The Structure of the Cow's Udder

C. W. Turner

COLUMBIA, MISSOURI
JANUARY, 1935
# Agricultural Experiment Station

## Executive Board of Curators
- Mercer Arnold, Joplin
- H. J. Blanton, Paris
- George C. Willson, St. Louis

## Station Staff, January, 1935

<table>
<thead>
<tr>
<th>Position</th>
<th>Name</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>President</td>
<td>Walter Williams</td>
<td>L.L.D.</td>
</tr>
<tr>
<td>Acting President</td>
<td>Frederick A. Middlebush</td>
<td>Ph. D.</td>
</tr>
<tr>
<td>Director</td>
<td>F. B. Mumford, M.S. D. Agr.</td>
<td></td>
</tr>
<tr>
<td>Asst. to Director</td>
<td>S. B. Shirk, A.M.</td>
<td></td>
</tr>
<tr>
<td>Secretary</td>
<td>Ella Pahmeier</td>
<td></td>
</tr>
</tbody>
</table>

## Staff Departments

### Agricultural Chemistry
- A. G. Hogan, Ph.D.
- L. D. Haigh, Ph.D.
- E. W. Cowan, A.M.
- Luther R. Richardson, Ph.D.
- U. S. Ashworth, Ph.D.
- S. R. Johnson, A.M.

### Agricultural Economics
- O. R. Johnson, A.M.
- Ben H. Frame, A.M.
- F. L. Thomsen, Ph.D.
- C. H. Hammar, Ph.D.

### Agricultural Engineering
- I. C. Wooley, M.S.
- Mack M. Jones, M.S.
- G. W. Giles, B.S. in A.E.

### Animal Husbandry
- L. A. Weaver, B.S. in Agr.
- A. G. Hogan, Ph.D.
- F. B. Mumford, M.S., D. Agr.
- F. F. McKenzie, Ph.D.*
- J. E. Comfort, A.M.*
- H. C. Moffett, A.M.
- S. R. Johnson, A.M.
- C. E. Terrill, B.S.

### Botany and Physiology
- W. J. Robbins, Ph.D.
- C. M. Tucker, Ph.D.

### Dairy Husbandry
- A. C. Ragsdale, M.S.
- H. E. Reed, A.M.
- Samuel Brody, Ph.D.
- C. W. Turner, Ph.D.
- H. A. Herman, A.M.
- E. R. Garrison, A.M.
- Warren C. Hall, A.M.
- R. C. Proctor, B.S.
- E. E. Reinzer, B.S.
- E. T. Gomez, A.M.

### Entomology
- Leonard Haseman, Ph.D.
- T. B. Birkett, A.M.

### Field Crops
- W. C. Etheridge, Ph.D.
- C. A. Helm, A.M.*
- L. J. Stadler, Ph.D.*
- B. M. King, A.M.*

*In cooperative service with the U. S. Department of Agriculture.

### Home Economics
- E. Marion Brown, A.M.*
- Miss Clara Furst, M.S.*

### Horticulture
- T. I. Talbert, A.M.
- A. E. Murkree, Ph.D.
- H. G. Swartwout, A.M.
- Geo. Carl Vinson, Ph.D.
- Frank Horstall, Jr., A.M.
- R. A. Schroeder, B.S. in Agr.
- George E. Smith, B.S. in Agr.

### Poultry Husbandry
- H. L. Kemper, M.S.
- E. M. Fune, A.M.

### Rural Sociology
- E. L. Morgan, Ph.D.
- L. G. Brown, Ph.D.

### Soils
- M. F. Miller, M.S.A.
- H. H. Krusekoff, A.M.
- W. A. Albrecht, Ph.D.
- Hans Jenny, Ph.D.
- L. D. Bayer, Ph.D.
- H. F. Winterkorn, Ph.D.

### Veterinary Science
- A. J. Durant, A.M., D.V.M.
- J. W. Connaway, D.V.M., M.D.
- Cecil Elder, A.M., D.V.M.
- O. S. Cisler, D.V.M.
- Andrew Urey, D.V.M.
- Harold C. McDougle, A.M.
- P. L. Piercy, D.V.M.

### Other Officers
- R. B. Price, B.L., Treasurer
- Leslie Cowan, B.S., Sec'y of University
- A. A. Jeffrey, A.B., Agricultural Editor
- L. R. Grinsdale, B.J., Ass't. Agr. Editor
- J. F. Barham, Photographer
- Leon Waughtal, Assistant Photographer
- Jane Frosham, Librarian

*On leave of absence.

---

**On leave of absence.**
The Structure of the Cow's Udder

C. W. Turner

The mammary glands of the cow are grouped together in a structure called the udder. There are two normal glands (the fore and rear quarters) in each half, and in addition there may be one to two supernumerary teats associated with small glands. The right and left halves of the udder are separated by a well defined longitudinal groove which extends upward as the median connective tissue septum. Viewed from the side, the udder presents a more or less rounded saccular appearance with attachments usually extending high behind and well forward.

The several dairy cattle breeders' associations have prepared pictures and models of cows showing ideal udders (Fig. 1). While there are some differences in these pictures, the reader will note that they are all characterized by good size, well blended attachment of the

---

Fig. 1.—The model udders of the dairy breeds.
fore quarters, levelness of the floor, well placed teats of good size, and with rear attachments wide and carried high behind.

**The Internal Structure of the Udder**

Upon dissection of the udder, it will be observed that each half is enclosed in a strong fibrous sac. On the inner side where the halves join, the fibers intermingle and extend upward to the abdomen where an attachment is made. This structure is known as the median suspensory ligament. On either side are the lateral suspensory ligaments, which in conjunction with the skin, serve as the chief support of the udder (Fig. 2).

The individual glands (the quarters) in each half of the udder are not as distinctly separated as are the halves. For this reason the earlier anatomists were of the opinion that the quarters were connected.

---

*Fig. 2.—Cross section of the rear quarters of a cow's udder.*
Several lines of evidence support the present view that each quarter is quite separate and distinct. In studies of the early development of the teat and gland the separation is distinctly shown (see Missouri Agricultural Experiment Station Research Bulletin 160). Bitting and many others since have injected varied colored dyes into fore and rear quarters (Fig. 3). The line of division thus shown appears to be a very thin connective tissue septum, irregular in outline but permitting no mingling of the secretion of the two glands.

In a recent study of 74 lactation records, the writer found that on the average the two front quarters each produced slightly more than 20 per cent of the total milk yield, whereas the two rear quarters each produced slightly less than 30 per cent. Considered together the front quarters produced 41.90 per cent and the rear quarters 58.10 per cent of the total milk. The milk production from the right and left halves was practically uniform, 49.93 per cent and 50.07 per cent, respectively. However, in a total of 16 lactation records, the largest quarter production occurred in one of the fore quarters.

At the entrance to the teat there is a duct called the streak canal or ductus papillaris. It is usually from $\frac{3}{4}$ to $\frac{3}{8}$ inches long and is held
closed by the aid of a circular sphincter muscle. The streak canal is designed to retain the milk in the udder against the pressure developed in the storage system during the interval between milkings. It also makes difficult the entrance of foreign matter and bacteria. At times the canal is so small that there is difficulty in milking (the so-called "hard milker"). This condition may frequently be remedied by surgical treatment.

Above the streak canal the cavity of the teat widens out gradually until a space of considerable size is formed. This is called the cistern of the teat. The upper end of the cistern of the teat opens into the cistern of the gland above. Frequently the teat cistern is sharply distinguished from the gland cistern by a constriction in the form of a circular fold which has a central or somewhat eccentric opening. It has been suggested that when the opening is very narrow, there is considerable hindrance to the outflow of milk. In a few cases a horizontal membrane of connective tissue may form which completely separates the two parts of the cistern at this point, resulting in a blind or imperforate quarter.

Above the teat cistern is found the cistern of the gland portion of the udder. Its function is to accommodate the milk as it is being secreted and store it during the interval between milkings. The cistern of the gland is a large cavity or sinus of variable size and conformation. In many cases the reservoir is divided by constrictions into pockets of various sizes into which the larger milk ducts empty (Fig. 4).

Leading into the gland from the cistern are usually from eight to twelve large milk ducts. They are generally short and wide. In an extended condition they appear in cross section as elliptical, while in an empty condition they appear as slits with the walls touching. It was thought at one time that there were circular (sphincter) muscles at the openings of these ducts which could close and thus permit the cow to "hold up her milk". Evidence accumulating indicates that this is not the mechanism by which the cow regulates the "pouring down" of milk. The branches of the large ducts are very irregular. In some cases the ducts branch into two ducts of about equal size, in other cases smaller branches are given off (Fig. 5).
Casts of the duct system, made in the laboratory by filling the cisterns and ducts with plaster of paris, are of great interest because they show a system of tubes which seem to be especially designed as a storage system (Fig. 6). The ducts are not like those of other glands, approximately of the same diameter for long distances, but rather change rapidly from being very narrow and short to large sinus-like enlargements (Fig. 7). It seems reasonable that these connecting spaces throughout the udder greatly increase the holding capacity and permit the accommodation in the gland of all the milk usually obtained at a given milking. The filling of the gland begins at the ends of the ducts with the filling of the sinuses of the ducts. As secretion continues the pressure forces the milk downward into the larger dilations or collecting spaces, and finally
into the cistern of the gland. The entire udder is capable of great expansion with the accumulation of milk within.

The larger divisions of the mammary gland may be seen with the naked eye, but to examine the finer structures it is necessary to cut the gland in very thin sections and examine the structure under the microscope. When this is done it will be found that the ducts continue to branch until finally there are enlargements at the ends called the alveoli or acini (Fig. 8). The gland may be compared to a tree in which the leaves represent the alveoli and the branches the connecting ducts. A somewhat better comparison would be to consider the alveoli as grapes and the ducts as the branching stems. A group of alveoli corresponding
to a bunch of grapes is called a lobule, and a group of lobules is called a lobe. These various divisions of the gland tissue are surrounded and supported by bands of connective tissue. The connective tissue appears as white fiber-like compartments surrounding the orange colored gland tissue (Fig. 9). Sometimes the connective tissue develops excessively and forms a hard fibrous udder. Such udders may be of large size, but due to the large amount of connective tissue which in no way aids in milk secretion, a false impression of the possible milk producing capacity of the udder may be gained.

The ducts of the gland are lined by two rows of epithelial cells, while in the alveoli only one epithelial cell layer is seen. It is within the cells lining the alveoli that milk secretion occurs.

**The Mode of Milk Secretion**

Let us now examine more closely the tiny epithelial cells in which the blood is synthesized or manufactured into the various component parts of milk: fat, milk sugar, protein, and mineral matter. All individual cells in an alveolus are similar in structure. Each contains a nucleus, a structure which is essential to a living cell. When cells multiply, the nucleus first divides into two parts. In addition to the nucleus there is a watery material called protoplasm which makes up the rest of the cell. In some way, yet unknown, the cells of the alveolus take certain component parts of the blood and transform them into milk. It is believed that each cell is capable of manufacturing all the constituents of milk rather than that certain cells produce only fat, others only protein, and yet others only sugar.

---

**Fig. 10.—** Shows the cycle of secretory activity within the epithelial cells. At the beginning the cells are low and cuboidal in form. The gradual synthesis of milk causes the epithelial cells to lengthen and particles of fat begin to collect in the end of the cells facing the lumina of the alveolus.

At the beginning of the cycle of secretion, the cells are low and cuboidal in form. The gradual synthesis of milk causes the epithelial cells to lengthen and particles of fat (fat globules) begin to collect in the end of the cells facing the lumen or cavity of the alveolus (Fig. 10).
As the cells fill with secretion, it is discharged into the lumen (Fig. 11). Several theories have been advanced as to the mode of discharge. Some believed that the milk was discharged through the intact cell membrane, while others thought that the discharge of the milk was accomplished by the rupture of the end of the cell extending into the lumen. The most recent evidence indicates that there is a direct discharge of the secretion through a rupture of the cell wall, although that does not necessarily mean that milk cannot pass through the cell wall.

Following the discharge of the products of the cell, the low cuboidal form again appears. The cell membrane becomes reunited and another cycle of secretion is commenced. The length of time required for a cell to complete the synthesis of a cell-full of milk and discharge the cell’s contents into the lumen of the alveolus is not known.

**The Blood Supply of the Udder**

As the blood is the source of the various constituents which are transformed into milk by the epithelial cells lining the alveoli, the description of the circulation of the blood to the udder and its return to the heart is of interest. The arterial blood which eventually reaches the udder passes from the heart into the aorta which extends upward
and backward until it reaches the spinal column (Fig. 12). It continues backward leaving the thoracic cavity and entering the abdominal cavity. It finally divides into the right and left external iliac arteries which eventually send branches to the right and left halves of the udder as follows: Internal iliac artery, femoral artery, prepubic artery, and external pudic artery. After passing through the inguinal canal and passing to the base of the udder the external pudic arteries become the mammary arteries which send branches to all parts of the udder. The single mammary artery enters the rear quarter of each half. It is interesting to note that the artery then sends branches to all parts of the half irrespective of the division of the quarters (Fig. 13). With constant branching, the arteries become smaller and smaller until they finally become capillaries.

Surrounding each alveolus is found a network of capillaries which bring the blood in close proximity to the secreting cells. It is possible for the blood plasma containing the precursors of the various constituents of milk to pass out of the capillaries into the intercellular spaces. The epithelial cells take up the plasma as needed to synthesize the various constituents and return the residual products back into the intercellular spaces where they are taken up again by the blood and lymph capillaries.

The veins carrying the blood returning to the heart, increase in size as they merge together. Usually there is a vein accompanying the artery
in the udder. However, upon leaving the udder, there is a rather unusual development in the venous system. While one group of veins (the external pudic) follow the arteries in a typical manner, two other groups of veins take independent courses (Fig. 14).
The most important independent path of the blood from the udder is by way of the subcutaneous abdominal veins commonly called mammary or "milk veins". These veins pass forward from the base of the udder beneath the skin to openings (called milk wells) into the abdominal cavity. The veins continue forward, finally reaching the heart. The milk veins are subject to great variations in tortuosity and diameter. Judges of dairy cattle believe the size and tortuosity of these veins are indicative of the productive ability of dairy cattle.

A second independent path of the blood is through the perineal veins which pass backward and upward from the udder. They pursue a tortuous course until they join the internal pudic veins and thus become united with the blood from the external pudic vein.

If one examines the veins of an udder which has been removed from a cow it will be noted that there is a large branch between the mammary veins in the rear basal portion of the udder so that venous blood may pass freely from one half to the other. By this arrangement the blood from every part of the udder can flow through the vein most suitable—either forward, upward, to the rear, or across to the opposite half through similar channels. (Fig. 15).

The importance of this arrangement and construction of the udder veins becomes evident when it is realized that the conditions regulating
the outflow of blood vary greatly, depending upon the way the udder may act upon the vessels. Thus, when the cow is standing there may be pressure applied to the veins passing upward, and in lying down one or the other veins might be shut off.

The vascular supply of the teats is worthy of mention. There is a network of blood vessels, most of which run the length of the teat. When these veins become filled with blood they may partly or completely replace the milk in the central teat cistern (Fig. 16). It was thought at one time that the cow was able to "hold up" her milk by the enlargement or dilation of these veins with blood. This is probably not true. It is true that this venous network has been a source of great difficulty in the successful removal of milk by machine. The application of a vacuum to the end of the teat causes a congestion of the blood which can only be prevented by a sufficient period of release, so that the modern milking machine employs a system of alternate vacuum and release to prevent the congestion of blood and the closing of the teat.

**The Lymphatic System of the Udder**

The lymphatic system consists of a series of ducts which collect the lymph from the various tissues of the body and return it to the jugular vein where it is mixed with the blood. In the course of this lymph vascular system are found lymph nodes or glands which add lymphocytes or white blood cells to the lymph.

In the mammary gland, the lymph capillaries surround the alveoli and absorb from the intercellular spaces part of the plasma and products returned from the secreting cells. The lymph is then conveyed by ducts upward and to the rear of the udder where are located the large supramammary lymph glands—in each half (Fig. 17). In addition to the ducts in the gland tissue, there is a series of large lymph ducts beneath the skin, and these flow in the same direction carrying the straw-colored lymph fluid.

After the lymph fluid passes through the supramammary lymph glands, it leaves the udder by way of a large duct which extends upward
in association with the external pudic artery and vein. Its further course to the jugular vein is indicated in Fig. 18.

As the lymphatic is only a one-way system, the question arises as to the cause of the circulation of lymph. The pressure in the blood capillaries and intercellular spaces aids in forcing the fluid into the lymph capillaries. It is then caused to move forward chiefly by the contraction of muscles. Along the ducts are found valves which prevent the back flow of lymph. Massage also aids in propelling lymph through the ducts. In the case of physiological congestion of the udder, such as occurs at the time of parturition, massage of the udder upward and to the rear following the course of the ducts will be helpful.

The Nervous System of the Udder

The various parts of the body are coordinated by two important systems—the nervous system and the endocrine system, the latter producing substances known as hormones. The prominence of the part played by hormones in regulating and controlling the growth and func-
tion of the udder should not be taken as evidence of a lack of nervous control, or that the nerves are not of great importance in the mechanism of milk secretion. As will be described shortly, the nerve network of the udder has been traced in considerable detail yet the exact function performed by the nervous system is not yet well understood.

It is possible that the nerves control to some extent the secretory activity of the gland epithelium either directly or indirectly through the vascular system of the gland dilating or contracting the blood vessels. A second possible action of the nerves is on the smooth muscle elements in the gland influencing the "letting down" of formed milk.

The nerves passing to the udder are partly of spinal and partly of sympathetic origin (Fig. 19). The spinal nerves follow two different paths, one permeating the gland tissue, and the second the skin of the udder. These spinal nerves emerge from the lumbar vertebra. Branches of the first lumbar nerve, called the iliohypogastric, proceed ventrally and supply the skin of the fore quarters of the udder.

Branches of the second and third lumbar nerves unite to form the ilio-inguinal nerve. It joins a branch of the external spermatic nerve, and the trunk so formed descends the inguinal canal as the inguinal nerves in company with the external iliac artery. Numerous branches of these nerves are distributed to the glandular tissue, milk collecting system and teats in association with the arteries.

The trunk of the sympathetic nervous system extends along each side of the vertebral column from the base of the cranium to the tail. The sympathetic nerves are connected with the spinal nerves by branches called the rami communicantes. Branches of the sympathetic nerves pass to the posteriormesenteric plexus, from which fibers join in the nerve trunk of the inguinal nerves which pass to the gland tissue.