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THE COW'S UDDER

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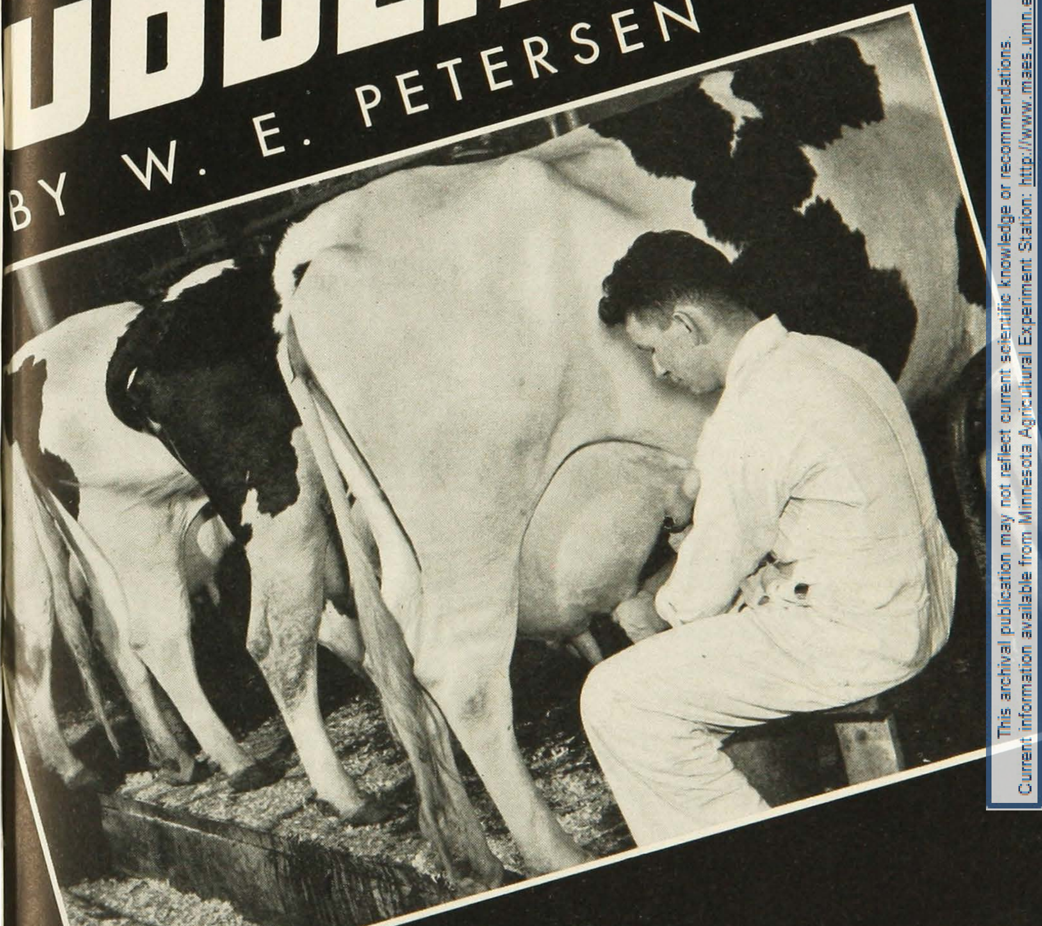

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Rules for Good Milking

1. Handle heifers carefully when they are first milked. A cow must like to be milked if there is to be a complete response to milking. Consequently, special care is necessary so that newly-freshened heifers do not come to associate unpleasant sensations with milking.

2. Avoid the unusual during milking. Such things as strange noises may attract the cow's attention and consequently prevent complete response to milking.

3. Do not treat the cow roughly at any time, particularly just before and during milking.

4. The milker must be a person who does not arouse the cow's suspicion. Some people, by their actions, create nervousness in cows and cannot be good milkers.

5. Do not wash or massage the udders or stimulate cows in other ways to let down their milk before milking is to begin.

6. Milk those cows first which let down their milk in response to preparations for milking, such as starting the milking machine, clanging of utensils, etc.

7. Milk rapidly. If milking takes more than seven minutes for most cows, the effectiveness of the hormone that is essential to letting down milk will be partly worn out and incomplete milking will result.

8. Do not practice prolonged stripping because this will ultimately make a stripper of the cow.

9. Operate milking machines according to the manufacturer's directions. Increasing the vacuum or altering the rate of pulsations from those recommended by the manufacturer may make milking unpleasant for the cow.

10. Do not leave the milking machine on the cow after the milk has ceased flowing because this may injure the delicate lining of the teat cistern.

11. Develop the technique of knowing by feel when the gland has been emptied of milk.

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The Cow's Udder

W. E. Petersen

FROM AN ECONOMIC standpoint the cow's udder might be said to be the most important unit in agriculture because nearly one fifth of the total farm income in the United States comes from milk. As a contributor to human well-being, the udder of the cow is most important, for nutrition authorities agree that milk and milk products are essential in a good diet. Because milk is so essential in the diet, the cow has been referred to as the "foster mother of the human race."

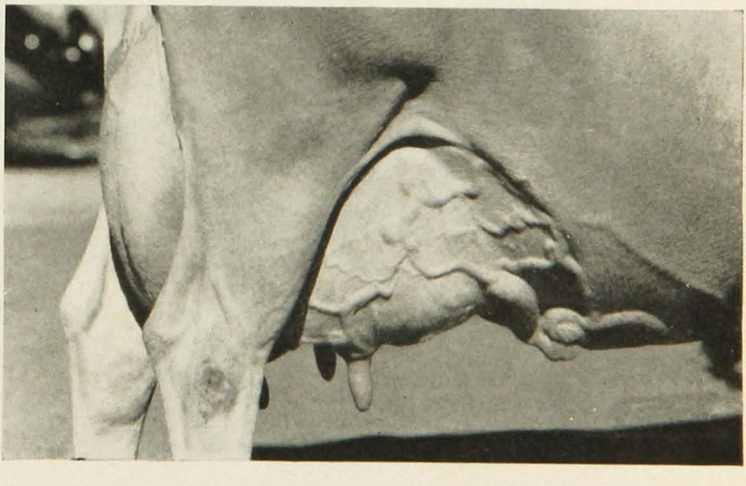
From the standpoint of activity and complexity of its processes, the udder of the high-producing cow is unexcelled by any other gland. Each year, good cows usually produce 10 times their weight in milk, and exceptionally good cows have produced 20 times their weight.

There is still much to be learned about the complex processes of making milk in the udder. Few dairymen appreciate the complexity of the machine that they are dealing with daily. A better knowledge of the structure, growth, development, and functioning of the cow's udder not only will bring a better appreciation of the work the cow is doing but will also form the basis for better management of this important gland. The purpose of this bulletin is to set forth the more important known facts about the growth and development, the structure, and the functioning of the cow's udder.

Growth and Development

Because of the hundreds of years of selection for high milk production, the mammary glands of the good dairy cow are proportionately better developed than in any other species. How this development has taken place is best understood by briefly considering the more important known facts about (1) the

FIG. 1. A well-developed udder



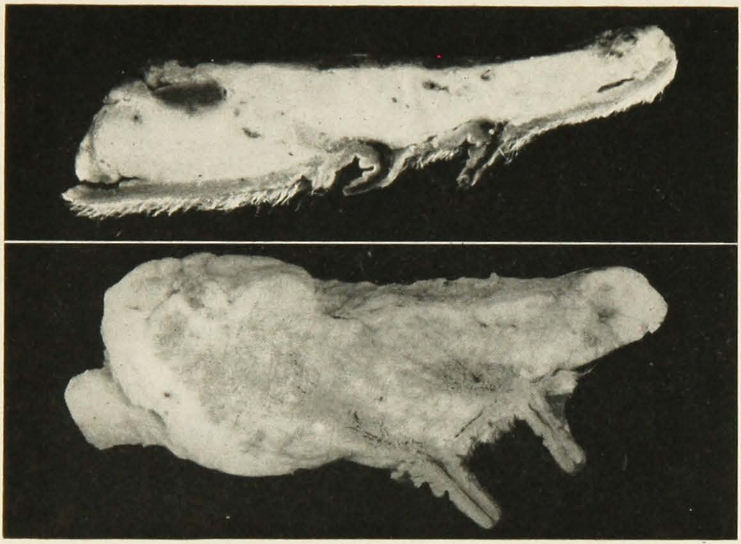


FIG. 2. (Above) A section of the udder of a calf at birth

(Below) A section of an udder of a 15-months-old heifer

evolution of the mammary glands, (2) development before birth, and (3) development after birth.

Evolution of Mammary Glands—From studies of the most primitive mammals, as well as from embryologic studies, there is good evidence that the mammary glands are modified skin (sweat) glands. In the simplest of the living mammals, the egg-laying echidna of Australia, the mammary glands look like sweat glands located on the abdomen. There are no teats. The milk from each of the 100 to 150 glands oozes out of a pore much like sweat gland pores, and the young lick the milk off the hair upon which it collects.

Evidence of the next step in the evolution of the glands is furnished by another egg-laying mammal, the Duckbill platypus, in which a number of ducts join to form a common opening in the skin, but there is not a teat. In animals such as the opossum and kangaroo comes the first evidence of the development of teats. In the simpler forms there are many teats and many ducts running through the teat, each to an opening in the end.

The development of the mammary gland from this point on has been combining more glands into one, development of a gland cistern into which the ducts drain, and a reduction of the number of ducts in the teat to just one in the case of the cow.

Development before Birth—Science produces further proof that the mammary gland is a skin gland. When the bovine embryo is about two-thirds inch long, the single layer of skin cells in the region of the udder starts multiplying and becomes many cells deep. From this multiplication of the cells, the embryologist has traced the development of the teats and the ducts of the gland. At first the cells form solid masses. One mass becomes the teats, and others (sprouts) extend into the tissue. These solid masses of cells canalize or open up in the center to form the teat cistern and ducts.

Development after Birth—At birth there is no essential difference in the development of the mammary glands of the bull and heifer calf. The small gland is mostly fatty tissue with a very limited duct development. In the male there is little change in the mammary gland development with maturity, but in the normal heifer progressive changes take place with increase in age.

With each recurring estrus or heat cycle, the gland becomes larger. The growth is due to an increase in the fat tissue and an increase in both the size and number of ducts. A section through the udder of a 15-months-old nonpregnant heifer is shown in figure 2. The tissue is mostly fat and the milk cisterns are as yet poorly developed. A microscopic examination would reveal no alveoli (milk secreting structures). Development in this stage is due to the secretion by the ovary of a hormone known as estrogen.

After pregnancy the estrogen secretion increases causing a more rapid development of the duct system, and another hormone (progesterin) secreted by the yellow body (corpus luteum) of the ovary comes into play. In rats progesterin causes the development of the alveoli and in all probability does the same for the cow, although this has not been proved.

While estrogen and progesterin are the main hormones involved in the growth and development of the mammary gland, they are by no means the only ones. Secretions of the pituitary gland, the thyroid, and several other glands are needed for a fully developed udder. Nutrition also plays a part in mammary gland development.

Structure

EXTERNAL STRUCTURE

The normal cow's udder consists of four glands or quarters arranged two on each side dividing the udder into two fairly distinct "halves." These halves are separated by a membrane and, except for some connecting veins, are independent of one another (Fig. 3). The two quarters on either side are also independent of each other, and the milk produced in one quarter cannot be drained out of the other. There is, however, no discernible membrane separating the two quarters of a half.

Size of Udder and Quarters—Other things being equal, the amount of milk a cow can produce depends on the size of her udder. Poor udder quality or failure to secrete the necessary hormones may prevent a cow with a large udder from being a high producer, but a large udder is essential for high milk production. Udder size varies greatly. Udders from mature cows have been recorded

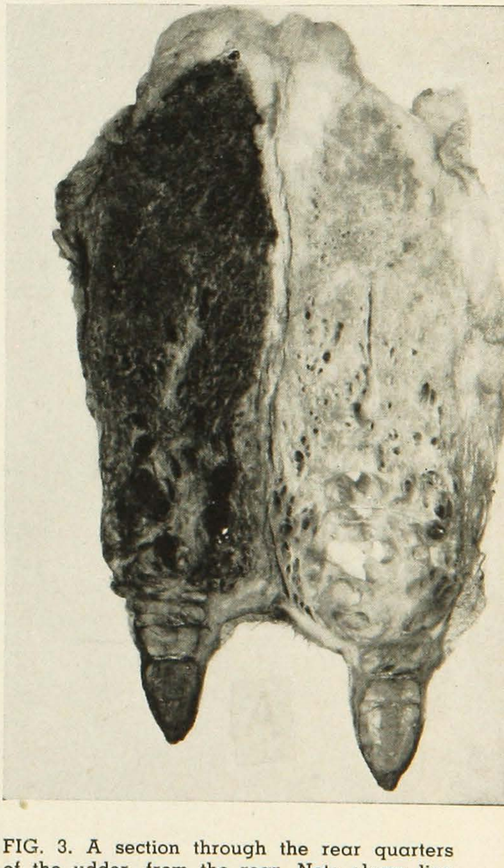


FIG. 3. A section through the rear quarters of the udder, from the rear. Note sharp line of demarcation between halves

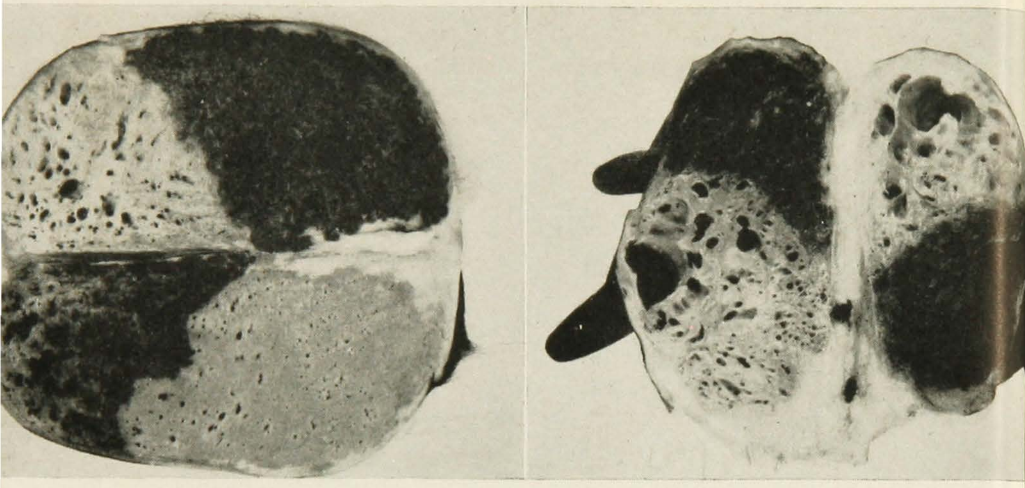


FIG. 4. Cross sections of the udder from different angles

(Left) Cross section approximately half way up. Front quarters are to the right. The right front and the left rear quarters were injected with pink dye; the right rear and left front quarters were injected with blue dye (dark areas).

(Right) Cross section through gland cisterns. Fore udder is shown in the lower part of the photograph. Note the greater porosity compared to the photograph to the left.

weighing but a few pounds to over 80.

Individual quarters vary greatly in size. On the average the front quarters make up about 40 and the rear quarters 60 per cent of the total weight of the udder. There are cases where the reverse may be true. The rear quarters are not as wide as, but much deeper than, the forequarters. The rear quarters also are usually longer from front to rear than they are wide (Fig. 4). This makes it impossible to judge the relative sizes of the quarters from external examination.

Attachment of Udder—The main supporting structure holding the udder to the body is the median suspensory ligament. This is a tough ligament arising from fibers coming out of the lower abdominal wall and sending fibers into each half of the udder. Additional support for the udder is provided by the lateral suspensory ligament, a tough membrane covering most of the top of the udder and extending part way down the sides. The skin covering the udder also assists in supporting the udder to the body, especially when the udder is distended with milk.

When fibers in the supporting ligaments become stretched or broken, the udder breaks away from the body and becomes pendulous. Strong udder attachments are of great importance because broken attachments and pendulous udders are unsightly and more subject to injury.

The Teat—Normally each quarter has a teat for expressing the milk. Teats vary greatly in size and shape, the ideal teat being 4 inches long and 1½ inches wide. Absence of hair from the skin of the teat is the only distinguishing line between the teat and the udder when the quarter is funnel shaped. At the end of the teat is an opening known as the streak canal which connects with the inside cavity of the teat. The streak canal is kept closed by ringlike muscles (sphincter muscles) that encircle it at the end of the teat. Milking is effected by applying enough pressure to the teat filled with milk to force open these ringlike muscles. If these muscles are too

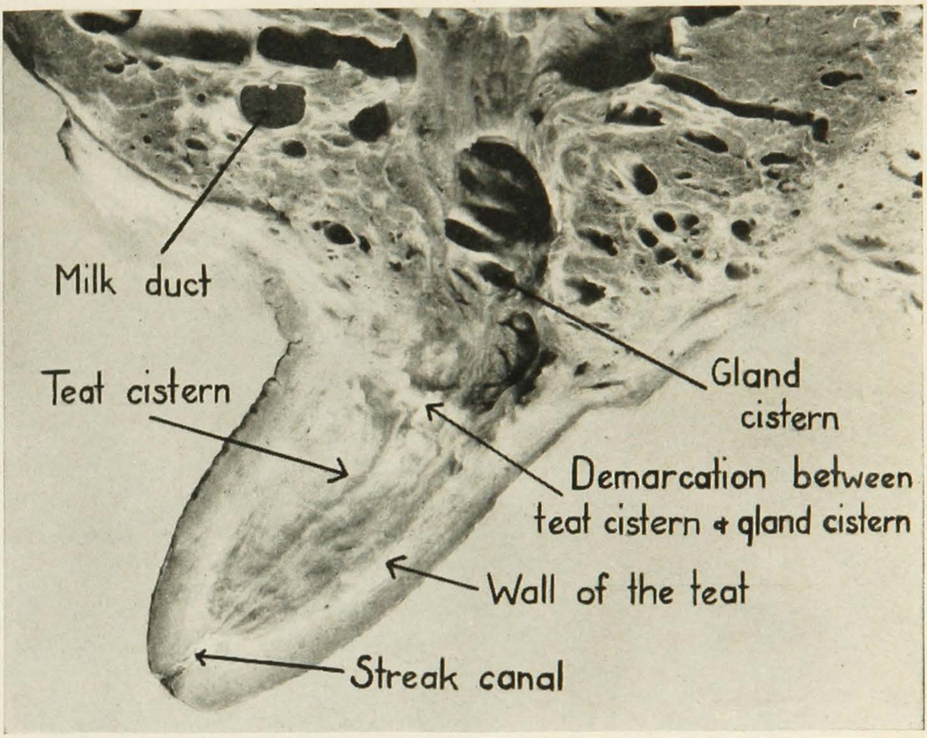


FIG. 5. A section through the teat and gland cistern

strong, the cow is a hard milker. If they are weak, the milk may leak out.

Extra Teats—From 20 to 55 per cent of cows have supernumerary or accessory teats. Supernumerary teats usually do not secrete milk, but occasionally they may be quite troublesome. The supernumeraries are most commonly located behind the rear teats. However, they may be between the fore and rear teats, to the fore of the front teats, or they may actually branch from either front or rear teats.

INTERNAL STRUCTURE

The internal structure of the udder can best be dealt with by tracing backward the path over which the milk has come, beginning with the teat and going back through the gland cisterns, ducts, secretory structure, and lobes. Consideration of the circulation and nervous connections logically follows.

The Teat—The teat consists of a wall, a cistern, and a streak canal as illustrated in figure 5. While the wall of the teat varies in thickness, a quarter of an inch is representative when the teat is distended with milk. The outside of the teat is covered with skin while the inside is lined with a delicate membrane. The rest of the wall consists of muscle and connective tissue as well as blood vessels. The teat wall is elastic, contracting so that the walls become thicker when emptied of milk and expanding when filled with milk.

The streak canal is from one-third to one-half inch long. It is lined with a continuation of the outer skin, which is arranged in longitudinal folds that in-

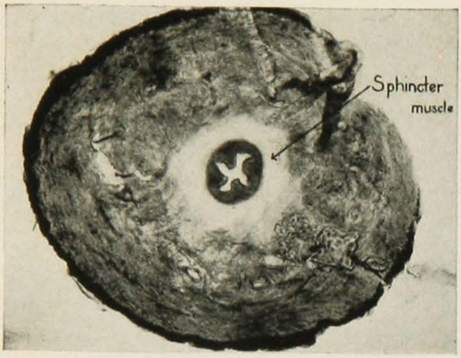


FIG. 6. A cross section of the end of the teat showing the streak canal partly opened. The light-colored area is the sphincter muscle that closes the streak canal

terlock when the canal is closed and which allow the canal to open without stretching the lining (Fig. 6). Beginning at the upper end of the streak canal, the teat cistern extends upward through the teat to the gland cistern from which it is separated by a circular fold of the membrane lining the teat. This fold serves as a distinguishing line between the teat cistern and the gland cistern. In some cases the fold may extend into the cistern so far that it interferes with the free passage of milk from the upper chamber into the teat cistern.

The Gland Cistern—As shown in figure 5, the gland cistern is an irregularly shaped chamber for collecting and storing milk that may vary in capacity from one-half pint to one quart. The cistern is lined with the same type of membrane as is the teat cistern. Frequently its outer walls may contain small milk secreting glands.

Milk Ducts—Radiating out from the cistern walls are from 20 to 50 or more large ducts which branch out innumerable times until finally the branches become microscopic in size. They are then known as **ductules.** The secretory structure of the very smallest branches or ductules ends in an enlargement known as the alveolus (Fig. 7). The alveoli are the chief place for the secretion of milk, although some secretion may take place in the lining of the ducts and ductules. The arrangement of alveoli in relation to a small duct and its branching ductules resembles a bunch of grapes in which the grapes are the alveoli and the stems are the ductules. The inside of each alveolus is lined with a single layer of cells that synthesize and secrete the milk. As these cells elaborate the milk, it is secreted into the alveolus where it is stored until withdrawn by milking. The outer walls of each alveolus are connected with a fine network of blood vessels from which the cells get milk-making materials.

Lobes—Each quarter is divided into several small units known as lobes. A lobe is that part of the udder that is drained by a duct. Therefore, a quarter contains as many lobes as it has ducts. The lobes are further divided into lobules. A lobule represents the part of the lobe drained by a branch of the main duct.

Connective Tissue—Other things being equal, the producing capacity of an udder is proportional to the number

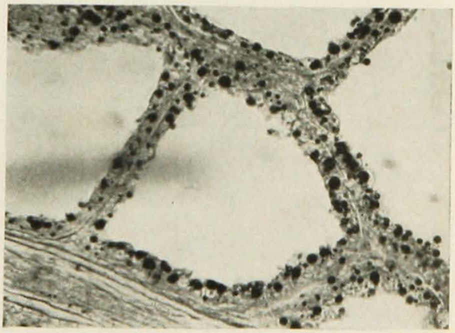


FIG. 7. Microscopic section of normal gland after milking

Alveoli are shown surrounded by single layers of secretory epithelial cells. Two layers of cells are separated by connective tissue which contains blood vessels by means of which the precursors of milk are carried from the external pudic artery to the seat of milk synthesis. The dark areas are droplets of milk fat stained with dye. At lower left is connective tissue.

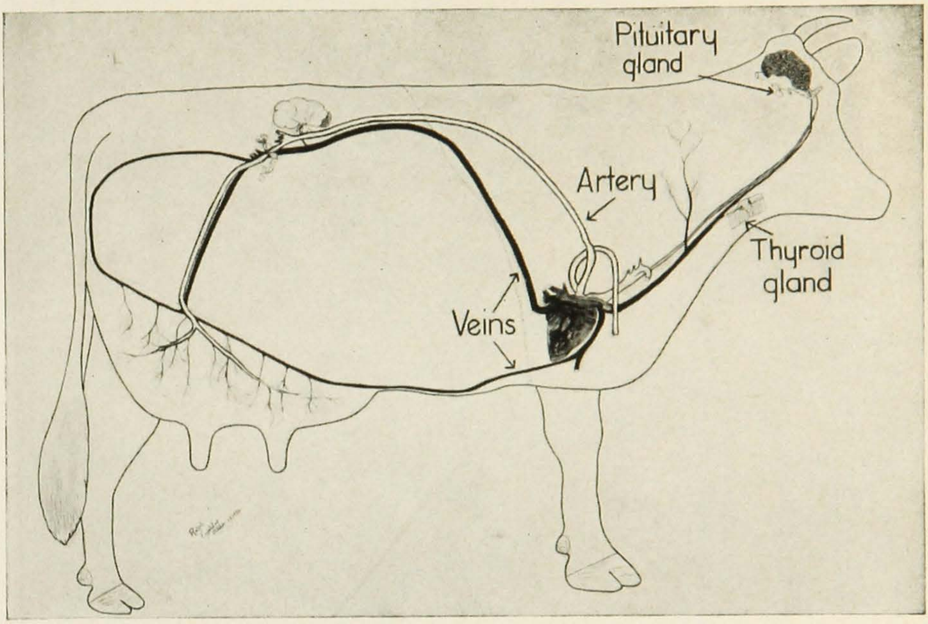


FIG. 8. Circulation to and from the udder

of alveoli that it has. The number of alveoli present in any part of the udder varies greatly depending upon the amount of other tissue present, which may be determined by inheritance or udder disease.

In the lower part of the gland, as the ducts become larger, there is more connective tissue than in the upper part where the ducts are smaller. The walls of the larger ducts contain large amounts of connective tissue.

Frequently the alveoli are destroyed by mastitis and replaced by connective tissue which in this case is the same as scar tissue.

An udder that contains a large amount of connective tissue feels firm and "meaty." The udder of good quality is soft and spongy.

Circulation—Since all milk comes from blood, the circulation of blood in the udder is of great importance. About 400 gallons of blood must pass through the udder for every gallon of milk produced. The circulation to the udder consists of the arteries which bring in the blood, the veins which carry it out, and the lymph system. Figure 8 diagrams the principal features of the circulatory system which supplies the udder with blood.

Arteries—The blood for each half of the udder comes in through a single artery which enters the udder from above at a point midway between the halves and about one-third way from the rear side. Here the artery divides into two branches, one for the fore quarter and one for the rear. As it progresses through the quarter, each branch divides and subdivides innumerable times until the smallest branches or capillaries afford close contact with every cell to supply it with blood.

Veins—After the arterial blood has given up its oxygen and nutrients to the cells and has picked up from them the carbon dioxide and other waste products, it must go back to the lungs to be purified and renewed. Here the udder's system of veins comes into operation,

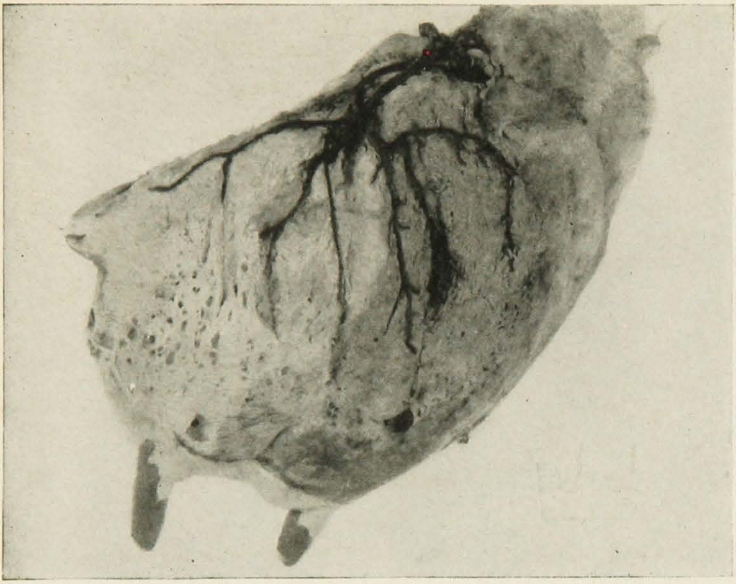


FIG. 9. Section of left half of an udder showing main arteries

Note that the external pudic artery divides into two branches, one supplying the rear quarter and the other the front quarter with blood.

the venous capillaries taking the stale blood from the cells and passing it along through larger and larger branches until it reaches the main veins which carry it to the lungs. As illustrated in figure 8, the veins leading from the udder follow three different routes. One, known as the abdominal mammary or milk vein, goes forward just under the skin of the belly. A larger one extends upward parallel to the main artery, while the third and smallest of these veins runs backward from the udder and then upward under the skin to enter the body through the pelvic arch. Either of the two larger veins can carry away all of the blood that enters the udder. Tying off of the mammary vein does not reduce the milk production as the other veins have ample capacity.

Lymph System—Lymph or tissue juice is produced in all tissues and is returned to the blood stream through a special system of ducts and lymph glands which filter the lymph. Lymph ducts in the udder reach every minute part. These ducts consolidate into larger and larger ducts in much the same way as the veins. In the udder the flow of lymph is first downwards from the smaller vessels and then upward and backward into the lymph glands, one of which is located on the upper rear side of each half (figure 10). The lymph gland is usually about the size of a walnut and can be felt from the rear. When there is infection in the udder, the lymph glands may become many times the normal size.

Most of the veinlike structures under the skin of the udder are lymph vessels and not blood vessels as commonly supposed. The swelling of the udder and abdomen before and after calving is due to the backing up of lymph in these tissues.

Nerve Supply to the Udder—The nerve supply to the udder is too complex for detailed discussion here. It must suffice to point out that each half of the gland proper is supplied with nerves from a nerve trunk which enters the udder near the main artery and branches to follow the arterial system of the gland.

The skin of the udder and teats is

richly supplied with nerves coming from the spinal column by way of the abdominal wall. The nerve endings in the skin of the udder and teats are of great importance in milking because they pick up sensations that ultimately result in the letdown of the milk. Presumably, endings for all skin sensations—touch, pain, cold, and hot—are to be found here.

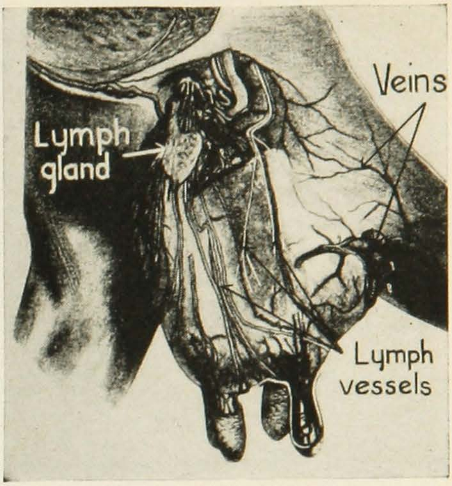


FIG. 10. Lymph system of the udder. Note that the lymph vessels (just under the skin) run upwards and backwards to the mammary lymph gland

ABNORMALITIES OF THE UDDER

In addition to functional supernumerary teats there are many abnormalities of the udder, a few of the more important of which will be briefly discussed as follows:

Blind Quarters—Frequently heifers will come in with one or more quarters completely inactive. For some unknown reason the gland tissue failed to develop and nothing can be done to correct the deficiency.

Fistulated Teats—The teat often may have an extra opening, known as a fistula, through which milk may leak. This fistula may be adjacent to the streak canal or may be located on any part of the teat. A veterinary surgeon can cauterize and get rid of teat fistulas.

Leaky Teats—Frequently the sphincter muscles around the streak canal may be injured or are too weak to withstand the pressure of accumulating milk and the milk will leak out. This condition can also be corrected by skilled surgery.

Hard Milkers—Hard milkers have too strong sphincter muscles or too much connective tissue around the streak canal. Skilled surgery can correct this condition.

Teat Spider—Sometimes a wartlike growth, commonly known as a spider, takes place in the teat cistern. It may be located on any part of the teat cistern wall and causes difficulty when the growth is large enough to stop the milk from getting through the streak canal. It requires skilled surgery to remove a spider.

Absence of Teat Cisterns—Occasionally, for unknown reasons, one or more teats may not have cisterns, the teat being a solid mass of tissue. There is no remedy.

Obstruction of the Gland Cistern—Although rare, the udder cistern may be separated from the teat cistern by a membrane. A skilled veterinary surgeon can correct this condition by cutting the membrane.

Accessory Glands on Teats or Udder—Sometimes small secreting glands without teats may be found on the teat and udder. In some cases there is no opening and the gland will be engorged with milk following calving. The swelling soon subsides as the milk is resorbed. When the milk is released through an opening (fistula), the condition becomes a nuisance and the gland should be destroyed by a veterinarian.

The udder may be affected by injuries and various diseases, including mastitis, none of which can be discussed here.

Functioning

THE COMPLICATED processes of the functioning udder may be divided into the following heads: starting and maintaining lactation; circulation and blood precursors of milk; equilibrium of milk and blood; time milk is secreted; and the "letdown" or ejection of milk.

STARTING AND MAINTAINING LACTATION

The fully developed udder does not secrete milk unless a hormone known as prolactin (and possibly others) is present. Prolactin, which is produced by the pituitary gland, normally is not secreted until about freshening time. However, in some cows it may be secreted before that time as is evidenced by coming into milk before calving. What prompts prolactin secretion at calving time is not known.

Not only is prolactin needed to start lactation, but its continuous secretion is necessary to keep lactation going. Because an injection of prolactin will increase milk flow, it is evident that many cows fall off rapidly in milk flow because of inadequate secretion of this hormone. It is also probable that too little prolactin prevents many cows with well-developed udders from reaching their milk producing capacity.

CIRCULATION AND BLOOD PRECURSORS OF MILK

In recent years it has been definitely proven that all of the major ingredients of milk are synthesized (made up) in the udder from constituents of the blood and not merely filtered out of the blood by the gland as was once thought. Milk fat and milk sugar, representing, on an average, 4 and 5 per cent, respectively, of the milk, are found nowhere else in the body. Of the proteins, casein averaging about 3 per cent and milk albumin about 0.5 per cent are likewise not found outside of milk. Milk globulin representing about 0.05 per cent of the milk is apparently the same as blood globulin and may simply filter in from the blood. The blood precursors (blood substances used for making milk) of these milk substances have been the subject of a great deal of study during the past few years. As a result something is known about them, although much is yet to be learned.

Studies of the uptake of materials from the blood by the udder have revealed that large volumes of blood pass through the udder of a high-producing cow. As about 400 pounds of blood must pass through the udder for each pound of milk produced, about 10 tons of blood must daily pass through the udder of a cow that produces 50 pounds of milk.

Milk Fat—Milk fat comes mainly, if not entirely, from the neutral fat of the blood, being changed by the cells of the udder. The exact method by which the blood fat is changed into milk fat is not known, but apparently a complicated mechanism is involved in which the fatty acids are broken down into shorter ones. Analysis of the fat in the udders of milking cows shows that it is intermediate between milk fat and body fat, while in the dry udder the fats are more nearly like body fat. It is also noteworthy that the active udder contains several times as much fat per unit of weight as does the dry udder.

Milk Sugar—The udder uses two blood substances for making milk sugar. These are blood sugar (glucose) and lactic acid. From these two substances and an extract out of an active udder milk sugar has been synthesized in the laboratory. As the udder contains about 0.2 per cent of glycogen (animal starch), it is probable that this substance enters into the making of milk sugar and that the process is very complicated.

Milk Proteins—Casein and milk albumin are different from the proteins of the blood, and they are made up in the udder from some blood substances. Only amino acids and proteins of the blood can be considered as possible precursors of milk proteins. Only about a third enough amino acids are taken out of the blood by the udder to account for milk proteins, and about enough urea is produced by the udder to account for the breakdown of the amino acids. It is, therefore, apparent that most, if not all, of the milk proteins must come from the blood proteins. As the globulin of the milk is apparently the same as the globulin of the blood, it is obvious that this protein passes through the membranes of the gland. Chemical analysis of simultaneously drawn arterial and mammary vein bloods also indicates that this protein is taken out of the blood in sufficient quantities to account for the milk proteins.

The method by which blood globulin is changed into casein and milk albumin is not known. It undoubtedly is a complicated process. It is possible that at least some, if not all, of the amino acids taken up by the gland are also used in the synthesis of milk proteins.

Salts of Milk—All of the salts of milk come from the blood but not by a simple diffusion process because the amounts and relationship of salts in milk are greatly different from those of blood. The salt content of milk in relation to that of the blood is very closely associated with the phenomena of equilibria or balances between milk and blood.

Diffusion from Blood into Milk—While the principal constituents of milk are synthesized in the mammary gland, there are a number of substances in blood that merely diffuse into the milk and are found in the same concentration in both milk and the blood. Among these are a number of normal substances of blood and many that come into the blood only if they are present in the feed.

The normal blood substances that may be found in the same concentration in milk as in blood are urea, uric acid, creatine, and creatinine.

The substances that will be found only in the blood and milk if they are present in the feed are many and of great importance to dairymen, for among them are the feed-flavoring constituents. Among the many feed substances that may find their way into the blood and from there into the milk are: alcohol, ether, chloroform, iodine, turpentine, paradichlorbenzene, the flavoring ingredients of onions, garlic, turnips, mustard, Frenchweed, silage, and many others.

EQUILIBRIA BETWEEN MILK AND BLOOD

While milk and blood have the same osmotic pressure, they are not in equilibrium; that is, they do not contain the same amounts of given parts. As a matter of fact, none of the major constituents of milk are in the same concentration as in blood. The mammary gland absorbs some blood constituents preferentially for a greater concentration in milk than in the blood and holds back other constituents in the blood. There is approximately 80 times as much sugar, 20 times as much fat, 15 times as much calcium, 7 times as much phosphorus, and 4 times as much magnesium in milk as there is in the blood. Blood contains 8 times as much sodium, 4 times as much chlorine, and 2 times as much protein as milk. Sodium bicarbonate, a prominent constituent of blood, is not found in normal milk.

The great concentrations of calcium and phosphorus in the milk are significant because these two substances pass through ordinary membranes less readily than sodium and chlorine, which are held back to a large extent by the mammary gland. Another significant fact is that when the calcium or phosphorus content of the blood is lowered, there is no lowering of these substances in the milk. When body calcium is too low in the milking cow, the blood calcium will be so lowered by the demands for the milk that milk fever is produced. Reduced blood phosphorus, as a result of the demands for milk, produces no such dramatic symptoms, but if continued, milk production will be lowered.

If blood sugar content is lowered as by the administration of insulin, the milk sugar is lowered. Milk fat is also lowered when the blood fat is markedly reduced by starvation.

Milk and blood will tend to come into equilibrium when there are any disturbances within the udder. Leaving the milk in the udder for long periods of time, injecting substances into the duct system of the udder, and mastitis will cause the milk to come toward the composition of blood. In all of these conditions the protein, sodium, and chlorine contents of milk will be increased. In addition sodium bicarbonate from the blood will pass into the milk to make it alkaline instead of slightly acid, which is the reaction of normal milk. This change causes the blue reaction to bromthymol-blue as a test for mastitis. Large numbers of white blood cells and catalase of the blood will also pass into the milk. Calcium, milk sugar, potassium, and phosphorus of the milk will pass into the blood to lower the levels of these constituents in the milk. The casein content of the milk is also markedly reduced, the increase in protein being due to increments in globulin and albumin.

Colostrum milk is more nearly in equilibrium with the blood than is normal milk. The reason for this is that colostrum milk has been in the gland for a comparatively long time. For the same reason, the milk of cows that are being dried off is also coming into equilibrium with the blood.

The characteristics of mastitis milk may be due either to an interruption of normal secretory function of the cells or to a change in the permeability of the membranes. In acute mastitis the milk characteristics are also affected by the breaking off of gland tissue.

A large number of substances have been injected into the duct system of cows' udders to study their effect upon the milk. Among these are various salts and salt mixtures, sugar solutions in various concentrations, blood serum, distilled water, and many other substances. All of these, except distilled water and very dilute salt solutions, have produced severe disturbances with a marked lowering of milk secretion and milk that resembled acute mastitis.

The mammary gland is unusual in its reaction to injected substances. Isotonic salt solutions and blood serum are nonirritating to body tissues but produce severe reactions in the mammary gland. Distilled water is very irritating to body tissues but has little effect when injected into the udder. A realization of the effect of injected solutions upon the udder is important in considering various injected agents in the treatment for mastitis.

TIME OF MILK SECRETION

It was formerly believed that most of the milk was actually secreted during the milking. It was thought that the milking act stimulated a rapid secreting activity of the cells because the udder and teats became distended shortly after milking began. It is now known that the old ideas were wrong and that the distention of the teats and udder is due to the "letdown" of milk and not to a rapid secretion. Proof that all of the milk given is present in the udder when milking begins was furnished by slaughtering cows at milking time, removing the udders, and then milking or analyzing them for the milk content. These experiments have shown that all of the milk expected at a milking was present in the udder.

Not only is the milk secreted in the

interval between milkings, but the rate is slowed up and secretion may even stop completely as milking time approaches because of the pressure built up by the accumulating milk in the alveoli. When pressure of the milk within the gland reaches 30 to 40 mm. of mercury, milk secretion is completely stopped and resorption of the milk begins.

The knowledge of the effect of pressure explains why more frequent milking increases milk production. The more often a cow is milked, the less pressure there will be at any time to retard or check milk secretion. It also explains the curative effects of air inflation of the udder on milk fever. The air pressure not only stops milk secretion to halt absorption of calcium from the blood but also actually causes the blood to take back calcium from the milk to hasten recovery. The fact that milk secretion stops and resorption of the milk begins when the pressure within the gland reaches one fourth to one third of blood pressure also explains why the best way to dry off cows is to abruptly stop milking.

THE LETDOWN OF MILK

To be a good producer a cow not only must be capable of synthesizing much milk but also must be able to let down her milk and then be milked in such a manner that all of the milk is obtained at each milking. When all of the milk thought to be in the udder is not obtained by milking, the cow is usually said to have "held up her milk." This is an incorrect statement of what happens. A cow cannot hold up her milk but under certain conditions she fails to "let it down" completely. The letdown of milk is a positive act requiring the secretion of a hormone (oxytocin) from the hind part of the pituitary gland.

It is normal for the milk to be stored in the tiny alveoli where it is made and from which it does not drain by gravity. The alveolus filled with milk may be likened to a tiny eye dropper filled with fluid. The fluid will not flow out of the eye dropper until pressure is applied to the bulb. The alveolus has tiny muscle cells around it that contract under the influence of the oxytocic hormone to force the milk out through the tiny ducts and ultimately down into the gland cistern from which it is drawn by milking.

Letdown Is a Reflex Act—The letdown of milk is a reflex act, that is, the response is not voluntary but automatic. It involves the sensory nerves which carry the stimulus to the pituitary which in turn ejects the hormone into the blood. About 40 seconds are normally required after the stimulus until the milk is let down. The normal stimulus for the letdown of milk is the milking act, but cows may be conditioned to respond to a number of different stimuli. If cows are fed immediately before milking for some time, this may become associated with milking, and the feeding may become the stimulus for the letdown of the milk. Cows frequently become conditioned to let down their milk to the starting of the milking machine, noises from the milking utensils, washing of the udders, and other stimuli that they may come to associate with milking.

Interferences with Response—The reflex act of response to milking is easily interfered with. If the cow is frightened or angry or has her attention called to any strange factor, there will be but partial or no response to milking. Experiments where rats were placed in the manger, inflated paper bags were exploded every 30 seconds, a cat was placed upon the back, or the cow stuck with needles resulted in a complete lack of response to the milking act. Placing grain feed where it could be seen but not reached by the hungry cow also caused complete failure of response to the milking act. People who have mistreated cows or by their actions arouse the cow's suspicion prevent complete response to milking. Cows that are anesthetized also fail to respond. There is now evidence to show that a hormone from the adrenals, known as adrenalin, interferes with the action of oxytocin. Adrenalin is secreted when the cow becomes excited. Cows were stimulated to let down their milk; then they were excited or adrenalin was injected and milking was incomplete.

Time When Hormone Is Active—Experiments have shown that the activity of the hormone is limited to a relatively short time after it is secreted into the blood. Usually one cubic centimeter of a standard solution of oxytocin injected intravenously will be effective in letting down milk for not over 10 minutes. As soon as the hormone is secreted into the blood, its destruction begins and it is, therefore, important that milking be completed before the hormone's effect is lost.

Effect of Incomplete Letdown—When the milk is not ejected from the alveoli at milking time, only the milk that has drained down into the gland cistern and larger ducts is obtained by milking. Because of the milk retained in the alveoli, a pressure is soon built up by the accumulation of the newly secreted milk and the rate of milk secretion is lowered. In addition the pressure may become great enough that resorption of the milk begins. When resorption begins, the drying off process sets in and the cow will soon stop secreting milk.

Experiments in which the cows were stimulated by washing the udders to let down their milk 20 minutes before milking caused as much as 15 per cent drop in milk production in two weeks. During the experimental period there was also a marked variation in the amounts of milk from milking to milking and from day to day. Marked differences in the amounts of milk, provided milking is done at regular intervals, are in most cases accounted for by incomplete letdown of the milk at times. When this happens the smallest milkings are usually followed by an unusually large milking.

Inherited Lack of Ability—How large a percentage of cows fail to completely respond to milking by total letdown of the milk is not known. However, investigations have revealed cows that under apparently normal conditions do not completely let down their milk at any time. Cows of this type are "short timers," that is, they dry off early. Their udders also are what is known as "meaty," which really is not the case because the hardness of the udders even after milking is due to the retained milk. One such cow was found normally to retain 6 to 8 pounds of milk under the best of milking conditions, as such amounts of milk could be obtained regularly after milking by injection of the oxytocic hormone.

Why such cows fail to let down their milk completely is not known. It may be due to improper response of the nervous mechanism or to inadequate hormone production in the pituitary gland.

Strippers—In nearly every herd there are cows that let down their milk slowly, particularly in advanced lactation. On the basis of facts now at hand this can be explained by a slow ejection of the hormone from the pituitary gland. Experience has shown that the habit of strippers can be established by improper milking methods. If too much time is taken in milking, many cows will adjust themselves to the situation by a gradual secretion of the hormone.