



OVERVIEW

The [Biomolecules on the Menu](#) Click & Learn illustrates the process of digestion and how it connects to metabolism and cellular respiration. Students embark on an engaging exploration of how food is digested into nutrients, how nutrients are absorbed into the bloodstream and delivered to cells, and how cells use nutrients in cellular respiration.

The two accompanying “Student Worksheet” documents guide students through different parts of the Click & Learn and ask them to reflect on the information provided. The main differences between the worksheet are summarized below:

Worksheet	Time Estimate	Content	Approach
High School	Two 50-min class periods.	<ul style="list-style-type: none"> • Digestion • Cellular respiration overview 	<ul style="list-style-type: none"> • Application based, starting with the scenario of an athlete trying to decide between two foods. • Explores food labels, what happens to food in the major digestive organs of the body, and how nutrients are used for energy or stored for later use.
Higher Ed	One 50-min class period or homework.	<ul style="list-style-type: none"> • Digestion • Cellular respiration in detail 	<ul style="list-style-type: none"> • Focused review. • Students first identify the major anatomical structures involved in mechanical and chemical digestion. • Students then investigate the relationship between digestion and metabolism and the interconnected chemical pathways that convert ATP and store energy.

The educator document contains multiple resources for implementing this case study with students, including the following (select links to go directly to each section in the document):

- suggested [procedures](#) using the Click & Learn and worksheets
- [assessment guidance](#) for the questions in the “[High School](#)” and “[Higher Ed](#)” worksheets
- [appendix](#) with additional background on the concepts and simplifications in the resource

Additional information can be found on [this resource’s webpage](#), including the suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

For both worksheets:

- Digestion breaks down food into molecules (nutrients) small enough to enter the bloodstream and participate in cellular metabolic processes.
- Some organs make secretions involved in the chemical breakdown of food (chemical digestion), some mechanically break down food (mechanical digestion), and some do both.

- Enzymes facilitate the breakdown of carbohydrates, proteins, and fats.
- Cellular respiration is a process that uses nutrients and oxygen to produce ATP. Water, carbon dioxide, and heat are byproducts of this process.
- Nutrients that are not used for energy immediately can be stored for later use.

For the “Higher Ed” worksheet only:

- Cellular respiration involves a series of chemical reactions, some of which occur only in the presence of oxygen.
- Metabolism includes catabolic and anabolic reactions that can interconvert molecules based on the needs of the cell.

STUDENT LEARNING TARGETS

For the “High School” worksheet:

- Compare the amounts of different biomolecules on food labels.
- Describe the roles of the digestive system’s major organs, including how they break down food into nutrients.
- Explain how cells can use nutrients for energy immediately or store them for later use.

For the “Higher Ed” worksheet:

- Describe the general locations and functions of the digestive system’s major organs.
- Identify mechanical and chemical digestion.
- Describe the small intestine’s role in absorbing nutrients into the bloodstream.
- Describe the overall function, inputs, and outputs of cellular respiration.
- Compare catabolic and anabolic pathways for different nutrients.
- Identify the role of oxygen and carbon dioxide in catabolism.
- Analyze a blood glucose level graph in a non-diabetic individual.

PRIOR KNOWLEDGE

For both worksheets, students should:

- be familiar with the basic structures of biomolecules (specifically, that they are composed of smaller units)
- know that enzymes are proteins and that enzymes are involved in chemical reactions

For the “Higher Ed” worksheet, students should also:

- be familiar with the roles of reactants, products, and byproducts in a chemical reaction

MATERIALS

- copies of the selected worksheet
- access to the [Biomolecules on the Menu](#) Click & Learn

BACKGROUND

The Click & Learn was designed to provide an overview of digestion and metabolism and to connect eating food to cellular respiration. To increase accessibility for all students, this Click & Learn makes several simplifications. The [“Additional Background” appendix](#) lists these simplifications, provides additional details, and addresses students’ questions. You may use this document for yourself or provide certain sections of it to your students.

TEACHING TIPS

- You are encouraged to modify the questions in the worksheets and procedures to fit your needs. In addition, you are free to mix and match questions from each worksheet.
- Look out for misconceptions that protein is only in animal products. You may point out that beans, lentils, quinoa, tofu, and nuts are all sources of protein that do not come from animals.

PROCEDURE

“High School” Worksheet

It is recommended to distribute each part of this worksheet separately.

Part 1 does not require access to the Click & Learn. Have students complete Part 1 in small groups or individually by recording their answers in the worksheet. Alternatively, you can complete Part 1 as a class discussion. Provide students with the first two questions first. After they answer those questions, provide the rest of Part 1, including the food labels.

Part 2 requires students to access the Click & Learn. Students can work on it individually, in small groups, or outside of class (as a homework assignment). Let students know that all the information they need to complete Part 2 is either in the Click & Learn or the worksheet.

Part 3 can serve as a final assessment or extension activity that students complete in class or individually as homework. This may be the only part of the worksheet that you require students to submit for feedback.

“Higher Ed” Worksheet

Parts 1 to 3 guide students through the Click & Learn. They can be completed individually as homework assignments before class or during class in small groups.

Part 4 can be completed in small groups and as a whole class discussion.

ASSESSMENT GUIDANCE

The answers below include more detail than would be provided by most students. They are meant to give teachers additional information they may want to discuss with their students.

“High School” Worksheet

PART 1: Which Food?

1. What are some similarities and differences between the two foods?

The goal is not for students to provide “correct” answers but to start thinking about what they might know about the two foods.

Similarities include that both foods provide energy and build our cells. Differences may include:

- ***Steak comes from animals, and spaghetti does not.***
- ***Spaghetti has more carbohydrates (which can provide the body with energy) than steak.***
- ***Steak has more protein (which is essential for building muscle) than spaghetti.***
- ***Steak has more fat than protein.***
- ***Some students may know that animal products, like steak, contain cholesterol and plant-derived products, like spaghetti, do not.***

Students may also suggest that the two foods could vary in Calories or other characteristics.

2. The athlete wants to choose foods that will help them:
- build their muscle mass as they exercise and train for their upcoming event
 - provide energy so that they can prepare for and perform well at the event

What questions might they ask to decide whether eating spaghetti or steak best meets their needs?

Potential questions include:

- **Which food provides more energy or is better for building muscle?**
 - **What is each food made of?**
 - **What are the costs of each food?**
 - **What are the health benefits of each food?**
3. Based on the food labels, what are the main similarities and differences between the two foods?
Similarities include that both foods have about the same amount of energy (Calories) per serving.
Differences include:
- **Only the spaghetti contains carbohydrates.**
 - **Only the steak contains cholesterol.**
 - **The steak has more protein, fat, and sodium than the spaghetti.**
4. Why do you think there are differences between the nutritional content of these two foods?
Students may suggest that:
- **The foods come from different sources (e.g., animal vs. plant).**
 - **The foods may have been manufactured or seasoned differently. (You may point out to them that there is no mention of seasoning in the food labels.)**
5. Which food do you think would provide more energy? Which food do you think would be better for building muscle?
The goal is not for students to provide “correct” answers but for you to get a sense of their prior knowledge.
For “which food would provide more energy”:
- **Students may notice that the steak has slightly more Calories per serving. However, because the serving size for steak is 4 oz (113 g) compared to 2 oz (57 g) for spaghetti, the spaghetti has more Calories by weight.**
 - **Students may know that carbohydrates or sugars are a preferred energy source for the body. The spaghetti has more carbohydrates than the steak.**
 - **Students may know that fats are the body's primary source of long-term stored energy. The steak has more fat than the spaghetti.**
- For “which food would be better for building muscle,” students may know that protein is typically used to build muscle. The steak has more protein than the spaghetti.**
6. Does the information on these food labels answer some of the questions you listed in your answer to Question 2? What additional questions might the athlete have?
Student answers will vary depending on their previous questions and prior knowledge. Additional questions could include:
- **What are the differences between fats, proteins, and carbohydrates?**
 - **Why are carbohydrates a good energy source?**
 - **Why are some people allergic to some foods?**
 - **Does protein come only from meat?**
 - **What does cholesterol do?**




- **What is sodium?**
- **How are Calories calculated?**

Some of these questions will be answered in the activity but not all. Please keep track of the questions so that you can revisit them at the end of the activity. Additional information is available in the [“Additional Background”](#) appendix at the end of this document. You may provide students with some of this information depending on your goals for this activity.

7. Once the athlete eats the spaghetti or steak, what happens to the biomolecules in the food?
Students may know that the food gets digested (broken down) in the body. Some students may understand that food is broken down into molecules small enough to be absorbed into the bloodstream and delivered to all the cells in the body.

PART 2: How Does the Body Use Food for Energy?

8. Why does your body need to digest food?
The body needs to digest food to build cells and fuel activities. Digestion breaks down food into molecules (nutrients) that are small enough to be absorbed into the bloodstream and delivered to cells in the body.
9. Fill in the table to show which biomolecule is represented by which symbol in the Click & Learn.

Symbol	Biomolecule
	Fats
	Carbohydrates
	Proteins

10. If the athlete eats the spaghetti or steak, what happens to the food in their mouth?
Teeth chew the food into smaller pieces (mechanical digestion). Saliva, which contains enzymes, mixes with these smaller pieces of food and begins to break them down (chemical digestion).
11. What are the two types of digestion that occur in the mouth?
Mechanical digestion and chemical digestion
12. The athlete decides to eat the spaghetti. The illustrations below represent what happens to the spaghetti in their stomach. Using the letters A–D, list the order of the illustrations from when the chewed-up spaghetti first enters the stomach to when it leaves the stomach.
C, D, A, B
13. How would illustrations for the steak be similar or different to the ones for the spaghetti?
The steak would also be broken down into biomolecules and nutrients. However, the steak would have no carbohydrates, more fats, and more proteins.

14. The illustrations below represent what happens to the spaghetti in the athlete's small intestine. Using the letters A–D, list the order of the illustrations from when the biomolecules in the spaghetti first enter the small intestine to when they leave.
B, C, A, D
15. What are the main molecules present in the small intestine when the athlete eats the spaghetti?
Monosaccharides, fatty acids, and amino acids
16. How would that list be different for the steak?
It would be all amino acids and fatty acids.
17. "Sugar" is another word for monosaccharide. Which food, spaghetti or steak, would be broken down to sugar in the small intestine?
Spaghetti
18. If someone experiences liver failure (i.e., their liver is not working), what would happen to digestion in their small intestine?
The liver produces substances that help break down food in the small intestine, such as enzymes, bile, and buffers. So if the liver is not working, the small intestine may not digest food as quickly or effectively.
19. Explain why eating the spaghetti would produce bulkier feces (i.e., more poop) than eating the steak.
Feces contain undigested food molecules, such as fiber. The spaghetti contains some fiber, which would bulk up the feces, but the steak has none.
20. What other molecule does the bloodstream deliver to cells so that they can convert the energy in nutrients into usable energy (i.e., ATP)?
Oxygen (O₂)
21. As cells produce ATP, they also form the following byproducts: carbon dioxide, water, and heat. What happens to each of these byproducts?
Some water and heat is used by the body. (Though not mentioned in the Click & Learn, some carbon dioxide is also used to maintain the blood's pH.) Excess byproducts can be harmful and are eliminated from the body in various ways:
- **Carbon dioxide leaves the body when you breathe out.**
 - **Water leaves through sweat, urine, feces, or water vapor in your breath.**
 - **Heat leaves the body and goes into the external environment.**
22. In between meals, cells do not receive any nutrients from food, so they use energy-rich molecules stored in the body.
- a. Which main storage molecule would be produced from eating spaghetti?
Glycogen
 - b. Which main storage molecule would be produced from eating steak?
Triglycerides. (Students may also answer proteins; however, point out to students that protein is not a main source of stored energy. Protein is used mainly for building structures in cells. If people eat more protein than they need for building cells, amino acids from their diet may be converted to ATP. If they are not needed for energy, the body will store excess protein as fat.)
23. What needs to happen to storage molecules before they can be used for energy?
They need to be broken down into nutrients.

PART 3: Extension

24. Explain how carb-loading might allow cells to produce more ATP during a marathon.

Carb-loading increases stored glycogen, which can be broken down to get nutrients for producing ATP during a marathon.

25. Some marathon runners eat **energy gels** (food label shown in Figure 3) *during* a marathon.

a. Based on the food label, what is the main energy source in energy gels?

Students may say carbohydrates, monosaccharides, or sugars. The carbohydrates consist exclusively of added sugars. (Added sugars are sugars that are added to foods during processing. Added sugars are different from naturally occurring sugars, such as the ones found in milk, fruit, and vegetables.)

b. What advantage might runners who eat energy gels have over runners who do not?

Students may say that energy gels are a source of sugars (monosaccharides) that can be quickly absorbed into the bloodstream and used in ATP production. Runners who do not eat energy gels rely on stored energy molecules that must be broken down before they can be used to produce ATP. (Glycogen stores typically run out after one hour or so, and cells will start breaking down stored fat. It takes longer to break down triglycerides to produce ATP.)

26. During the race, the runners' breathing and heart rates will increase. Why is that?

Running requires energy in the form of ATP. Faster breathing and heart rates allow the runners to take in more oxygen, which they can use to produce more ATP. Students may also say that this helps the runners get rid of excess carbon dioxide.

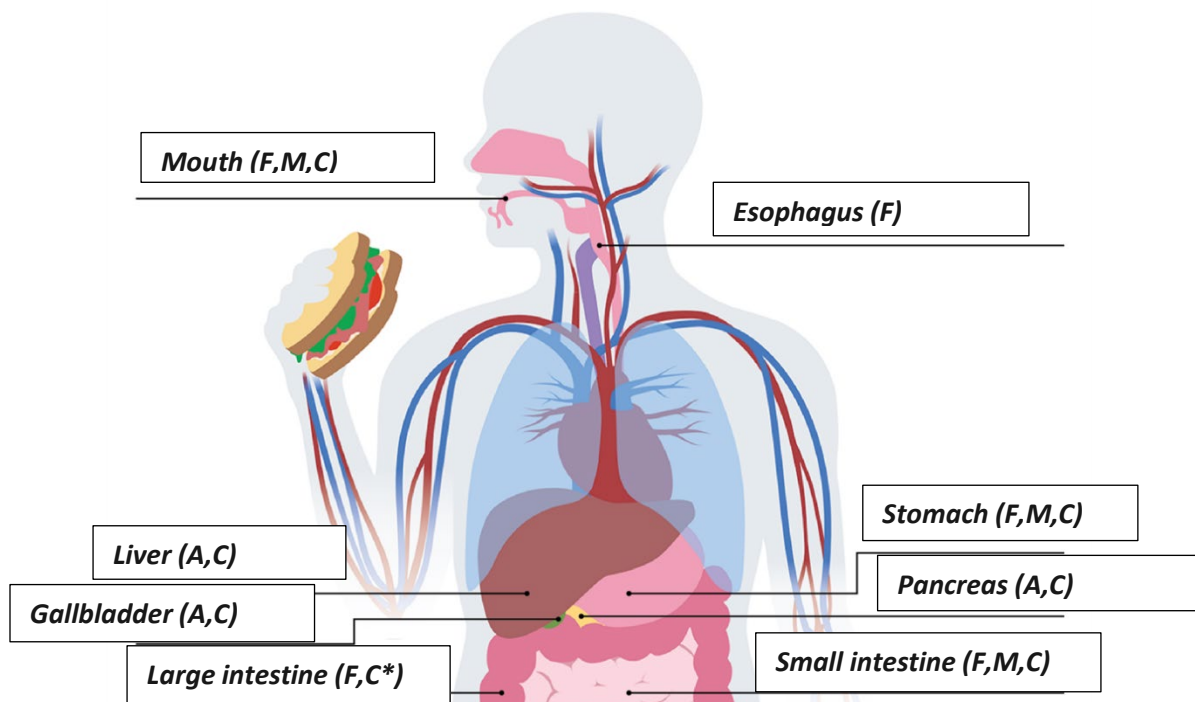
"Higher Ed" Worksheet**PART 1: Digestion**

1. Label Figure 1 as follows:

a. Identify the names of the major body structures of the digestive system as indicated on the figure.

b. Note the letter "**F**" next to the names of the structures that receive food (i.e., food goes directly through them) and "**A**" next to the names of **accessory structures** (structures that help with digestion but do not receive food).

c. Note the letter "**C**" next to the names of the structures that play a role in chemical digestion and the letter "**M**" next to the ones that play a role in mechanical digestion. Add both letters to any structure that helps with both chemical and mechanical digestion and no letter to a structure that helps with neither.









**Students may need clarification on the role of commensal bacteria in digestion. Bacterial metabolism involves chemical processes that break down specific molecules in food.*

2. Read the following statements labeled A–H. Then fill in the table below by writing the letter of the statement that answers the question.
 - A. This organ transports swallowed food to the stomach.
 - B. This organ produces bile.
 - C. This liquid in the mouth is involved in chemical digestion.
 - D. This organ contains lots of beneficial (commensal) bacteria.
 - E. These structures in the mouth perform mechanical digestion.
 - F. This organ produces enzymes and buffers that are delivered to the small intestine.
 - G. Most nutrient absorption happens in this organ.
 - H. This organ produces acid, which breaks down food into smaller pieces.

Question	Statement
What is saliva?	C
What are teeth?	E
What is the esophagus?	A
What is the stomach?	H
What is the small intestine?	G
What is the liver?	B
What is the pancreas?	F
What is the large intestine?	D

In class, you could read out the statements and have students ask the questions in the style of a game show like Jeopardy.

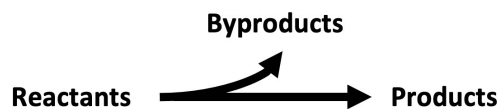
3. Digestion breaks down the biomolecules in food into smaller molecules called nutrients. Fill in the last column of the table with the name of the nutrient that each biomolecule is broken down into.

Biomolecules	Nutrients
 Carbohydrates	 Monosaccharides <i>(Students could also say sugars or glucose depending on their prior knowledge.)</i>
 Fats	 Fatty acids <i>(Students could also include glycerol depending on their prior knowledge.)</i>
 Proteins	 Amino acids

4. After passing through the digestive organs, where do the nutrients go before they can be delivered to the cells of the body?
They are absorbed into the bloodstream.

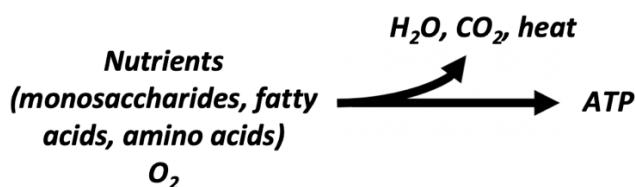
PART 2: Metabolism

5. What do cells need to take in from the bloodstream to get usable energy?
Nutrients (monosaccharides, fatty acids, amino acids) and oxygen
6. What byproducts do cells get rid of?
Water, carbon dioxide, and heat
7. This diagram represents the equation for a general chemical reaction.



Write a similar equation that represents cellular respiration. Include the following components as either reactants, byproducts, or products. Some components may be included in multiple places:

- amino acids
- adenosine triphosphate (ATP)
- carbon dioxide (CO₂)
- fatty acids
- heat
- monosaccharides
- oxygen (O₂)
- water (H₂O)



PART 3: Metabolism in Detail

8. Where do the four processes of cellular respiration — glycolysis, pyruvate oxidation, citric acid cycle, and electron transport chain — occur? Select the most accurate answer below.
 - a. ***In cells throughout the body***
 - b. In the bloodstream only
 - c. In the small intestine only

9. Select the “Cellular Respiration” button on the “Overview” page and observe how the diagram changes.
 - a. What changes in the diagram, and what do you think these changes mean?
Students should indicate that triglycerides, glycogen, and proteins become less visible or less prominent. These are all storage molecules. They are less prominent to show that they do not participate directly in cellular respiration. They must first be broken down into smaller molecules, which can then participate in cellular respiration.
 - b. What happens when you select the “Storage” button?
The most visible or prominent parts of the diagram are the storage and nutrient molecules at the top. The arrows between them indicate that the storage molecules can be broken down into nutrients, and the nutrients can be used to make the storage molecules.

10. Scroll down to the “Metabolism” section. Select the “Catabolism” button and then the “Anabolism” button. Are most cellular respiration reactions anabolic or catabolic?
Catabolic

11. Scroll down to the “Presence of Oxygen” section and select the “O₂ not required” button. Which process in cellular respiration does not require the presence of oxygen?
Glycolysis

12. Now select the “O₂ required” button.
 - a. What changes in the diagram, and what do you think these changes mean?
All the processes except for three — pyruvate oxidation, citric acid cycle, and electron transport chain — become less visible or prominent. This indicates that only these three processes require the presence of oxygen.
 - b. Compare the amount of energy (as indicated by the size of the ATP icons) released from nutrients in the presence and in the absence of oxygen. What do you observe?
More usable energy, in the form of ATP, is released in the presence of oxygen. The electron transport chain, in particular, produces much more ATP than the other processes.

13. Select the “Next” arrow to continue to the “Nutrients to ATP” section. Explore the diagram and read the following statements labeled A–D. Then fill in the table below by writing the letter of the statement that answers the question.
 - A. This process uses acetyl-CoA to release ATP, loaded electron carriers, and carbon dioxide.
 - B. This process produces acetyl-CoA, carbon dioxide, and loaded electron carriers.
 - C. This process breaks down glucose to release some ATP, pyruvate, and loaded electron carriers.
 - D. This process uses oxygen and electrons from loaded electron carriers to drive production of a lot of ATP, plus water and heat.

Question	Statement
What is glycolysis?	C
What is pyruvate oxidation?	B
What is the citric acid cycle?	A

What is the electron transport chain?	D
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14. Which biomolecules do our bodies:

a. Mainly use for energy?

Carbohydrates and fats

b. Mainly use to build and repair tissues?

Proteins

15. Complete the following sentence by filling in the blanks:

When the cells' energy needs are met, cells convert excess acetyl-CoA to **fatty acids**, which can be stored as **triglycerides**.

16. Marathon runners will often "carb-load" in the days leading up to a long-distance run. This involves eating more carbohydrates than usual and decreasing physical activity several days before the event.

a. Which storage molecules are made by carb-loading, and where are these molecules stored?

Glycogen, which is stored in the liver and muscles

b. Which specific nutrient can this storage molecule supply when runners need energy?

Glucose

PART 4: Putting It All Together

17. Explain how digestion and metabolism are distinct but related processes.

Digestion is the process that breaks food down into molecules (nutrients) that are small enough to be absorbed into the bloodstream. Metabolism consists of chemical reactions that convert the energy in nutrients into energy that your cells can use.

18. When you are active, your metabolism increases to satisfy your body's ATP needs. You may start to breathe more rapidly and feel hotter. Explain why each response happens:

a. Rapid breathing

To convert more nutrients to ATP, the body needs more oxygen for cellular respiration (specifically, for the electron transport chain). Cellular respiration also produces excess carbon dioxide, which needs to be released from the body. Breathing more rapidly helps you get in more oxygen and release more carbon dioxide.

b. An increase in body temperature

Heat is a byproduct of cellular respiration. So the more cells convert nutrients to ATP, the more heat they produce, which increases body temperature.

19. If a person loses five pounds of fat, where does that weight go? (Note that triglycerides are made up of carbon, hydrogen, and oxygen. Be sure to consider each in your response.)

They breathe it out as carbon dioxide (CO₂) and lose it as water (H₂O) or heat.

20. Answer the following questions based on Figure 2.

a. What do you observe in the graph for the first 45 minutes? How do you interpret this observation based on your knowledge of what's happening in the body?

Blood glucose increases for 45 minutes after the meal. This is because the food is being broken down into smaller nutrient molecules, including monosaccharides like glucose, which are absorbed into the bloodstream.

b. What do you observe in the graph after 45 minutes? How do you interpret this observation based on your knowledge of what's happening in the body?

Blood glucose decreases after 45 minutes. This is because the bloodstream delivers glucose to the cells, where it can be converted to ATP or storage molecules. As the cells convert/use up the glucose, the amount of glucose in the blood decreases.

(Students with prior knowledge may mention that the hormone insulin facilitates this process.)

- c. Between meals, blood glucose levels stay at a fairly constant range above zero. Why would it be important for the body to keep blood glucose levels above zero?

Glucose is converted to ATP, which the body needs to power cellular activities even in between meals. For example, several organs, including the brain, require glucose to function at all times.

- d. Where does the blood glucose between meals come from?

This glucose comes from breaking down the storage molecule glycogen in the liver or muscle cells.

21. In individuals with diabetes mellitus, blood glucose levels remain high for a longer period after a meal. This leads to hyperglycemia (*hyper-* = too much, *glyc/o-* = glucose, *-emia* = in the blood) and can be dangerous if it's not treated. What might be causing the hyperglycemia?

Students' answers will vary depending on their previous knowledge, and any answer is fine as long as they try to apply their learning to this scenario. They may suggest that the body's cells are not taking up glucose from the bloodstream. Some students may know about the role of the hormone insulin in regulating this process.

CREDITS

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APPENDIX: ADDITIONAL BACKGROUND

To increase accessibility, the *Biomolecules on the Menu* Click & Learn simplifies and omits details that students may be familiar with and/or interested in. You may want to make some of these simplifications apparent to students or provide additional background. This appendix includes the following topics:

TERMINOLOGY

[Use of the terms “biomolecules” and “nutrients”](#)

[Use of the terms “fats” and “lipids”](#)

[Use of the terms “carbohydrates” and “sugars”](#)

[Use of the term “byproducts”](#)

DIGESTION

[Biomolecule illustrations](#)

[Steps of digestion](#)

[Absorption in the small intestine](#)

[Commensal bacteria](#)

[Dietary fiber](#)

METABOLISM

[Depiction of cellular respiration](#)

[Storage molecules](#)

NUTRITION AND HEALTH

[Calories](#)

[Dietary guidelines](#)

[Diabetes mellitus](#)

TERMINOLOGY**Use of the terms “biomolecules” and “nutrients”**

The Click & Learn is called *Biomolecules on the Menu* and uses the term “biomolecules” to describe complex carbohydrates, proteins, and fats. Students may have heard these molecules referred to as “macromolecules” or “organic molecules.”

In the Click & Learn, the smallest units (monosaccharides, fatty acids, amino acids) of carbohydrates, fats, and proteins are called “nutrients” to differentiate them from the larger biomolecules. You may introduce your students to the terms “polymers” and “monomers” as alternatives to biomolecules and nutrients, respectively.

In addition, this Click & Learn focuses on energy-providing nutrients. Food contains many other nutrients necessary for life (e.g., water, salt, vitamins, and minerals).

Use of the terms “fats” and “lipids”

Students may wonder about the relationship between fats, lipids, and cholesterol. **Lipids** encompass a variety of hydrophobic biomolecules. Lipids include fats, which are used for energy and energy storage, and cholesterol, which is essential for cell structure, hormone production, and vitamin absorption.

Triglycerides are one type of fat that can be broken down into fatty acids and glycerol. This Click & Learn does not mention glycerol for simplicity. Fatty acids can be saturated or unsaturated; the Click & Learn does not make this distinction.

Use of the terms “carbohydrates” and “sugars”

The Click & Learn uses the term “carbohydrate” for the biomolecule/polymer and “monosaccharides” for the corresponding nutrient/monomer. Students may wonder about the relationship between sugars and carbohydrates. In food labels and most scientific texts, **sugars** represent mono- and disaccharides.

Use of the term “byproducts”

Cellular respiration produces carbon dioxide, water, and heat in addition to ATP. These additional products are often referred to as “waste products.” In this Click & Learn, they are called “byproducts” because they are useful to the body and may be retained at certain levels. For example:

- Carbon dioxide is vital in regulating the blood’s pH and respiration rate.
- Water is used in cells or as part of bodily fluids.
- Heat helps maintain the body’s temperature.

However, excess amounts of carbon dioxide, water, and heat can be harmful and must be eliminated from the body.

Ammonia is a waste product of the metabolism of proteins that is not mentioned in this Click & Learn. Ammonia is excreted in the urine. More information about ammonia is provided in the [“Storage molecules”](#) section below.

DIGESTION

Biomolecule illustrations

The images used for carbohydrates, fats, and proteins in the Click & Learn (Figure A1) are simplified models. There are many types of fats, carbohydrates, and proteins of different sizes and shapes and many different fatty acids, monosaccharides, and amino acids.



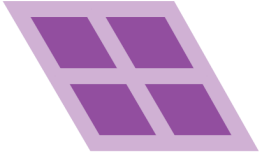



Biomolecule	Carbohydrates	Fats	Proteins
Complex (polymer)			
Simple (monomer)			

Figure A1. Illustrations used in the Click & Learn to represent different biomolecules.

One extension activity would be to provide the chemical structure of different molecules and ask students to match them with the simplified illustrations used in the Click & Learn.

Steps of digestion

The “How is food digested” tab of the Click & Learn shows the main steps of digestion without mentioning the actions of specific digestive enzymes in different organs. For example, the chemical digestion of carbohydrates starts in the mouth, while protein digestion occurs in the stomach. These additional details are captured in Table A1.

Organ	Main action shown in the Click & Learn	Mechanical digestion	Chemical digestion	Biomolecules broken down
Mouth	Food is mixed with saliva and broken down into smaller pieces.	Chewing breaks down food into smaller pieces and mixes it with saliva.	Saliva contains the enzyme amylase, which breaks down starches.	Starches (complex carbohydrate)
Esophagus	Food moves down to the stomach.	None	None	None
Stomach	Food pieces are broken down into large biomolecules.	Stomach muscles mix food with liquid to break apart pieces of food.	Stomach acid and enzymes, like pepsin, that work at acidic pH, start to digest protein.	Protein
Small intestine	Large biomolecules are broken down by substances from the intestine, liver, and pancreas.	None	A number of different enzymes produced by the small intestine, liver, and pancreas digest various biomolecules.	Starches, other carbohydrates (not including cellulose, or dietary fiber), fats, and proteins
Pancreas	Substances (enzymes and buffers) from the pancreas are delivered to the small intestine.	None	Substances from the pancreas contain several enzymes that break down different biomolecules.	Starches, fats, and proteins
Liver	Bile from the liver is delivered to the small intestine.	None	Bile solubilizes fats and contains acids that break down fats.	Fats
Gallbladder	The gallbladder stores bile between meals.	None	Bile solubilizes fats and contains acids that break down fats.	Fats
Large intestine	Undigested food molecules in the large intestine can be broken down by commensal bacteria or eliminated in feces.	None	Bacterial metabolism involves chemical processes that break down specific molecules in food, such as dietary fiber.	Dietary fiber

Table A1. Summary of the main steps in the digestive process.

One extension activity could be to provide students with Table 2 and ask them how they would change the images in the Click & Learn to make it more complete.

Absorption in the small intestine

This Click & Learn talks about the absorption of nutrients in the small intestine. It could be an interesting extension to discuss the small intestine's structure (consisting of villi and microvilli) and how this structure creates more surface area for absorption. You could also discuss the different types of absorptive cells that line the small intestine and how their structures enable their absorptive function.

Commensal bacteria

Certain bacteria in the gastrointestinal tract help with digestion. The Click & Learn mentions their role specifically in the large intestine. They are referred to as “commensal bacteria” and can also be called “gut flora” or the “microbiome.”

Commensal bacteria in the large intestine break down undigested food (e.g., fiber) into products (e.g., glucose) that can be absorbed into the bloodstream. Most fiber leaves the body undigested; without the action of commensal bacteria, all fiber would be undigested. Students may enjoy learning that these bacteria may create gases during digestion — a mixture of carbon dioxide, methane, hydrogen sulfide, and hydrogen. Therefore, eating a lot of fiber can make a person gassy. Also, commensal bacteria produce vitamins B and K, which enter the bloodstream and are necessary for survival.

Students may have heard that taking antibiotics can kill commensal bacteria, so doctors sometimes recommend that patients take **probiotics** (supplements containing commensal bacteria) when on antibiotics.

Dietary fiber

Students may have questions about the importance of fiber in food. (Another name for dietary fiber is **cellulose**.) Dietary fiber increases the weight, size, and softness of a person's stool (feces). A bulky, softer stool is easier to pass, decreasing the chance of constipation.

Fiber may help lower levels of low-density lipoprotein (LDL), or “bad” cholesterol. Studies also have shown that high-fiber foods may have other health benefits, such as reducing blood pressure and inflammation.

METABOLISM

Depiction of cellular respiration

The Click & Learn refers to the fourth and final stage of cellular respiration as the “electron transport chain,” which is how it is typically referred to in general high school biology textbooks. This description is a simplification of the process. In upper-level courses, educators may want to clarify that the last stage of cellular respiration is more accurately called **oxidative phosphorylation**. Oxidative phosphorylation consists of the loaded electron carriers donating high-energy electrons to the electron transport chain, which produces an electrochemical gradient, and the process by which the energy stored in the gradient is used to synthesize ATP. At the end of the electron transport chain, oxygen accepts the electrons and picks up protons to form water.

The “How are nutrients used for energy?” tab of the Click & Learn shows a diagram of metabolic processes, including cellular respiration. Some clarifications for this diagram are as follows:

- Because of how the connections between molecules were drawn, it may look like glycolysis is the first step of cellular respiration for all nutrients. However, glycolysis refers only to the process by which *glucose* (not fatty acids or amino acids) is converted to pyruvate.
- Several connections are not displayed for simplicity — for example, places where intermediates of the citric acid cycle can be converted to specific amino acids.

Storage molecules

Excess nutrients are stored by the body to provide an energy source between meals. Excess monosaccharides are stored as glycogen, and excess fatty acids as triglycerides. Most amino acids in food are used to build proteins for cellular structures and functions. Proteins are not a preferred energy source and are only broken down for energy if other fuel sources are unavailable.

Excess amino acids that are not used by cells to build proteins can undergo **deamination**, a process that involves removing the nitrogen-containing amino group. They are then converted to glucose, which is used for energy if other sources are not available, or fatty acids, which are stored in the body as triglycerides. Deamination occurs primarily in the liver, where the removed amino group is converted into ammonia, which is highly toxic to the body. The liver converts ammonia into urea, which is then eliminated from the body in urine.

One extension activity might be for students to research some of the health problems associated with eating too much or too little protein.

NUTRITION AND HEALTH

Calories

Students may wonder what calories are and how they relate to energy in food. A **calorie** (lowercase) is a unit that is used to measure energy. The **Calorie** (capitalized) on a food package is a kilocalorie (kcal), or 1,000 calories. A Calorie is the energy needed to raise the temperature of 1 kilogram of water by 1 degree Celsius.

Originally, the number of Calories in each food was determined by burning the food and measuring the energy it produced using an instrument called a calorimeter. Today, Calories in food are estimated using the following average values: 4 Calories/g for protein, 4 Calories/g for carbohydrate, and 9 Calories/g for fat. (These numbers were determined initially by burning each type of biomolecule and then averaging.) More information can be found in [this Scientific American article](#).

Students may also have questions about the percent Daily Value (% DV) of different biomolecules. The % DV is calculated based on a 2,000-Calorie daily diet, based on the “average” number of Calories US adults eat to maintain their weight. Of course, that will vary depending on a person’s size, level of activity, age, and many other factors. [This Food Politics article](#) provides more information about the origin of the 2,000-Calorie diet.

Dietary guidelines

Students may know of different diets that restrict the amounts of specific biomolecules (for example, the keto diet restricts the consumption of carbohydrates). Emphasize that dietary guidelines recommend eating foods that provide a mix of *all* biomolecules, for reasons such as the following:

- Different biomolecules play roles in many processes in the body, not just cellular respiration/ATP production. The Click & Learn mentions that amino acids contribute to structural and functional proteins. Similarly, fats are essential for structures like the plasma membrane.
- Different biomolecules contribute to ATP production at different rates depending on the body’s activities.
- Some biomolecules have health benefits beyond providing energy or building cells. One example is dietary fiber ([discussed above](#)).

For more information about dietary guidelines, direct students to the United States Department of Agriculture’s (USDA) [MyPlate](#) website.

Diabetes mellitus

Students will likely have questions about how metabolism differs between people with and without diabetes.

Diabetes mellitus is a condition that affects the ability of body cells to take in glucose from the bloodstream, which leads to elevated blood glucose levels (Figure A2).

There are different types of diabetes mellitus. Most adults have type 2 diabetes mellitus, which is caused by insulin signaling not working correctly. **Insulin** is a hormone that regulates the movement of glucose from the bloodstream into the cells.

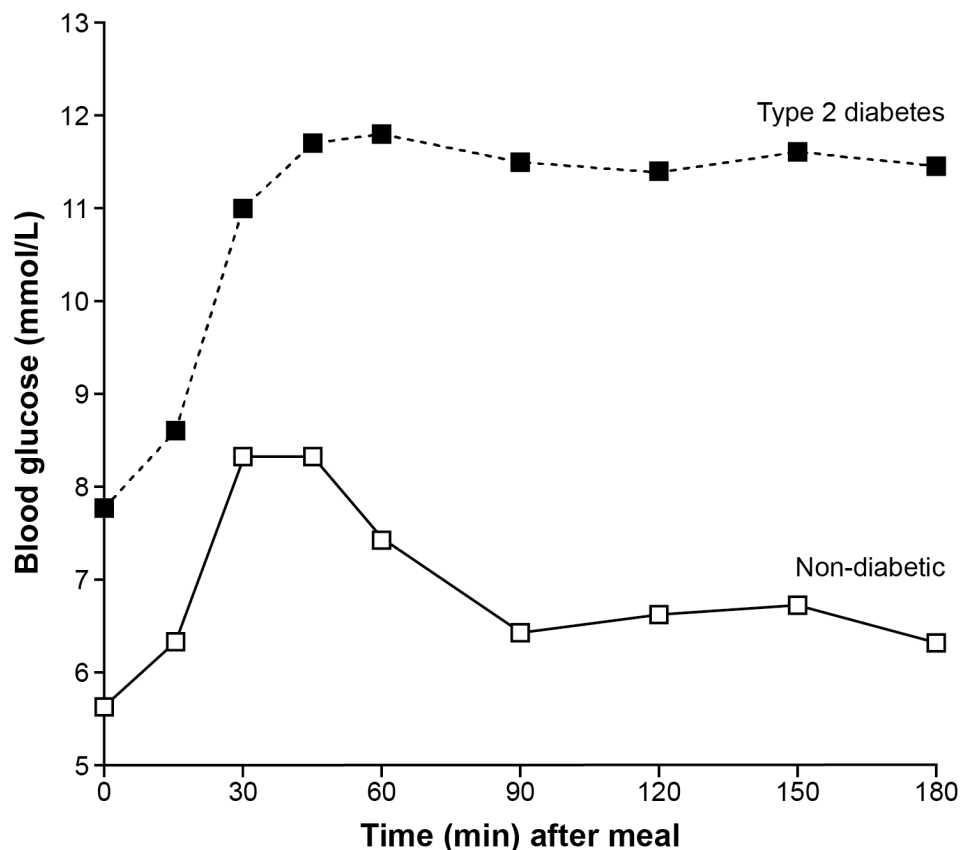


Figure A2. Representative blood glucose levels several hours after eating a meal, in a person with type 2 diabetes and a person without diabetes. In the person with diabetes, glucose levels are higher, and after the meal, they increase and remain high for longer.

For a potential extension activity, have students research the causes of the two main types of diabetes — type 1 and type 2 — and explain how they lead to sustained high blood glucose levels.