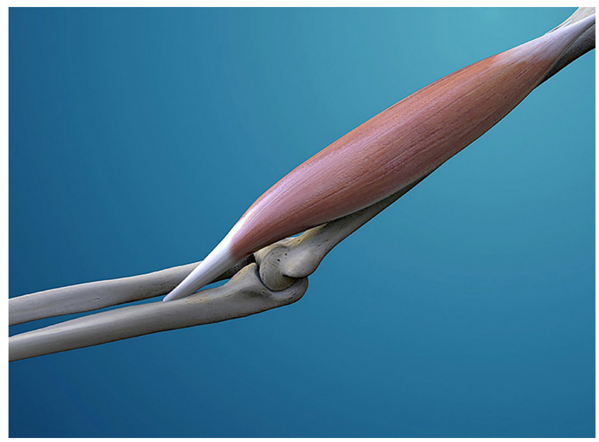
Moving the Body

The skeleton can help keep us upright, but there are lots of things it can't do, like move on its own. Bones and cartilage need muscle to help them get from place to place. The entire skeleton is covered in a type of muscle called skeletal muscle, which makes movement possible. Muscles can only move in two ways: they contract (get shorter) and relax (get longer). To make bones move, skeletal muscles work in pairs. When one muscle contracts, its partner on the other side of the bone relaxes, or gets longer. The bone always moves toward the muscle that's contracting. By working together, skeletal muscles allow people to sit, stand, walk, run, dance, and do a million other things!



When the bicep muscle contracts, the arm bends.



When the bicep muscle relaxes, the arm straightens.

Holding the Body Together

Bones, cartilage, and muscles work together to keep the body upright and moving, but there's one more category of tissue that makes the musculoskeletal system work: connective tissue, which ties bones and muscles together. Connective tissues are tough, flexible strips of tissue that come in three different types: tendons, ligaments, and fascia. Tendons connect muscles to bones, ligaments connect bones to other bones, and fascia connect muscles to other muscles. All three types of connective tissue are made of elastic fibers to help them stretch and tough collagen fibers to give them strength. This combination of fibers helps them stay strong under pressure and withstand a lifetime of bending and motion.

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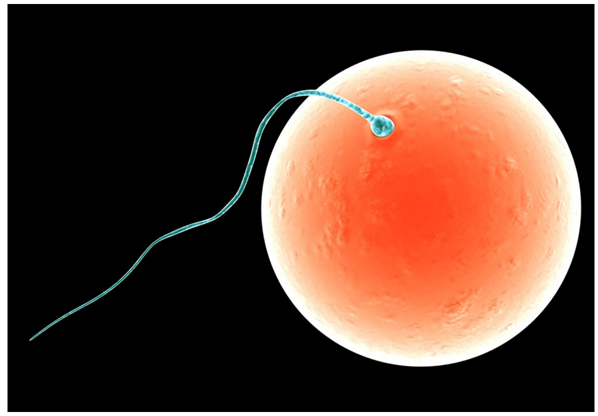
Systems of the Human Body: The Reproductive System

Humans reproduce through sexual reproduction—that is, an egg cell from a female and a sperm cell from a male combine to make the first cell of an offspring. The human reproductive system supports this process.

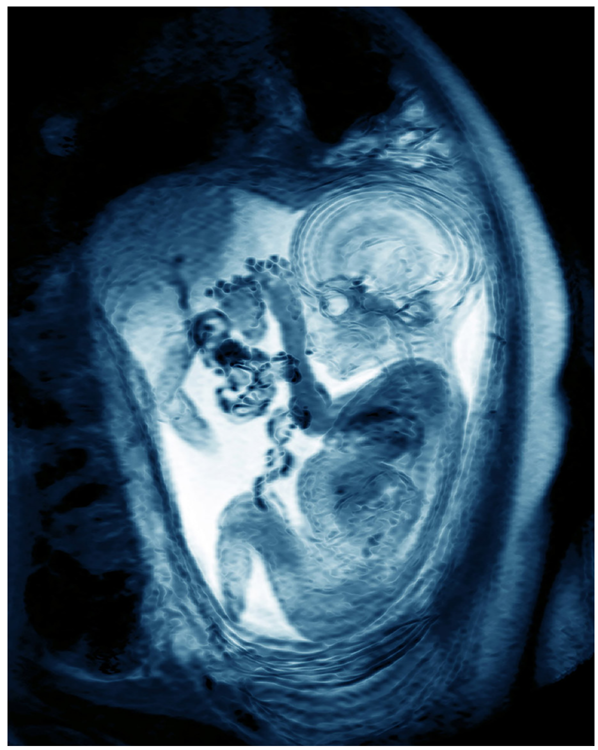
Sexual reproduction is all about the combination of two cells called gametes, which carry DNA. Female gametes are called eggs (the eggs people eat are the female gametes of chickens or other birds) and male gametes are called sperm. Each has half of the DNA needed to make a new organism. To make a new organism, the gametes have to combine and form a full set of DNA. This process is called fertilization.

Making Gametes

In humans, reproduction takes place when a sperm from a male fertilizes an egg from a female. But where do sperm and eggs come from? Males and females have different organs that make these cells. In females, eggs are stored in a pair of organs called ovaries, which release one egg per month. Females are born with all the eggs they're ever going to have, and they can't make more. Unlike females, males usually have an endless supply of gametes: after puberty, their bodies can always make more sperm. Sperm are formed in a pair of organs called the testicles.



Sexual reproduction takes place when a sperm cell fertilizes an egg cell.



The uterus supports and protects a fetus while it develops.

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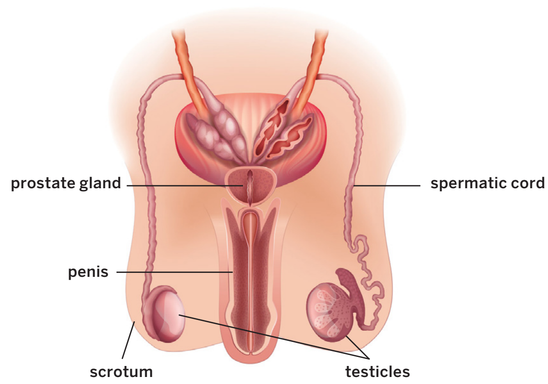
The Male Reproductive System

The testicles are located in a pouch called the scrotum, which is visible from the outside of the body. Being located outside the body allows the scrotum to draw close to the body in cold temperatures or move away from the body in warm temperatures, keeping the testicles at the best temperature for making sperm. The testicles are connected to the penis, or male sex organ, by a series of tubes that form the spermatic cord. After sperm leave the testicles, they pass through the prostate gland, which makes seminal fluid. The sperm are mixed into the seminal fluid to create semen, the fluid that carries sperm out of the male body.

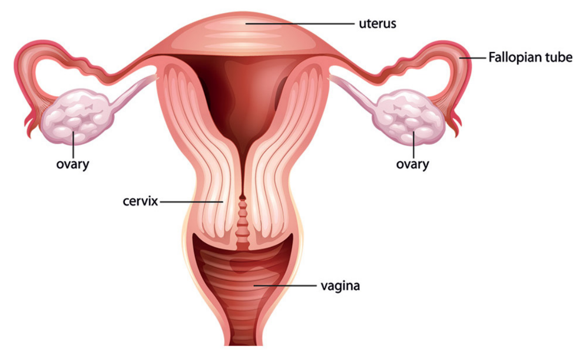


The male reproductive system produces the male gametes, called sperm.

The Female Reproductive System

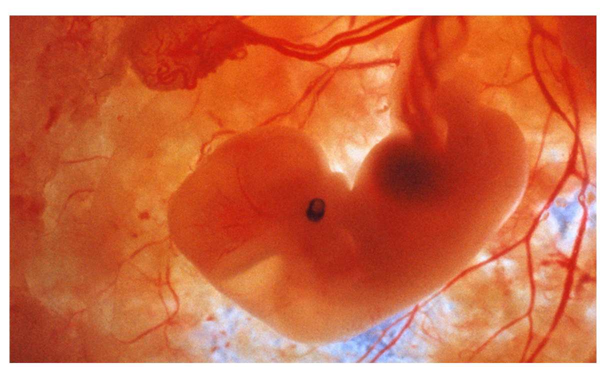
In females, the ovaries are connected to the uterus, an organ that can support the growth of a fetus until it is ready to be born. After a sperm fertilizes an egg, the egg attaches to the wall of the uterus, where it begins to divide: two cells, then four, then eight, until it forms a whole fetus! The uterus grows new blood vessels and everything it needs to support the fetus during about nine months of pregnancy.

The uterus is connected to the ovaries by a pair of tubes called the fallopian tubes. The bottom of the uterus connects to a series of organs that form a passage to the outside of the body: closest to the uterus is the cervix, which is a two-centimeter tube that connects to the vagina. The vagina leads out of the body through the vulva, or female sex organ. All three of these organs are small, but can stretch to allow a baby to pass through during childbirth—that's why they're sometimes called the birth canal.



The female reproductive system produces the female gametes, called eggs, and supports embryos after fertilization as they grow into fetuses.

Although this article describes "typical" male and female reproductive systems, not every human body fits neatly into one of those categories. A small percentage of people are born with characteristics that are in between, or possibly a mix of male and female reproductive systems. The term 'intersex' is used to describe the range of variations that occur.



While a fetus develops in the uterus, the female reproductive systems grows new blood vessels to support the fetus.

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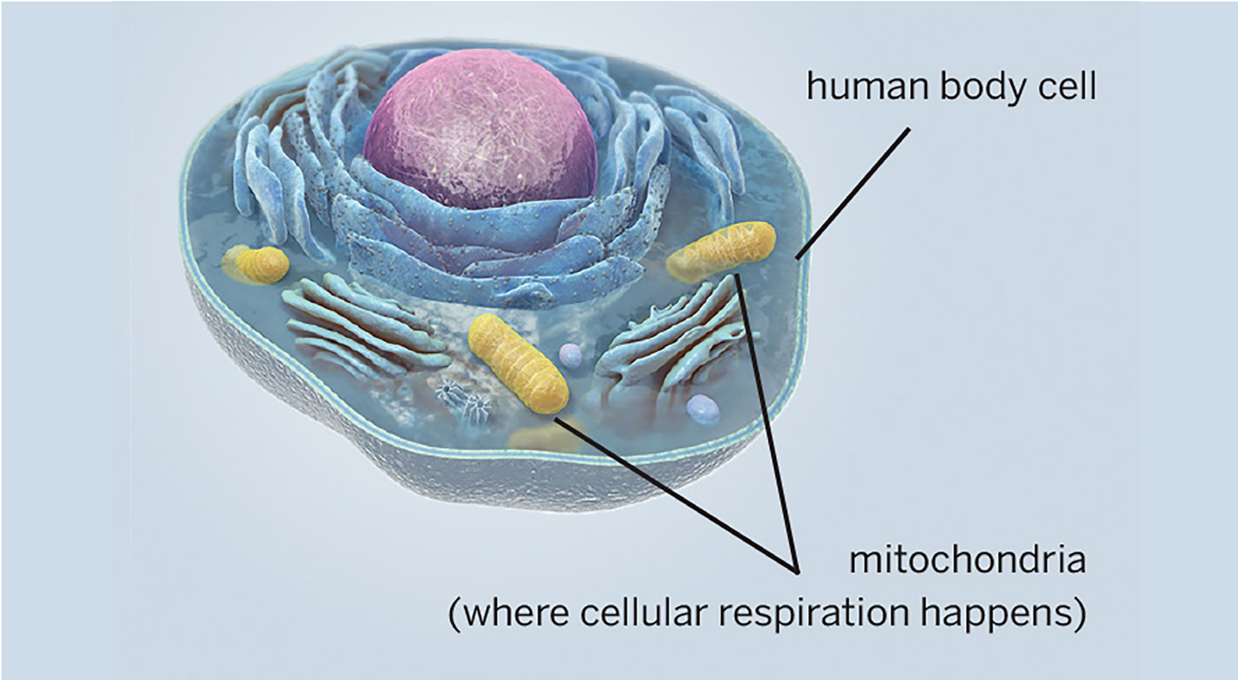


Cellular respiration takes place in parts of the cell called mitochondria.

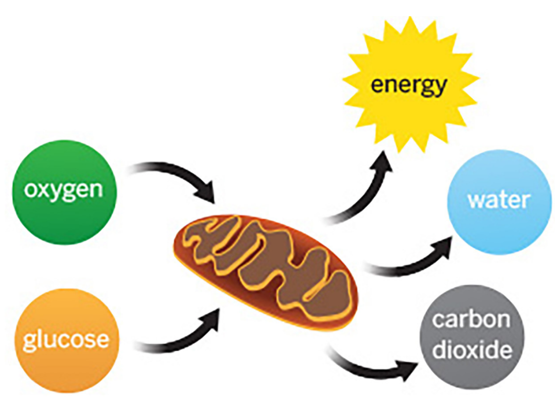
Cellular Respiration

Cellular Respiration © The Regents of the University of California. All rights reserved. Image credit: Shutterstock

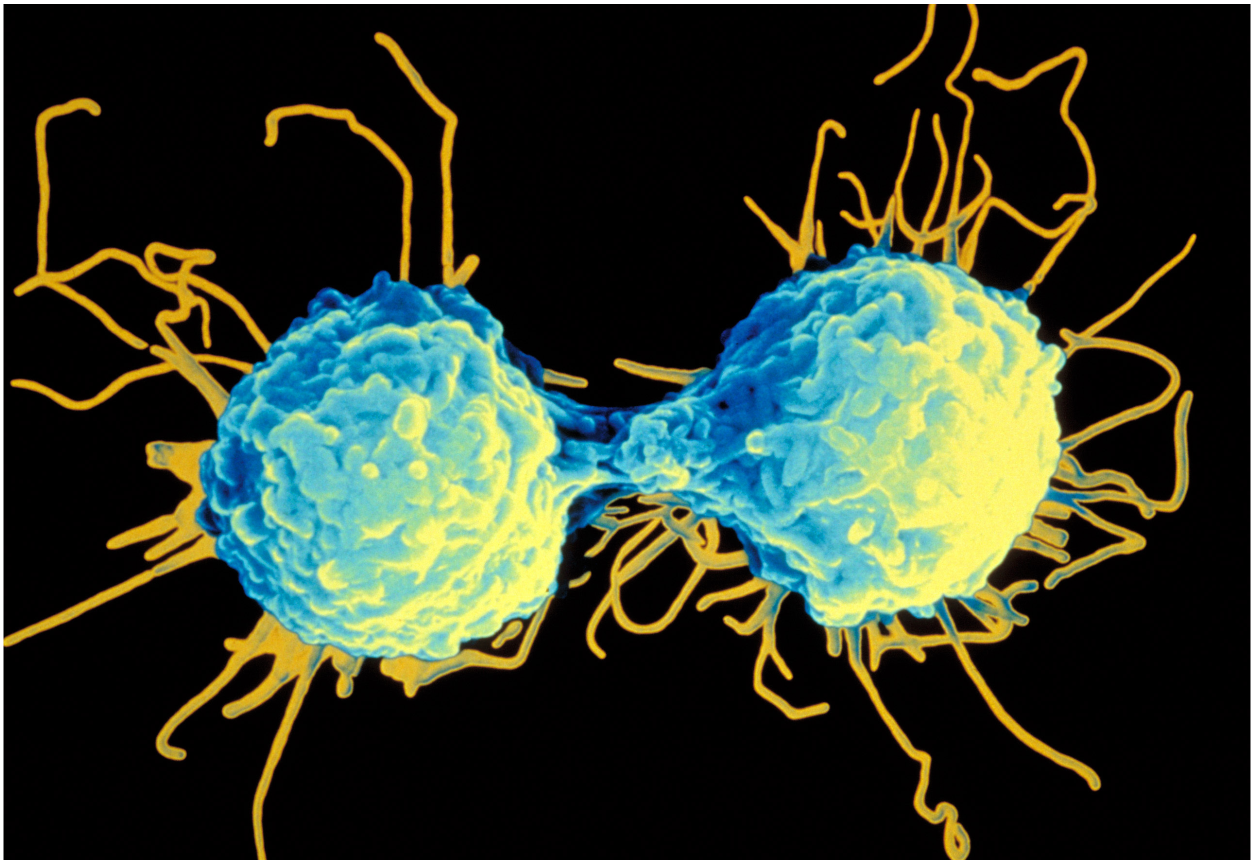
You may have heard the word respiration to refer to breathing air: taking oxygen into your lungs and releasing carbon dioxide through your mouth and nose. What is cellular respiration, then? *Cellular* means "having to do with cells"—so do cells breathe, too? In a certain way, yes. Individual cells do take in oxygen and produce carbon dioxide. But cellular respiration is more than that: it's a chemical reaction that releases energy to power everything that cells, and your body as a whole, need to function.

How Cellular Respiration Works

Cells take in oxygen and glucose molecules. These molecules are the inputs needed for cellular respiration. In tiny cell parts called mitochondria, the oxygen and glucose combine in a chemical reaction. The outputs of cellular respiration are carbon dioxide molecules, water molecules, and energy. The cell uses the energy, stores the water or sends it out to be used somewhere else in the body, and gets rid of the carbon dioxide. Every time you breathe out, you release the carbon dioxide produced by cellular respiration in your cells. Cellular respiration is always happening in your body, whether you are exercising, sitting still, or sleeping.



In the parts of cells called mitochondria, glucose plus oxygen combine to make carbon dioxide plus water, releasing energy. This is called cellular respiration.



When the body grows or repairs itself, cells divide into more cells.

Growth and Repair

Cellular Growth

What does it mean to grow? For a body to grow, its systems and organs need to grow, too—and that growth all happens on a tiny scale at the cellular level. Cells are always making new proteins, growing, and dividing to make more cells. This is what makes bodies grow over time. You may not be able to watch a person getting taller, but through a microscope, you could watch his or her cells dividing to make more cells. When millions of healthy cells grow and divide to make millions more cells, the whole body grows.

Repair Is Really Growth

When you're recovering from an injury or just healing from a cut, you're actually growing— at least on a cellular level. The body repairs itself by growing the new cells and cell parts needed to fix damaged ones. Individual cells get old and die, and need to be replaced by new cells. Cellular growth is always happening, even in adults—who may not be getting taller anymore, but still need to grow new cells to replace old ones and repair damaged ones.

What Cells Need for Growth and Repair

To grow and repair themselves, cells combine amino acid molecules to form larger protein molecules. Those new proteins build new cells and cell parts. Growth and repair also require energy, so cells also need glucose and oxygen to release energy for these important functions.

Growth and Repair © The Regents of the University of California. All rights reserved. Image Credit: Science Source

Diego and Gabe prepare to begin climbing after months of training.

The Big Climb

A Story in Large and Small Scale

Diego and Gabe stand by a tree at the bottom of a huge cliff. The rock goes up for hundreds of feet above them. By tomorrow, the brothers plan to be standing at the top, looking back down at this tree. First they'll need to haul themselves, their gear, and all their food and water up the rock. Diego is excited to go on his first overnight climb with his older brother. They'll sleep tonight on a special tent platform part of the way up, then finish the climb to the top tomorrow morning. Diego and Gabe have been planning for this trip for months by training in the gym and outdoors.

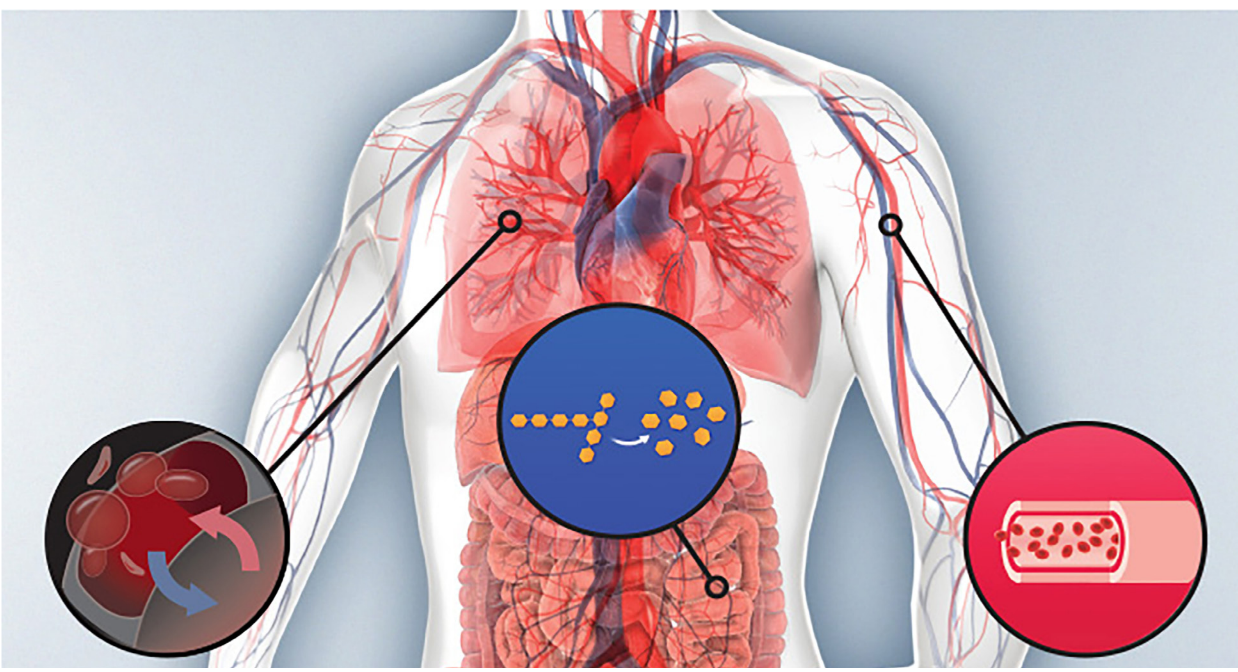
7:46 a.m.: Getting ready

What's happening at a large scale

This morning, Diego and Gabe filled up on big bowls of oatmeal and nuts for breakfast. Their meal had plenty of starch, and some protein as well. Standing at the bottom of the cliff, Diego stretches and takes a deep breath.

What's happening at a small scale

Diego's metabolism is already going strong, even though he hasn't started the climb. The food that Diego ate for breakfast is travelling



oxygen entering the blood

starch molecules breaking down into glucose

blood transporting oxygen and glucose

Diego's body uses glucose and oxygen to release the energy he needs to climb.

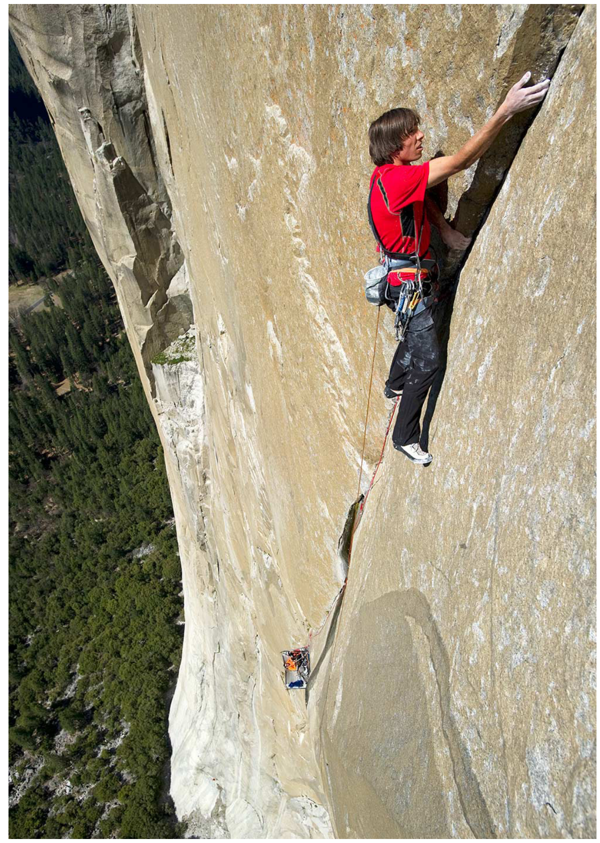
The Big Climb © The Regents of the University of California. All rights reserved. Image Credit: (t) Getty Images

through his digestive system. Digestive enzymes are breaking down starch molecules from the food into glucose molecules and breaking down protein molecules into amino acid molecules. Some of the molecules are already moving into Diego's blood in his circulatory system. As Diego breathes in, oxygen enters his respiratory system and passes from his lungs into his blood. Diego's cells are going to need these molecules as he climbs the cliff.

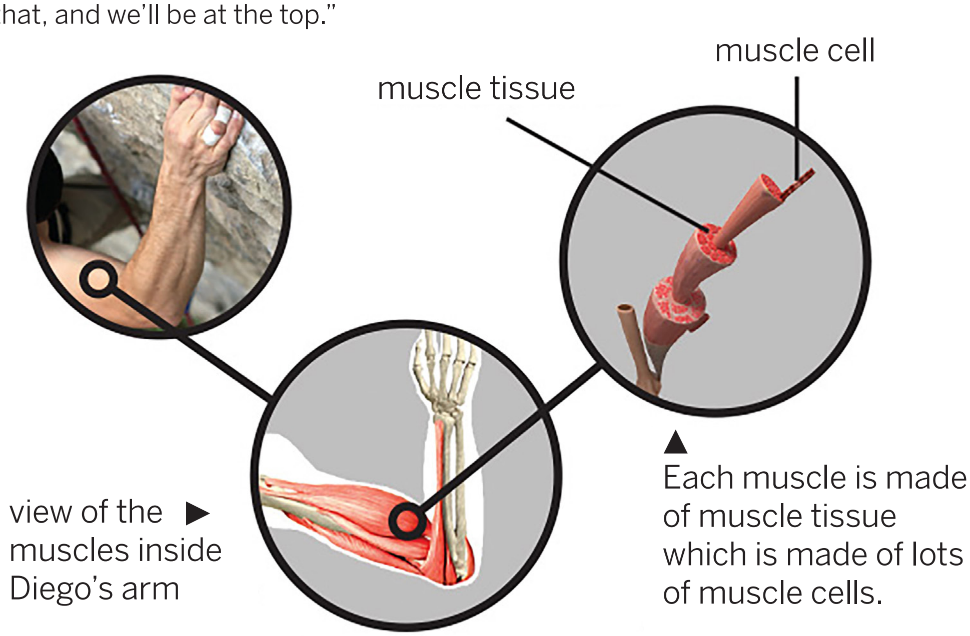
9:13 a.m.: Reaching the first ledge

What's happening at a large scale

Diego starts climbing up toward his brother, who went first and is waiting for him on the first rock ledge. Diego grabs handholds and pulls himself up. He reaches high for a small crack in the rock, and braces himself as he pushes with his legs. His leg and arm muscles feel like they are burning as he climbs up and up. The last move is the hardest, but Diego does it, then sits on the ledge by his brother, breathing hard. "Nice work!" says Gabe, "About twenty more climbs like that, and we'll be at the top."



Diego's muscles work hard as he climbs up the rock wall.



When Diego moves his arm, the muscles in his arm move. When the muscles in his arm move, every cell in his arm muscles moves.

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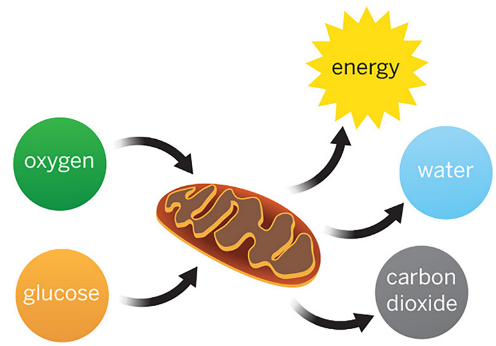
What's happening at a small scale

As Diego reaches for a handhold and pulls himself up, the muscles in his arm pull on his bones to make the movements happen. Diego's muscles are made of muscle tissue, and muscle tissue is made of tiny muscle cells. For Diego's muscles to move, each muscle cell has to move. The movements of billions of muscle cells add up to Diego's move on the rock.



In the mitochondria, glucose and oxygen combine to form carbon dioxide and water, releasing energy. This process is called cellular respiration.

Each muscle cell needs to release energy to move. Energy is released inside parts of the cells called mitochondria. Inside the mitochondria, when glucose molecules and oxygen molecules combine in a chemical reaction called cellular respiration, energy is released. The cells in Diego's muscles bring in oxygen and glucose from his blood. The cells use up these molecules quickly, and they send signals telling his brain they need more. These signals cause Diego to breathe faster and make him start to feel hungry.

1:17 p.m.: A big decision

What's happening at a large scale

They've made it past the halfway point. Diego pauses to put some chalk on his hands and calls out to Gabe. They've been taking turns leading and following. Now Diego is in the lead, searching for footholds and handholds as he climbs. Diego has to decide where to put the next piece of equipment that will hold their rope. He sees two small cracks in the rock that might work, but he's not sure which is better. If he chooses the wrong one, and he falls, the equipment could come loose, and that would be bad—very bad.

Diego looks closely at the two cracks and feels them with his fingers, trying to decide. It's hard to concentrate. Diego takes a deep breath. He looks again, and now he's sure: the crack on the left is perfect. He puts in the piece of equipment and attaches the rope.

As Diego thinks, cells in his brain send signals back and forth. This takes energy! That's why his brain cells need lots of oxygen for cellular respiration.

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What's happening at a small scale

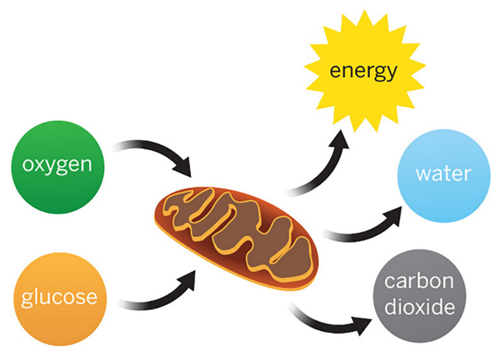
As Diego looks at and feels the rock, sensory receptors in his eyes and fingers gather information about what the rock looks like and feels like. The sensory receptors send signals to Diego's brain cells. These signals are messages that help Diego figure out what to do next. As Diego thinks, more signals move from one brain cell to another. Each signal takes energy to send. The energy is released by cellular respiration in Diego's cells. Diego might have had trouble concentrating because his brain cells were running low on the glucose or oxygen needed to release energy. Brain cells actually release and use twice as much energy as any other kind of cell in the body! Taking a deep breath brought more oxygen to Diego's brain cells.

Gabe is shivering just like Diego. Cells all over his body are releasing energy to keep warm, digest his dinner, and do all the other things cells need to do.

6:23 p.m.: Staying warm at night

What's happening at a large scale

Diego and Gabe have set up a special tent platform that's attached to the cliff—tonight they'll sleep hundreds of feet up! They are close to the top, but the sun is starting to set and they can't climb in the dark. Diego feels hungrier than he ever has in his life. Who knew instant noodles could taste so good? Now the sun is down and it's cold. Diego and Gabe get into their sleeping bags in their tent. Diego shivers, his whole body shaking. But soon he feels warm and falls asleep, dreaming of ropes and rock.



All the time, mitochondria in cells all over the body are taking in oxygen and glucose and releasing energy through cellular respiration.

What's happening at a small scale

As Diego shivers, his muscles shake with tiny movements. These movements warm up his body. Each muscle cell that moves releases energy through cellular respiration. These cells use glucose from his dinner and oxygen from his breath. All night, as Diego sleeps, his metabolism continues to work. His cells don't use as much oxygen and glucose as they did during the day, but they still release energy for pumping blood, digesting the rest of his dinner, keeping warm, repairing small injuries, and even dreaming.

11:34 a.m.: The top

The next day, after a morning of climbing, Gabe and Diego reach the top. They look down at the tree where they started, which now looks as small as a pin. It is a huge accomplishment, and all thanks to invisible actions inside their bodies and cells.

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The world of international bicycle racing can be so competitive that some athletes cheat by blood doping.

Blood Doping:

Messing with Metabolism to Win Races

To win international bicycle races, you can't just be in good physical shape—you have to be in AMAZING shape. Your metabolism has to work like a well-oiled machine. The world's top cyclists work to perfect their muscles and body systems so that they process oxygen, glucose, and amino acids better than almost any other humans on Earth.

A Cyclist's Metabolism

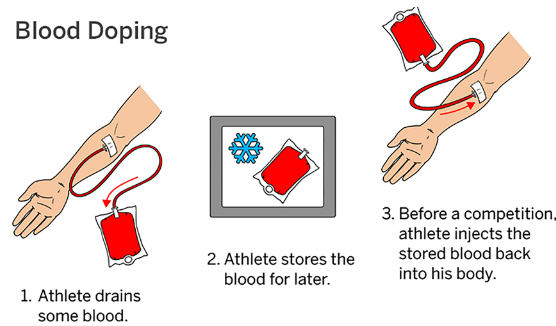
What's so special about a top cyclist's metabolism? Cyclists' muscle cells contain unusually high numbers of mitochondria, where glucose and oxygen combine to release energy. That means their muscles can release more energy than most people's muscles. To bring in more oxygen, top cyclists breathe hard: up to 75 breaths per minute. To bring in more glucose, they eat lots of carbohydrates, such as starch, even while they're riding! Cyclists often slurp down special gels filled with glucose while they're on their bikes, one hand on the handlebars and the other popping open the gel. To transport these molecules more quickly to their muscle cells, their hearts beat fast: up to 200 beats per minute. A faster heart rate pushes the molecules through the circulatory system more quickly and out to all the cells in the body sooner.

The problem for top cyclists is that even all that isn't always enough to win. Every cyclist in the race is in perfect physical shape, and all of them are looking for an edge to help them win. Sadly, that means some decide to break the rules to help them get ahead . . . not by taking a shortcut on the racecourse or breaking a competitor's bike, but by injecting themselves with extra blood from their own bodies—a practice known as blood doping. Blood doping is banned, meaning it's not allowed in competition, but some cyclists secretly do it to improve their performance. The most famous example of an athlete who used blood doping is Lance Armstrong, who was known as the best cyclist in the world until he admitted to blood doping in 2013.

Blood Doping © The Regents of the University of California. All rights reserved. Image credit: Shutterstock

What Is Blood Doping?

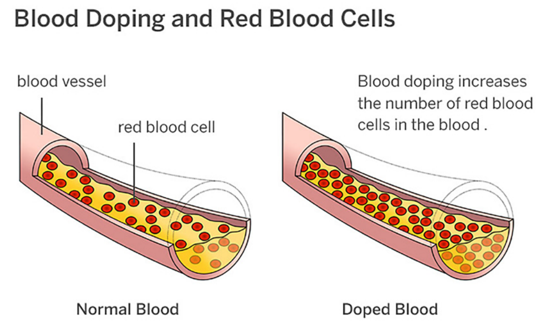
In most cases of blood doping, an athlete drains some of his or her own blood, chills the blood to keep it fresh, and stores it for several weeks or even months. The athlete's body naturally works to replace the lost red blood cells. Then, just before a competition, the athlete injects the stored blood back into his or her body. Injecting blood increases the number of red blood cells in the athlete's body.



Blood doping requires athletes to remove and store their own blood, then inject it back into themselves later.

How Blood Doping Works in the Body

Red blood cells carry oxygen from your lungs to every cell in your body, including your muscle cells. The red blood cells fill up with oxygen in the lungs and then are pumped out to the body cells, where they drop off the oxygen before returning to the lungs. Each red blood cell can only carry a certain amount of oxygen. Once your red blood cells are full, you can't get any more oxygen into your blood with that breath, no matter how much air you take in. Blood doping improves the body's ability to carry oxygen by increasing the number of red blood cells in the circulatory system. With more red blood cells, the circulatory system can deliver more oxygen to all the cells of the body. The extra oxygen delivered to the body's cells can increase the rate of cellular respiration, which can help an athlete perform better and for a longer time without becoming tired. This happens because oxygen is necessary for the release of energy in the body.



Blood doping increases the number of red blood cells in the body.

The body's cells release energy through a chemical reaction called cellular respiration. For cellular respiration to happen, cells need both oxygen and glucose. Oxygen enters the body through the respiratory system and is delivered to all the cells of the body by the circulatory system. At the same time, the circulatory system provides the cells with glucose produced when the digestive system breaks food down. Inside the cells, the glucose and oxygen react to produce carbon dioxide

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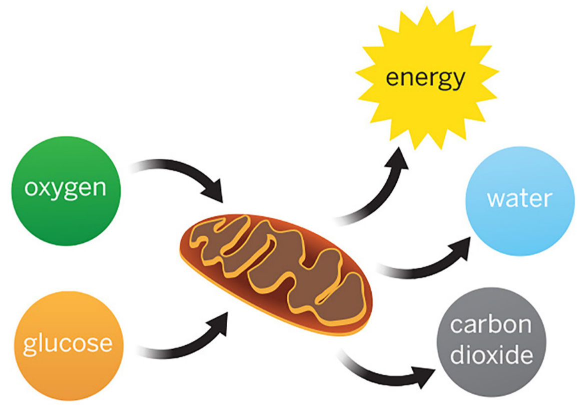
and water, and release energy for the body in the process. More oxygen in the body means a faster rate of cellular respiration and increased release of energy.



In the parts of the cells called mitochondria, glucose and oxygen combine to make carbon dioxide and water, releasing energy. This is called cellular respiration.

Catching Blood Dopers

Blood doping is very difficult to detect. Since the body always contains red blood cells, it is difficult to find evidence that an athlete has injected extra red blood cells into his or her bloodstream. One detection method involves testing the age of the red blood cells in a blood sample. The human body constantly produces new red blood cells to replace cells that have died. Blood doping means injecting stored blood, and the red blood cells in stored blood are older than the new red blood cells constantly being produced in the body. A blood sample with an unusually high number of older red blood cells can be evidence of blood doping.

Another method scientists use to detect blood doping is testing the amount of hemoglobin (HEE-moe-globe-in) in the athlete's blood. Hemoglobin is a protein made by the body that carries oxygen in red blood cells. The more red blood cells a person has, the more hemoglobin you'll find in his or her blood. If an athlete has a hemoglobin level that is higher on the day of a race than it was a week before the race, that provides evidence that the athlete might be blood doping. The athlete might even be disqualified from the race if his or her hemoglobin levels are too high.

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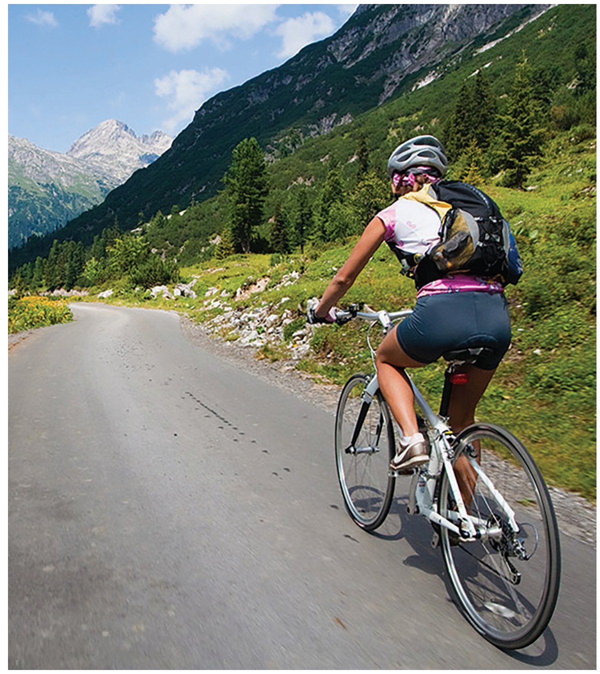
Dangerous Side Effects

One serious potential side effect of blood doping is that increasing the number of red blood cells also increases the thickness of the blood. This unusually thick blood makes the heart work harder and can even cause heart failure.

An Alternative to Blood Doping

There is a legal way for athletes to increase the number of red blood cells in the body: high-altitude training. In the weeks leading up to a competition, some athletes train in the mountains. At high altitude, there is less oxygen in the air than there is at sea level. The athlete's body adjusts to the lack of oxygen by producing more red blood cells: because the body senses that less oxygen is available, it produces more red blood cells so that more oxygen can be picked up with each breath. It takes the body several weeks to adjust and increase the number of red blood cells. High-altitude training takes a longer time than blood doping, but it has the same effect and is not considered cheating. However, high-altitude training may have the same harmful side effect of making blood thicker.



High-altitude training has similar effects to blood doping, but it's legal.

Blood Doping © The Regents of the University of California. All rights reserved. Image credit: Shutterstock

Odd Organisms

and How They Get the Molecules They Need

Blue whales are the largest animals on Earth.

Some organisms can seem very odd if you look closely at how their body systems work! All organisms need to take in molecules from their environment. However, different organisms may have very different ways of taking those molecules in and getting them where they need to go. For example, in order to take in enough oxygen to supply its huge body during long dives, a blue whale's lungs are almost 5,000 times larger than yours. Grasshoppers don't have lungs at all—they take in oxygen from the air through tiny holes along the sides of their bodies! Trout and other fish use gills instead of lungs, and they take in oxygen directly from the water they live in. Sea sponges and water bears have even stranger body systems. To learn more about blue whales and their amazing body systems, keep reading.

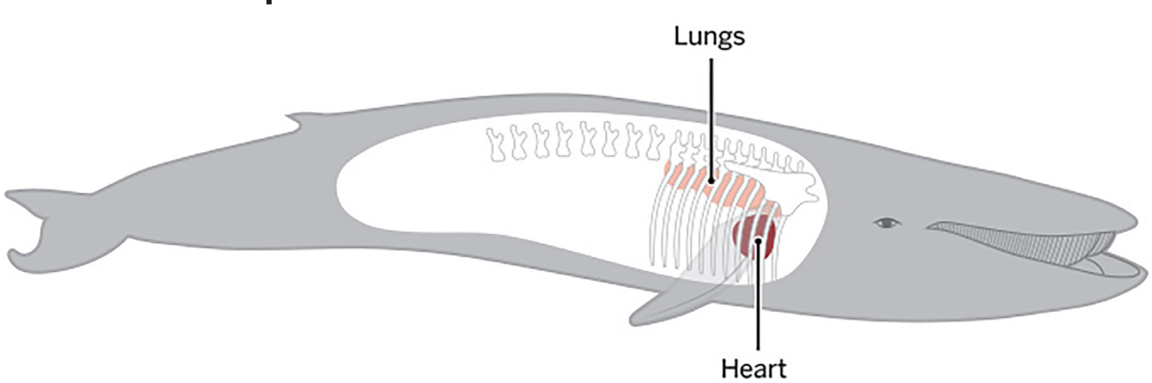
Blue Whale

Imagine that you are swimming next to the largest animal ever to have existed. It's as long as three school buses, weighs between 200,000 and 300,000 pounds, breathes air, and lives in the ocean. This animal is a blue whale, and its enormous size means that it needs to eat a lot of food and take in a lot of oxygen. Blue whales must dive deep underwater to feed, which means that they spend a lot of time holding their breath. How can a blue whale survive 20 minutes without taking a breath?

Getting Oxygen from the Air

Like humans, blue whales breathe air. Whales can't get oxygen from the water, so they have to hold their breath underwater, transporting oxygen through their respiratory systems. Whales breathe air into their lungs, which are lined with blood vessels called capillaries. Because whales are so big and because one breath of air has to last them a long time, the lungs of a blue whale are very large—nearly

Blue Whale Respiration



Blue whales are mammals, and must breathe oxygen from the air.

Odd Organisms: Blue Whale © The Regents of the University of California. All rights reserved. Image Credits: (t) Getty Images

5,000 times bigger than a human's lungs! Capillaries allow oxygen to enter the whale's blood, which carries it to the heart. The heart pumps the blood through the circulatory system, bringing oxygen to all the cells of the body. Cells use the oxygen for cellular respiration and must get rid of carbon dioxide produced during the cellular respiration reaction. The carbon dioxide goes into the circulatory system, where blood moves it to the heart and then to the lungs, where it will be breathed out.

Food for Energy Release

Just like humans, blue whales need energy to live and grow. Whales get the molecules they need to release energy from the air they breathe and the food they eat. Blue whales eat krill, a type of tiny animal that looks similar to a shrimp. Krill are high in fat and protein. To get enough food to maintain such large bodies, blue whales eat thousands of pounds of krill a day. The blue whale does not have teeth; instead, it has a part in its mouth that acts like a filter to keep the krill in and spit water out. The swallowed krill pass through the whale's digestive system. In the stomach, acids and enzymes begin to break them down. This partially digested food is then broken down into amino acids and molecules from fats, which are absorbed in the small intestine.

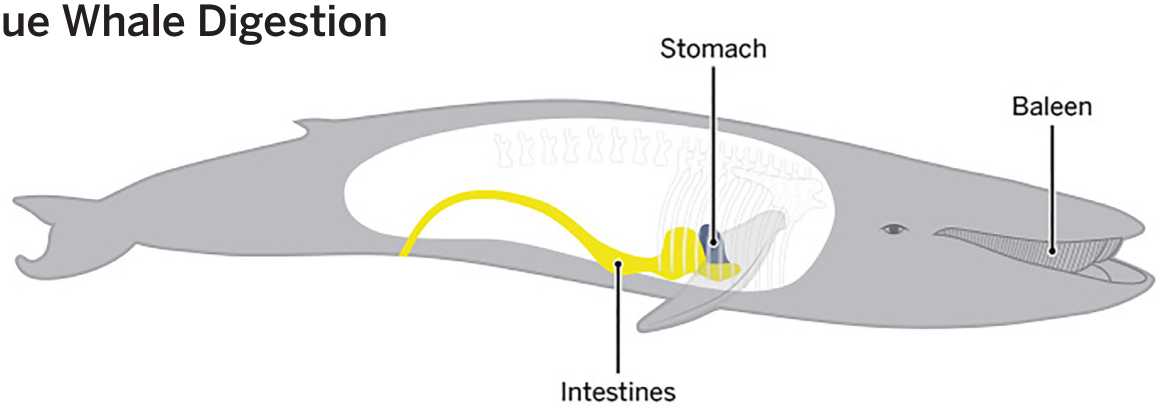
Bringing Matter to Cells

Since whales cannot breathe underwater, but spend most of their time there, their circulatory systems have adapted to the lack of oxygen. When a blue whale goes on a long dive, its heart slows down so it uses less oxygen. If the heart were pumping fast, it would quickly use up all of the oxygen stored in the lungs.

Another way blue whales use less oxygen underwater is by decreasing blood flow to certain parts of the body. Since the brain always needs molecules from blood for energy, blood temporarily stops flowing to less important organs, such as those in the digestive tract, and to the muscles of the tail fins and flippers.

Although whales can hold their breath longer than humans can, they still need oxygen and food, which they break down into molecules that can be used to release energy. Despite the many physical differences between blue whales and humans, our cells still have the same survival needs.

Blue Whale Digestion



Blue whales digest their food and use oxygen and molecules from the food to release energy.

Odd Organisms: Blue Whale © The Regents of the University of California. All rights reserved.

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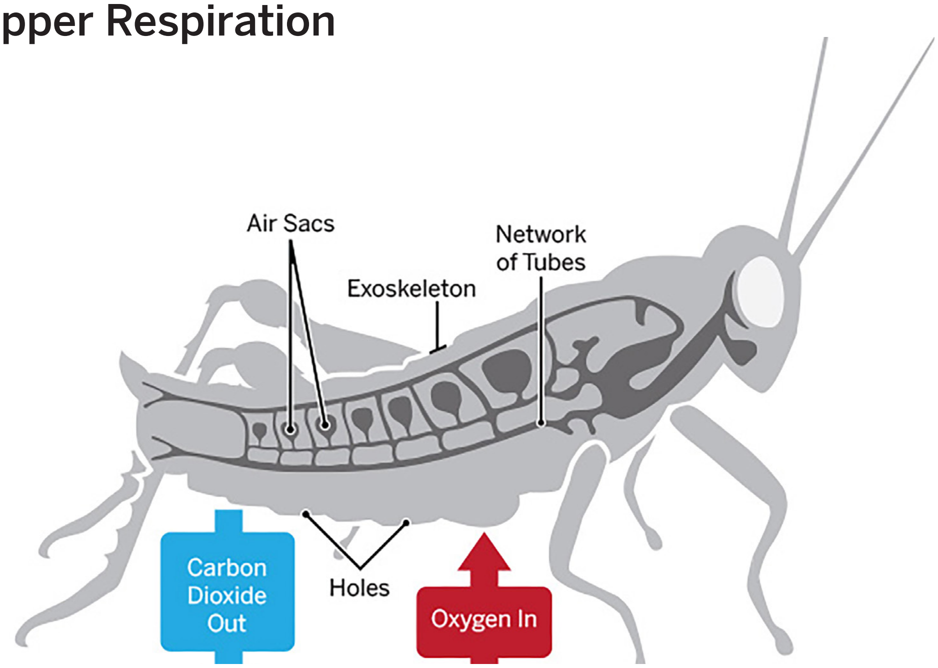
Grasshoppers can jump very high in comparison to their small size.

Grasshopper

Imagine being able to jump 180 feet into the air over and over again. If you were a human-sized grasshopper, you could—but you'd also need to eat twice your body weight in food every day! Like you, grasshoppers get glucose and oxygen from food and air and use those molecules to perform cellular respiration, which releases energy in their cells. It's this reaction that gives grasshoppers the energy they need to jump so high, so often.

Grasshopper Respiration



Grasshoppers don't have lungs; instead, they take air in through tiny holes on the outsides of their bodies.

Odd Organisms: Grasshopper © The Regents of the University of California. All rights reserved. Image Credits: (t) Shutterstock

Getting Oxygen Without Lungs

Grasshoppers need to take in oxygen molecules and get them to their cells, just as humans do. However, the system that moves oxygen around in the grasshopper body is very different from the one that does the same in humans—grasshoppers don't have lungs, and they don't carry oxygen in their blood. Oxygen enters the body through tiny holes in the grasshopper's abdomen and travels to the cells in the body through a complex network of tubes.

Converting Food Into Glucose

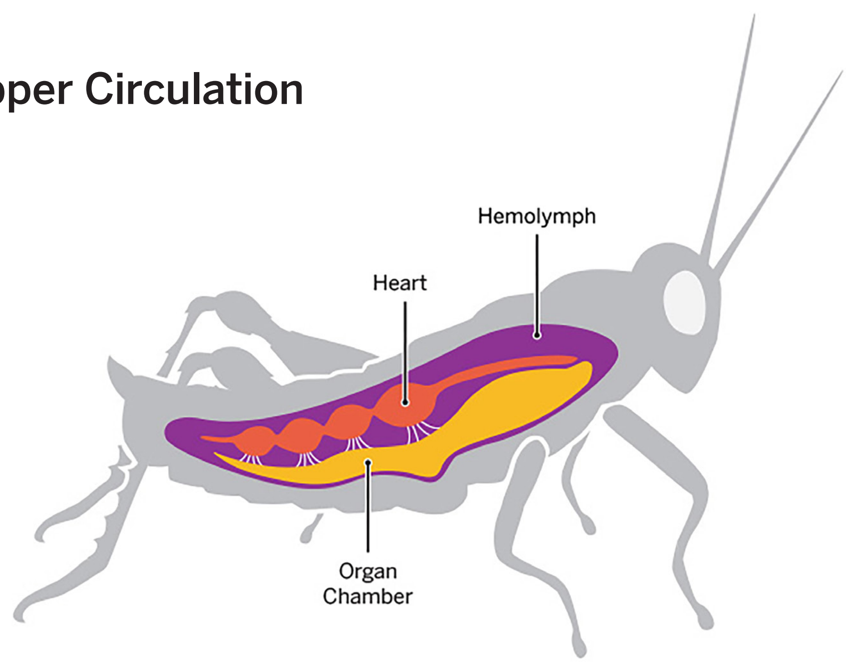
What do grasshoppers eat? Grass, of course! Grass is mostly made of a substance called cellulose. Humans eat cellulose, too: we call it fiber. However, humans can't actually digest cellulose: it passes through our digestive systems without breaking down. Grasshoppers, on the other hand, have enzymes that can break down cellulose into glucose. Although grasshoppers and humans have different organs in their digestive systems, those organs share the function of converting food into glucose and then sending the glucose into the circulatory system, where it's carried to cells all over the body.

Bringing Matter to Cells

Like you, a grasshopper has a circulatory system for carrying molecules to its cells. However, a grasshopper's circulatory system is very different from a human's circulatory system. Your circulatory system is filled with blood. Instead of blood, grasshoppers have a different fluid called hemolymph. Human blood is always contained within blood vessels and pumped through the body by the heart. Instead of a single heart and many blood vessels, grasshoppers have a single tube that runs down the top of the body, with several hearts inside it. The blood-like hemolymph simply fills up the space surrounding a grasshopper's organs, bringing glucose to the cells. The main function of a grasshopper's circulatory system is to carry glucose and other nutrients. It doesn't have to carry oxygen the way a human circulatory system does, because oxygen enters through holes in the grasshopper's body and goes directly to the cells.

Grasshoppers obtain oxygen and glucose differently than humans do, but the resulting chemical reaction is the same—cellular respiration occurs, releasing energy.

Grasshopper Circulation



A grasshopper has multiple hearts in its circulatory system.

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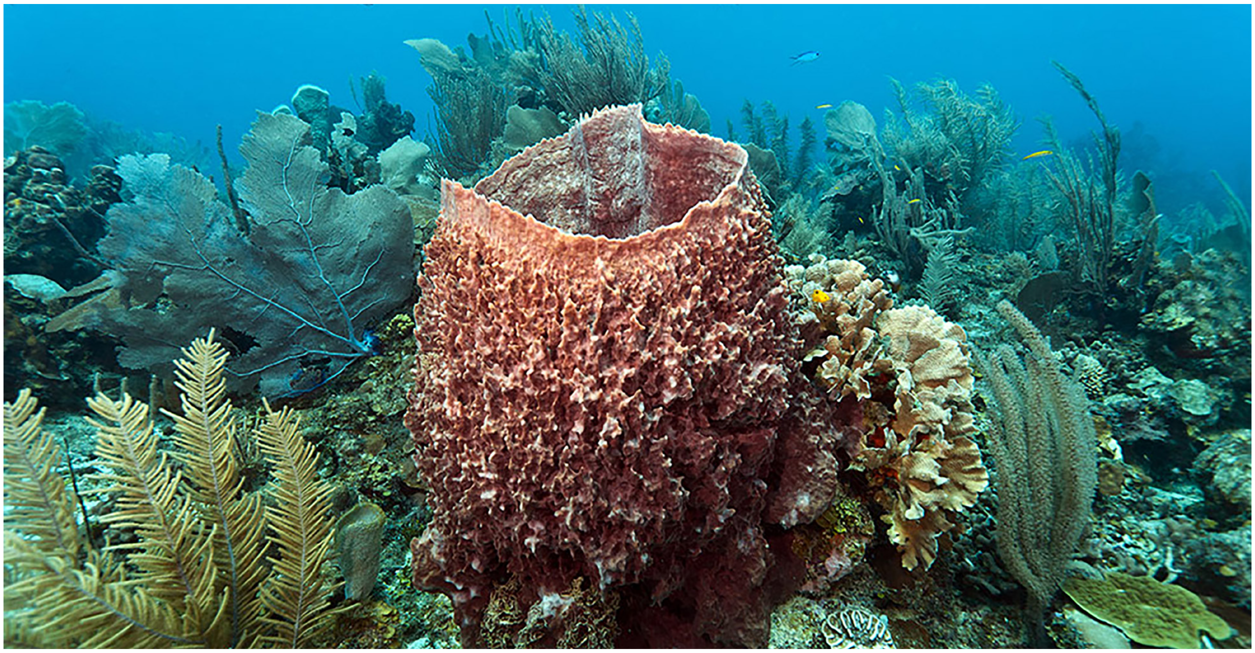

Some sponges are barrel-shaped and can grow large enough for a human to fit inside.

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Sea Sponge

Did you know that you can use a sea creature to clean your house? For hundreds of years, people used the skeletons of animals called sea sponges, which had been brought up from the sea floor and dried, to clean up spills and scrub their houses—and both the name and the shape stuck! Most of the sponges we use today are made in factories, but they are modeled after the sponges found on the bottom of the ocean.

Sea sponges come in all shapes and sizes, from very tiny to large enough to fit an entire human inside! They're very simple creatures, though: a sponge doesn't have a respiratory system, a digestive system, or a circulatory system. Instead, sponges rely on the flow of water through their bodies to bring them food and oxygen and carry waste away. Most sponges are shaped like tubes, with one end stuck to a rock, coral reef, or the sea floor. They bring water in through pores, or small holes, on the outsides of their bodies, and release it from the top of the tube. As the water flows through, the sponge takes what it needs and gets rid of what it doesn't.

Odd Organisms: Sea Sponge © The Regents of the University of California. All rights reserved. Image Credits: (t) Shutterstock

Getting Oxygen from the Water

Just like you, sea sponges need oxygen to survive. Instead of breathing oxygen from the air, sponges take in oxygen directly from the water they live in. The water has oxygen molecules dissolved in it. Water enters the sponge through tiny pores and is spread through the body by whip-like structures called flagella. Wherever it goes, the water carries oxygen molecules to the sponge's cells.

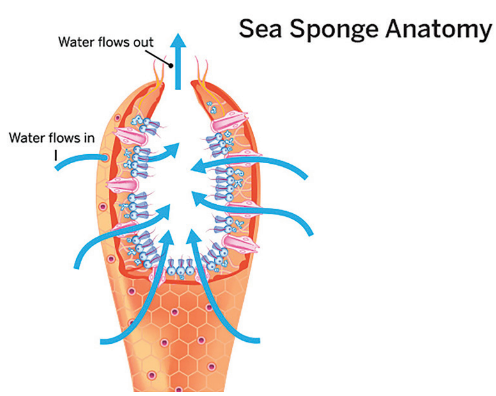
Food for Cellular Respiration

Sponges stay in one place, and can't move to go find food—which means their food has to come to them. Like everything else they need, sponges get their food from the water that flows through them. The water carries tiny bits of food, which the sponge filters out as the water passes through it. Cells in the sponge's body break the food down into glucose molecules. Then the cells can use the glucose molecules, along with the oxygen molecules they took in from the water, for cellular respiration. Through cellular respiration, the cells release the energy they need in order to function.

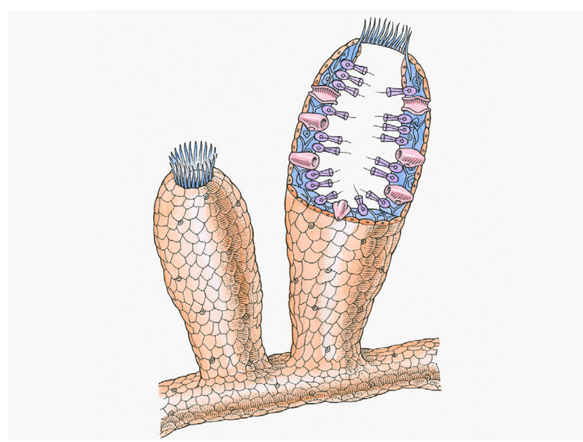
Bringing Matter to Cells

Sea sponges don't have circulatory systems. Many of a sea sponge's cells get all the molecules they need directly from the seawater that flows through the sponge. However, some cells deep inside the sponge's body don't come into direct contact with seawater, and those cells need help getting glucose. Special cells in the sponge's body actually take glucose to the cells that can't filter food directly from the water.

The bodies of humans and sea sponges don't have very much in common—but both are animals, both need oxygen and glucose to stay alive, and both have bodies that make sure their cells get the molecules they need.



Sea sponges take in water through holes near their bases and let it flow out through their tops.



The cells that line the insides of sea sponges catch food from the water that passes through them.

Odd Organisms: Sea Sponge © The Regents of the University of California. All rights reserved.

Trout are fish that live mainly in rivers and lakes.

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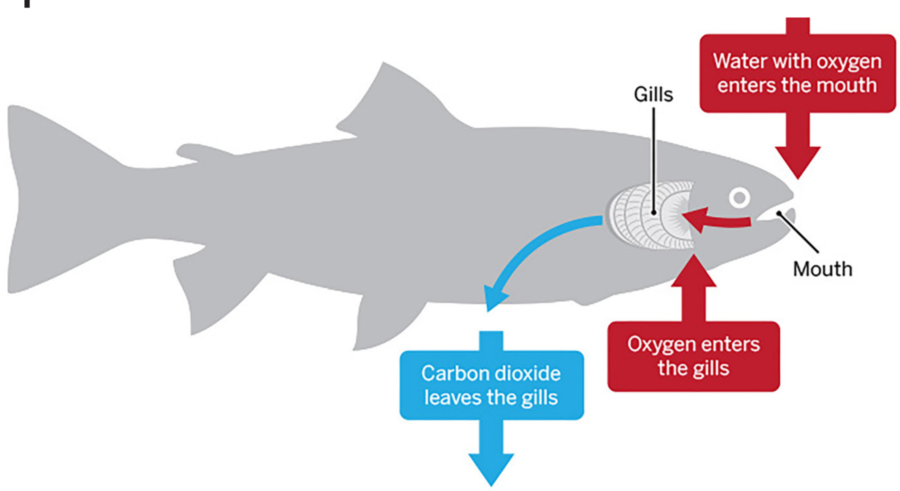
Trout

How is a human like a trout? After all, humans walk on dry land and breathe air through lungs, while trout swim underwater and don't have lungs at all. Still, both humans and trout must take in food and oxygen to release energy through cellular respiration. Humans get oxygen from the air, but trout live underwater—so where does their oxygen come from?

Getting Oxygen from Water

Trout need oxygen to survive and release energy, but they can't get it from the air. So how do they get oxygen underwater? Most water has oxygen dissolved in it—the oxygen isn't visible, but it's there, and fish can use it. Fish have gills that serve the same purpose as lungs do in humans: exchanging gases. They open their mouths and take in water containing oxygen. This water passes through the gills, which absorb oxygen from the water and send it into

Trout Respiration



Trout take in oxygen from water using organs called gills.

Odd Organisms: Trout © The Regents of the University of California. All rights reserved. Image Credits: (t) Getty Images

the blood. The blood carries oxygen to every cell in the body.

Food for Cellular Respiration

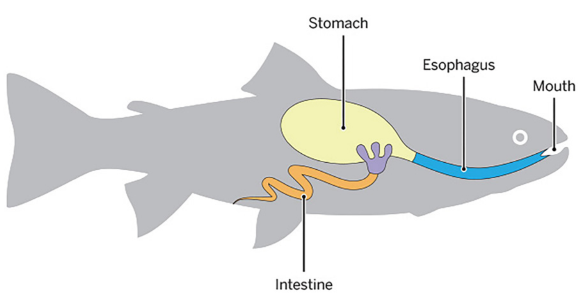
Like humans, trout eat many different things, and their digestive systems break food down into smaller molecules they can use. The trout diet includes bugs, worms, plants, and other fish. Trout get some glucose for cellular respiration from starch in the plants they eat: the glucose from the plants reacts with oxygen in the trouts' cells to release energy. Trout can also break down fats from the bodies of animals they eat into molecules that can be used to release energy. Food enters the trout's body through the mouth, then moves into the esophagus. Trout don't chew their food with teeth, but their esophaguses can stretch to allow large pieces of food to pass through. In the trout's stomach, enzymes and acid begin to break food down. At the end of the stomach, there are several small tubes that produce more enzymes that convert the food into glucose. The breakdown of food is completed in the intestine. There, glucose and other molecules pass through the walls of the intestine and into the circulatory system.

Bringing Matter to Cells

The circulatory system of a trout is similar in many ways to a human circulatory system. Just like you, a trout has a heart that pumps blood, carrying glucose and oxygen molecules through a network of blood vessels and capillaries. In both trout and humans, blood vessels also carry away the carbon dioxide that is produced in the process of cellular respiration.

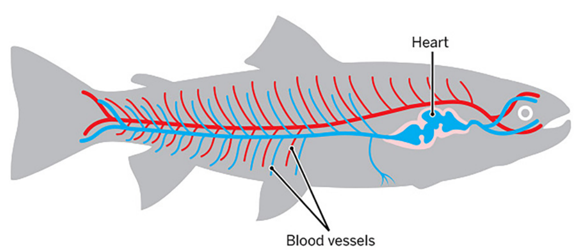
Trout obtain oxygen and glucose differently than humans do, but the end result is the same: cellular respiration occurs in the cells and energy is released.

Trout Digestion



Trout eat bugs, worms, plants, and other fish, and their digestive systems break down their food into smaller molecules they can use.

Trout Circulation



The circulatory system of a trout carries oxygen and glucose to all its body cells, just as a human circulatory system does.

Odd Organisms: Trout © The Regents of the University of California. All rights reserved.

Water bears got their name because they look and move a little like tiny bears.

Odd Organisms: Water Bear © The Regents of the University of California. All rights reserved. Image Credits: (t) Getty Images

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Water Bear

If you were to think of the toughest animal you could imagine, what would it be? Maybe a huge animal with large claws and sharp teeth? What about a tiny animal with no teeth and no lungs that moves slowly and eats algae and bacteria? This animal may not sound tough, but it can withstand pressure, heat, and cold that would kill any other living organism. What animal is this? A water bear! When conditions are tough, and there is no oxygen, water, or food available, water bears go into a state of hibernation called the tun (toon) stage. During this time, cellular respiration stops almost completely and the water bear does not move or react to its environment—but it can come back to life as soon as conditions return to normal.

Getting Oxygen from the Water

Water bears don't have respiratory systems. Instead, the water bear's body simply absorbs oxygen directly from the water it lives in. Water contains dissolved oxygen. Water bears can live wherever there is water, even in tiny amounts, like under leaves on damp soil. Humans have lungs and respiratory systems because we are too big to let oxygen just float into our bodies the way water bears do. Even though water bears get oxygen in a different way than humans do, we both need oxygen for the same reason: to release energy through cellular respiration.

Getting Glucose from Food

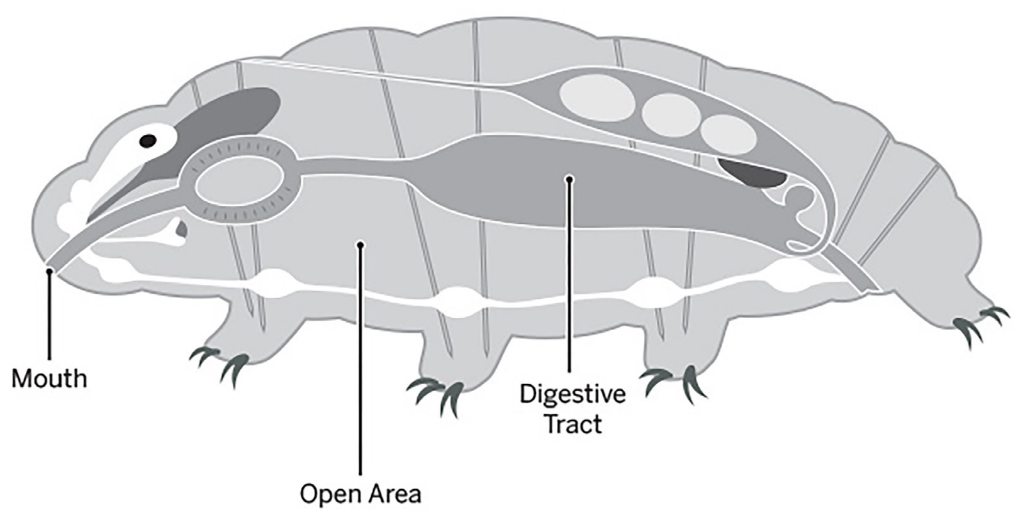
Different species of water bears eat different things, like moss, algae, bacteria, and very small animals. The water bear has a simple digestive system. It uses its tube-shaped mouth to poke through the cell membranes of the microorganisms it eats. Then it sucks the fluid from inside the cell. This food matter supplies water bears with amino acids and the glucose they need for cellular respiration.

Getting Matter to Cells

We humans need a circulatory system to make sure all of our cells get the molecules they need, but it's simpler for water bears to get molecules to their cells. A human body has about 10,000,000,000,000 (ten trillion) cells, while the body of a water bear only has about 40,000 cells. With such a small number of cells, water bears don't need circulatory systems: they get matter to their cells in a different way. The water bear moves a little bit like an inchworm, and it uses special squeezing muscles to move around. As the water bear moves, it also moves body fluids through an open area that's surrounded by every cell in the water bear's body. Oxygen, glucose, and amino acids get to every cell in the water bear's body through that open area.

The water bear has adapted to the way its environment sometimes dries up, but it can only do this by extreme hibernation. When they are not hibernating, water bears still need glucose and oxygen to live. Despite the many differences between water bears and humans, we need oxygen and glucose for the same reason: cellular respiration.

Water Bear Anatomy



Water bears have simple body systems that absorb oxygen directly from water and transport matter to their cells.

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Metabolism:
Making the Diagnosis

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