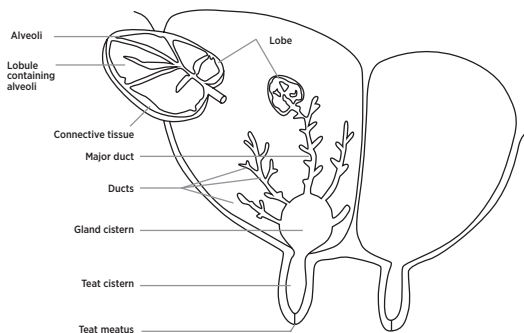


Examining the Milk Production System of Dairy Cows



Overview:

The *Mammary Gland Anatomy – Examining the Milk Production System of Dairy Cows* lesson is designed to introduce participants to the general anatomy of the lactating mammary gland and flow of milk letdown using the bovine (cattle) mammary gland as a model.

Objectives:

After completing this activity, participants will be able to:

- ▶ Describe the general anatomy of the mammary gland and the method in which milk reaches the teat.
- ▶ Construct a model lactating mammary gland system to observe the path of milk components from the gland to the teat.
- ▶ Understand and describe the roles of each part of the gland system.
- ▶ Discuss the importance of mammary gland function and health.

Skill Level:

- ▶ Advanced

Life Skills:

- ▶ Critical thinking, decision-making and teamwork

Setting:

- ▶ An outdoor or indoor space that allows for any water spillage and where participants can use craft materials. A wall or other sturdy surface can be used to display the mammary gland but is not required.

Time:

- ▶ 30-45 minutes

Materials:

- Standard 8 ½-inch by 11-inch sheets of paper, white or notebook (one per individual or group)
- Markers (one per individual or group)
- For one gland-teat system for group of two to three participants:
 - ▶ 1 pair of scissors
 - ▶ 1 kitchen sponge cut into 3 smaller oval-shaped pieces
 - ▶ 3 small funnels (you can make your own using a circular piece of durable paper or utilize plastic or metal kitchen funnels)
 - ▶ 3 large diameter drinking straws that will fit together with the funnels (milkshake straws approximately 1 centimeter in diameter were used in figures 1 and 2)
- ▶ 1 small plastic pop or water bottle (1 liter or smaller) with 1 to 2 inches of the bottom removed (carefully using the scissors), leaving a hollow tube for water to flow through
- ▶ 1 rubber glove with 4 of the fingers tied off or taped back, leaving one finger to represent a “teat”
- ▶ 1 cotton ball
- ▶ Small safety pin
- ▶ Masking tape or other similar tape (one roll to share between two to three groups)
- ▶ Electrical or other waterproof tape to prevent leaking around funnels (optional, 1 to 2 rolls is plenty depending on the group size)
- ▶ Strong tape such as duct or packaging tape to secure model to a wall or other sturdy surface (optional, 1 roll is plenty)
- ▶ Small bucket for water (approximately 1 gallon size)
- ▶ Water
- Large paper for instructor to draw diagram on (optional)
- Markers for instructor to draw diagram with (optional)
- Overhead projector (optional)
- “Basics of Bovine Mammary Anatomy and Milk Letdown” resource sheet (Use overhead projector to project for the group, or make enough copies to hand out to each group or individual.)

PROCEDURE:

Before the meeting:

1. Review the lesson and resource sheet, and gather any supplies you will need.
2. Print off the “Basics of Bovine Mammary Anatomy and Milk Letdown” resource sheet. You can print one for projection, one for each group or individual, or just use as an instructor resource. If you pass the resource sheet out to participants, it’s best to wait until part way through the lesson.
3. Prepare the materials for the activity based on the number of participants. You will have each group of two to three participants construct one mammary gland. You may also choose to construct one of your own as a demonstration, or use a large sheet of paper to draw a diagram as you progress through the lesson.
4. Set up a supply table. Group materials for each mammary system on the supply table so they can be easily passed out.
5. Consider making a demonstration model to aid in participant construction and understanding.
6. Refer to the table below regarding the representations of each structural component:

Mammary Structure Components	
Items	What they represent
Sponge and funnel	Lobe (lobules and alveoli): The funnel and sponge represent a lobe of the mammary gland. The sponge represents the lobules consisting of many alveoli.
Straws and plastic bottle	Ducts: The straws represent the secondary interlobular ducts that drain the milk between lobules. The plastic bottle represents the primary duct that drains milk between the lobes.
Rubber glove	Gland cistern, teat, and teat cistern: The palm of the rubber glove represents the gland cistern, while the finger of the glove represents the teat, with the inside being the teat cistern.
Cotton ball	Teat Sphincter: The cotton ball represents the teat sphincter, which prevents milk from leaking from the streak canal when the udder is full.

During the meeting:

1. Introduce the activity by telling the group they are going to build a model that will help them learn about the structure of the cow's mammary gland and find out how milk reaches the teat. Read or paraphrase the following:

Most mammals produce milk in similar ways, but today, we are going to concentrate on dairy cattle as they supply most of our country's milk. We're going to learn more about milk production. We'll make models of a cow's mammary gland and replicate the milk production process. The mammary gland is the part of the animal that is responsible for milk production, also called lactation. As we go through the process, we will discuss what each part does and how milk reaches the teat.

2. Ask the group the following questions:
 - ▶ What is the main function of the mammary gland? (To produce milk for its offspring)
 - ▶ Why is the function of the mammary gland important? (*Possible answers: Species survival, healthy young, dairy products in the case of the dairy cow or dairy goat, sheep, camel, and other animals. Milk may be collected from several species for human consumption. Cow's milk is the most common in the United States, but not necessarily in other countries around the world.*)
3. Divide the participants into groups of two to three people, depending on the size of the larger group.
4. **Starter activity:**
 - ▶ Hand each individual or group a sheet of paper and a marker.
 - ▶ To encourage thought about how many teats various animals have, ask the group: "How many teats do you think a pig has?" Allow participants time to think or discuss with the group and write down their answers. Repeat the question for each species you would like to discuss. (*Average teat numbers: Cow: 4, Pig: 10-16, Goat: 2, Dog: 8-10, Horse: 2, Cat: 8, Mouse: 10, Camel: 4*)
 - ▶ Next, have the participants hold up their papers containing their answers. Discuss the answers and reflect on why there are differences in the number of teats.
 - ▶ Number of young: Pigs and dogs have many offspring, or litters, while cows and goats usually have one offspring. Therefore, these animals with litters will have more teats.
 - ▶ In animals that have more than one teat for one offspring, it is possible that the young will go to one teat after another to get enough milk.

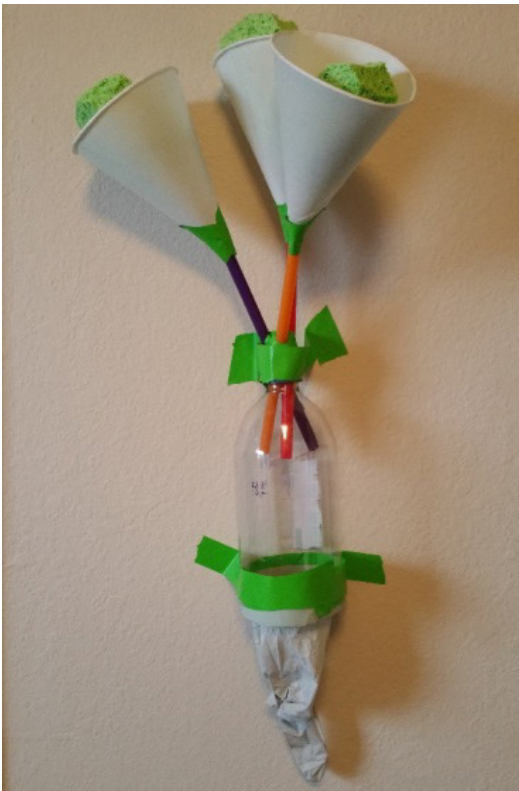


Figure 1. Completed model of a mammary gland system before water is added.

5. Announce to the group that now it's time to start building their own mammary systems. Have a member of each group retrieve the materials from the supply table to construct a model mammary gland.
6. Once all of the groups have their materials, begin to explain the construction process. Read or paraphrase the following:

The mammary gland is an important part of a species' survival, providing nutrients to the young offspring through the milk. In the case of the dairy cow, the milk is also sold for human consumption and used to make other dairy products such as cheese and yogurt. We will begin by looking at where the milk is produced in the gland.

7. Have the participants pick up one sponge, one straw, one funnel, and the masking tape. Next, connect the straw and funnel and place tape around the connection site on the outside to hold it in place. (See top part of Figure 1 that shows funnels and sponges.) If you have your own demonstration materials, demonstrate this to the group. If you have electrical or other waterproof tape, place this over the masking tape to help prevent any possible leaks.
8. On the resource sheet (pages 8–10), refer to the information as well as the drawing of the lobe and lobules, “Bovine Mammary Gland.” Read or paraphrase the following:

The funnel and sponge act as a single lobe, or milk-producing area in the mammary system. These lobes have many milk-producing cells called alveoli, which are bunched together in small groups called lobules. Each lobe has many lobules with many milk-producing cells in each lobule. The small holes within the sponge represent the milk-producing alveoli.

9. Have the participants construct the other two “lobes” using the remaining straws and funnels. When the groups are finished, have them take the plastic bottle with the bottom removed and place all three of the straws into the top opening, then tape them into place by taping the straws together, and then taping them to the small top opening of the bottle. (See middle part of Figure 1 that shows the bottle and straws.) If you have your own demonstration materials, demonstrate this to the group. Continue explaining the significance of the straws and bottle by referring to the resource sheet and reading or paraphrasing the following:

The straws represent the smaller ducts that the milk will travel through from the cells where milk is produced, leading toward a bigger main duct. The bottle represents this main duct. The smaller, secondary (interlobular) ducts allow milk to travel from the milk-producing cells

to the bigger, primary (interlobar) duct. This bigger duct leads directly to the holding area for milk above the teat. These ducts are what allow milk that is created in the groups of alveoli to travel down to the teat.

10. Have the participants pick up the rubber glove and with a small safety pin, very carefully poke a tiny hole into the end of the remaining finger on the rubber glove. Then, have them take a small nickel-sized piece of the cotton ball and place it inside of the glove and into the finger slot so it is covering the small hole. If you have your own materials, demonstrate this to the group.
11. Next, stretch the opening of the glove over the open bottom of the bottle and tape it in place. You may want to cover the open edge of the bottle with a piece of tape if it is not smooth as to prevent the bottle from tearing the glove. (See bottom part of Figure 1 that shows the glove stretched over the bottle.) If you have your own demonstration materials, demonstrate this to the group.
12. Refer to the resource sheet and explain the significance of the materials by reading or paraphrasing the following:

The palm area of the glove represents the gland cistern. This area acts as a storage tank and holds milk before it leaves the teat. The finger of the glove represents a single teat of the cow’s udder, with the inside being the teat cistern. This is connected to the gland cistern and like the gland cistern also acts as a storage space for milk right before it leaves the teat. The cotton inside of the finger represents the teat sphincter, the muscle that lines the bottom of the teat that helps prevent milk from leaking out when the udder is full. The opening at the bottom of the teat is called the streak canal, a small hole that allows the milk to flow outside of the mammary gland while also preventing bacteria from getting inside.

13. Now have the groups begin to simulate milk production by dipping the sponges into the water and squeezing them into the funnels. The water will flow down into the glove into the “teat.” (See Figure 2.) Participants can gently grab the glove just above the “teat” and squeeze downward to simulate milk ejection.
14. If your participants are not familiar with milking, read or paraphrase the following:

When milking a cow, the udder and milking equipment are cleaned and disinfected and the milking takes place in a clean area to prevent bacteria from entering the teat. The individual will hold the teat with two fingers while using the other three to force the milk out of the teat.



Figure 2. Completed model of a mammary gland system after water is added.

TALKING IT OVER:

Ask the group the following questions:

- ▶ Why is it important to know the structure and function of the mammary gland? *(treat any medical issues, important in health and development of young animals, maximize milk production)*
- ▶ Where is milk produced in the mammary system? *(in the alveolar cells, these are located in the lobes)*
- ▶ How does milk reach the teat to leave the mammary system? *(Milk is created by alveoli. Then it travels through the secondary ducts to the primary duct, which leads to the holding area. The holding area consists of the gland cistern and the teat cistern. There, it can leave the inside mammary system.)*
- ▶ What are some of the challenges that are currently facing any animal species that is primarily used for milk production such as cows, goats or sheep? *(Answer may include: Mastitis, production life and longevity, market availability, cost of raising and producing animals, rising feed costs, concerns from organizations such as the People for the Ethical Treatment of Animals and the Humane Society of the United States, limited availability of approved treatments and medications)*
- ▶ How can we as an agricultural industry better explain the process of milk production and the reasons animals are used for milk to the general community?
- ▶ What are the benefits of having an informed consumer?

Many dairy farms also use machines that attach to the cows' teats and perform the same stimulation of a calf nursing to release milk out of the teats for collection. This is aided by the release of oxytocin from the pituitary gland (located in the brain), a naturally existing hormone responsible for milk letdown.

15. If your participants are experienced with milking, explain the action of milk secretion in further detail by reading or paraphrasing the following:

Each of the alveoli also has a layer of myoepithelial (my-o-epi-thel-ial) cells lining the outside. The myoepithelial cells contract, which forces the milk in the lumen (the middle area of the alveolar cell) out into the small ducts and eventually into the holding area for milk (gland cistern and teat cistern). The squeezing of the sponge simulates this process.

16. While the participants are using their creations, challenge them to think about the following questions:
- ▶ Where do the building blocks for milk production come from? *(small blood vessels known as capillaries, surrounding alveolar cells, nutrients from the diet)*
 - ▶ How much milk does a single alveolar cell hold at one time? The gland cistern? *(Alveoli are estimated to hold about 1/5 of a drop of milk, the gland cistern can hold 100 to 400 milliliters, or about 1/2 cup to 2 cups of milk)*
 - ▶ How much milk do you think a cow produces in one day on average? *(About 6.5 gallons each day)*

ALIGNMENT TO SCIENCE & ENGINEERING PRACTICES:

How 4-H Increases Science Literacy

Nationally and in Michigan, 4-H has long enjoyed a reputation for engaging young people in positive, experiential (hands-on), and nonformal activities that are inquiry-based. The lessons in the *4-H Animal Science Anywhere* series can be used to enhance classroom science education in Michigan and elsewhere. The lesson activities are aligned with the eight Scientific and Engineering Practices (SEP) from *A Framework for K-12 Science Education* (National Research Council, 2012, p. 42).

The Michigan State Board of Education adopted a set of new state science standards in late 2015 that are based on the SEP. The activities in the *4-H Animal Science Anywhere: Examining the Milk Production System of Dairy Cows* lesson were evaluated for their alignment with the SEP by MSU Extension Educator Tracy D’Augustino in 2016.

Table 2. How This Lesson Aligns With the Science and Engineering Practices (National Research Council, 2012, p. 42)

Science & Engineering Practice	Action	Activity Step Number
1. Asking questions and defining problems	▶ Participants discuss the function of mammary glands.	2
	▶ Participants discuss why different mammal species have different numbers of teats.	4
2. Developing and using models	▶ Participants build models of a cow mammary gland.	6-13
	▶ Participants use their models to explain how the mammary gland functions.	Talking It Over
3. Planning and carrying out investigations		
4. Analyzing and interpreting data	Participants learn about the functions of the cow mammary gland and discuss and demonstrate how it functions using their models.	8-12 Talking It Over
5. Using mathematics and computational thinking		
6. Constructing explanations and designing solutions	▶ Participants explain how a cow mammary gland functions.	4
	▶ Participants discuss the number of teats related to litter size.	Talking It Over
7. Engaging in argument from evidence	▶ Participants explain the importance of knowing the basics about a mammary gland.	2 & Talking It Over
	▶ Participants explain how milk moves through the mammary gland.	Talking It Over
8. Obtaining, evaluating, and communicating information	Participants learn about the cow mammary gland, and build and use a model to explain how the mammary gland functions.	Whole lesson

ACKNOWLEDGMENTS:

Authors

- ▶ Sarah Erwin, Michigan State University Undergraduate Student, Class of 2015
- ▶ Julie Thelen, 4-H Livestock and Veterinary Science Educator, Michigan State University Extension
- ▶ Some of this information was based on the 2015 mammary gland anatomy presentations of Elizabeth Karcher in ANS 435 at Michigan State University, East Lansing, Michigan.

This bulletin was produced by ANR Creative (anrcom.msu.edu) for MSU Extension (msue.anr.msu.edu).

MICHIGAN STATE UNIVERSITY | Extension

Mammary Gland Anatomy © 2016 by Michigan State University Board of Trustees. 4-H and Cooperative Extension System groups and other nonprofit educational groups may print up to 25 hard copies of this material for noncommercial, educational use, provided that attribution is given to Michigan State University. All other rights reserved. For information, contact 4-H Youth Development, 108 Morrill Hall of Agriculture, 446 West Circle Drive, East Lansing, MI 48824.

MSU is an affirmative-action, equal-opportunity employer, committed to achieving excellence through a diverse workforce and inclusive culture that encourages all people to reach their full potential. Michigan State University Extension programs and materials are open to all without regard to race, color, national origin, gender, gender identity, religion, age, height, weight, disability, political beliefs, sexual orientation, marital status, family status or veteran status. Issued in furtherance of MSU Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Jeffrey W. Dwyer, Director, MSU Extension, East Lansing, MI 48824. This information is for educational purposes only. Reference to commercial products or trade names does not imply endorsement by MSU Extension or bias against those not mentioned. The 4-H Name and Emblem have special protections from Congress, protected by code 18 USC 707. 11P-1R-Web-05:2016-PA & MR WCAG 2.0 AA

ADAPTATIONS & EXTENSIONS:

For Younger or Less Experienced Participants:

- ▶ Consider using one or two pre-made mammary gland systems and walk through the process using the descriptions and drawing “Bovine Mammary Gland” in the resource sheet.

For Older or More Experienced Participants:

- ▶ Have participants brainstorm how the composition of milk and number of teats might differ between species (for example, a seal compared to a pig).
- ▶ Have participants think about various challenges related to milk production in dairy cows, such as health issues.
- ▶ Have participants research how milk secretion and letdown is stimulated and report back to the group at a later date.
- ▶ Have participants research where individual milk components are synthesized and report back to the group at a later date.
- ▶ Use the basics of this lesson to model the mammary glands of other animals. Note differences and similarities.

REFERENCES & RESOURCES:

- Hurley, W. L. (2010). *Mammary macro-structure dairy cow udder anatomy*. Urbana, IL: University of Illinois Department of Animal Science. Retrieved from http://ansci.illinois.edu/static/ansc438/Mamstructure/anatomy_1.html
- Purdue University. (2008). *Dairy Facts*. West Lafayette, IN: Author. Retrieved from <http://www.ansc.purdue.edu/faen/dairy%20facts.html>

Basics of Bovine Mammary Anatomy and Milk Letdown

Key Terms:

Alveoli: Multiple alveolar cells.

Alveolar cell (alveolus): Sack-like structure where milk is produced.

Ducts: Tubes that milk flows through from where it is created and down to the teat.

- ▶ Primary or interlobar (between lobes) » lead to milk holding area.
- ▶ Secondary or interlobular (between lobules) » lead to primary duct.
- ▶ Tertiary or intercalary (small ducts that exit from the alveolar cells) » lead to secondary duct.

Gland Cistern: Hollow area above the teat that holds milk for storage.

Lobe: The milk-producing area having many lobules close together connected to one primary duct that leads to the gland cistern and the teat.

Lobule: Group of cells that create milk.

Streak Canal (or Teat Meatus): Opening between outside environment and internal mammary system, located at the bottom of the teat that allows the milk to flow outside of the mammary gland while also preventing bacteria from getting inside.

Teat: Rounded part where milk leaves the body and where the young nurse.

Teat Cistern: Hollow area inside of the teat that holds milk; part of the gland cistern.

Teat Sphincter: Muscle in the teat wall that prevents milk from leaking out when the udder is full.

Introduction

An important part of species survival and health, the mammary gland is a modified skin gland that produces nutrient-rich milk to keep offspring healthy and strong while they are growing. In the case of the dairy cow and other species such as the goat and camel, milk is also sold for human consumption and used to make other milk products such as cheese and yogurt.

Mammary Anatomy

The general anatomy of the mammary gland consists of the streak canal, the teat and gland cisterns, the ducts, and the lobes.

- ▶ The streak canal acts as an exit point for milk, but can also be an entry point for bacteria.
- ▶ The teat cistern holds milk just before it leaves the teat. The teat sphincter is located at the bottom of the teat cistern just above the streak canal. This is a muscle that acts to prevent milk from leaking out when the udder is full.
- ▶ The gland cistern holds the milk that was created until it exits through the streak canal.
- ▶ The ducts are the tubes through which milk travels. The secondary or interlobular (between lobules) ducts lead milk from the alveoli (milk-creating cells) of the lobules to the primary ducts. The primary or interlobar (between lobes) ducts allow milk to travel from the secondary ducts to the main milk holding area (gland and teat cisterns). There are many secondary ducts that bring milk from the lobes to one primary duct. There are also tertiary or intercalary ducts, which are very small ducts connected to the alveoli that let milk flow from the cell into the secondary ducts.
- ▶ The lobe is the milk-producing area of the gland. The lobe has many alveoli that are in groups called lobules. Each primary duct will have many lobes branching off of it.

Further anatomy for more experienced groups:

- ▶ The alveolar cells each have a single layer of cells called epithelial cells that line the inner wall of the membrane. These cells create the milk in the alveolar cell. Each alveolar cell also has a layer of cells on the outside that contract to squeeze milk out of the cell into the duct. These are called myoepithelial cells.
- ▶ These alveoli are also in close contact with many capillaries that bring nutrients and blood to the cells to create milk.

Milk Production and Letdown

- ▶ Milk is produced in the alveoli (sack-like cells) in the lobules (groups of alveoli). The milk from the lobules then flows into the secondary ducts. The milk from this lobe (group of lobules) then flows from the secondary duct to the primary duct. This primary duct allows milk to flow to the gland and teat cisterns (holding areas for milk) where it is held before it is released to the outside through the streak canal (small opening) at the bottom of the teat.

Additional information

- ▶ Blood flow to the mammary gland brings nutrients for creating milk to the alveoli (milk-producing cells) through the small blood vessels (capillaries). The epithelial cells of the alveoli create milk components that end up in the lumen (middle space of the cell). The myoepithelial cells on the outside of the alveoli contract, squeezing the milk out of the lumen and into the small tertiary ducts connected to the alveolar cells.
- ▶ The tertiary ducts allow milk to flow from the alveoli into the secondary ducts, which then bring milk into the primary duct.
- ▶ The primary duct leads to the gland cistern, the area where the milk is stored. The gland cistern is continuous with the teat cistern, where milk is held just before milk ejection (release from the holding area to the outside) through the streak canal (small opening) at the bottom of the teat.

Key Terms

(continued):

For more experienced groups:

Capillaries: Small blood vessels that bring nutrients to the cells to create milk.

Epithelial cells: Cells that line the inside of the alveolar cells; these cells produce the milk.

Lumen: Middle area of the alveolar cell.

Myoepithelial cells: Cells that line the outside of the alveolar cells that contract to squeeze milk from the middle area of the alveolar cell (lumen) into the ducts.

Bovine Mammary Gland

