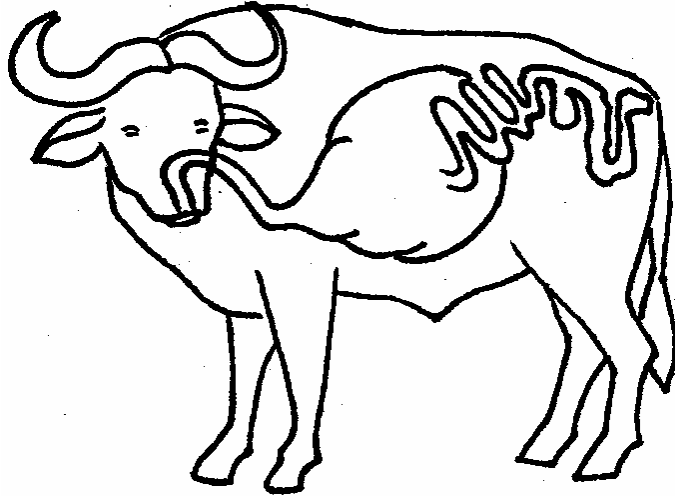


# The Herbivore Digestive System

Name \_\_\_\_\_

## Buffalo

Ruminant:



The purpose of the digestion system is to

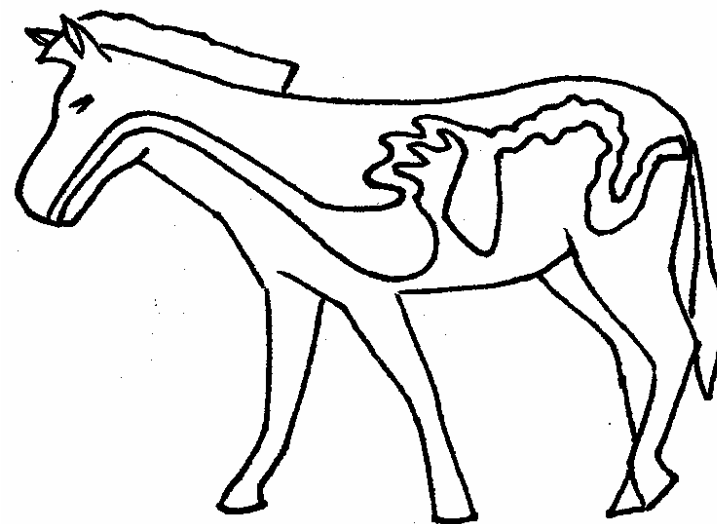
\_\_\_\_\_.

Bacteria help because they can digest

\_\_\_\_\_, a sugar found in the cell walls of \_\_\_\_\_.

## Zebra

Non-Ruminant:



What is the name for the largest section of a ruminant's stomach?

\_\_\_\_\_



### Organ Color Key

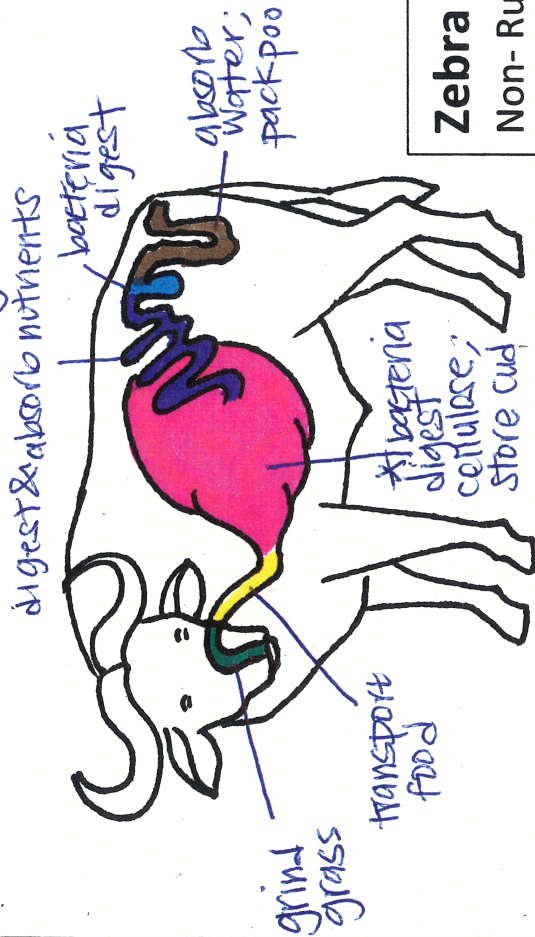
- Mouth
- Esophagus
- Stomach
- Small Intestine
- Cecum
- Large Intestine

# The Herbivore Digestive System

Name TEACHER ANSWER SHEET

## Buffalo

Ruminant: a hooved mammal that regurgitates its cud to chew it again

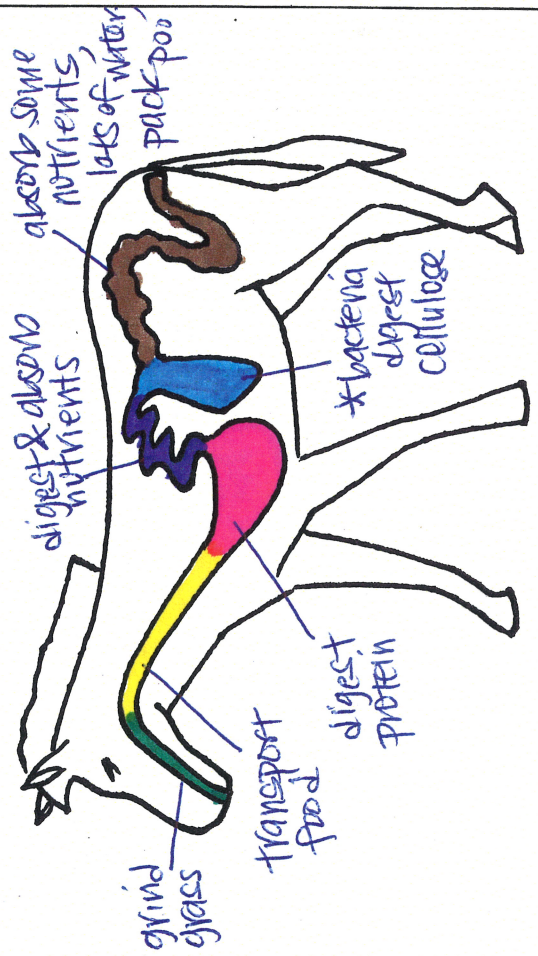


The purpose of the digestion system is to break-down food and absorb nutrients into the blood.

Bacteria help because they can digest cellulose, a sugar found in the cell walls of plants.

## Zebra

Non-Ruminant: a hooved mammal that doesn't regurgitate its food



### Organ Color Key

- Mouth
- Esophagus
- Stomach
- Small Intestine
- Cecum
- Large Intestine

What is the name for the largest section of a ruminant's stomach?

Rumen

# Background Information for the Teacher



## Two Strategies of Digestion in Hoofed Mammals

	<b>Ruminant</b>	<b>Non-ruminant</b>
<b>Representative species</b>	<b>Buffalo</b> , cows, sheep, goats, antelope, camels, giraffes, deer	<b>Zebra</b> , pigs, horses, asses, hippopotamus, rhinoceros
<b>Does the animal regurgitate its cud to chew material again?</b>	<b>Yes, regurgitation</b> Grass is better prepared for digestion, as grinding motion forms small particles fit for bacteria.	<b>No regurgitation</b> Bacteria can not completely digest cell walls as material passes quickly through, so stool is fibrous.
<b>Where in the system do you find the bacteria that digest cellulose?</b>	<b>At the beginning, in the rumen</b> This first chamber of its four-part stomach is large, and serves to store food between rumination and as site of digestion by bacteria.	<b>Near the end, in the cecum</b> In this sac between the two intestines, bacteria digest plant material, the products of which pass to the bloodstream.
<b>How would you compare the nutrition obtained via digestion?</b>	<b>Higher Nutrition</b> Reaps benefits of immediately absorbing the products of bacterial digestion, such as sugars and vitamins, via the small intestine.	<b>Lower Nutrition</b> The digestive products made by the bacteria are produced nearer the end of the line, after the small intestine, the classic organ of nutrient absorption.
<b>Which animal spends more time each day actually picking grass?</b>	<b>Less Time Foraging</b> Has a large stomach for storage, and can regurgitate as needed. Also able to efficiently extract nutrients from plant material.	<b>More Time Foraging</b> A single stomach means many small meals a day. Also, system needs to process higher volume to gain adequate nutrition due to low quality feed.
<b>How would you compare the speed of digestion?</b>	<b>Slower Digestion</b> Takes more time to regurgitate, re-chew, digest, and absorb all parts of plant.	<b>Faster Digestion</b> No regurgitation leads to lower efficiency in obtaining nutrients. Must eat about twice as much as ruminants at approximately twice the speed.

COMPARISON BY LENGTH (m)		
Buffalo		Zebra
Ruminant		Non-Ruminant
1		1
48		20
1		1
10		8
<b>60</b>		<b>totals</b>

COMPARISON BY VOLUME (L)		
Buffalo		Zebra
Ruminant		Non-Ruminant
160	stomach	10
65	small intestine	65
10	cecum	30
25	large intestine	95
<b>260</b>	<b>totals</b>	<b>200</b>

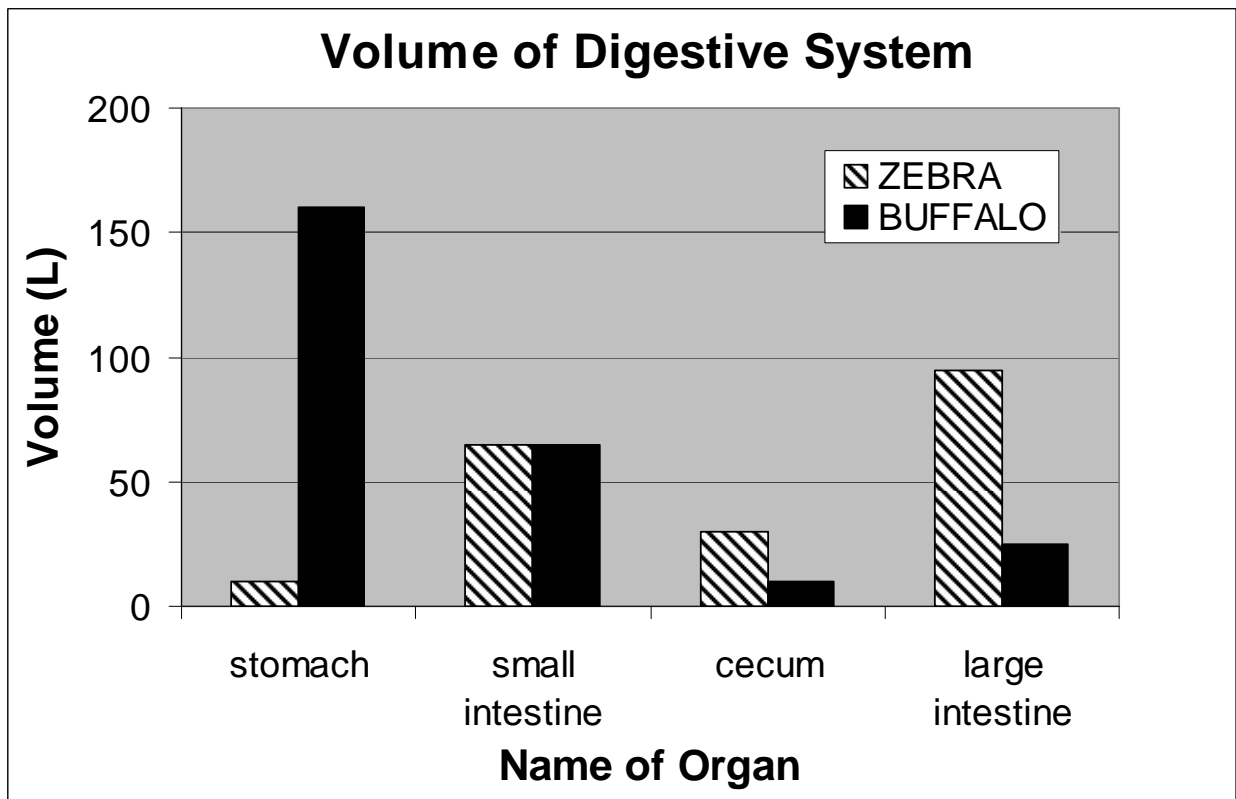
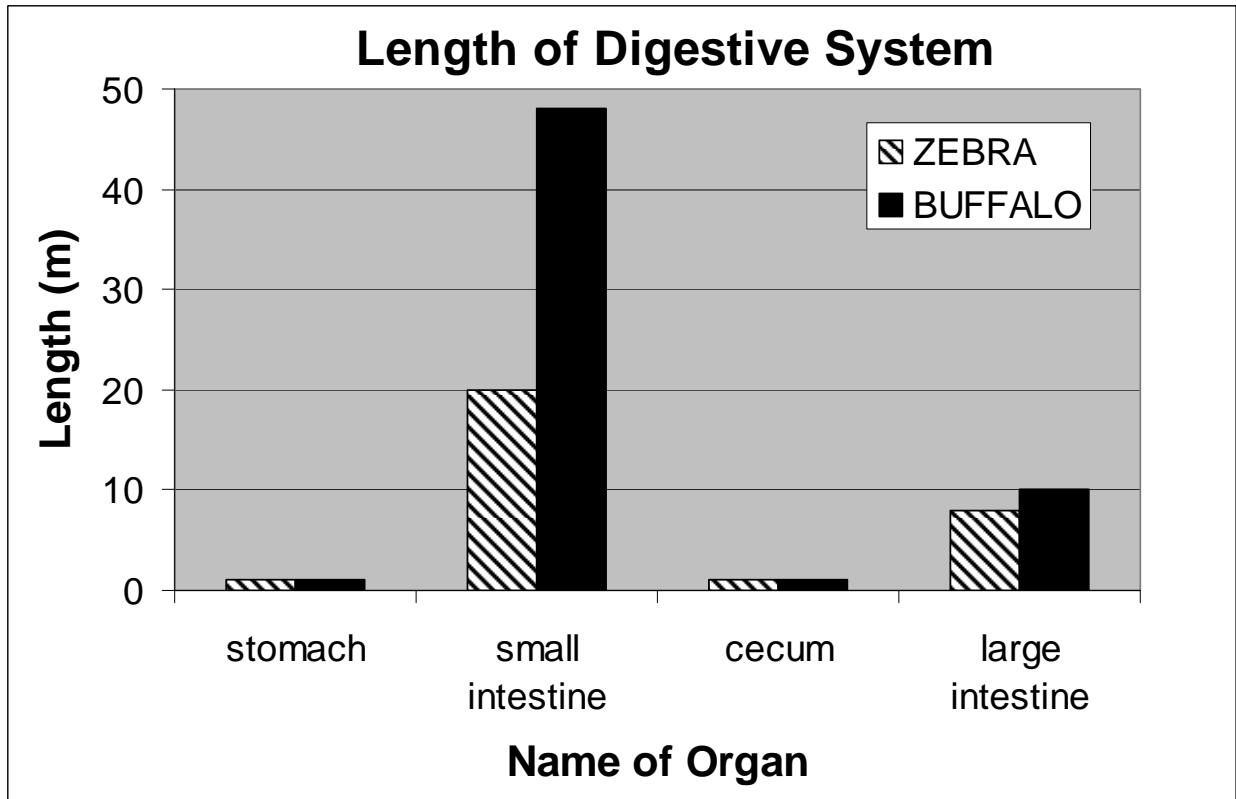
(NOTE: Data is estimated from measurements of domestic cattle and horses, respectively)

### Discussion Questions:

- ❖ Why does the Buffalo's stomach hold so much food?
- ❖ Why does the small intestine need to be so long? How does this contrast with the esophagus?
- ❖ Why does the large intestine need to be so long?
- ❖ How is the Zebra stomach different, and what does this mean for the animal?
- ❖ Why is the Zebra cecum more full than that of the Buffalo, even though it's the same size?
- ❖ How might the plant matter in the large intestine of the Zebra be different than that in the Buffalo?
- ❖ What is the role of the small intestine? Why is this organ so much longer in the Buffalo?

# Ruminating on the Digestive System

Graphical Representations



# Lesson: Ruminating on the Digestive System

<b>GRADE LEVELS</b>	5 <sup>th</sup> -11 <sup>th</sup> ; California Content Standards for 5 <sup>th</sup> , 7 <sup>th</sup> , and Career Pathways
<b>SUBJECTS</b>	Life Sciences
<b>DURATION</b>	Preparation: 10 minutes    Activity: Two 45-minute sessions
<b>SETTING</b>	Classroom; playground

## Objectives

By comparing the digestive system of two African herbivores, the buffalo (ruminant) and the zebra (non-ruminant), students will:

1. review the functions of the basic components of the digestive system.
2. understand how diet affects digestive specialization in herbivores.
3. diagram the digestive tract of a ruminant and non-ruminant.
4. compare the lengths (and volumes) of digestive organs in an outdoor demonstration.

## Materials

[The Herbivore Digestive System Student Worksheet](#) and [Teacher Answer Sheet](#)  
[Two Strategies of Digestion in Hoofed Mammals](#) teacher background and data chart  
overhead transparency  
dry-erase markers  
colored pencils or markers  
jumbo sidewalk chalk (at least 5 pieces)  
meter stick or measuring tape  
hula hoops or colored ribbon, rope, or towels (optional)  
1-L bottle (optional)

## Vocabulary

- ❖ digestion: the process by which food is broken down into simple chemical compounds that can be absorbed and used as nutrients for the body
- ❖ absorption: the movement of digested molecules across the lining of the gut into the bloodstream to be transported to the body's cells
- ❖ cellulose: the complex carbohydrate (sugar) that forms the cell wall of plants
- ❖ bacteria: single-celled microorganisms, some of which can chemically digest cellulose
- ❖ cecum: the bacteria-rich pouch connecting the small and large intestines
- ❖ cud: a wad of food regurgitated by a ruminant for further chewing
- ❖ ruminant: a hoofed mammal such as a cow, antelope, or sheep that regurgitates its cud for further chewing
- ❖ non-ruminant: a hoofed mammal such as a horse, zebra, or giraffe that does not regurgitate its food
- ❖ rumen: the first chamber of the four-part ruminant stomach, where food is digested by bacteria

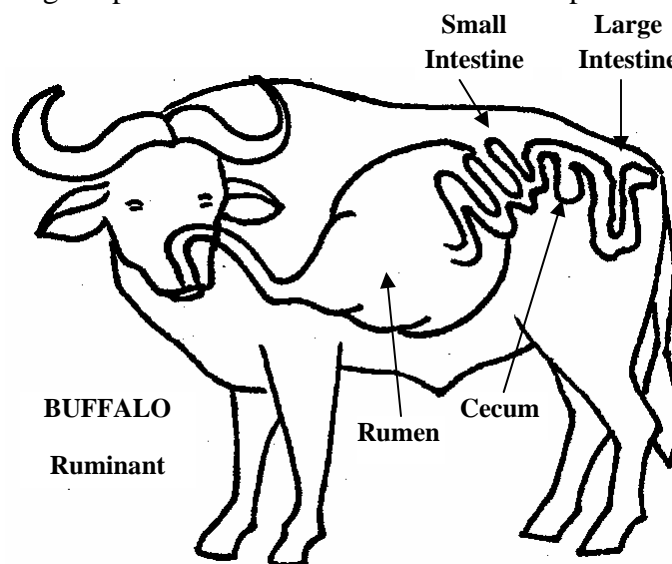
## Teacher Background

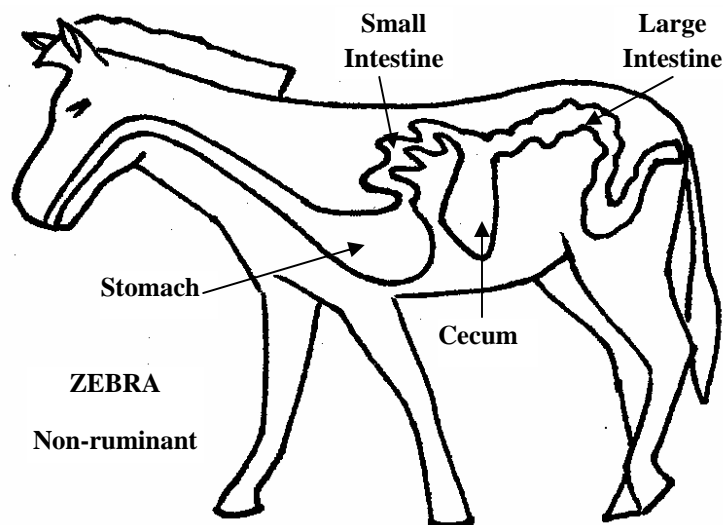
The following information is summarized in the [Two Strategies of Digestion in Hoofed Mammals](#) chart for teachers. Consider printing out a copy for yourself to refer to as you read!

The purpose of the digestive system is to break food into particles small enough to pass through the gut to enter the bloodstream, which transports these nutrients to all the cells in the body. The basic components of the vertebrate digestive tract often serve similar purposes in diverse creatures, from fish to mammals. Yet, depending on an animal's feeding behavior, regions used for the transport, storage, and processing of food have evolved specializations. These organs have adapted to be more efficient when digesting and absorbing nutrients from a particular diet.

This lesson compares the digestive systems of two herbivores feeding together on the fibrous, nutrient-poor grasses of the African savanna: a buffalo and a zebra. Because grass contains less usable energy than other plant parts such as fruits or nuts, these grazers need to spend a relatively large portion of their day chewing and digesting food to obtain sufficient energy. To reach the nutrients available in the body of a plant cell, the cellulose-rich cell wall must be broken. No vertebrate has the necessary chemicals to digest cellulose in order to capture the energy stored in this complex sugar. Instead, the mammalian digestive tract harbors symbiotic microbes that perform the digestive work, releasing simpler, absorbable molecules.

A buffalo, being a ruminant like antelope, sheep, and goats, chews grass only briefly before swallowing it for the first time. This material travels to the rumen (hence "ruminant"), the largest chamber in its four-part stomach. It is here where bacteria specialized to digest cellulose live and reproduce, digesting cellulose as the rumen churns. With the help of the muscle in the second stomach compartment, the ruminant periodically regurgitates wads of coarser material to be re-chewed, physically preparing the tough plant walls for subsequent chemical digestion by bacteria. Ruminants tend to chew their cud while resting rather than while grazing; a dairy cow might devote 6-8 hours of the day ruminating in sporadic 30 minute sessions. Antelopes often ruminate during the hottest parts of the day, when they would rather hang out in the shade. Re-chewed cud is swallowed to return to the digestion vat in the rumen. End products move through the third and fourth stomach sections, responsible for further digestion and absorption; note that in many species, 60-75% of the plant matter has been broken down prior to touching the mammal's own gastric juices! Because ruminants like buffalo have bacteria working upstream, they maximize the amount of nutrients absorbed later in the small intestine.





Zebras, by contrast, are non-ruminants, so plant matter passes through their system in one fell swoop. Their single, relatively small stomach necessitates several small meals a day. Much like in humans, stomach juices begin to digest protein, but the function of the stomach is mostly temporary storage. From there food is pushed to the small intestine, where the majority of starch, protein, fat, and vitamins are digested in a complex mixture of chemicals. However, recall that the zebra cannot digest

cellulose. Although the small intestine is the principal organ of absorption, because bacteria have yet to digest the plant cell walls, many nutrients get passed along. This fibrous feed then enters an enlarged cecum, a pouch-like structure connecting the small and large intestines. Notice that the entrance and exit to the cecum is at the top of the organ, so that it resembles a sack rather than a tube. This equivalent to the rumen of a ruminant is the site for bacterial digestion in a non-ruminant. The nutrients from cellulose digestion are absorbed into the zebra's blood next via the walls of the large intestine. But remember, the role of the large intestine is mostly to reabsorb the water used during digestion to recycle it in the body; this action also packs the indigestible matter into convenient balls to be eliminated.

Overall, the rougher fiber passing through the non-ruminant's system results in a lower potential for acquiring nutrients; as such, the zebra compensates by eating more grass, and at a quicker rate. For example, a domestic horse weighing 1000 lbs must eat 2.5-3% of its bodyweight daily; that amounts to 25-30 lbs of grass each day! Although it may seem that non-ruminants (zebras) get the short end of the stick, because they are able to digest low-quality, fibrous grasses, they can survive in habitats lacking the higher-quality shoots, roots, and leaves preferred by ruminants.

### Activity

#### Part 1: In the Classroom (45 minutes)

##### Preparation (5 minutes)

1. Make copies of the worksheet for your students and one transparency for yourself.
2. Transcribe vocabulary words onto the board, without definitions.

##### Introduction (5 minutes)

- ❖ Ask students: If you held an apple long enough, would your hand be able to soak up all its sugars and nutrients? Nope! Your body needs to digest food, or break it down into bits that are small enough to be used by individual cells.
- ❖ Have students discuss with a partner what fruits and vegetables they have eaten recently, and what they think happens to these plants while passing through their



body. What plant parts can you eat, and why are they good for you? What about the parts you throw away?

- ❖ Introduce the term **cellulose**, and explain how vertebrate animals (humans included) use **bacteria** in their gut to digest this complicated sugar molecule.
- ❖ Ensure students are comfortable with the terms **digestion** and **absorption**.

### Procedure (40 minutes)

1. Distribute a worksheet to each student, and instruct them to take out materials for coloring. Using your own copy on the overhead projector, fill in the section at the upper right to review the basic premise.
2. Inform students that today's lesson deals specifically with herbivores, those animals whose diet consists mainly of plants. Introduce the two types of hooved herbivores, **ruminants** and **non-ruminants**. Write short, simple definitions on the worksheet. Give common examples of animals representing each group.
3. Model how to create a color-coded legend to diagram the digestive system, and lead a discussion on the function of each organ as you go. Work your way through the Buffalo before moving on to the Zebra.
4. As the class codes the diagrams, help students label the organs with text describing the function of each part, rather than its name. Put a star near the location of bacteria!
5. These diagrams are simplified, because the organs are actually long and tangled up. How long is the small intestine of the zebra, which looks slightly curvy? Have students guess a few values and record them on the board.
6. Tell students that in the next period, the class will go outside and draw on the playground to learn how long the digestive organs really are!

### Part 2: On the Playground (45 minutes)

#### Preparation (5 minutes)

1. Receive permission to draw with sidewalk chalk on the blacktop.

#### Procedure (40 minutes)

1. Bring the data chart, chalk, and a meter stick outside for the demonstration. (Colored props to mark the location of bacteria are optional, as is a 1-L bottle to demonstrate volume).
2. At one end of the schoolyard, use chalk to write "**RUMINANT DIGESTIVE SYSTEM: BUFFALO**". Write the word "**Mouth**" and draw a circle around it. The mouth is the entrance to the digestive tract, which the class will draw on the blacktop.
3. Lay down the meter stick and model how to take one big pace to represent one meter. Draw a thin, tube-like esophagus of this length. Likewise, students will estimate distances using wide paces while others follow at their heels to mark the ground with chalk.
4. Build the Buffalo's digestive system one organ at a time, reviewing the function of each part, by assigning student teams to measure, draw, and label subsequent organs.
  - ❖ **Stomach:** Draw as a large circle or sac.

- ❖ **Small Intestine:** Because the organ is so long, students show loop back and forth to fit it in a tighter space. A thin tube is appropriate.
  - ❖ **Cecum:** Draw as a circle or sac.
  - ❖ **Large Intestine:** Make a wider width than the small intestine, but with similar curves.
5. Repeat with the data for the Zebra to construct a “**NON-RUMINANT DIGESTIVE SYSTEM**”.
  6. Ask students if they recall where bacteria are housed in each animal. (Place a colored hula hoop or other prop around the Buffalo rumen and Zebra cecum, respectively, to remind students where these important microorganisms help by digesting cellulose.)
  7. The diagram compares length, but you can use the data chart to highlight any differences in volume, if desired. Use the 1-L bottle to reference size.
  8. Use the drawings to review function and promote critical thinking. Discussion questions might include:
    - ❖ Why does the Buffalo’s stomach hold so much food? (*needs to store in between ruminating sessions; houses bacteria for digestion; four parts*)
    - ❖ Why does the small intestine need to be so long? (*absorption only occurs through the wall of the tube, so food in the center would be wasted unless it has time to float in a liquid to the edge*)
    - ❖ How does this contrast with the esophagus? (*the esophagus is just for transport, like a pipe. No digestion or absorption occurs here, so surface area of the pipe wall is not important*)
    - ❖ Why does the large intestine need to be so long? (*the animal needs to reabsorb all the water it put into the digestive tract to dissolve food, but needs to do it slowly because blood vessels are narrow*)
    - ❖ How is the Zebra stomach different, and what does this mean for the animal? (*one compartment; doesn’t store for too long since doesn’t regurgitate; small, so needs to eat many small meals each day; less bacteria here, uses own stomach juice to digest protein but can’t break down cellulose*)
    - ❖ Why is the Zebra cecum more full than that of the Buffalo, even though it’s the same size? (*this is the site of bacterial digestion for the non-ruminant*)
    - ❖ How might the plant matter in the large intestine of the Zebra be different than that in the Buffalo? (*more fibrous, since bacteria never completely broke down the sugar*)
    - ❖ What is role of the small intestine? Why is this organ so much longer in the Buffalo? (*absorption of nutrients; ruminant has more food available to absorb since bacteria finished the work upstream*)
  9. Consider having two students race through the tracts, having to stop and spin around at the mouth (x2 for ruminants!), stomach, and cecum. Which route was faster? (*the zebra tract is faster – no need to return to the mouth; the tubes are shorter; the animal can’t absorb all the plant material, so a large amount exits as roughage*)

### Wrap-Up (5 minutes)

Have students turn to a partner and share two similarities and two differences between the buffalo and the zebra. Select a few to share with the group; as students tell you **what** is different between the two animals, challenge them to explain **how** or **why** this is so, especially in relation to the function of organs as they pertain to a diet of plants.

### Extensions

- ❖ Use these [graphical representations](#) of the data to further develop your students' analytical skills. Consider giving student groups a version with a blank legend, title, and/or axes: can they guess which animal is which? How do they know? What do they remember from the exercise outside?
- ❖ **Communities and Competition:** If zebras, rhinos, and antelopes all eat grass, why don't they fight over food on the African savanna? Non-ruminants like zebras will eat the lower-quality tips of the grass, which is older and more fibrous. It will pass through their system quick enough. Then gazelles, as ruminants, can eat the younger, low-cellulose shoots that are left exposed. They won't have to eat nearly as much, but will want their rumen to take advantage of all the nutrients in the plant. So each hoofed animal fills their own niche, or environmental role.
- ❖ **Mutualism:** This lesson shows how bacteria serve important purposes outside of the 'germ' category. Herbivores could not digest cellulose without them, and the bacteria take advantage of a safe habitat full of constant food. Both the microbes and the animal benefit from these arrangements, so this symbiosis (or "living together") is an example of mutualism -- a relationship between two organisms in which both benefit from the association. What are other classic (or obscure) examples of mutualism? What other roles do bacteria play in an ecosystem?
- ❖ **Belching:** As the rumen bacteria digest cellulose, gas is produced. When the bacteria in our small intestine digest vegetables, we also produce gas, and expel it by farting. However, the ruminant digestive tract is so long, that it would be uncomfortable to expel gas out the back, so instead, they belch all day! How does this byproduct contribute to global warming?
- ❖ **Ruminate:** Can humans ruminate too? In addition to referring to the act of chewing cud, this word means "to ponder; reflect on over and over again; think long and hard about." That's food for thought! What other terms from science have associated meanings in everyday language?
- ❖ **Dung Detective:** If you were wandering amid a mixed herd of zebras and buffalo, you might be able to tell apart their dung. How? The zebra, who can't digest plants completely, will have dung with coarser, undigested grass sticking out. The dung of the buffalo, a ruminant, should be more uniform throughout. What are some other ways to track, glimpse, photograph, or document wildlife? Consider all of the five senses!

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- Swinker, Dr. A.M. (2004). *4-H Horse Project*. Fort Collins, Colorado: Colorado State University Cooperative Extension. Retrieved December 15, 2007, from <http://extension.unh.edu/4H/4HPubs/COHorMan.pdf>

## Correlated California Content Standards

### Grade Five

#### Life Sciences

- 2a. Students know many multicellular organisms have specialized structures to support the transport of materials.
- 2c. Students know the sequential steps of digestion and the roles of teeth and the mouth, esophagus, stomach, small intestine, large intestine, and colon in the function of the digestive system.

### Grade Seven

#### Life Sciences

- 5b. Students know organ systems function because of the contributions of individual organs, tissues, and cells. The failure of any part can affect the entire system.

### Career Technical Education

#### Animal Science Pathway

- D2.2 Understand the principles for providing proper balanced rations for a variety of production stages in ruminants and monogastrics.
- D2.3 Understand the digestive processes of the ruminant, monogastric, avian, and equine digestive systems.
- D3.1 Understand the major physiological systems and the function of the organs within each system.