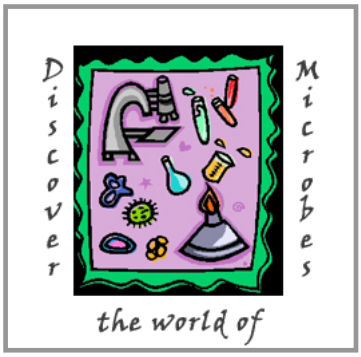
Microbial Discovery Activity

Bacteria That Help and Hurt Cows



Authors

Bill Aukerman – aukerm_b@denison.edu
Katie Esselburn – esselb_k@denison.edu
Joe Freundlich – freund_j@denison.edu
Cristin Mustillo – mustil_c@denison.edu

Denison University
Department of Biology
c/o Christine Weingart
Samson Talbot Hall
350 Ridge Road
Granville, OH 43023

Intended Audience

K-4	X
5-8	
9-12	

Activity Characteristics

Class room setting	X
Requires special equipment	X
Uses hands-on manipulatives	X
Requires mathematical skills	
Can be performed individually	
Requires group work	
Requires more than (45 min) class period	
Appropriate for special needs student	

American Society for Microbiology
Education Department
1752 N Street, NW
Washington, DC 20036
Education@asmusa.org

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Introduction

Abstract

This lesson introduces students to the microbial world and provides insight on their function by examining bacteria that both help and harm cows. Although multiple bacteria inhabit the cow's rumen, this lesson focuses on two harmless microbes; *Ruminococcus* and *Selenomonas*, which break down cellulose and starch in plant matter, respectively. These bacteria obtain nutrients from the cow's diet, and the cow gains energy from the products of bacterial metabolism. Therefore, these bacterial species are in a symbiotic relationship with the cow. Other bacterial species can harm cows. Such is the case with *Escherichia coli*, a non-ruminant bacterium that can cause the udder infection known as mastitis.

Core Themes Addressed

Microbial Cell Biology	x
Microbial Genetics	
Microorganisms and Humans	
Microorganisms and the Environment	x
Microbial Evolution and Diversity	
Microbial Evolution and Diversity	
Microorganisms and Animals	x

Keywords

Ruminants, Microorganisms, Symbiosis, Pathogenesis

Learning Objectives

At completion of this activity, the learner will be able to:

- Define the term microorganism.
- Understand the effect ruminant bacteria on foods.
- Differentiate three bacterial species based on cell shape and location in a cow's rumen.
- Understand the difference between symbiosis and pathogenesis

National Science Education Standards Addressed

This activity addresses Life Science Content Standard C for grades K-4 through demonstration of specific organism needs (both living and non-living) for survival. Ruminant bacteria need plant matter, but also need a cow to provide them with that food source, and a cow rumen as a habitat.

Teacher Handout

Bacteria that Help and Hurt Cows

Teacher Handout

Student Prior Knowledge

Students should have some understanding about the basic needs of mammalians: food, shelter, water, oxygen, and sunlight. They should also know that livestock are able to feed on grass and silage as their main dietary component. These needs will be extended to note their differences and similarities, and the needs of microbes that live in the rumen or on injured udders. Students should also have a general knowledge about the basics of milk production, i.e., the sources of milk and how milk is collected. This activity will extend information about milk production and look at how microbes aid or deter in this process.

Students will also use a microscope to observe the different microorganisms that can exist in dairy cows.

Teacher Background Information

Livestock are capable of synthesizing proteins and vitamins from cellulose, an indigestible material for humans. Cellulose is a substance found in roughage like corn silage, hay silage, and grass, which are frequently fed to dairy cows. Dairy cows are ruminants capable of breaking down cellulose from that food source and obtaining energy form it; using that energy to increase their own mass. For this to be a successful process, different microorganisms need to be present in the rumen of the cows.

One type of microbe, known as *Ruminococcus,* are present in increased numbers in ruminants with a high-forage diet and are specific for breaking down cellulose. Additionally, ruminants require a separate set of microbes to break down grains such as corn, barley, oats, and wheat which are high in starch. Corn is the primary grain fed to dairy cows. The microbe needed for grain utilization is called *Selenomonas*. This microbe utilizes the carbohydrates (sugars) derived from the presence of these grains. Animals with a high grain diet will have increased levels of *Selenomonas* in their rumen.

The rumen of the cow is an anaerobic environment (no oxygen), and both *Ruminococcus* and *Selenomonas* are organisms that extract energy from carbohydrates and release fatty acids as waste products. Some of these waste products can be absorbed by the ruminant's digestive tract and used as a source of energy by the animal. The microbes also use cellulose or starch to synthesize vitamins needed for their own growth, and provide those vitamins to the cow.
As microbes present in the rumen aid in the digestion of cellulose and grains, they help ruminants, such as a cow, gain nutrients from these food sources. Similarly, a cow helps these microorganisms through its food consumption, by providing them with the cellulose or starch that they need for survival. As the cow and microorganisms aid each other, they are in a symbiotic relationship.
Microorganisms can also be the cause of disease in dairy cows which could ultimately affect milk production. For example, milk is collected from cows by squeezing their teats located under the udder. (To see how to milk a cow go to http://www.wonderhowto.com/how-to-milk-a-cow-131312_2/).

Sometimes mastitis—an udder infection—can develop in cows as a result of the friction during milking. This friction causes abrasions that allow bacteria to penetrate the epidermis barrier. One of the microorganisms that cause mastitis in cows is *Escherichia coli*. Typically, *E. coli* is found in an animal's digestive tract helping the animal digest food, so it is commonly found in feces. If the abraded udder comes into contact with feces, *E. coli* could seize the opportunity to use the damaged skin tissue as a source of nutrients. Consequently, *E. coli* could grow causing mastitis. While many microorganisms can cause mastitis, *E. coli* is one of the few that is responsible for first colonizing an abraded udder when they leave their usual habitat.

The occurrence of mastitis may be evident in the milk coming from sick cows. Mastitis infection causes an increase in the number of white blood cells present in the milk, and alters its sugar, fat, and protein composition. Consequently, milk that comes from a sick cow is easily detectable because milk becomes more watery and severely discolored. Additionally, swelling and inflammation can be observed on the cow's udder. This is an example of a pathogenic relationship in which bacterial growth harms the cow.

This information is optional: In the delicate balance of microorganism levels in the rumen, diet must be strictly regulated to ensure that the rumen has developed appropriate levels of microbes to degrade its typical food source. Quick change from one type of diet to the next will adversely affect the rumen by altering levels of the microbes specific to the main component of the diet. This leads to a change in the waste products. These different products will contribute to altered pH levels of the rumen. If this pH lowers significantly from a normal level, the animal could experience rumen acidosis. In addition the animal could produce excess gas which could lead to bloat. Bloating puts excess pressure on the heart and lungs, causing great harm on those organs. The acidosis destroys the microbial balance hindering further metabolic activity thereby stopping the animal's nutrient source. But the bigger problem and even possible cause of death from rumen acidosis stems from pressure put on the heart and lungs.

To avoid situations such as rumen acidosis and bloat, large-animal scientists can directly examine the effect of a specific diet on the balance of microbes. An opening, called a fistula, is surgically inserted to provide a gateway to the rumen. Consequently the type of waste products and type/number of microbes can be examined. (To see a fistulated cow go to http://www.news.cornell.edu/stories/April05/eyh.cover.ak.html)

Class Time

This activity should take approximately 55-60 minutes to complete.
Part I consists of the entire class viewing a large interactive and informative cow poster that will describe the locations of the various microorganisms, how food is processed through their gastrointestinal tract, what a rumen looks like, and a basic overview of microorganisms involved in secondary wound infections or in causing mastitis. Please see Appendix I for an example of the cow poster.

In Part II, students (in groups of 2-3) will view a preparation of the microorganisms often found in a dairy cow's rumen. The slides will consist of ruminant bacteria and bacteria involved in mastitis or wound infections. The waiting time here will be getting students through the rotation of looking at each microscope. During the wait time, students can watch the "how to milk a cow" video and complete their worksheet.

Teacher Preparation Time

The teacher should be familiar with using compound light microscopes and stained bacterial smears. (For a tutorial on using a compound microscope please see http://www.hometrainingtools.com/how-to-use-a-microscope-teaching-tip/a/1120/)

A poster representation of the cow will be most useful in providing an interactive overview of the parts of a cow and allowing students to see physically where these bacteria are located in a cow. An example poster is displayed in Appendix I.

A student worksheet should be available for each student.

Materials and Equipment

- Compound light microscopes (minimum 1 for every 3 students)
- Immersion oil
- Computer with internet connection and LCD projector
- Commercially stained *E. coli* slides. Ward's Scientific Cat #90V2042
- Commercially stained slides of a coccus bacterium to represent *Ruminococcus*. Ward's Scientific Cat #90V0111
- Commercially stained slides of a curved rod bacterium to represent *Selenomonas*. Ward's scientific Cat #90V3020
- Interactive cow poster
- Poster board
- Construction paper in different colors
- Scissors
- Glue

Methods

Part I:

1. Provide a copy of the worksheet to each student.

2. The activity begins by introducing students to the concept of microorganisms. One easy way to do this is to explain the concept of an organism (anything alive), and explain microorganisms as being so small they cannot be seen without a microscope. Students should be made aware that microorganisms are everywhere -- even on them! Ask students to complete Question #1 on the worksheet.

3. The prior knowledge can then be used as a transition into microorganisms in cows. Ask students where they think microorganisms live on cows. Ask students how many stomachs a cow has, and introduce the rumen as the biggest one, special for breaking down plant matter. Have a volunteer come up and point to the stomach on the interactive poster, then pull up the flap and expose the stomach (See Appendix III).

   At this time, students can be introduced to two genera of bacteria (a type of microorganism) that inhabit the rumen: *Ruminococcus* and *Selenomonas*. Explain that *Ruminococcus* likes to eat grass (cellulose), while *Selenomonas* likes to eat corn (starch). Introduce each bacterium separately, holding up the representative picture (See Apendix III) and have students repeat the names.

   Now that students know the foods these microorganisms like, ask them how they get those foods. Can they come out of the rumen and find the food they like? No – they are dependent on the cow. Attach one type of each bacterium to the stomach and explain that both live there all the time.

   Now, pose a situation in which students will have to formulate a hypothesis. If the cow eats grass, which type of bacteria will increase in the rumen? Ask students to complete Question #2 in their worksheet. Choose a volunteer, who will then come up and attach grass and *Ruminococcus* to the poster. Then, ask what will happen if the cow eats corn. Ask students to complete Question #3 in their worksheet. Choose a volunteer who will then come up and attach corn and *Selenomonas* to the poster.

   Ask students to fill out Question #4 in their worksheet. Reinforce that the cow helps in providing these bacteria with food and that the bacteria help the cow in digestion. This is a symbiotic relationship.

4. At this time there can be a discussion about dairy cows and milk production. Ask students to fill out Question #5 in their worksheet.

5. An example of bacteria that could cause problems would be *E. coli*, which can cause the udder infection mastitis. Segue into a discussion of mastitis by asking students if microorganisms live on the udders. Have a volunteer come up and place *E. coli* on the cow's udders. Explain what can happen to milk if mastitis occurs. This is a pathogenic relationship. Ask students to fill out Question #6 in their worksheet.

Part II:

Invite students to take turns looking at *E. coli, Ruminococcus,* and *Selenomonas* under a microscope. Ask students to fill out Question #7 in their worksheet. Those students waiting to view the slides can view the "how to milk a cow" video, and continue to work on their worksheet.

Delivery

The lesson should be presented in the most interactive manner possible. Students should be asked questions throughout the lesson and invited to participate by interacting with the poster and observing organisms under the microscope.

Technology Utilization

Microscopes with a 100x objective will be used to view bacteria. For ease of viewing, instructors should set the microscope to proper viewing magnification before student viewing. A computer connected to the internet and a projector will be used to show the on-line video on How to Milk a Cow.

Microorganisms (if applicable)

No live microorganisms are utilized in this lesson.

Safety Issues

The teacher should be the only person handling the glass smears. Smears should be disposed of in an appropriate sharps container.

Assessment and Evaluation of Activity

This activity can be evaluated through the worksheet testing the main points of the lesson. For feedback regarding this activity field test see Appendix I.

Supplementary Information

1. Define microorganism.
   A microscopic organism (cannot be seen with the naked eye)

2. If the cow eats grass, which type of bacteria will increase in the rumen?
   Ruminococcus

3. If the cow eats corn, which type of bacteria will increase in the rumen?
   Selenomonas

4. How do microorganisms in the rumen help the cow? How does the cow help the microorganisms? M*icroorganisms help the cow by digesting foods that the cow ingests. The cow provides the nutrients for the microorganisms' survival as well as a place to live.*

5. Is the association between Selenomonas and the cow a pathogenic or symbiotic relationship? Circle one.

   PATHOGENIC SYMBIOTIC

6. Where does milk come from? Name three food items that come from milk?
Milk is collected from the cow's udder. Yogurt, cheese, ice cream, etc

7. What is mastitis?
An infection of the cow's udder.

8. Is the association of *E. coli* and the cow's udder a pathogenic or symbiotic relationship? Circle one.

(PATHOGENIC) SYMBIOTIC

9. Where does *E. coli* live? How does it get to the udder?
It is found in the cow's intestines. Cow feces can come into contact with the cow's udder through fecally-contaminated milking equipment, bedding, and human hands.

10. Complete the following table.

Bacterium	Draw what you see. Record the shape name (i.e., bacillus coccus, or crescent).	Where can you find this microorganism in the cow?	What type of relationship does it have with the cow?
Ruminococcus	Coccus	Rumen	Symbiotic
Selonomonas	Crescent	Rumen	Symbiotic
Escherichia coli	Bacillus	Intestines, but can also be found on the udder when associated with mastitis.	Pathogenic

Modifications/Extensions

If modification is desired, material can be extended to include a discussion of bloat, rumen acidosis and fistulated cows related to an imbalance of *Selenomonas* and *Ruminococcus*. This imbalance is a result of an extreme change in diet. Additionally, an extended discussion of mastitis could occur. However, these extensions are recommended for an older age group, perhaps 5th or 6th grade. For additional references, teachers are encouraged to look to our works cited in Appendix II.
Students can also be organized to work in groups so they can discuss their answers.

Student Handout

Bacteria that Help and Hurt Cows

Introduction

Microorganisms are the most common living organisms on Earth. They can be seen under a microscope as living alone or in groups. These living organisms can be found in many places such as in the soil, in freshwater or saltwater habitats, and in/on animals (including the human body!), and are important for survival. More specifically, you will focus on the strong role they play in the cow's digestion. Food eaten by cows is broken down into nutrients used by many of these microorganisms. In return, microorganisms make nutrients needed for the cow to survive.

Most microorganisms are helpful to the organism in which they survive; others can cause disease. Here, we will explore and discover how microorganisms can affect a cow. We will also view various microscope slides to demonstrate a closer look at these microorganisms' characteristics.

Student Background Knowledge

Students should have a basic understanding about the basic needs of mammalians: food, shelter, water, oxygen, and sunlight. They should also know that livestock are able to feed on grass and silage as a main dietary component. These needs will be extended to note the differences and similarities of these needs and the needs of microbes that live in the rumen, in udders, or in wounds of dairy animals. Students should also know the basic information concerning milk production. This project will extend information about milk production and look at how microbes aid or deter in this process.

Students will be required to use a microscope in this project to observe the different flora of microorganisms that can exist in dairy cows.

Vocabulary

1. Microorganism: Small organisms seen with a microscope.
2. Rumen: The first and largest part of the stomach of a ruminant animal such as a cow, goat, or deer.
3. Coccus: Bacteria having a sphere shape.
4. Bacillus: Bacteria having a rod shape.
5. Cellulose: Plant material that provides energy to ruminants.
6. Mastitis: An infection of the udders.
7. Symbiotic: A relationship in which two living things work together to help each other.
8. Pathogenic: A relationship in which one organism causes disease in another.
9. Udder: The location of milk production in a cow.
10. Ruminant: A hoofed mammal that has a rumen to help digest cellulose.

Safety Considerations

Students should not handle the glass microscope slides. If help is needed, they should ask for the teacher's assistance.

Materials check list
A writing utensil and paper or a lab notebook for students to draw their observations.

Procedure for Participants
Students should engage in answering and asking various questions related to the provided lesson. They will also engage in an activity related to ruminant animals. Students will observe various microscope slides, and draw what they see. If they are not using the microscope, students can view a cow image in which a "fistula" has developed, the "how to milk a cow" video, or try to answer the questions in their worksheet.

Results
See worksheet on next page.

Bacteria that Help and Hurt Cows

Name _____ Grade _____

1. Define microorganism.

2. If the cow eats grass, which type of bacteria will increase in the rumen?

3. If the cow eats corn, which type of bacteria will increase in the rumen?

4. How do microorganisms in the rumen help the cow? How does the cow help the microorganisms?

5. Is the association between Selenomonas and the cow a pathogenic or symbiotic relationship? Circle one.

   PATHOGENIC SYMBIOTIC

6. Where does milk come from? Name three food items that come from milk?

7. What is mastitis?

8. Is the association of *E. coli* and the cow's udder a pathogenic or symbiotic relationship? Circle one.

   PATHOGENIC SYMBIOTIC

9. Where does *E. coli* live? How does it get to the udder?

10. Complete the following table.

Bacterium	Draw what you see. Record the shape name (i.e., bacillus coccus, or crescent).	Where can you find this microorganism in the cow?	What type of relationship does it have with the cow?

Appendix J

Fig. 1 - Cow Interactive Poster

Fig. 2 - Exposure of the cow's rumen.

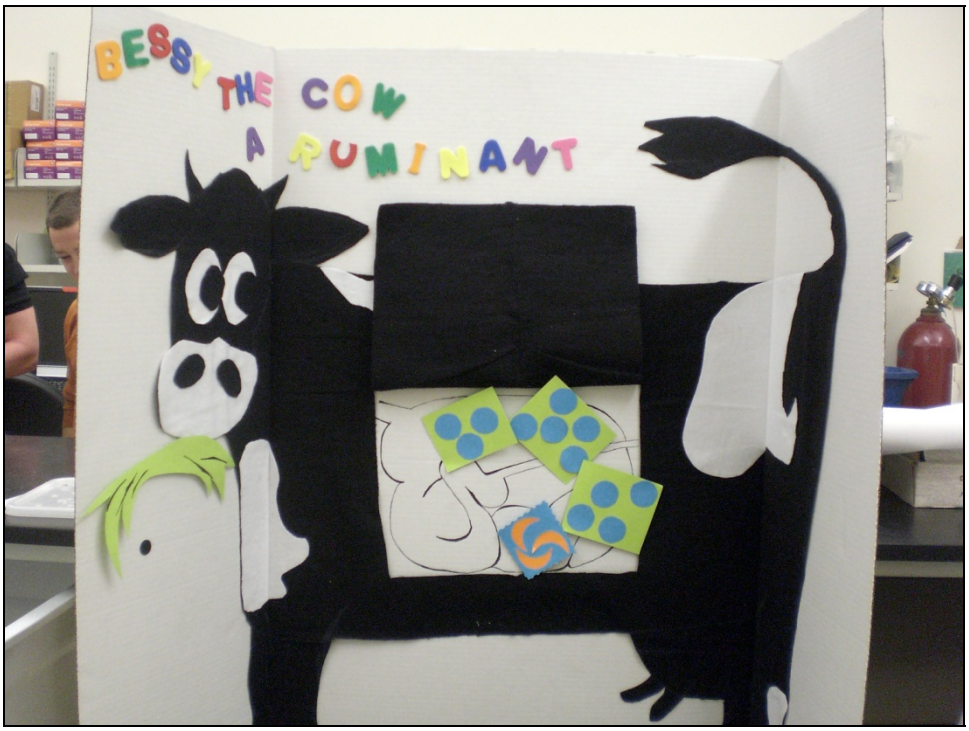

Fig. 3 - As the cow eats grass (cellulose), *Ruminococcus* increases in number.

Fig. 4 - As the cow eats corn (starch), *Selenomonas* increases in number.

Fig. 5 - *E. coli* on the udders.


Fig. 6 - Display of poster pieces. Curved yellow rods represent *Selenomonas*, The blue circles represent *Ruminococcus,* and the red rods represent *E. coli.*

Appendix JJ

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Appendix JJJ

Activity Field Test

On December 8, 2009 this lesson was field tested at John Clem Elementary School in Newark, Ohio. The lesson was presented during an after-school care program to 3rd through 5th graders. Our lesson involved an explanation of microorganisms, and a description of bacteria that live in the cow rumen. We asked for participants to place the "correct" bacteria into the cow's rumen based upon the cow eating either grass or corn. Students learned that when two organisms work together they are in a symbiotic relationship. We also made the distinction between good and bad bacteria through a discussion of mastitis caused by *E. coli*. Therefore, the good bacteria were presented as those that live in the rumen, while the bad bacterium is *E. coli*, which causes mastitis. Students were then asked to fill out an evaluation while taking turns observing these organisms with a microscope.

Our evaluation results indicated that, overall, students were able to grasp these concepts. For example, 68% of students got all questions correct, 23% got one wrong, and 9% got two wrong. We chose to discount question number four because we were unable to address the rumen as an anaerobic environment and therefore found the question to be unfair. Although students were talking to each other, comparing answers, and asking for help in the completion of the evaluations, we felt as though they were fairly accurate indicators of at least their potential mastery. It is difficult to ascertain actual comprehension from one half-hour session with students who were tired from a full day of classes. If this lesson were taught in a curriculum in which teachers were able to reinforce the material for multiple days, there is no reason why students would be unable to retain it. Additionally, we found that the student handouts were very helpful. When answering questions, students would refer to their handouts, which lead us to believe that in preparing for a test, such a handout would serve as an excellent study guide.