

AGA 2110 Anatomy and Physiology of Farm Animals

Mammary Gland and Physiology of Lactation

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Mammary glands are the major features that distinguish mammals from other kinds of animals.



Cow



Goat



Sheep

Mammary glands are the organs that, in mammals, produce milk for the sustenance of the young.

The teats and glands can occur anywhere along the two milk lines, two roughly-parallel lines along the ventral of the body.



Pig



Cat



Mouse

In general most mammals develop mammary glands in pairs along these lines, with a number approximating the number of young typically birthed at a time.

The number and positioning of complex and simple mammary glands varies widely in different mammals.



Elephant



Human

The number and position of glands normally found in a range of mammals:

Species	Anterior (<u>thoracic</u>)	Intermediate (<u>abdominal</u>)	Posterior (<u>inguinal</u>)	Total
<u>Goat, sheep, horse</u>	0	0	2	2
<u>Cattle</u>	0	0	4	4
<u>Cat</u>	2	2	0	4
<u>Dog</u>	2	4	2-4	8-10
<u>Mouse</u>	6	0	4	10
<u>Pig</u>	6	6	4	16
<u>Elephants, primates</u>	2	0	0	2

Suckling baby elephants





The mammary gland nourishes the neonate

- ❑ Exocrine gland; common to all mammals
- ❑ Function: nourish the neonate
 - **Food source:** fat, protein, sugar (CHO), vitamins, minerals, water
 - **Protection:** immunoglobulins (first Ab protection; absorbed via intestinal tract)

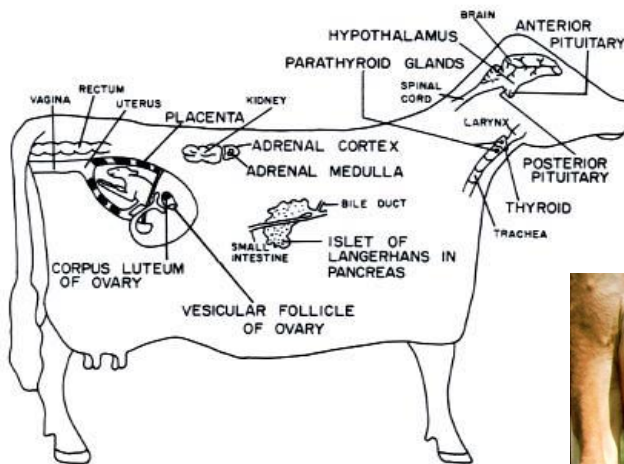


The mammary gland is part the reproductive system

- The mammary gland is loosely considered part of the reproductive system:
 - Serves a “reproductive function”; nourishment of the neonate = survival of species.
 - Relies on same endocrine (hormonal) support for development and function.
- Example:** gonadal steroids, prolactin, etc.



Endocrine Glands Affect Mammary Function



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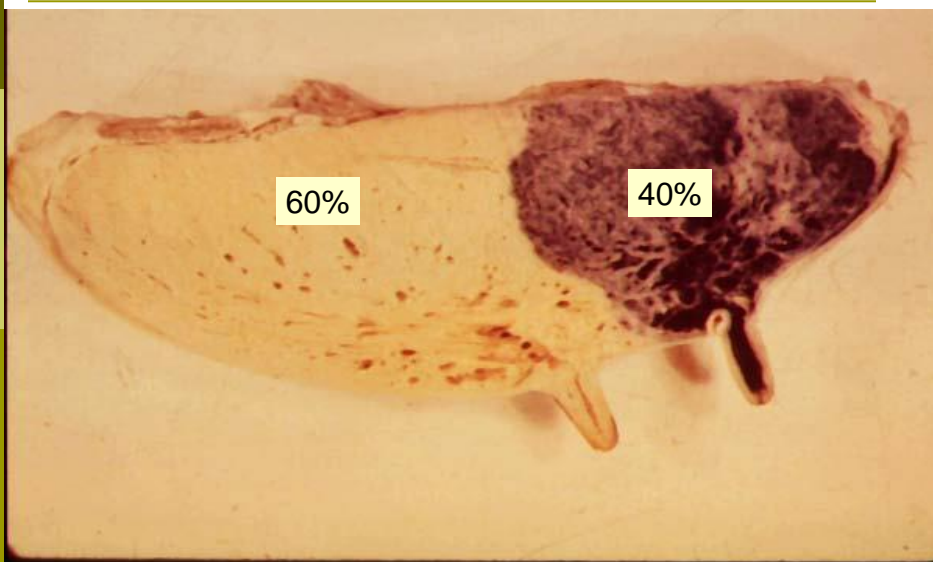
Mammary Gland Structure

- Udder consists of four separate glands
 - A teat hangs from each quarter
 - Bottom of teat closed by sphincter muscle known as streak canal
 - Can have extra nonfunctional teats
 - Called supernumerary teats
 - Removed when calf is young
- Conformation of teats
 - Vary in shape from cylindrical to conical
 - Rear teats are usually shorter
 - Each teat has one streak canal
 - Teats should be moderately sized and located centrally on each quarter
 - Sphincter in each teat should be tight enough to prevent leakage
 - Teats are hairless

Mammary Gland Structure

- Support system = **Stroma** (*connective tissue*)
- Glandular; secreting tissue = **Parenchyma**
 - **Alveoli**- secreting epithelial cells
 - **Duct system**- lined by epithelial cells
 - **Lobules & lobes**- clusters of alveolar tissue supported by connective tissue

Separate Mammary Glands-Quarters



Mammary Gland Structure/Suspension

- ❑ Intermammary groove separates left and right halves of the udder
- ❑ Udder can weigh anywhere from 7 to 165 pounds
 - May support up to 80 pounds of milk
 - Rear quarters secrete 60% of the milk
 - Udder continues to grow in size until cow is 6 years of age
- ❑ Well attached udder fits snugly against the abdominal wall in front and on the sides
 - Extends high between thighs in rear
- ❑ 3 major supporting structures
 - Skin
 - Median suspensory ligament
 - Lateral suspensory ligament

Mammary Gland Suspension

- ❑ Skin
 - Minor role in support
- ❑ Median suspensory ligament
 - Separates right and left halves of udder
 - Connects udder to abdominal wall
 - ❑ Lamellae
 - Elastic tissue which responds to weight of milk in udder
- ❑ Lateral suspensory ligament
 - Inflexible
 - Surround the outer wall of udder
 - Attached to prepubic and subpubic tendons
- ❑ Intermammary groove formed where lateral suspensory ligament and median suspensory ligament meets

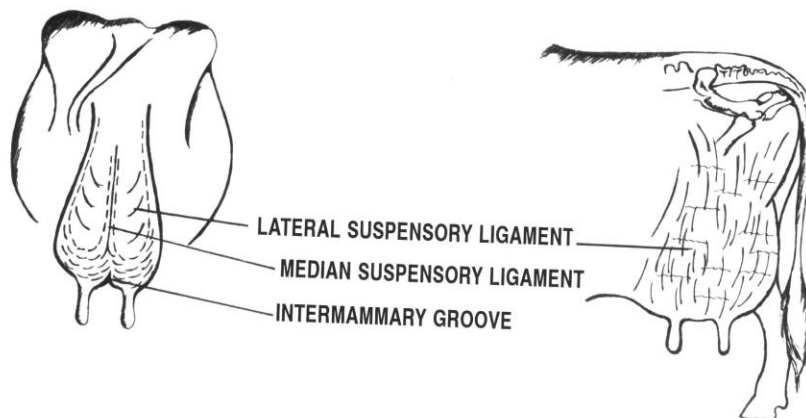
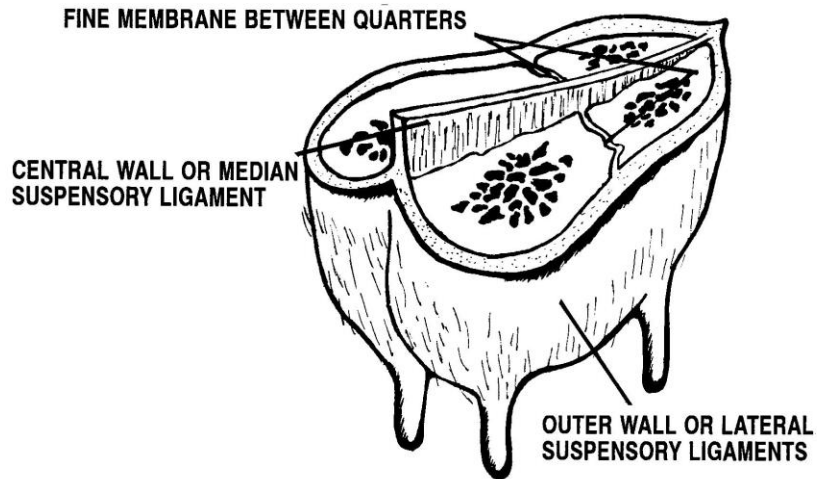
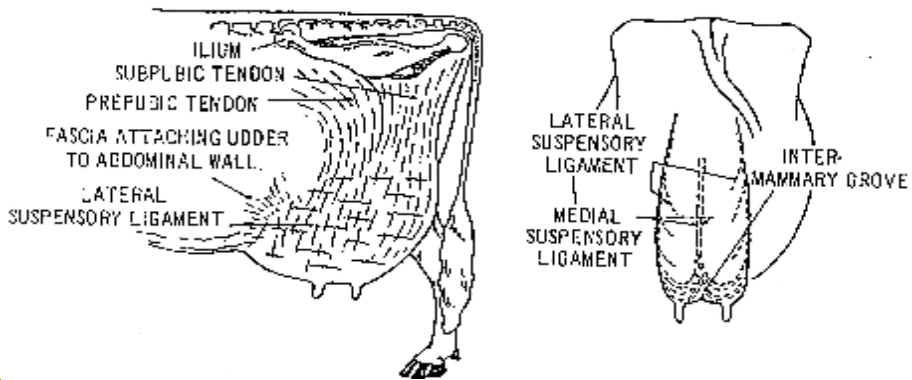
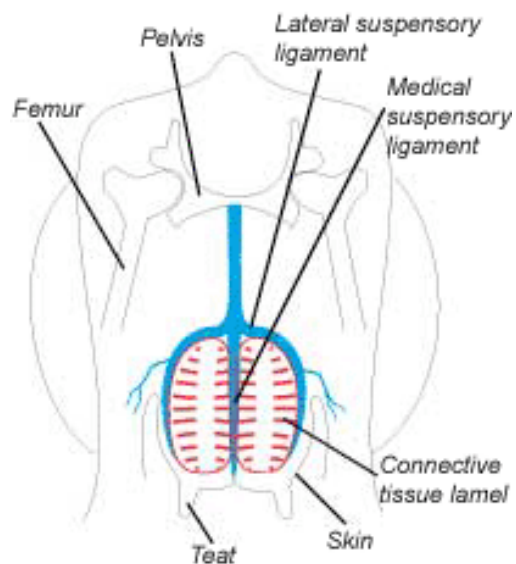


Fig 29-3. An illustrated view of the ligaments that permit udder suspension (Courtesy of Iowa State University)

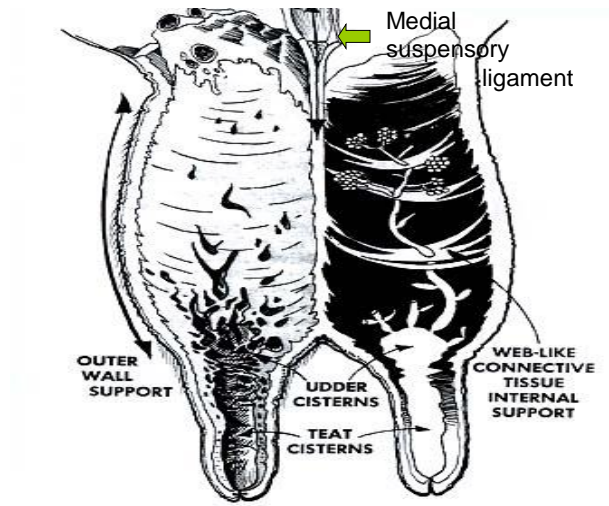
Suspension of the Udder



Udder Suspension



Mammary Gland Support



Internal Anatomy

- Streak canal
 - Functions to keep milk in udder and bacteria out of udder
- Teat cistern
 - Duct in teat with capacity of 30-45 milliliters
 - Separated from streak canal by folds of tissue called Furstenberg's rosettes
- Gland cistern
 - Separated from teat cistern by the cricoid fold
 - Holds up to 400 milliliters of milk
 - Collecting area for the mammary ducts
 - From this branches the mammary ducts

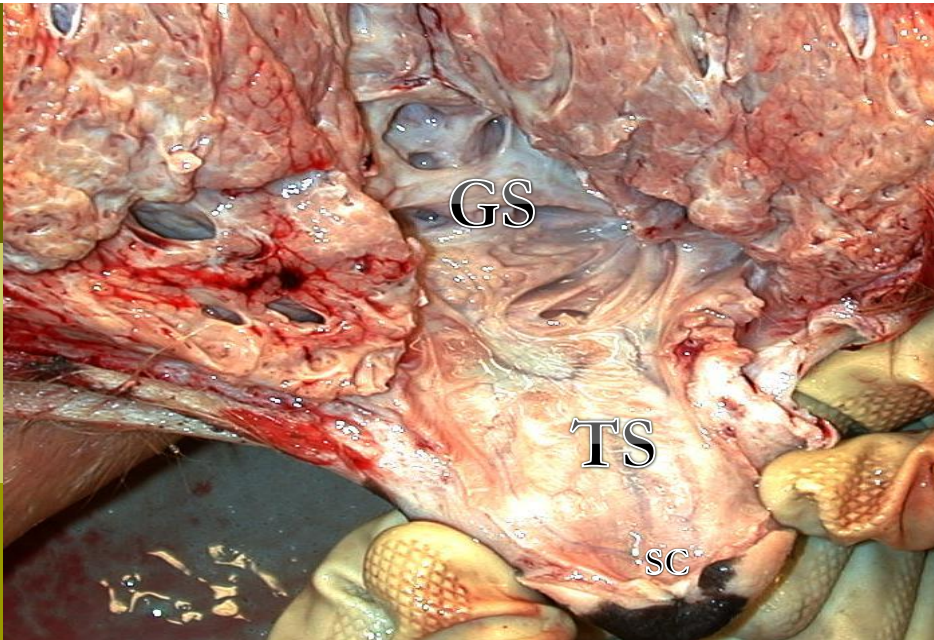
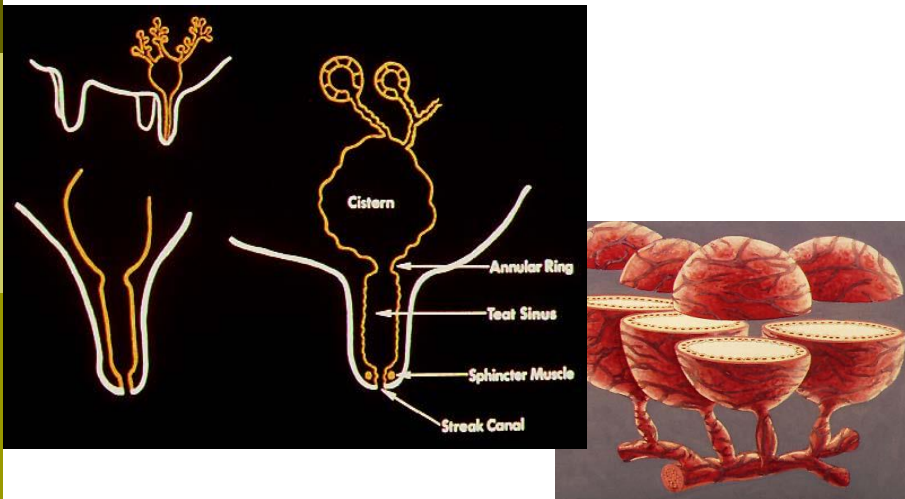


Fig 29-4. A dissected mammary gland showing the gland cistern, teat cistern and streak canal (Courtesy of Mark Kirkpatrick)

Alveoli and Duct System

- Alveoli is the basic milk producing unit
 - Small bulb-shaped structure with hollow center
 - Lined with epithelial cells that secrete milk
- Each cubic inch of udder tissue contains 1 million alveoli
- Each alveoli surrounded by network of capillaries and myoepithelial cell
 - Contraction of myoepithelial cell stimulates milk ejection
- Groups of alveoli empty into a duct forming a unit called a lobule
 - Several lobules create a lobe
 - Ducts of lobe empty into a galatophore, which empties into the gland cistern
- Ducts provide storage area for milk and a means for transporting it outside
 - Lined by two layers of epithelium
 - Myoepithelial cells are arranged in longitudinal pattern
 - Shorten to increase diameter to facilitate flow of milk

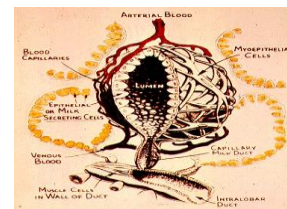
Alveoli and Duct System

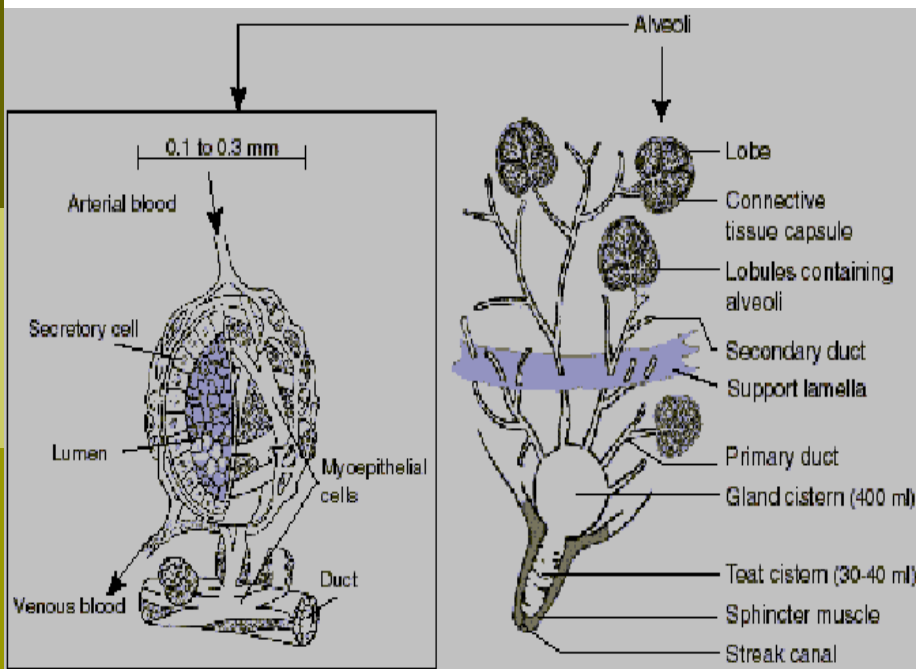


Alveolar Structure

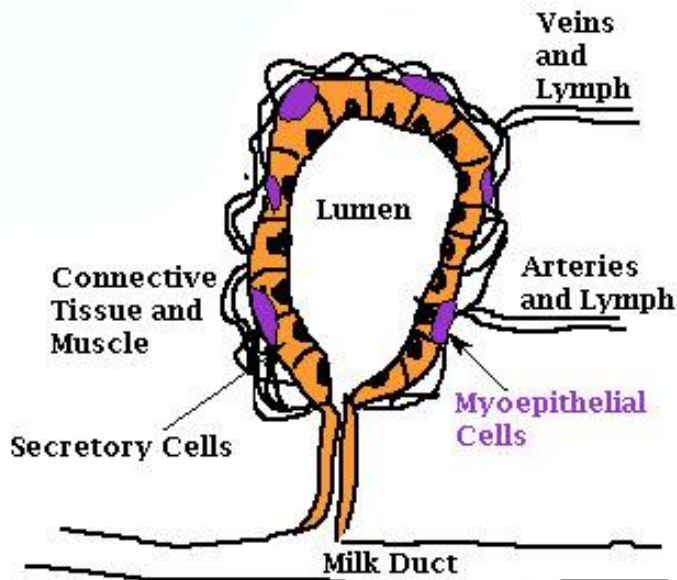
□ Alveolar components & function:

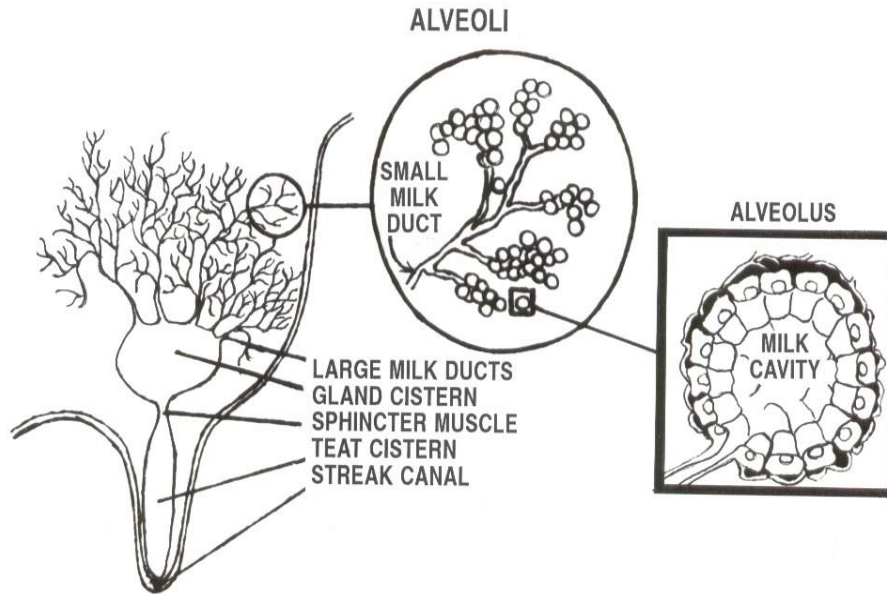
- **epithelial cells** - milk synthesis & secretion
- **lumen** - collect milk components & water
- **myoepithelial cells** - milk ejection
- **basement membrane** - selective transfer
- **terminal duct** - milk transport out of alveoli
- **capillary system** - supply milk precursors and deliver hormones





Alveolus





Mammary Cell Function

- **Alveolar milk component synthesis:**
 - **RER > lipid, caseins**
 - **Golgi apparatus > lactose (also packages lactose, caseins, minerals, water)**

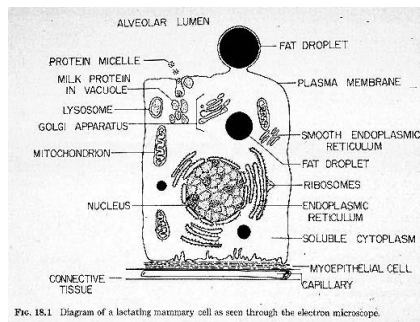


FIG. 18.1 Diagram of a lactating mammary cell as seen through the electron microscope.

Alveolar Products



□ Alveolus:

- basic secretory unit; lined by **epithelial** cells which synthesize and/or secrete:
 - **lipid** - triglycerides & free fatty acids (FFA)
 - **protein** - caseins
 - **lactose** - disaccharide; major CHO; osmoreactive molecule (draws water)
 - **minerals & vitamins** - Ca, P, K; Vits. A, B, C, D
 - **water**

Interior of the Udder

⌘ Gland cistern

- ☒ 100-400 ml. milk storage
- ☒ duct systems drains into
- ☒ used to detect end of milking

⌘ Duct system

- ☒ drains secretory tissue
- ☒ no secretory function

⌘ Alveoli

- ☒ Milk producing units
- ☒ secretory cells, myoepithelial cells and capillaries, duct

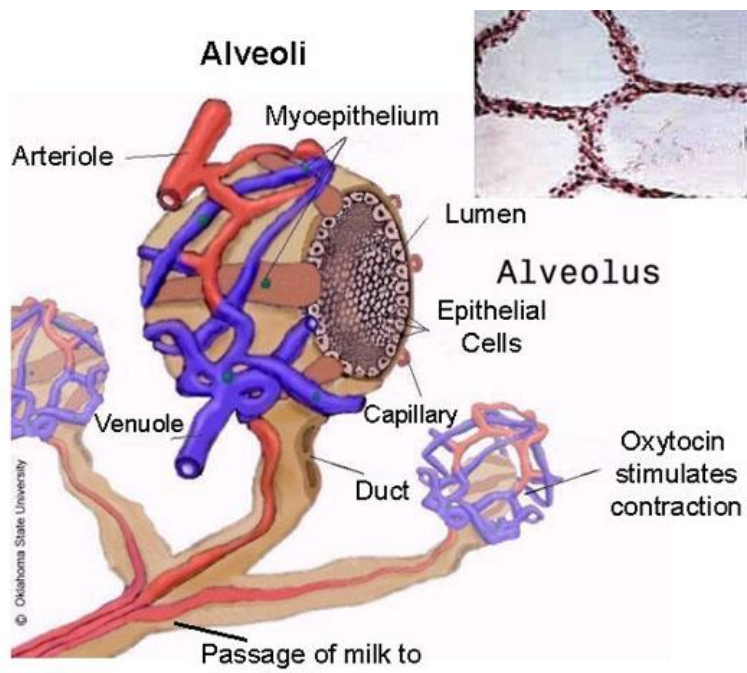
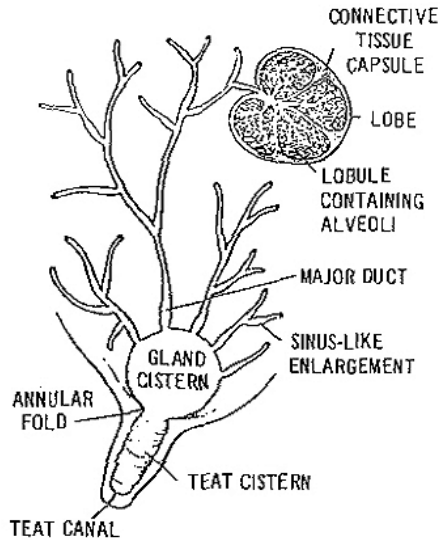
⌘ Lobules

- ☒ 150-200 alveoli, common duct

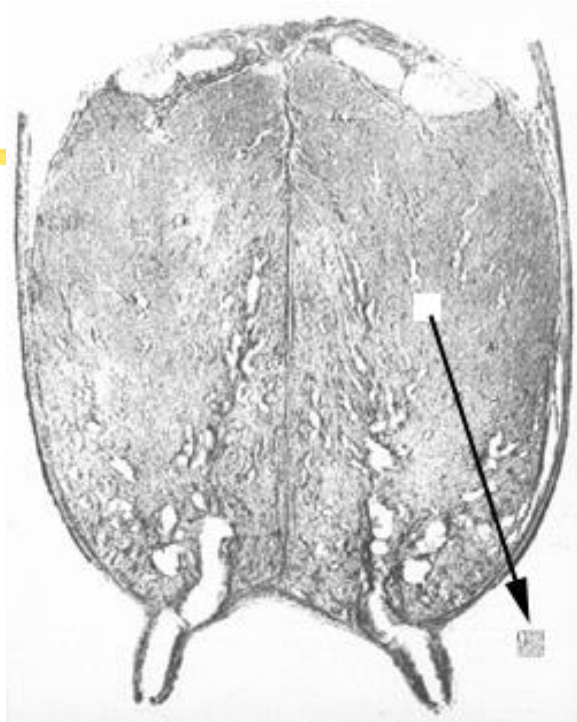
⌘ Lobes

- ☒ group of lobules

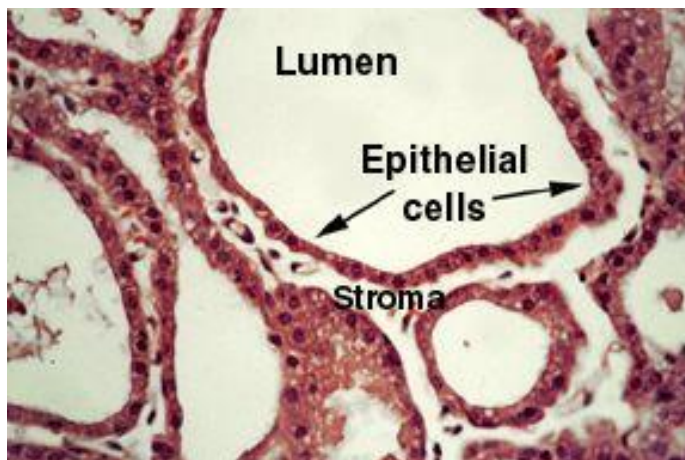
Diagram of Duct System



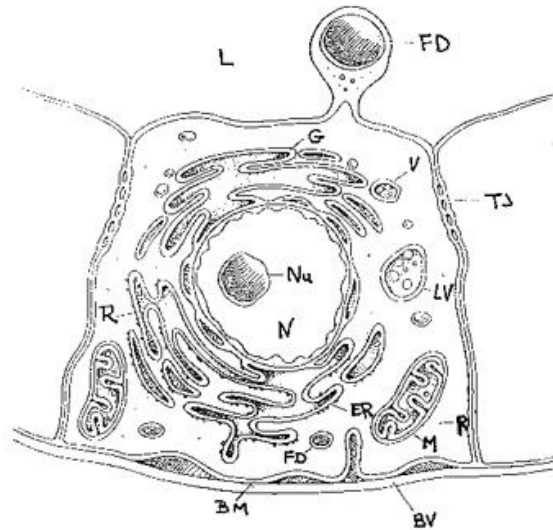
Redrawn from Bearden, H.J. and Fuquay (1997) Applied Animal Reproduction



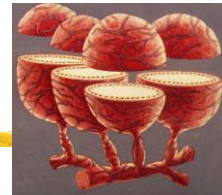
Alveolus



Mammary Cells



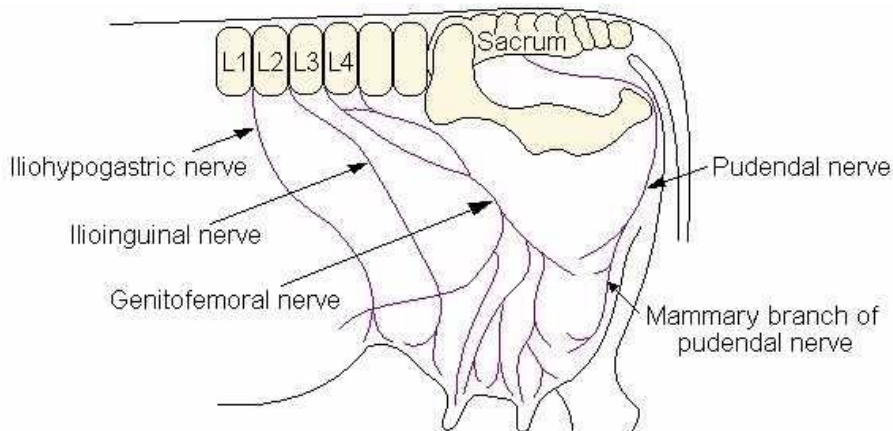
Alveolar Products



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 - ⊠ **lipid** - triglycerides & free fatty acids (FFA)
 - ⊠ **protein** - caseins
 - ⊠ **lactose** - disaccharide; osmoreactive molecule (draws water)
 - ⊠ **minerals & vitamins** - Ca, P, K; Vits. A, B, C, D
 - ⊠ **water**

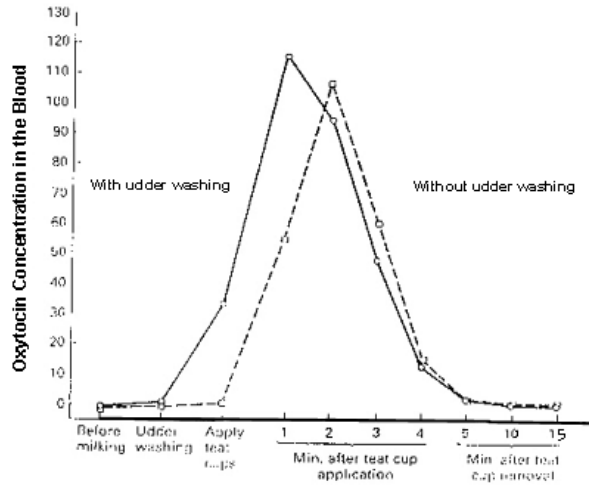
Innervation of the Mammary Gland



Milk Ejection Reflex

- ⌘ Neuroendocrine
- ⌘ Pressure sensitive receptors on the teats feed back to the supraoptic and paraventricular nuclei
- ⌘ Stimulation of these neurons causes release of oxytocin
 - ☒ Other stimuli can cause letdown
- ⌘ Oxytocin causes myoepithelial cells to contract
 - ☒ Peak oxytocin 2 mins following stimulation
 - ☒ Half life of .55 - 3.6 mins
- ⌘ Timing of stimulation important to milk flow rate and machine-on time
- ⌘ Machine attachment in 20-45 seconds
- ⌘ Adrenalin blocks letdown by:
 - ☒ Decreasing mammary blood flow
 - ☒ Reducing myoepithelial response
 - ☒ reducing oxytocin release

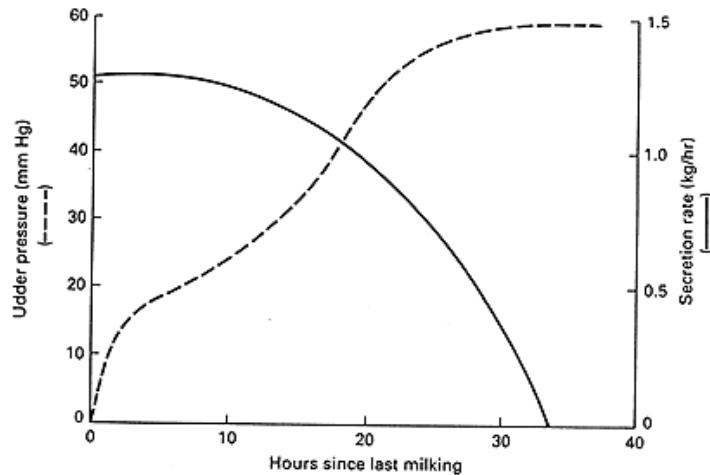
Oxytocin Release



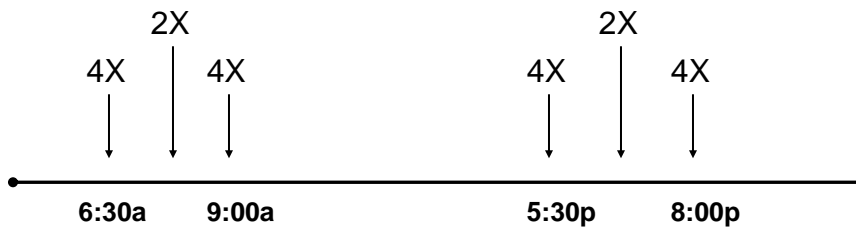
Effect of Increased Milking Frequency (IMF) on Milk Production

Milking Frequency Change	Increased Milk Production
1X - 2X	13.6 lb.
2X - 3X	7.7 lb.
2X - 4X	10.8 lb.

Effect of Udder Pressure on Milk Secretion



IMF Milking Interval

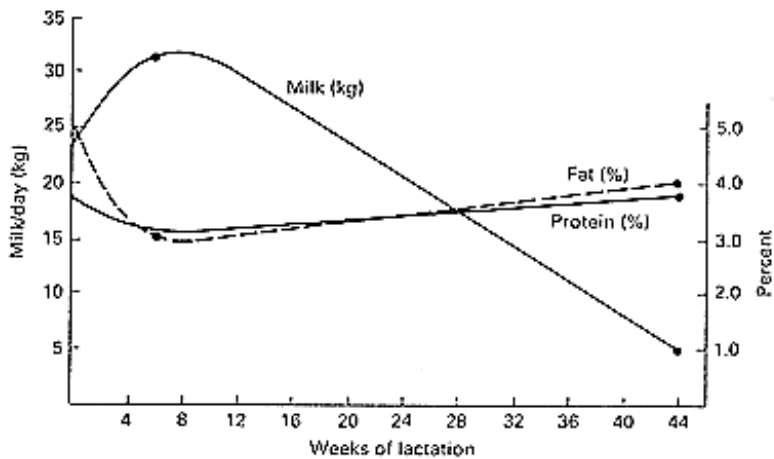


- IMF cows milked before and after the normal 2X milking
- ~2 ½ hours between 2 AM and 2 PM milkings
- 8 ½ hours between AM and PM milkings

Effect of Milking Interval

Interval	Cows	Days	Milk
12-12	35	305	13.760
14-10	35	305	13.716
16-8	35	305	13.582

Schmidt & Trimberger (1963)



Normal Lactation Curve of a Dairy Cow

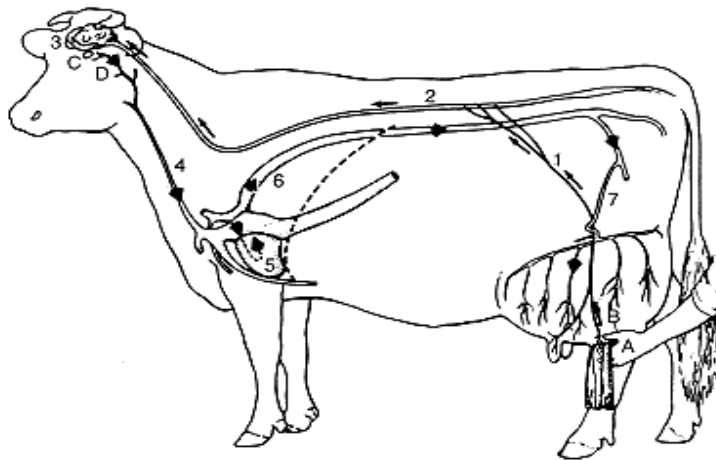


Figure 10-6 The neurohormonal reflex of milk ejection. Stimulus(A) that a cow associates with milking causes a nerve impulse (B) to travel via the inguinal nerve(1) to the spinal cord(2)and the brain(3). The brain causes the release of oxytocin (D) from the posterior pituitary (C). Oxytocin is released into a branch of the jugular vein(4) and travels to the heart(5) and is then transported to all parts of the body by the arterial blood. The oxytocin reaching the udder leaves the heart by the aorta(6) and enters the udder through the external pudic arteries (7).In the udder, it causes the myoepithelial cells to contract, resulting in milk ejection from the alveoli.

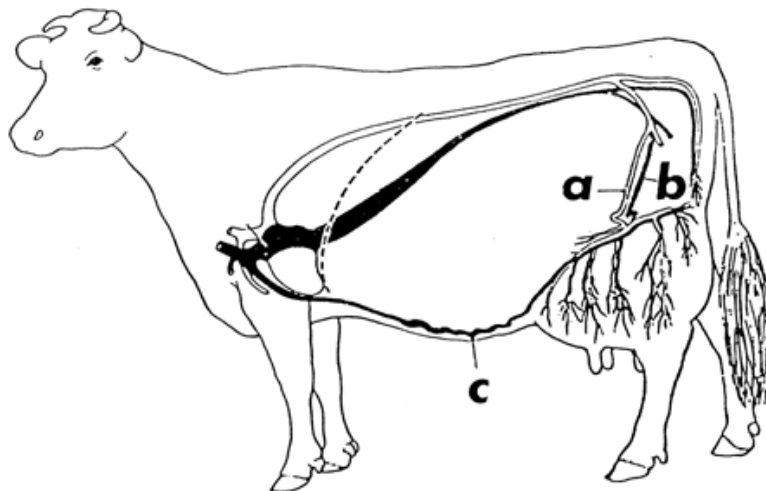
Circulation

- ⌘ One gallon of milk requires 400 gallons of blood being passed through udder
 - ☒ Ratio may increase in low producing cows
- ⌘ Blood enters the udder through external pudic arteries
- ⌘ Blood exiting udder from veins at the base of udder blood can travel through two routes
 - ☒ Via external pudic veins
 - ☒ Via subcutaneous abdominal veins

Vascular System

- Blood:Milk Ratio; 500:1
- 2 Arteries
 - External pudic
 - Perineal
- 3 Veins
 - External pudic
 - Perineal
 - Subcutaneous abdominals
 - milk wells
 - Venous circle

Blood System to the Udder



Venous Circle

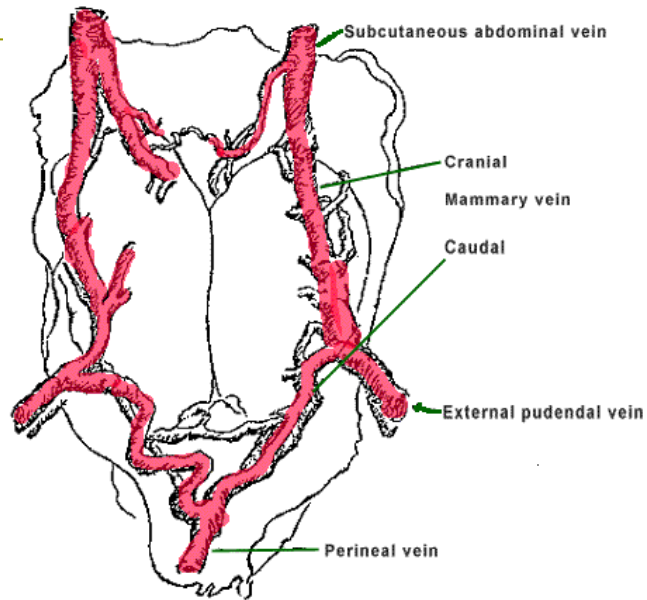
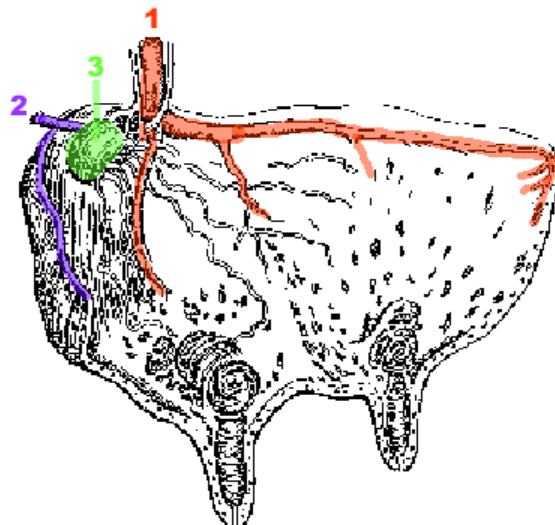
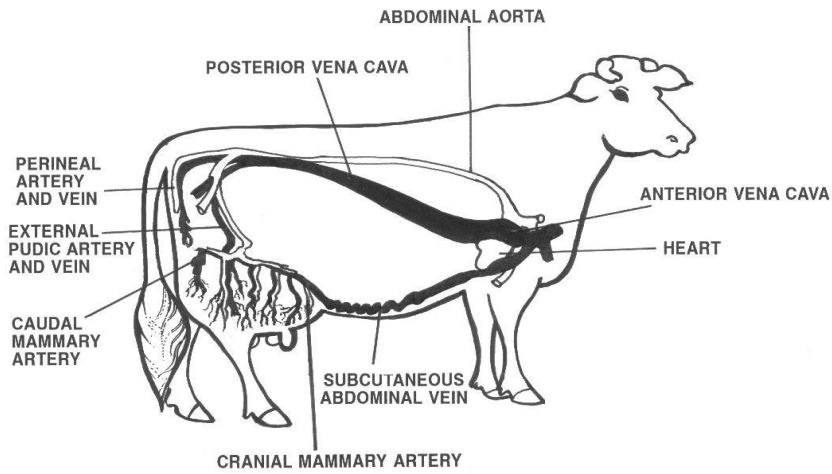


Diagram of Arteries and Lymphatics

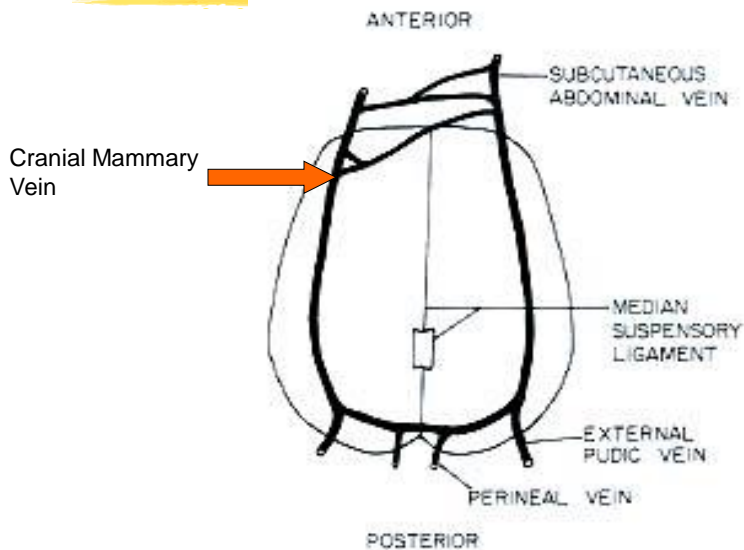




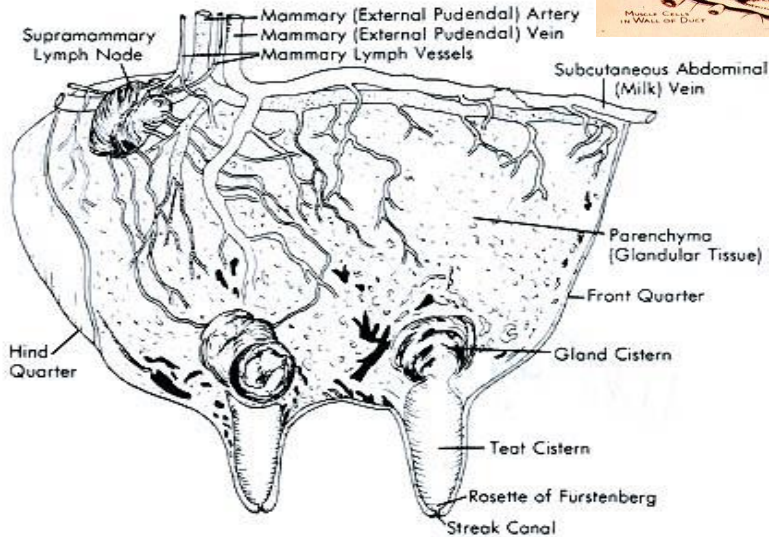
18-5

Fig 29-6. Blood flow to and from the mammary gland determines milk producing capability of the cow (Courtesy of Iowa State University)

Mammary Venous Circle



Mammary Vessels



Mammary gland defense system

- ⌘ **Smooth muscle sphincter** surrounding the teat canal inhibits bacterial closure. Because the teat canal lumen remains dilated for up to 2 hours after milking, feed cows after milking to keep them on their feet.
- ⌘ **Keratin**, a waxy substance derived from the teat canal lining partially occludes the lumen of the teat canal and inhibits bacterial penetration. Only infuse the tip of intramammary infusion cannulas into the teat canal.
- ⌘ **Somatic Cells** are the most important natural defense mechanism to infection. Leukocytes (mostly PMN, polymorphonuclear neutrophils) function by phagocytosing and killing bacteria. They may reach in the millions.
- ⌘ **Antibodies** and other soluble factors in milk. They coat bacteria and enhance PMN engulfment. They also interfere with bacterial adhesion to tissues, reducing multiplication and neutralizing toxins.

Lymphatic System- Edema

□ **Oedema:**

- **low pressure, passive system fed by a high pressure vascular system!**
 - this situation results in pooling of interstitial fluid if evacuation of lymph is impaired

Example: tissue trauma; increased mammary blood flow at parturition

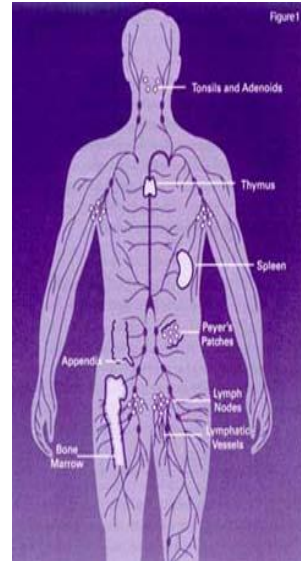


Alleviating Mammary Oedema

- ⌘ Preparturient milking may be helpful
 - ☒ store colostrum from healthy cows to feed calves
- ⌘ Frequent milkout to reduce mammary pressure
- ⌘ Diuretics, corticoids to reduce swelling
- Mammary massage, icing
 - work fluid towards supramammary lymph nodes
- Reduce salt intake
- Don't feed too much, too early before calving

Lymphatic System

- **Lymph is clear, colorless**
 - contains less protein than blood plasma
 - contains high [] of *lymphocytes* (WBC's) which play a role in immune defense
 - contains few RBC's
 - carries glucose, salts, fat (chylomicra from intestine)
 - dissipates heat
 - carrier of fibrinogen (clotting protein)



Lymphatic System

- **Movement of lymph is passive:**
 - lymph moves through vessels by:
 1. muscle movement (exercise, etc.)
 2. breathing
 3. heart beat
 4. tissue massage



Lymphatic System

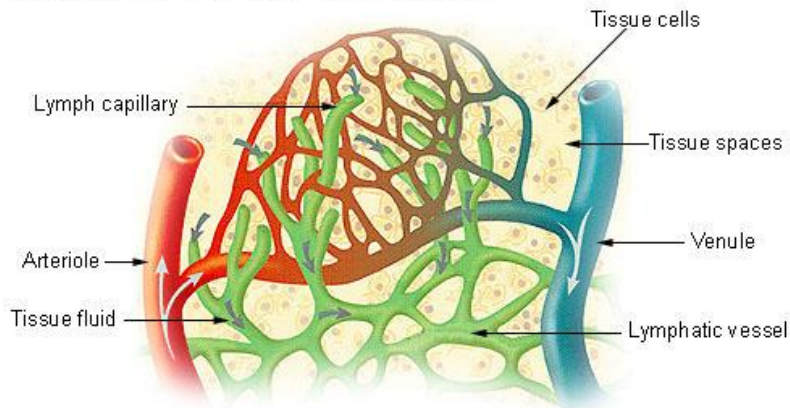
- Helps regulate proper fluid balance within udder and combat infection
- Fluid drained from tissue only travels away from udder
 - Blood capillary pressure
 - Contraction of muscles surrounding the lymph vessels
 - Valves that prevent backflow of lymph
 - Mechanical action of breathing
- Lymph travels from udder to the thoracic duct and empties into blood system
- Flow rates of lymph depend on physiological status of the cow

Lymphatic System

- **Fluid enters the lymph system through open-ended vessels called *lacteals***

Function of the Lymphatic System

Lymph Capillaries in the Tissue Spaces



Lymph System

- Lacteals
 - Originate in the peripheral tissues of the teat ends
 - Move fluids to the lymph nodes
- Ducts
 - 2-4 main ducts drain the rear udder
 - 1-3 main ducts drain the fore udder
- Supramammary Lymph Nodes
 - Located in the rear udder

Lymphatic Drainage

