

LESSON 7

Surface Area and Absorption



Lighting a campfire takes patience, and you have to start small. Why might that be?

INTRODUCTION

Have you ever built a campfire? Did you start with logs or twigs? Even though you will eventually need logs to keep the fire burning, you have to use twigs to get the campfire started.

Keep that idea in mind as you perform the inquiries in this lesson. Just as in Lesson 6, you will be investigating the small intestine. The topic you'll be exploring this time, however, is surface area. You'll begin your inquiry with a clay cube. You will measure it, calculate its surface area, and then explore how to increase its surface area. Next, you will build a model of a cross-section of the small intestine and calculate the surface area of your model. By the end of this lesson, you should be able to identify more reasons why the small intestine is such an efficient digestive organ.

OBJECTIVES FOR THIS LESSON

Calculate the surface area of a cube and a rectangular solid.

Explore how to increase the surface area of a cube while working within constraints.

Build a model of a cross-section of the small intestine.

Calculate and compare the surface areas of folded and unfolded strips of tickets.

Discuss the relationship between surface area and absorption in the small intestine.

Read about what happens to undigested food and water in the large intestine.

Getting Started

1. Review the Introduction to this lesson with your teacher.
2. With the class, discuss how you would calculate the surface area of the top of your desk. Then discuss how to calculate the *total* surface area of a cube. Finally, discuss how to calculate the total surface area of a rectangular solid. In your science notebook, record the formulas and any notes that might help you remember how to perform these calculations.

Inquiry 7.1 Increasing the Surface Area of a Clay Cube

PROCEDURE

1. Have a volunteer pick up a plastic box of materials for your group.
2. Remove a lump of clay from the plastic box. Run your fingers over the entire piece of clay.

How would you define the “surface area” of the clay?

3. Working with your partner, use the ruler to form the clay into a cube that measures 2 cm on each side.

MATERIALS FOR LESSON 7

For you

- 1 copy of Student Sheet 7.1: Study Guide—The Digestive System

For your group

- 1 plastic box
- 2 metric rulers
- 2 lumps of clay in a plastic resealable storage bag
- 2 plastic knives
- 2 30-ticket strips, fanfolded
- 2 12-ticket strips, unfolded
- Masking tape

4. Using the formula you discussed in the “Getting Started” section, calculate the surface area of the cube. Record it in your science notebook.
5. With your partner, find a way to increase the surface area of the cube. Your method must meet two guidelines:
 - A. You must not greatly increase the total volume occupied by the clay. (In other words, if the clay came in a small box, it must still fit into that box once you have increased its surface area.)
 - B. You must still be able to calculate the total surface area of the cube.
6. Diagram your method in your science notebook. Defend your answer mathematically by calculating the new surface area and comparing it with the original area.
7. Share your method and results with the rest of the class.
8. Roll the clay into a ball and put it in the bag.

be the total surface area of the inside of the cylinder? Record this in your science notebook.

3. Fanfold the strip of 30 tickets. Place the fanfolded strip of tickets on edge inside the circle of tickets to form an inner layer. Use a small piece of masking tape to join the ends of the folded strip.
4. You now have a model showing the folds in the walls of the small intestine. Compare your model, which is illustrated in Figure 7.1, with the illustration of a cross-sectional view of the small intestine that appears in Figure 7.2.

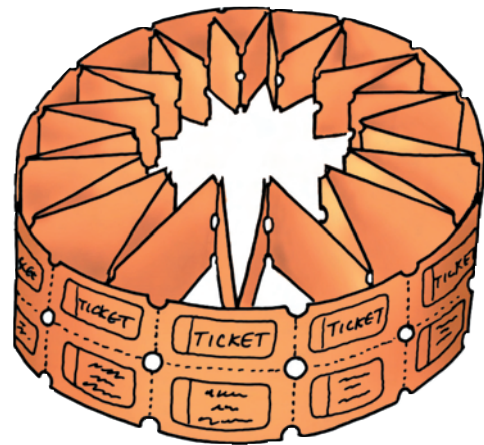


Figure 7.1 Model of a cross-section of the small intestine

Inquiry 7.2

Modeling the Inside Surface of the Small Intestine

PROCEDURE

1. Working with your partner, form a cylinder with the 12-ticket strip. Join the ends of the strip with a small piece of masking tape.
2. Assuming that one side of each two-part ticket has a surface area of approximately 25 square centimeters (cm^2), what would

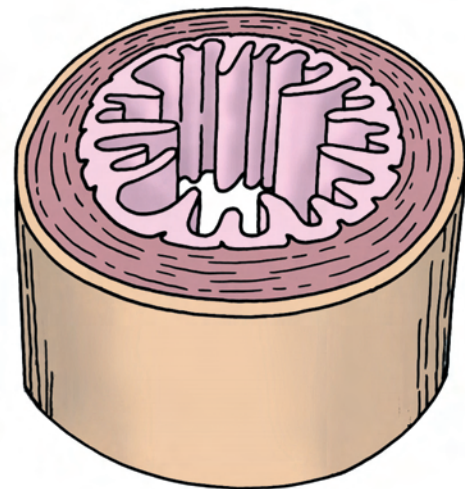


Figure 7.2 Cross-section of the small intestine

5. Calculate the surface area of the inside of the folded strip of tickets and record it in your science notebook.
6. Compare the surface areas of the folded and unfolded tickets and express the relationship between the surface areas as a ratio (for example, 5-to-1). Record your answer in your science notebook.

REFLECTING ON WHAT YOU'VE DONE

1. Discuss your method of increasing the surface area of the clay. Explain how you proved that the surface area increased.
2. Share your results from Inquiry 7.2. Discuss the advantages of the enormous surface area of the small intestine. Do you think that other human organs might need a large surface area? Which ones? Record your ideas in your science notebook.
3. Your teacher will ask two questions about surface area. Discuss your answers with the class.
4. Many tools and instruments we use in daily life are designed with folds. How many can you think of? What are the advantages of the folds? Consider the accordion in the photo to the right. Discuss this with the class.
5. On the basis of what you read in “Spies: Leftovers,” summarize what happens to water and undigested wastes in the large intestine. Record these ideas in your science notebook. Be sure to mention the conditions that may occur when food moves through the large intestine too quickly and too slowly.

CORBIS/TODD GIPSTEIN



The bellows of this accordion have a surface that is similar to the folded surface of the small intestine. This accordion player would not be able to carry his instrument around as easily if it did not have folds.

SURFACE AREA:

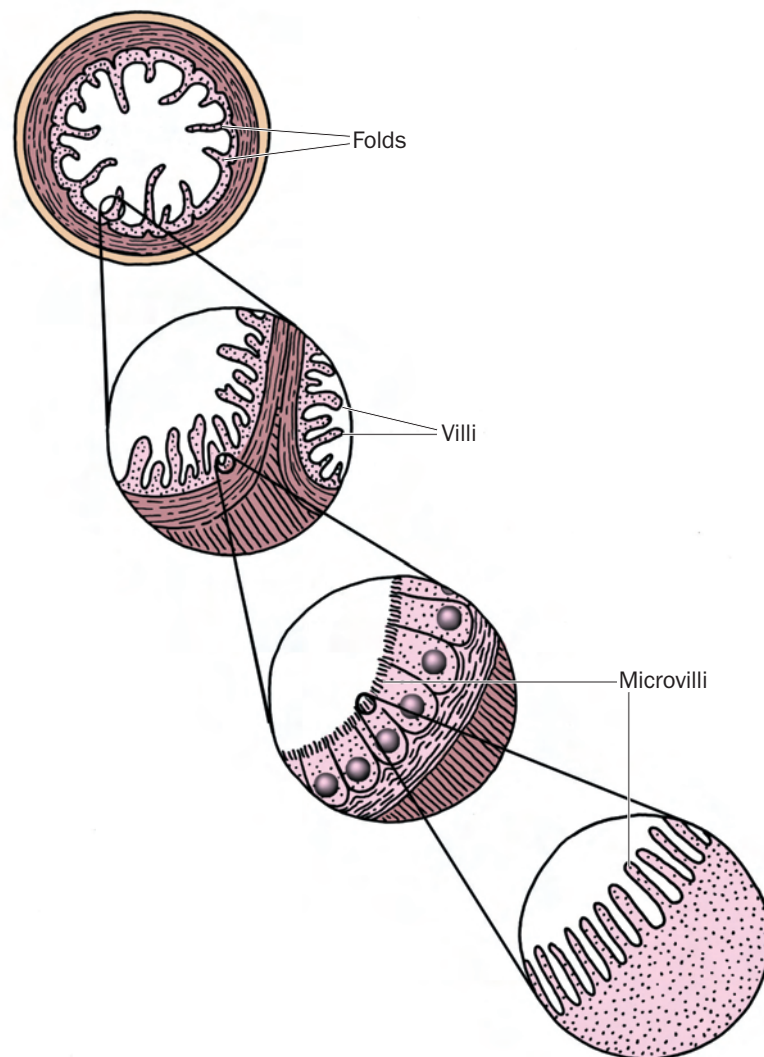
Your Intestine Isn't Small at All

What's the best way to get the most out of the nutrients in your food? It is to make sure that most of those nutrients get into the right places in your body.

Your digestive system has some special features to make this happen. First, it has ways of making sure the surface area of the foods you eat is as large as possible. Second, your digestive system packs as large a surface area as possible into a limited space.

As soon as you begin to chew your food, you start to increase its surface area. Your teeth break the food into smaller and smaller pieces. The surface area of the food continues to increase, allowing the digestive enzymes greater access to them. When the food gets to your stomach, it is broken into even smaller pieces by gastric juices and muscular action. Then the food mixture moves into your small intestine.

Lining of the small intestine, shown with increasing magnification



The small intestine is a hollow tube about 7.0 meters long and 2.5 to 5.0 centimeters in diameter. The first 25 centimeters of the small intestine is known as the duodenum. That's where most digestion is completed. As the digested carbohydrates, proteins, and fats move through the remainder of the small intestine, they are absorbed through the intestinal wall into your bloodstream. If its inside wall were smooth, your small intestine would have an internal surface area that is about the same as about the top of a dinner table. That's a lot, but it's not enough to let all the nutrients you need pass into your bloodstream.

So maybe it's not surprising to learn that the inside of your small intestine isn't smooth. Instead, it is packed with wrinkles and folds. The surface of these folds is covered with tiny projections called villi. The villi are covered with even tinier projections known as microvilli.

The folds, villi, and microvilli may be compared with the fluffy threads of a bath towel. Just like the threads of a terry cloth towel absorb water better than a flat cloth, the villi allow your intestine to absorb more nutrients than a smooth surface would.

The folds, villi, and microvilli increase the internal surface area of the intestine by about 600 times. In fact, scientists estimate that if you could flatten out the surface of your small intestine, it would almost cover a football field. That's a lot bigger than a table top. □



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Microscopic, fingerlike villi line the walls of the small intestine and increase its surface area (SEM \times 140).

SPIES

LEFTOVERS

Peppi and Bollo have now seen more than their share of villi and microvilli. They've traveled nearly the entire 7 meters of the small intestine.

Just when they're about ready to stop for a break, they see an opening ahead.

"The large intestine, right?" says Bollo.

"That's one word for it," Peppi replies. "It's also called the colon."

"What's that opening?" Bollo asks, looking to his right.

"That's the entrance to the appendix," says Peppi. "Scientists on planet Earth believe that the appendix once helped humans digest the cellulose in plant matter.

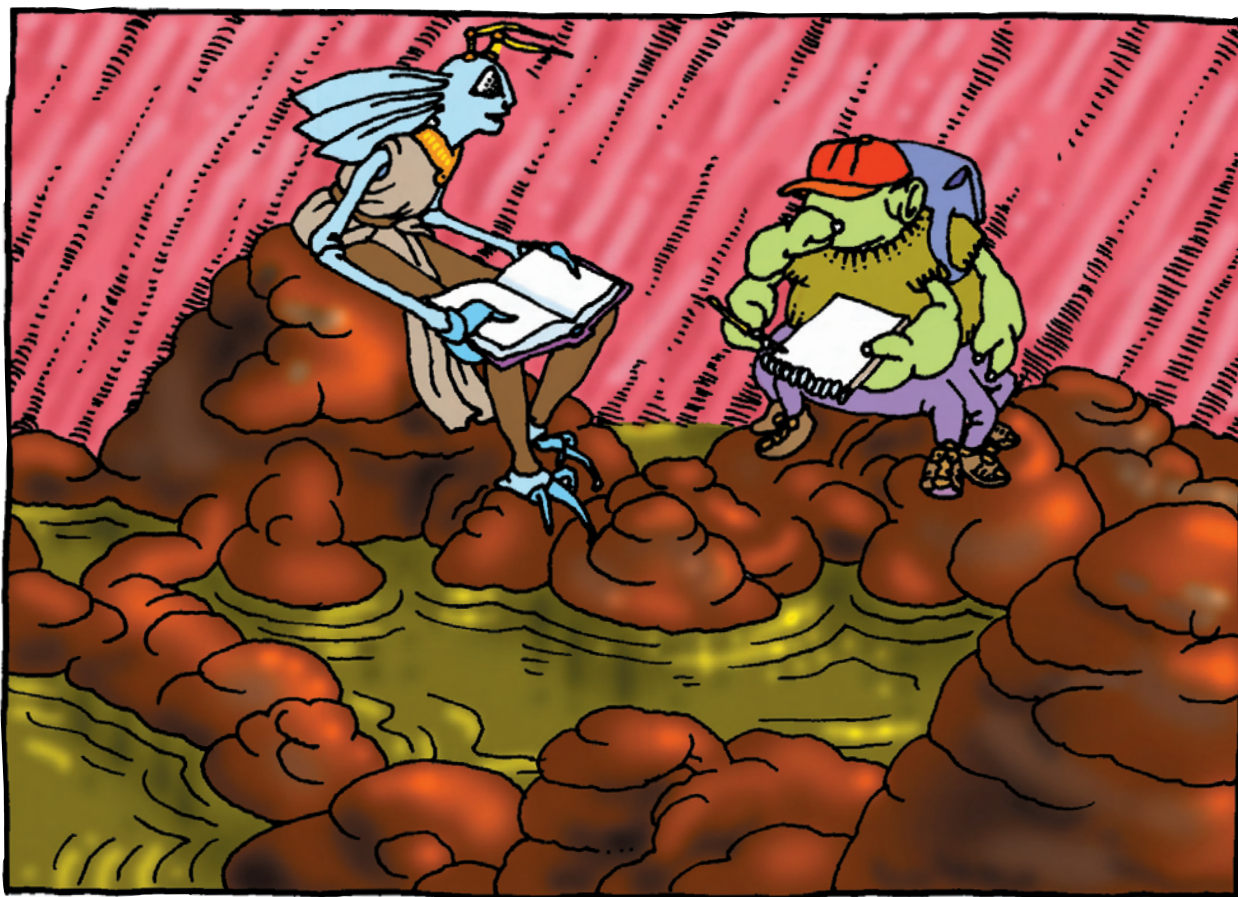
"The only time humans ever hear about the appendix today is when it causes trouble—appendicitis. When the appendix becomes blocked, it

may become swollen and infected by bacteria.

This causes pain. If the appendix bursts, it releases bacteria into the abdomen. This can be serious. Appendicitis is treated by surgery. Since the appendix no longer has a function, a human wouldn't miss it."



Peppi and Bollo have nearly completed their trip through the villi. Next stop: the large intestine!



Peppi and Bollo in the large intestine. Peristalsis keeps things moving here!

Peppi and Bollo continue their trip. First they go up. Then they turn sharply. As they travel, the amount of water decreases. The undigested waste clumps together.

“In some ways, the colon is like the body’s storage tank,” explains Peppi. “It doesn’t produce enzymes. It doesn’t need to, because the food is already digested. The leftover food, now undigested waste, spends time here before it is eliminated through the anus.

“The name for the material that passes through the colon is ‘feces.’ Feces are composed of water, undigested food, mucus, dead cells, and bacteria.

“Even though the colon has no role in digestion, it has an important part in keeping the body in balance. That’s because of its role in the absorption of water and minerals. Water and minerals pass through the walls of the large intestine back into the bloodstream.”

“Nothing very exciting about that,” says Bollo. “I think we know a lot about absorption already.”

“You’re right. But things can go wrong here, even though no digestion is taking place. If the feces move through the large intestine too quickly, there’s not enough time for water to be absorbed. The result? Diarrhea. Diarrhea is often accompanied by cramps, which are strong contractions of the wall of the large intestine. Diarrhea can be dangerous, especially in an infant or a young child. If humans lose too much water, they become dehydrated.

“Sometimes the opposite situation occurs. The feces move through the colon too slowly. Too much water is absorbed. The feces become larger, harder, and drier. The result is constipation. One way to prevent constipation is to eat foods with high fiber content. If that does not relieve constipation, humans sometimes take a laxative. A laxative is a medication that causes the peristaltic contractions to increase and to move wastes through the colon more quickly.”

“Yuk. It smells awful in here,” says Bollo.

“That’s gas. It’s released when bacteria in the large intestine start to feast on undigested food.

“If too much gas builds up, it causes pain. One way to relieve it is to let the gas pass out through the anus. But that isn’t polite in most human societies!”

Pretty soon the action comes to a halt. The feces collect at the end of the colon, in a place called the rectum.

Suddenly the wall of the colon starts to contract powerfully. Peppi and Bollo try to hold on. Out they go into a brilliant white bowl with crystal-clear water!

“Let’s get out of here before it’s too late!” says Bollo. They grab the top rim of the bowl. Directly below, they see a powerful whirlpool. Water and feces disappear.

“We made it!” says Peppi. “Back to civilization at last!”

Summing Up

“Let’s review what we’ve learned,” says Peppi, as they dry off on the top of the toilet tank.

“First, the digestive system works like a food-processing factory. Its job is to change raw materials into a form the body can use to grow and maintain health. The body does this through mechanical and chemical actions. Now what else have you learned, Bollo?”

“Well, the digestive system is specialized. Different organs have different functions,” says Bollo.

“You’re right. A pretty impressive system, wouldn’t you agree? We have learned quite a bit, but we’re far from finished. There’s another exciting journey just ahead.” □



The spies' first journey is complete, but more adventures lie ahead.