

Anatomy of the Mammary Gland

(Adapted from

http://www.delaval.com/Dairy_Knowledge/EfficientMilking/The_Mammary_Gland.htm)

The gross anatomy of the mammary gland differs a lot among different species. The number of glands and teats are not the same for the cow, the sow or the horse. However, the microscopic anatomy is very similar among species.

The development of the mammary gland starts early in the fetal life. Already in the second month of gestation teat formation starts and the development continues up to the sixth month of gestation. When the calf fetus is six months, the udder is almost fully developed with four separate glands and a median ligament, teat and gland cisterns.

The developments of milk ducts and the milk secreting tissue take place between puberty and parturition. The udder continues to increase in cell size and cell numbers throughout the first five lactations, and the milk producing capacity increases correspondingly. This is not always fully utilized, since the productive life time of many cows today is as short as 2.5 lactations.

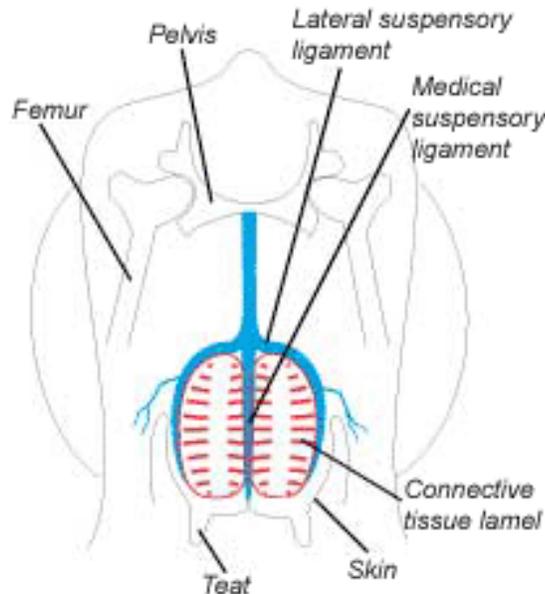
The mammary gland of the dairy cow consists of four separate glands each with a teat. Milk which is synthesized in one gland cannot pass over to any of the other glands. The right and left side of the udder are also separated by a median ligament, while the front and the hind quarters are more diffusely separated.

The udder is a very big organ weighing, around 50 kg (including milk and blood). However, weights up to 100 kg have been reported. Therefore, the udder has to be very well attached to the skeleton and muscles. The median ligaments are composed of elastic fibrous tissue, while the lateral ligaments are composed of connective tissue with less elasticity. If the ligaments weaken the udder will become unsuitable for machine milking since the teats then will often point outward, demonstrated in the picture below.

The mammary gland consists of secreting tissue and connective tissue. The amount of secreting tissue, or the number of secreting cells is the limiting factor for the milk producing capacity of the udder. It is a common belief that a big udder is related to a high milk production capacity. This is, however, not true in general, since a big udder might include a lot of connective and adipose tissue. The milk is synthesized in the secretory cells, which are arranged as a single layer on a basal membrane in a spherical structure called alveoli. The diameter of each alveoli is about 50-250 μ m. Several alveoli together form a lobule. The structure of this area is very similar to the structure of the lung. The milk which is continuously synthesized in the alveolar area, is stored in the alveoli, milk ducts, udder and teat cistern between milkings.

60-80% of the milk is stored in the alveoli and small milk ducts, while the cistern only contains 20-40%. However, there are relatively big differences between dairy

cows when it comes to the cistern capacity. This is of importance for the milking routines to be applied (see later demonstrated in the picture below).



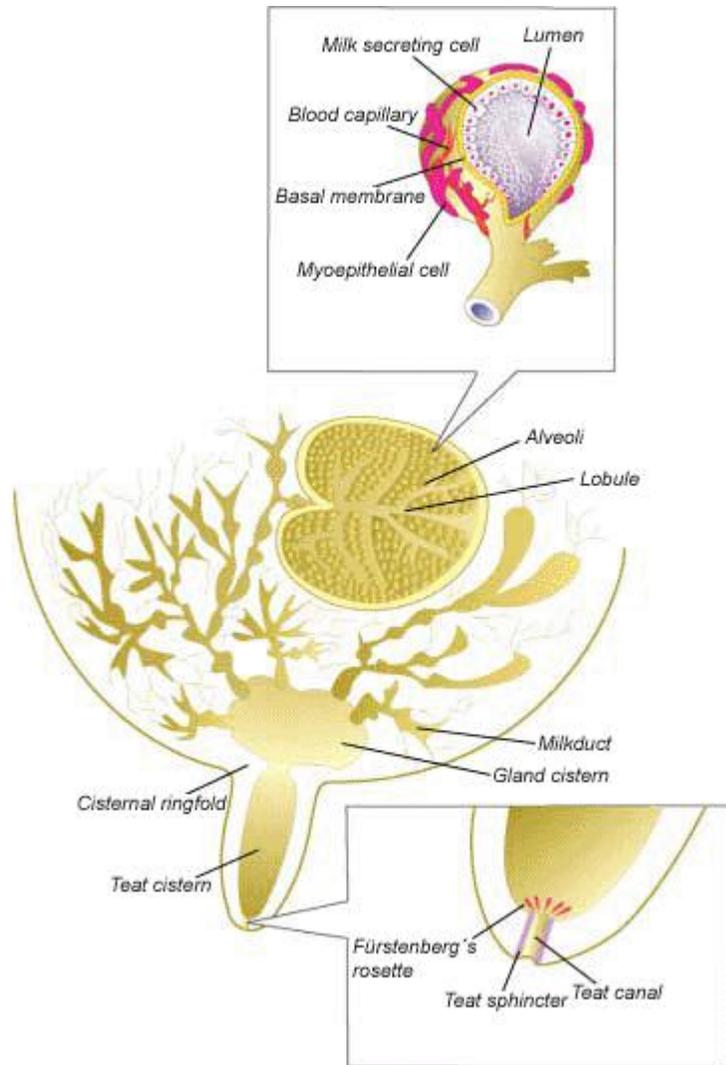
The suspensory structure of the udder

(Adapted from The Bovine Udder and Mastitis, ed Sandholm et al. 1995).

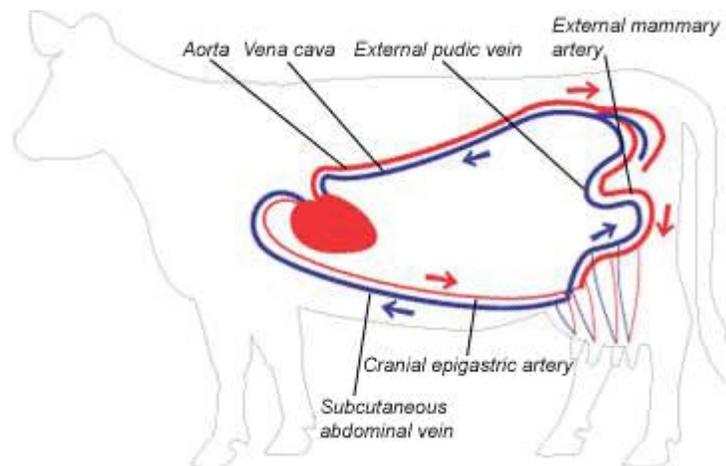
The teat consists of a teat cistern and a teat canal. Where the teat cistern and teat canal meet, 6-10 longitudinal folds form the so called Fürstenberg' s rosette, which is involved in the local defense against mastitis. The teat canal is surrounded by bundles of smooth muscle fibers, longitudinal as well as circular. Between milkings the smooth muscles function to keep the teat canal closed. The teat canal is also provided with keratin or keratin like substances which between milkings act as a barrier for the pathogenic bacteria.

The mammary gland is densely innervated especially in the teat. The skin of the teat is provided with sensory nerves which are sensitive to the suckling performed by the calf, and thus influenced by pressure, heat and frequency of suckling. The udder is also provided with nerves connected to the smooth muscles in the circulatory system and the smooth muscles in the milk ducts. However, there is no innervation directly controlling the milk producing tissue.

The mammary gland is very well supported with blood vessels, arteries and veins. Right and left udder halves generally have their own arterial supply, there are some small arterial connections that pass from one half to the other. The primary function of the arterial system is to provide a continuous supply of nutrients to the milk synthesizing cells.



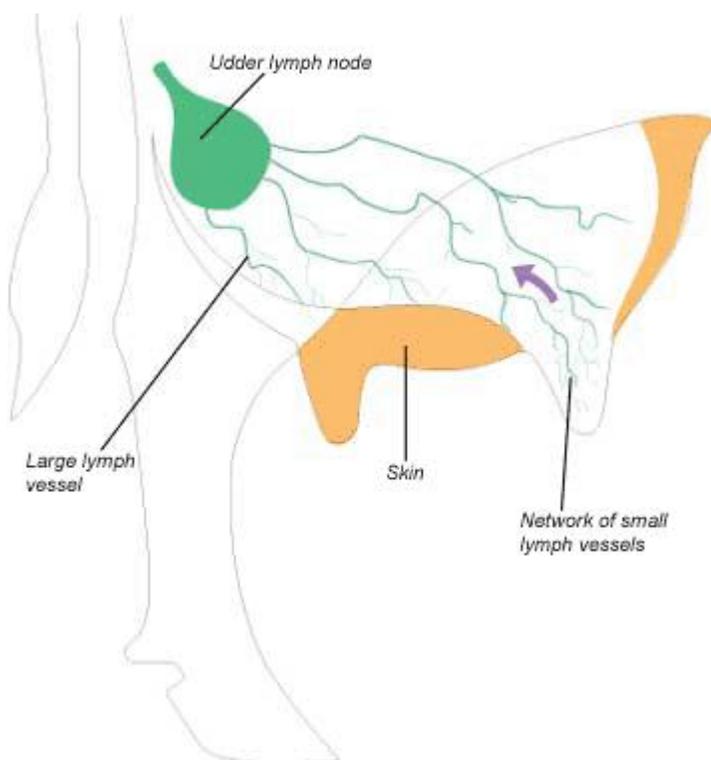
Schematic picture of the anatomy of the udder.



Schematic picture of the vascular system of the udder, illustrating arteries supplying the udder with blood versus veins draining blood from the udder.

To produce 1 liter of milk 500 ltr. of blood have to pass through the udder. When the cow is producing 60 liters of milk per day, 30,000 liters of blood are circulating through the mammary gland. Thus, the high producing dairy cow of today is exposed to very extreme demands.

The udder also contains a lymphatic system. It carries waste products away from the udder. The lymph nodes serve as a filter that destroy foreign substances but also provide a source of lymphocytes to fight infections. Sometimes, around parturition first lactation animals suffer from edema, partly caused by the presence of milk in the udder which compresses the lymphatics, demonstrated in the picture below.

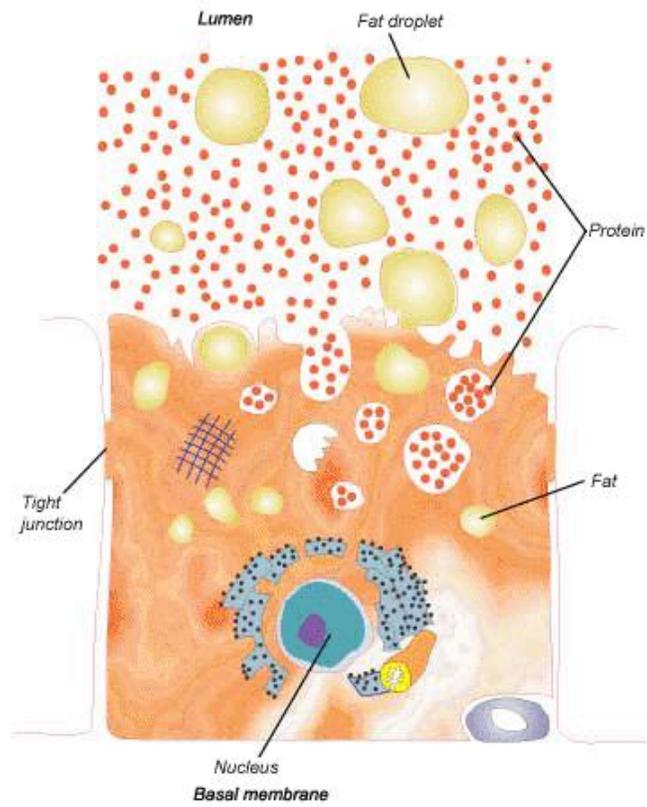


Lymphatics of the udder.

Milk secretion and milk composition

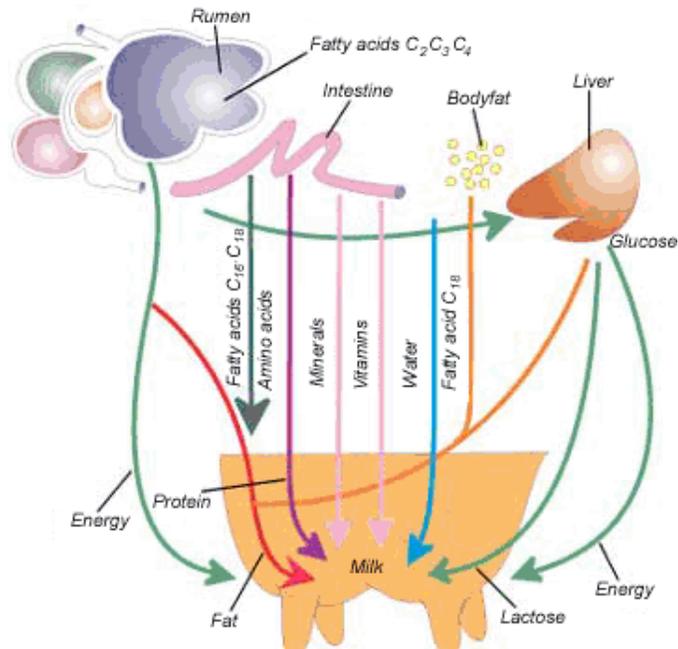
Milk synthesis takes place in the alveoli where the milk secreting cells in the mammary gland are provided with a continuous supply of nutrients, demonstrated in the picture below.

Milk fat consists mainly of triglycerides, which are synthesized from glycerols and fatty acids. Long chained fatty acids are absorbed from the blood. Short chained fatty acids are synthesized in the mammary gland from the components acetate and beta hydroxybutyrate which have their origins in the blood. Milk protein is synthesized from amino acids also with origin from the blood, and consists mainly of caseins and to a smaller extent whey proteins.



Schematic structure of alveolar cell.

Lactose is synthesized from glucose and galactose within the milk secreting cell. Vitamins, minerals, salts and antibodies are transformed from the blood across the cell cytoplasm into the alveolar lumen, demonstrated in the picture below.



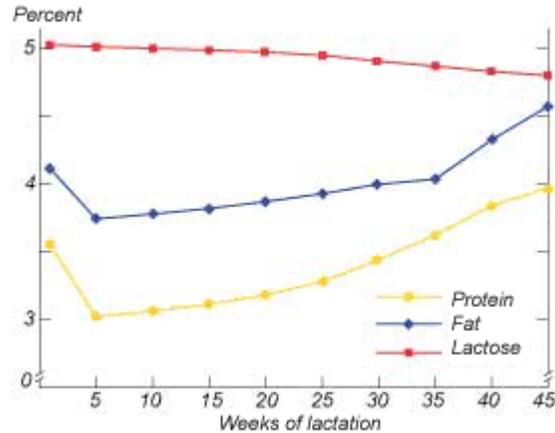
Precursors of milk, transported where the synthesis of milk fat, milk protein and lactose take place, to the udder.

The composition of the milk varies between different breeds but also during lactation within breed, demonstrated in the table below.

Breed	Total solids%	Fat %	Casein %	Why protein %	Lactose %	Ash %
Brown Swiss	12.69	3.80	2.63	0.55	4.80	0.72
Holstein	11.91	3.56	2.49	0.53	4.61	0.73
Jersey	14.15	4.97	3.02	0.63	4.70	0.77

*Composition of milks of three breeds of dairy cattle
(Adapted from B.L. Larson, in Lactation, ed. Bruce L. Larson 1985).*

In the beginning and at the end of lactation the fat and protein contents are higher compared to mid lactation, demonstrated in the picture below.



The higher concentration of dry matter in milk at early lactation is due to the special needs for the young. As an example, the higher contents of protein during the first days after parturition depends upon the high amounts of immunoglobulins. On average the milk from dairy cows has a fat content between 3.0 and 5.5%, protein content between 3.0 and 3.8% and lactose in the range of 4.0 and 4.8%.

Are the yield and composition possible to influence?

It is well known that the amount of milk to be produced is highly influenced by the amount of feed given to the animal. It is also partly possible to influence the composition of the milk by feeding, especially by the composition of the feed. As an example, diets with low fiber content or diets with a high ratio of starch rich concentrate can cause a decrease in milk fat content. Such diets may alter the volatile fatty acid composition in the rumen, which influences the fat metabolism in the mammary gland. It is, however, more difficult to alter the protein content through feed composition. The possibility to alter milk composition through milking is also evident, but is most related to fat content and less to protein content. The content of fat and protein in milk are also important factors in the breeding programs.