One of the learning bottlenecks that students often have is recognizing that enzymes identify and interact with their substrates on the basis of complementary shapes. What makes the shapes complementary is a combination of the surface shapes of the molecules and the distributions of charge and hydrophobicity, but these details are secondary in importance to the basic idea of *recognition by shape*.

We have built this series of scenarios around two other interesting things. One, which is amusing to students, is flatulation. Just what causes beans to give people gas? A second interesting thing is lactose intolerance. Why can some people tolerate lactose, while others cannot? These physiological effects result from the interactions of various carbohydrates with enzymes that digest them. If we have appropriate digestive enzymes, then we can take advantage of the carbohydrate. If we do not have appropriate enzymes, then our intestinal bacteria may get the carbohydrate instead. If neither we nor our bacteria have appropriate enzymes, then the carbohydrate passes through undigested--something we euphemistically refer to as fiber.

There are two types of scenarios here. The first includes all four of the carbohydrate types that we consider, in a single page.

The other three scenarios consiider only three of the four carbohydrate types, derived from different types of meals. The use of different scenarios among different groups of students is that each group can come to “certainty” that they have understood their scenario. However, a certain degree of cognitive dissonance ensues when the whole-class discussion reveals that different groups have different answers. Resolving this conflict helps deepen the learning of the basic principles.

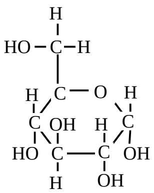
The first page of diagrams is common for all scenarios; the subsequent pages are alternate versions of “page 2."

Carbohydrate Digestion...Humans *vs* Bacteria

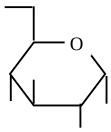
Most carbohydrates that we eat are composed of several sugar molecules bonded together (they are “complex carbohydrates”).

But, our digestive systems can absorb *only* single sugars (“simple carbohydrates”). Therefore, we must digest complex carbohydrates before we can use them.

We also have bacteria in our digestive systems. They, too, can digest carbohydrates, take them up, and use them. Our digestive physiology, and how we feel after a meal, depends on the enzymes that we have, the enzymes our bacteria have—and, therefore, who gets the sugars.

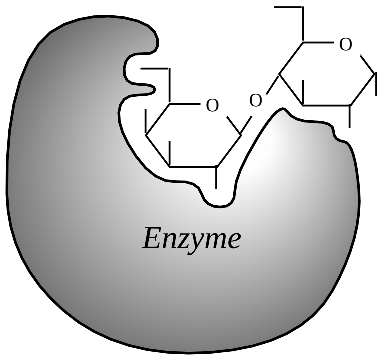


Glucose



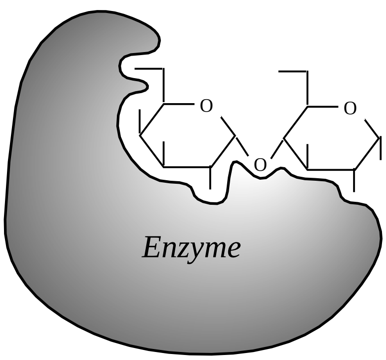
Glucose simplified

We’ll use a simplified picture of the sugar molecule...



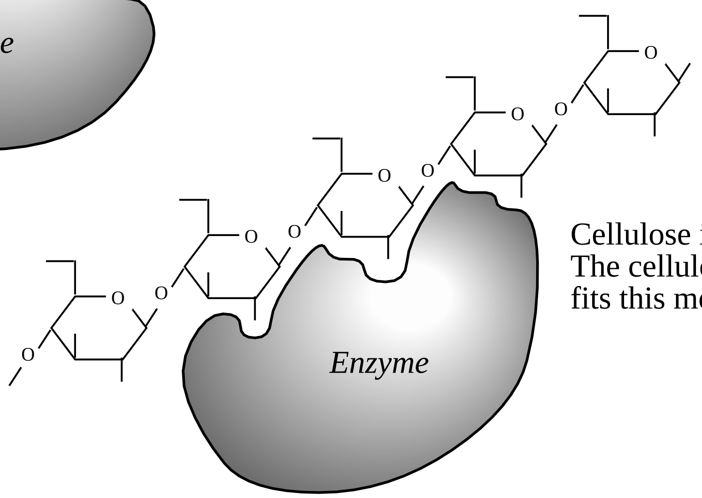
Lactose = (ß)galactose-glucose. The lactose-digesting enzyme, lactase, fits this molecule.

“Lactaid” is prepared by purifying this enzyme.

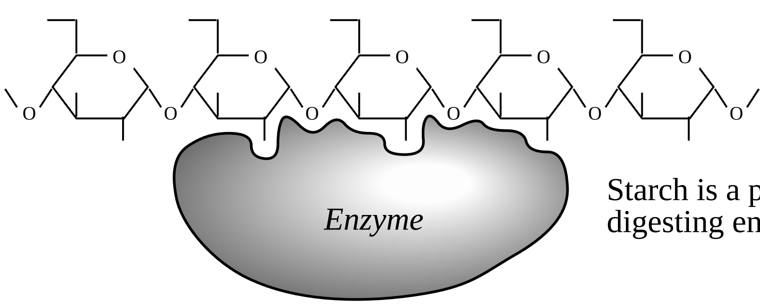


“Bean sugar” = (α)galactose-glucose (or other sugars). A specific enzyme fits this molecule.

“Beano” is prepared by purifying this enzyme.

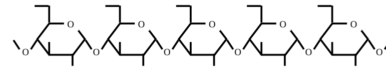


Cellulose is a polymer of (ß) glucose. The cellulose-digesting enzyme, cellulase, fits this molecule.



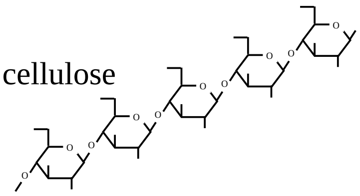
Starch is a polymer of (α)glucose. The starch-digesting enzyme, amylase, fits this molecule.

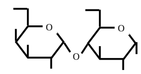
Suppose you are a typical adult human...

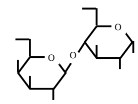


starch

cellulose



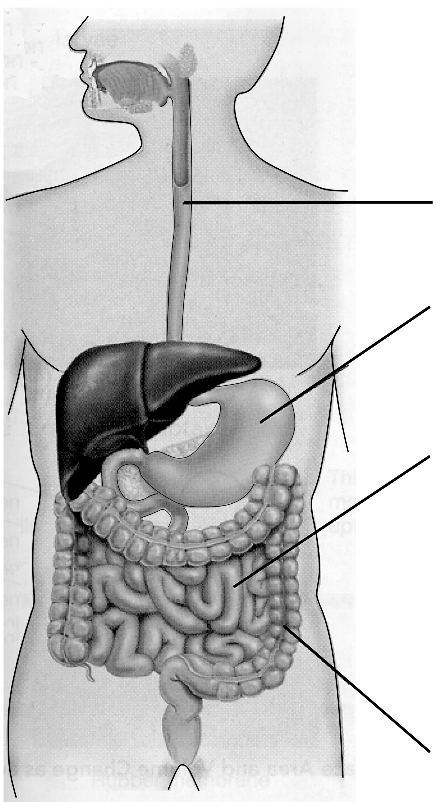




"bean sugar"   lactose

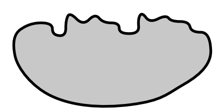
You eat a meal that contains rice and beans. You have ice cream for dessert.
Rice contains a large amount of starch, and a modest amount of cellulose.
Beans contain starch, cellulose, and a large amount of "bean sugar."
Ice cream contains lactose.

What happens? Who gets to use the simple sugars, you or your bacteria? To figure this out, follow the meal through your digestive system:

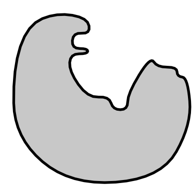


- Esophagus

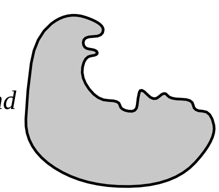
- Stomach
- mixes and digests foods for which it has the enzymes
- has this enzyme:



- Small intestine
- entrance: stomach, exit: large intestine
- absorbs only single sugars
- contains bacteria *E. coli*
- *E. coli* can absorb single sugars *and* double-sugars like lactose
- *E. coli* digest sugar to CO_2 and H_2O
- *E. coli* have this enzyme:



- Large intestine
- entrance: small intestine, exit: anus
- contains methanogen bacteria
- methanogens can absorb single sugars *and* double-sugars like "bean sugar."
- methanogens digest sugar to methane gas (CH_4) and H_2O
- methanogens have this enzyme:



What happens to the starch?

What happens to the cellulose?

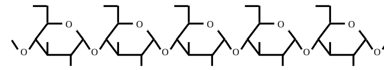
What happens to the "bean sugar"?

What happens to the lactose?

For each one of these, who gets the simple sugars, you or your bacteria? How do you feel?

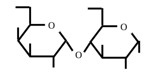
Suppose you are a typical adult human...

You eat a meal that contains potatoes and beans.
Potatoes contain a large amount of starch.
Beans contain some starch, and a large amount of "bean sugar."

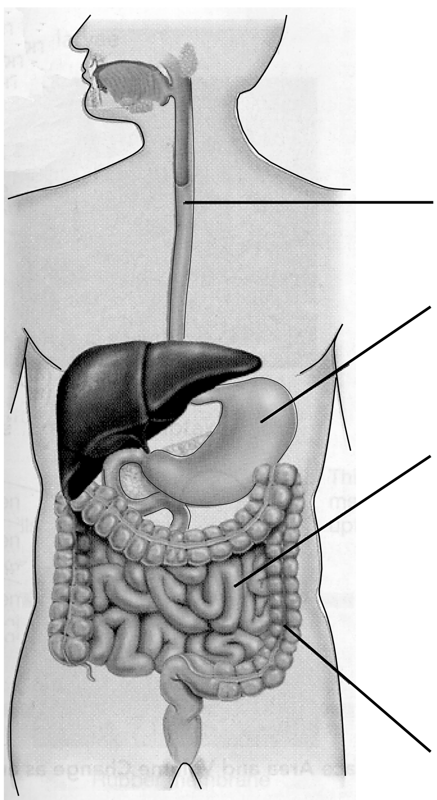


starch

What happens? Who gets to use the simple sugars, you or your bacteria? To figure this out, follow the meal through your digestive system:

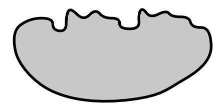


"bean sugar"

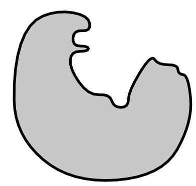


- Esophagus

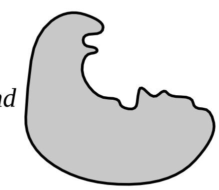
- Stomach
- mixes and digests foods for which it has the enzymes
- has this enzyme:



- Small intestine
- entrance: stomach, exit: large intestine
- absorbs only single sugars
- contains bacteria *E. coli*
- *E. coli* can absorb single sugars *and* double-sugars like lactose
- *E. coli* digest sugar to CO_2 and H_2O
- *E. coli* have this enzyme:



- Large intestine
- entrance: small intestine, exit: anus
- contains methanogen bacteria
- methanogens can absorb single sugars *and* double-sugars like "bean sugar."
- methanogens digest sugar to methane gas (CH_4) and H_2O
- methanogens have this enzyme:

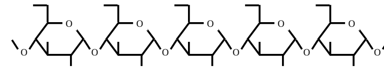


What happens to the starch?

What happens to the "bean sugar"?

So, who gets the simple sugars, you or your bacteria?
How do you feel?

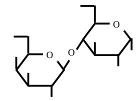
Suppose you are a typical adult human...



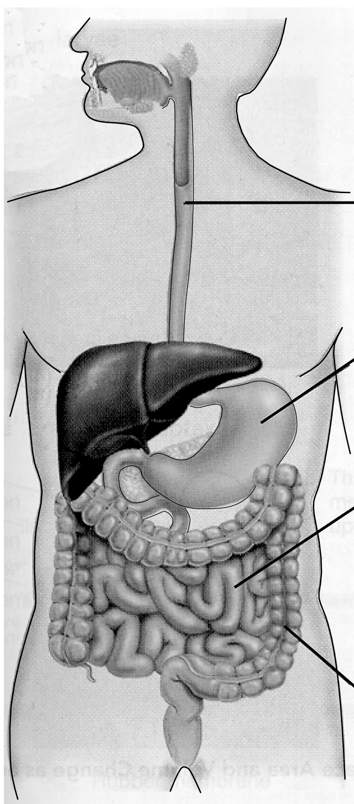
starch

You eat a meal that contains potatoes and fresh milk.
Potatoes contain a large amount of starch.
Milk contains a large amount of milk sugar, lactose.

What happens? Who gets to use the simple sugars, you or your bacteria? To figure this out, follow the meal through your digestive system:



lactose



- Esophagus

- Stomach
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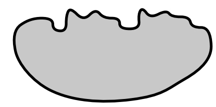
- has this enzyme:



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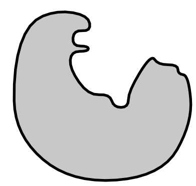
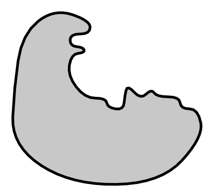
- contains bacteria *E. coli*
- *E. coli* can absorb single sugars *and* double-sugars like lactose
- *E. coli* digest sugar to CO_2 and H_2O
- *E. coli* have this enzyme:



- Large intestine
- entrance: small intestine, exit: anus
- contains methanogen bacteria
- methanogens digest sugar to methane gas (CH_4) and H_2O
- methanogens have this enzyme:

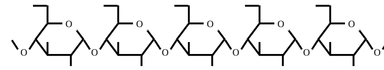


What happens to the starch?

What happens to the lactose?

So, who gets the simple sugars, you or your bacteria?
How do you feel?

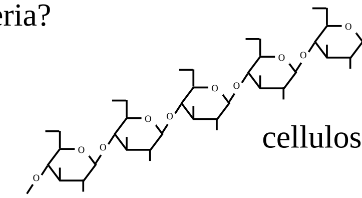
Suppose you are a typical adult human...



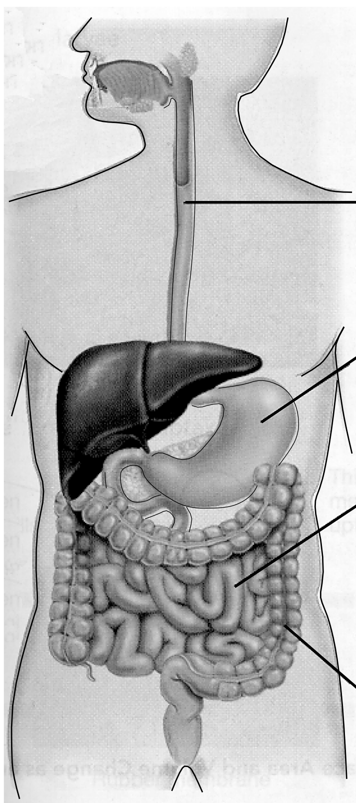
starch

You eat a meal that contains potatoes nad carrots.
Potatoes contain a large amount of starch, and a modest amount of cellulose.
Carrots contain very little starch, and a large amount of cellulose.

What happens? Who gets to use the simple sugars, you or your bacteria?
To figure this out, follow the meal through your digestive system:

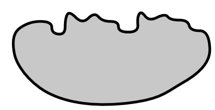


cellulose



- Esophagus

- Stomach
- mixes and digests foods for which it has the enzymes
- has this enzyme:



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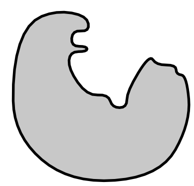
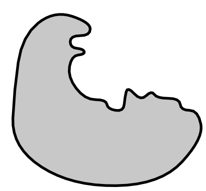


- Large intestine
- entrance: small intestine, exit: anus
- contains methanogen bacteria
- methanogens digest sugar to methane gas (CH_4) and H_2O
- methanogens have this enzyme:



What happens to the starch?

What happens to the cellulose?

Who gets the simple sugars, you or your bacteria?
How do you feel?