Stomach of Pig: *Open the stomach by incising and removing part of the parietal (cranial) wall. Clean the inside of the stomach to observe the mucosa.* The most obvious modification of the pig stomach is the small out-pocket at the apex of the fundus, termed the **gastric diverticulum** (Figs. 4-20 & 4-29).

The proventricular (nonglandular) part of the stomach is small and is represented by a narrow strip of stratified squamous epithelium that extends from around the cardia into the gastric diverticulum (Fig. 4-20). This nonglandular area is where gastric ulcers typically occur in pigs. Gastric ulcers are a common problem in the modern swine-production industry, and can result in significant economic loss to the producer.

The **cardiac gland region** is remarkably large in the pig, extending from the diverticulum through the proximal third of the stomach (Fig. 4-20). The **region of proper gastric glands** is characterized by its brownish-red color and more prominent folds (Fig. 4-20). The **pyloric gland region** has less conspicuous folds and a paler color (Fig. 4-20). Another unique feature of the pig stomach is the prominence of lymphatic tissue in the gastric mucosa, especially in the area of the lesser curvature, where the different gland regions meet.

Open the stomach along the greater curvature, out through the pyloric sphincter. This should expose another interesting feature of the pig stomach, the **torus pyloricus** (Fig. 4-30). The torus pyloricus is a musculofatty protuberance from the lesser curvature, which represents an innovative concept in pyloric sphincter design.[19] With the surrounding circular muscle fibers, the torus forms a sort of ball-and-seat valve for more efficient, watertight closure of the pylorus.

Stomach of Ruminant: The **ruminoreticulum** occupies the entire left half (and more) of the abdominal cavity of an adult ruminant. It is difficult to observe all the grooves and other features in a large animal, but this can easily be accomplished in the newborn calf.[20] These *potential ruminants* have all the right parts, they just haven't gotten big and bulky yet.[21] Therefore, first examine the small ruminoreticulum of the newborn, and then look at the adult's. Identify the **dorsal**, **ventral**, and **cranial sacs**, and the **cranial**, **left longitudinal**, **caudal**, **right longitudinal**, **dorsal coronary**, **ventral coronary**, and **ruminoreticular grooves** (Fig. 4-6).

The internal anatomy of the ruminoreticulum is to be studied *in situ*. *Open the rumen by reflecting a liberal flap of the left wall.* Flip a coin to see who gets to remove the ingesta as necessary to identify all the internal features, and then proceed with doing so.[22] Identify the **dorsal**, **ventral**, and **cranial sacs**, and the

[19] The torus pyloricus is also found in the stomach of our common domestic ruminants. Like so many other anatomic peculiarities- "its only significance is it is of no significance, which is in itself significant."

[20] Inflated and hardened demonstration specimens of the ruminant stomach are valuable learning tools at this point.

[21] I call them *potential ruminants* because, although they are anatomically ruminants, they aren't physiologically capable of rumination until their forestomachs grow up some and become seeded with the necessary fermentative organisms.

[22] Double plastic OB sleeves provided at this point are appreciated by the student charged with ruminoreticular evacuation. Tomato juice, lemon juice, and tooth paste have all been proposed to make the student more socially acceptable following this procedure. The smell usually wears off in about a week. (Hint: If you've got a big date coming up on the week-end, it might be best to feign illness at this time.)

caudodorsal and **caudoventral blind sacs** (Fig. 4-31). The cranial sac is relatively smaller in the sheep and the goat. Identify the **cranial**, **left longitudinal**, **caudal**, **right longitudinal**, **dorsal coronary**, and **ventral coronary pillars**.

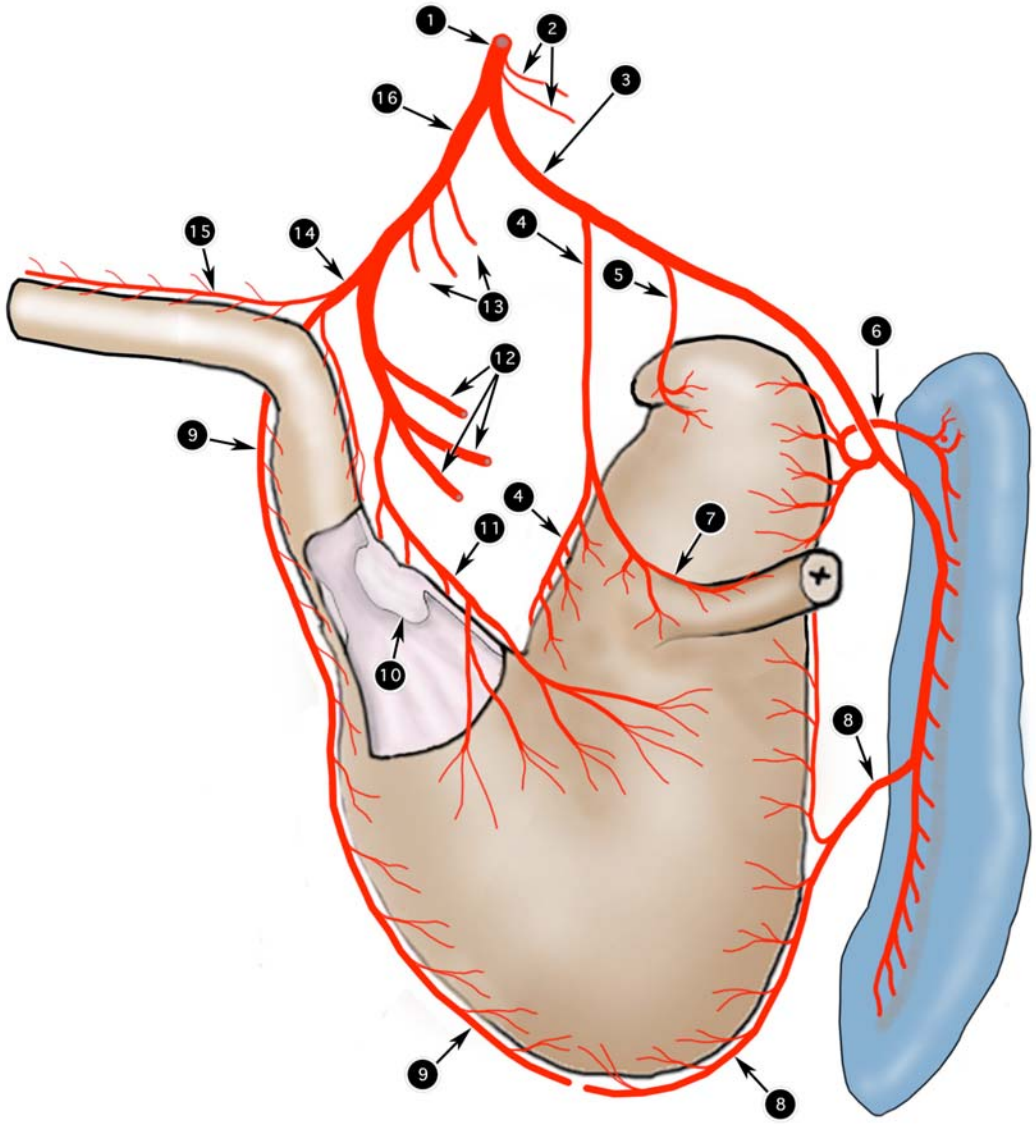


Figure 4-30. Semischematic representation of blood supply to porcine stomach and spleen, cranial view with part of pyloric wall of stomach removed: (1) celiac artery; (2) caudal phrenic arteries to diaphragm; (3) splenic artery; (4) left gastric artery; (5) branch of splenic artery to gastric diverticulum; (6) gastrosplenic branch of splenic artery (gastric branches homologous to short gastric arteries); (7) esophageal branch of left gastric artery; (8) left gastroepiploic artery; (9) right gastroepiploic artery; (10) torus pyloricus; (11) right gastric artery; (12) branches of hepatic artery to liver and gallbladder; (13) branches of hepatic artery to left lobe of pancreas; (14) gastroduodenal artery; (15) cranial pancreaticoduodenal artery to descending duodenum and right lobe of pancreas; (16) hepatic artery.

It should be obvious at this point that the grooves on the outside of the rumen correspond with the pillars on the inside, which carry the same designations. The ruminal pillars represent in-foldings and thickenings of the muscular wall. Identify the **recess of the rumen**, which is that part of the ventral sac below the cranial pillar (Fig. 4-31). The ruminal recess is not considered a true blind sac because it is not

demarcated by coronary pillars. Although a caudodorsal blind sac is usually described in small ruminants, the absence of dorsal coronary pillars in the sheep and the goat makes this a poorly defined area in these animals.

The nonglandular, stratified squamous mucosa of the rumen is characterized by the presence of closely packed, tongue-shaped **ruminal papillae**, which give it the appearance of *Astroturf* (or should I say *gastroturf*). The papillae are longer and more prevalent in the ventral and cranial sacs, where the fluid and more finely divided ingesta settle. In contrast, the papillae are sparse in the dorsal part of the dorsal sac, where gas and the lighter, unmasticated food material accumulate. (As you well know, ruminants have an "eat now, chew later" plan.) Ruminal papillae create a many-fold increase in the absorptive surface area. In addition, the carpet-like lining aids in mixing the fermenting mass, continuously bringing new ingesta in contact with the stomach wall as it is slowly churned and kneaded by the *relentless* ruminal contractions.

The ruminoreticular groove corresponds with the internal **ruminoreticular fold** (Fig. 4-31), which forms an incomplete division between rumen and reticulum. It is because the **ruminoreticular opening** is so large that these two compartments are often considered together, both anatomically and physiologically, as the ruminoreticulum. *Open the reticulum and examine its characteristic honeycomb lining. Be careful as you are removing the reticular contents because you may find foreign bodies (e.g., nails, wire) in this area.*

Ruminants are generally indiscriminate eaters and don't chew their food well at the time of ingestion. The lining of their oral cavity is so tough that they frequently overlook even relatively large foreign objects that would have been surely detected by a more discriminating eater.[23]

The **cardia**[24] is actually located in the reticulum, not in the rumen. Anatomists almost invariably state that the esophagus enters at the junction of rumen and reticulum. Notice, however, that the cardia is located cranial to the dorsal part of the ruminoreticular fold (Fig. 4-31). If we believe that this fold separates rumen from reticulum, and that the esophagus does in fact enter on the reticular side of said fold, then it would certainly follow that the esophagus enters the reticulum.

The momentum of the coarse, light material that is propelled through the cardia with reasonable velocity undoubtedly clears the ruminoreticular fold and enters the rumen. On the other hand, heavy objects such as nails, spark plugs, or flashlight batteries more probably fall out of the cardia into the reticulum, where they may reside for life.[25]

---

[23] To date, the largest foreign object I have encountered in the laboratory was an empty pint liquor bottle that one group of students tried to convince me they had found in the reticulum of their cadaver. I still have my doubts about that- a half-pint maybe, but not a full pint.

[24] cardia- opening of the esophagus into the stomach, so named because of its proximity to the heart.

[25] The collection of nails, wire, bolts, nuts, washer, etc. in this part of the stomach has even led to a common name, "hardware," for the reticulum (*NAA Nomina Anatomica Abattoir*).

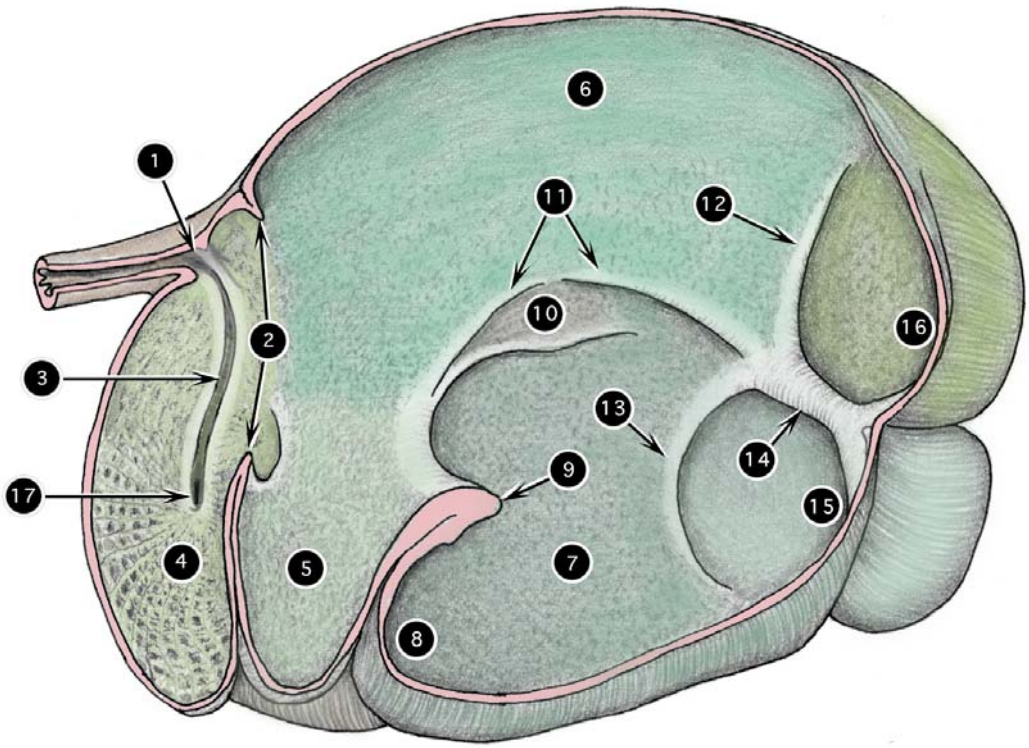


Figure 4-31. Internal features of ruminoreticulum of adult ox, left lateral view: (1) cardia; (2) ruminoreticular fold; (3) reticular groove; (4) reticulum; (5) cranial sac of rumen; (6) dorsal sac of rumen; (7) ventral sac of rumen; (8) recess of rumen; (9) cranial pillar of rumen; (10) insula ruminis (area of right ruminal wall between dorsal and ventral branches of right longitudinal pillar); (11) of right longitudinal pillar of rumen; (12) right dorsal coronary pillar of rumen; (13) right ventral coronary pillar of rumen; (14) caudal pillar of rumen; (15) caudoventral blind sac of rumen; (16) caudodorsal blind sac of rumen; (17) reticulo-omasal opening.

Now consider the consequences of having a nail wedged into the honeycomb cells of the reticulum and then squeezed by the reticular contractions. Even though the lining is pretty tough, sharp objects frequently penetrate the reticular wall and cause pain and infection (traumatic reticulitis). With continued contractions, the object may, of course, migrate out of the reticulum and penetrate other neighboring organs, such as the liver. It may also penetrate the diaphragm, carrying with it a healthy supply of organisms, and puncture some other relatively vital structures such as the lung, the pericardial sac (traumatic pericarditis), and even the heart itself.

Under conditions in which there is an abundance of metallic debris in the pasture, particularly with dairy cattle that spend a good deal of time hanging around the barn, it used to be a common *preventative* practice to give the cows a *reticular magnet* (Fig. 4-32). The rationale for this practice is to hold these objects out in the lumen of the reticulum, where they are less likely to penetrate the wall and hopefully will rust away eventually. (Unfortunately, most roofing nails are galvanized.) The reticulum of the sheep and that of the goat, are proportionately smaller than that of the ox.



Figure 4-32. Reticular magnet removed from cow in anatomy laboratory. Note metallic debris that had been collected by magnet.

Return now to the cardia. The more observant students have undoubtedly noticed by now that there is a distinct groove beginning at the cardia and spiraling down the reticular wall, where it appears to end abruptly. Actually, it doesn't end here at all but leads to the reticulo-omasal opening (Fig. 4-31/17). This groove is the first part of the gastric groove, and because this segment is located in the reticulum, it is more specifically termed the **reticular groove**.[25] Do not confuse the ruminoreticular groove (Fig. 4-6/3), an external feature of the ruminant stomach, with the reticular groove, an important internal structure.

Because the reticular groove plays an important role in the suckling animal, the newborn calf should receive special attention here. When the young ruminant suckles milk, it initiates a strong (vagal) reflex closure of the muscular lips of the reticular groove, converting it from a groove to a tube (Fig. 4-33). Simultaneously, there is dilation of the reticulo-omasal opening and omasal groove so that, ideally, the milk completely bypasses the forestomach and is delivered directly to the abomasum, where the digestive enzyme rennin is secreted.

Initiation of the reflex is brought about by several factors: physical, chemical, and psychological. Physical factors include the act of sucking from a teat versus drinking from a bucket or trough*; sucking and drinking are different*, and closure occurs more quickly during sucking. Chemical stimulation involves receptors in the mouth and pharynx that are sensitive to certain salts present in milk, which stimulate the strong vagal reflex that closes the groove.

Psychological factors are related to the great pleasure and delight in *sucking*, as opposed to just *thirst*. Have you ever seen a calf wag its tail when drinking water from a trough? Even in the adult ruminant, certain chemicals such as copper sulfate have been used to direct medication to the abomasum, but the effects of specific salts vary among ruminant species.

Now let's consider the movement of ingesta in the ruminoreticulum of the adult ruminant. As noted, the ruminant has an eat now, chew later plan. Not taking time to chew obviously gives the ruminant the competitive advantage of being able to ingest large quantities of food in a relatively short time. Thus ruminants, and particularly the family Bovidae, have been very successful as evidenced by the total number of modern species (Fig. 1-33). Once they have ingested it, they have essentially captured that food for their own use.

On initial ingestion of roughage, the material is merely "chomped" a few times, formed into a quick bolus, and swallowed. When it arrives at the cardia, it is still coarse and relatively lightweight, so it is propelled into the dorsal part of the rumen. Here, the material more or less floats around on the fluid tide and accumulates as the animal continues to graze or eat. Sooner or later, the animal becomes full and goes to lie down or rest in the shade for chewing, a process known as rumination.

[25] Note: I did not say or imply in any way that this was the *esophageal groove*. It is not part of the esophagus, does not form from the esophagus, and does not belong to the esophagus.

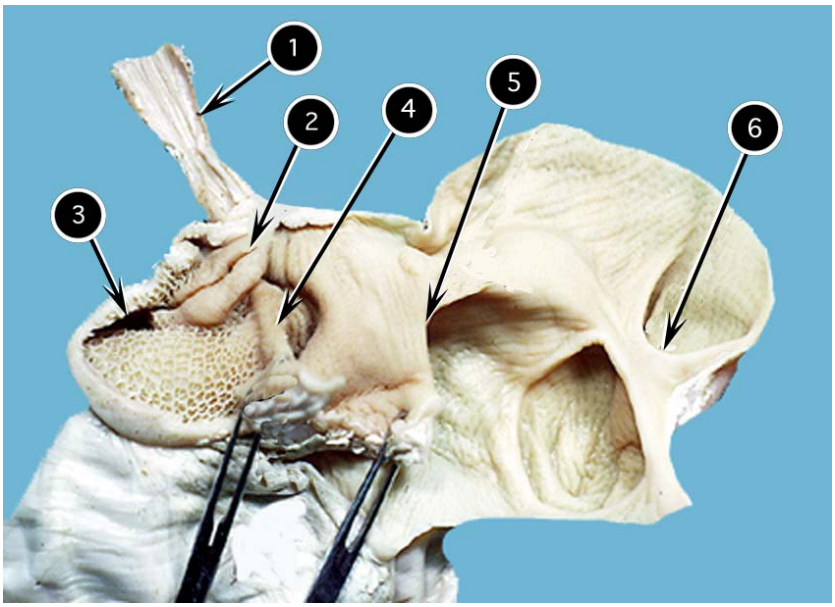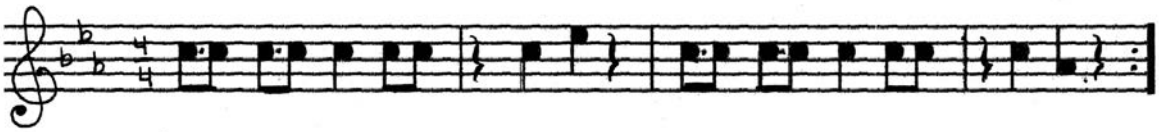


Figure 4-33. Internal features of ruminoreticulum of newborn calf, left lateral view: (1) esophagus; (2) reticular groove, extending from cardia to reticulo-omasal opening; (3) reticulum; (4) ruminoreticular fold; (5) cranial pillar of rumen; (6) caudal pillar of rumen. Closure of the reticular groove during suckling diverts milk past the ruminoreticulum, where it continues *via* the dilated omasal groove directly to the abomasum.

The tunica muscularis of the ruminant esophagus, like that of the dog, is composed of skeletal muscle, some of which even radiates out over the ruminoreticulum. The skeletal muscle facilitates rapid transport of material in both directions in the esophagus. Normally, rhythmic ruminoreticular contractions (motility) occur at a rate of about two cycles per minute and are regulated by vagal nerve stimulation. Every other ruminal contraction is preceded by a double contraction of the reticulum, whereas, the other ruminal contraction is followed by an eructation of gas from the ruminoreticulum. The beat goes something like this:



tica tica, room and a room, burp tica, tica, room and a room, burp[26]

(Musical score kindly provided by Kristen Rowlingson, NC State DVM, Class of 2002)

Ruminoreticular motility can be observed and palpated in the living animal by placing your hand in the left paralumbar fossa. The ruminal contraction begins in the cranial sac, passes across the dorsal sac, and then to the ventral sac. When the latter contracts, the paralumbar fossa bulges from the increased pressure in the dorsal sac. During eating, the tempo typically picks up to about three cycles per minute.

As any of you who have ever made wine or spent time with a ruminant in a closed environment know, fermentation is a

[26] *tica* = reticular contraction; *room* = ruminal contraction; *burp* = eructation (belch)

gaseous process. In order for fermentative digestion to continue, these gases must be expelled, normally by eructation. Anything that interferes with the normal eructation of gas from the ruminoreticulum leads to distention of the organ with gas (bloat). This clinical sign can have numerous causes, including obstruction of the esophagus, interference with vagal stimulation, or the production of foam-like gas bubbles in the rumen, which cannot be expelled by eructation.

During rumination, the animal regurgitates material from its ruminoreticulum, chews it, and then re-swallows it. Because the unmasticated, coarsely divided material is light, it floats on the fluid tide of the ruminoreticulum and is thus presented to the cardia when the animal regurgitates. The rapid movement of the bolus up the esophagus can be observed in the living animal from the left side of the neck. Once the *cud*[27] has been thoroughly chewed (≈ 40-60 chomps or more), it is re-swallowed, and a new bolus is regurgitated.

The masticated bolus that enters the ruminoreticulum is more finely divided and has a higher *specific gravity*. Thus, it sinks rather quickly to the more ventral part of the rumen, where the papillae are best developed (Fig. 4-34). As fatty acids and sodium are released by fermentative digestion, they are absorbed here- that is, the products of fermentative digestion are continuously removed, and the process goes on.

In effect, then, the ruminoreticulum not only acts like a mixer but also functions as a separator of the ingesta based on specific gravity. Urged along by ruminal contractions, the heavier ingesta makes its way from the ventral sac, through the cranial sac, and over the ruminoreticular fold to reach the reticulum. Absorption of fatty acids and sodium continues. The unique lining of the reticulum also functions as a sort of quality- control separator. The cells of the reticulum separate the finely divided material from the coarser ingesta. By contractions of the reticulum, the coarse material (not ready for prime time) is kicked back into the cranial sac of the rumen, whereas the finer ingesta is presented to the reticulo-omasal orifice, where it is carried into the omasum.

Using a large knife, remove a section of the omasum to expose the omasal groove and pillar (Figs. 4-8 & 4-35). Because of its rather complex internal structure, function of the omasum is difficult to study in the living animal and is, therefore, sort of the "black box" of the forestomach. Note that the **omasal laminae** vary in size from very short ones to those that actually reach the omasal groove (Fig. 4-8), in effect converting it into an omasal canal. The laminae are studded with rough papillae, which give them the look of very coarse sandpaper.

It was once believed that this design produced mechanical abrasion of the ingesta, and that the omasum functioned as a sort of grinder, similar to the gizzard of a bird. Research has not supported this contention, and physiologists now believe that the omasum functions as a two-stage pump in the transfer of ingesta from the reticulum to the abomasum. During the first stage, ingesta is aspirated from the reticulum by contraction and dilation of the **omasal groove**, which is coordinated with ruminoreticular contractions. The more fluid part of the aspirate is forced into the

[27] cud- common name for regurgitated bolus of ruminant. It is not an anatomic structure. Some folks used to believe that if a cow ever lost her cud, she would surely die. Actually she stopped chewing her cud because she was sick- and then she died.

interlaminar recesses, but the coarser material is captured by the laminae and can be kicked back into the reticulum (another quality-control separation). The second stage involves contraction of the omasal body, which is independent of ruminoreticular contractions, and forces omasal contents into the abomasum. Absorption of fatty acids, sodium, and water continues in the omasum. Note that the omasum of the goat (and sheep) is more oval and proportionately smaller than that of the ox.

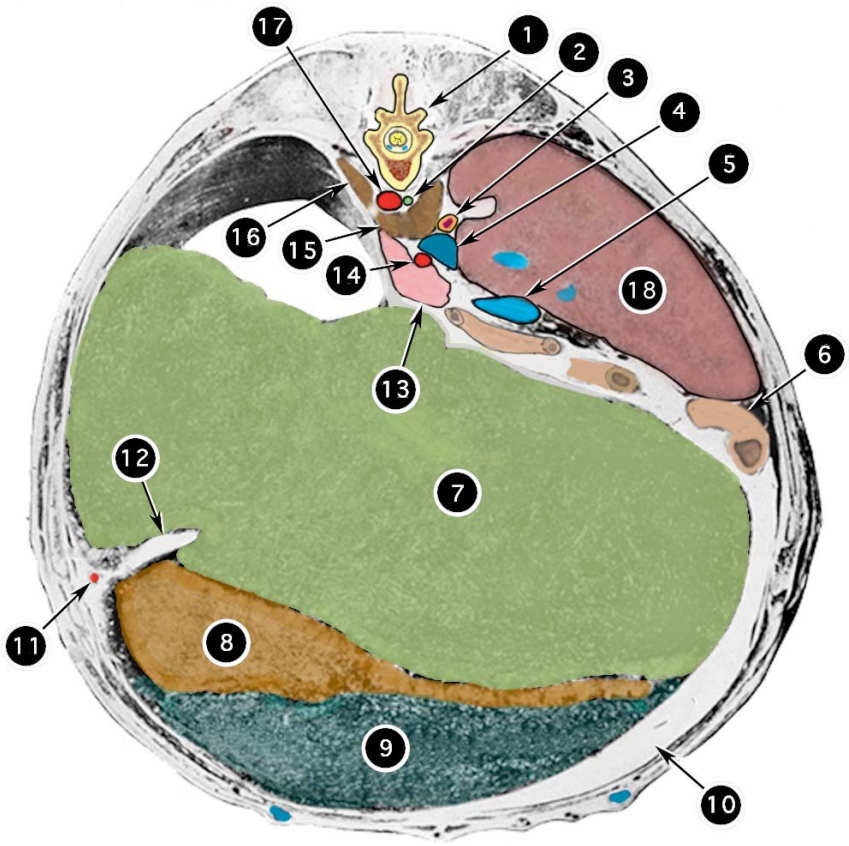


Figure 4-34. Transverse section through cow at level of T13, caudal view: (1) thoracic vertebra 13; (2) thoracic duct; (3) right adrenal gland; (4) caudal vena cava; (5) portal vein; (6) cranial part of duodenum; (7) hay from morning feeding; (8) grain from morning feeding; (9) feed from preceding day; (10) fat-filled greater omentum; (11) left ruminal artery; (12) cranial pillar of rumen; (13) pancreas; (14) celiac artery; (15) right curs of diaphragm; (16) left crus of diaphragm; (17) aorta; (18) liver. (Modified from *The Anatomy of Domestic Animals*, 4th Ed., Sisson and Grossman, W. B. Saunders, Co., 1953, p. 469.)

Carried with the ingesta that enters the abomasum is a healthy supply of fermentative organisms that helped the ruminant convert cellulose into volatile fatty acids. It is now time for the ruminant to repay its microbial friends for all their fermentative assistance by promptly digesting them. (Not everyone who provides you with a warm, happy environment is your friend.) This represents one of the major advantages of plan A over plan B- fermentative digestion precedes hydrolytic digestion. Such an arrangement enables ruminants to capitalize on the fact that the microbes of the forestomach convert non-protein nitrogen (*e.g.*, in the form of urea) to microbial protein, which can then be digested and used by the host. (Hey, who said cows were dumb animals?)

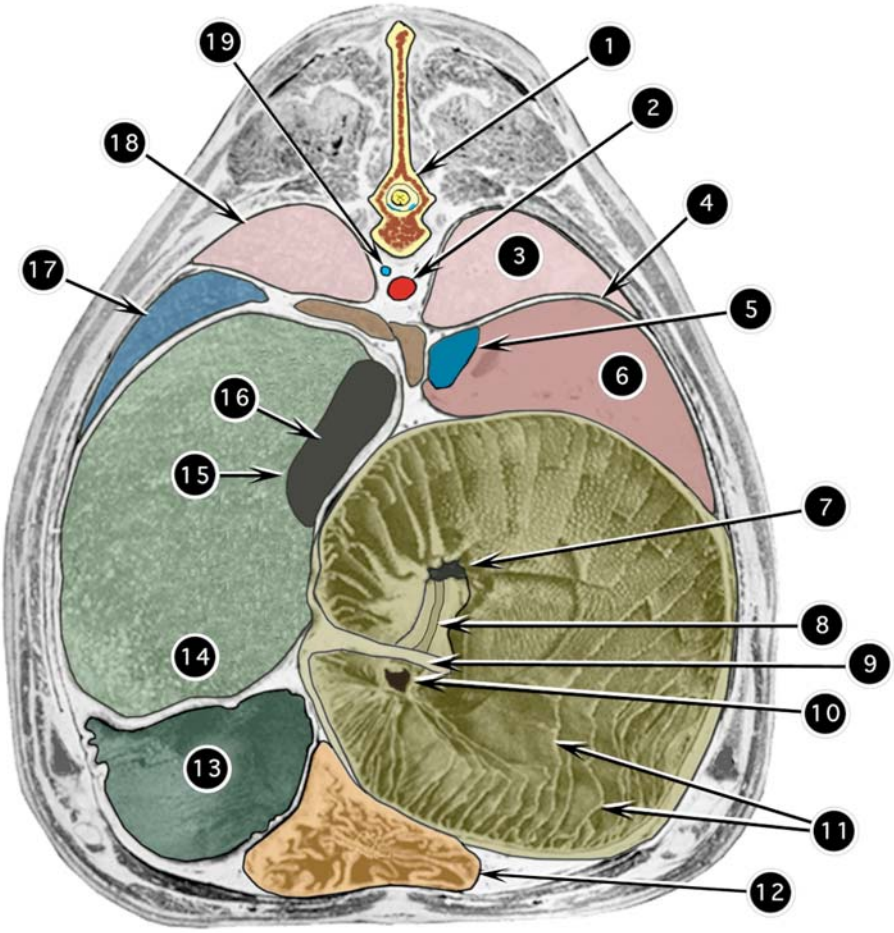


Figure 4-35. Transverse section through cow at level of T9, caudal view: (1) thoracic vertebra 9; (2) aorta; (3) right lung; (4) diaphragm; (5) caudal vena cava; (6) liver; (7) reticulo-omasal opening; (8) omasal groove; (9) omasal pillar; (10) omasoabomasal opening; (11) omasal laminae; (12) body of abomasum with spiral folds; (13) recess of rumen; (14) cranial sac of rumen; (15) ruminoreticular fold; (16) ruminoreticular opening; (17) spleen; (18) left lung; (19 left azygos vein. (Modified from *The Anatomy of Domestic Animals*, 4th Ed., Sisson and Grossman, W. B. Saunders, Co., 1953, p. 467.)

Open or remove a section of the wall of the abomasum. Cut along the greater curvature and out through the pyloric sphincter. Locate the knob-like **torus pyloricus**, which, as previously noted, is also present in the pig (Fig. 4-30) and assists in closure of the pylorus. Depending on the nursing history of the newborn calf, the abomasum may contain curdled milk, which should be removed. (Don't call an instructor over at this point. Just get rid of the stuff.)

Coagulation of the milk results from the action of the enzyme rennin, which accounts for a common name for the abomasum, the rennet. Calling it the "true stomach" is a bit ridiculous, because there is only one stomach per animal and the other parts are real too.

The dominant internal feature of the abomasum is the presence of about a dozen permanent mucosal elevations known as **spiral folds** (Figs. 4-8 & 4-35), which are best developed in the body and fundus regions. At the omasoabomasal opening, two of these folds form a valve-like protrusion, the vela abomasica, which

projects back into the opening and helps prevent reflux into the omasum.

The region of the proper gastric glands (Fig. 4-21) corresponds to the area of the spiral folds, the fundus and body of the abomasum. The pyloric gland region is characterized by less prominent gastric folds or rugae.

Note the normal position of the body of the abomasum and observe that it is not firmly fixed in this position. Displacement of the abomasum is a relatively common clinical problem, especially in dairy cattle that are on a relatively low-roughage diet. Particularly when the abomasum is compressed (kinked) and the rumen has been displaced by a gravid uterus, the abomasum may slip under the rumen. Then, because of gas trapped in the organ, and assisted by ruminal contractions, the abomasum is buoyed dorsally between the rumen and left abdominal wall. This condition, referred to as a **left displaced abomasum** (LDA), typically requires surgical correction. It can be diagnosed by a combination of percussion and auscultation.

The gas trapped in the distended LDA produces a distinct "ping" that can be heard with the stethoscope when the patient is tapped over the area where the distended abomasum is in contact with the left abdominal wall (usually at about the eleventh ICS). It sounds like someone thumping the end of an empty coffee can.[28] Less often, the abomasum may rotate toward the right side and produce a right displaced abomasum (RDA).

As noted, the complex and coordinated contractions of the ruminant stomach are regulated by impulses carried by the vagal nerves. Distribution of the dorsal and ventral vagal trunks need not be dissected. The **dorsal vagal trunk** is primarily responsible for parasympathetic innervation of the rumen, but it also contributes branches to the omasum and abomasum. The **ventral vagal trunk** is distributed more to the reticulum, omasum, and abomasum. Thus, the integrity of vagal innervation is critical to proper function of the complex ruminant stomach. Damage to these nerves creates major disturbances in gastric motility, which may be fatal. For a more detailed discussion of vagal indigestion, see deLahunta and Habel.[29]

BLOOD SUPPLY TO GI TRACT

Basic Mammalian Pattern: It is important that students refresh their understanding of the basic distribution of arterial supply to the GI tract as studied in the dog (Fig. 4-36). Once that has been reviewed and understood, the arterial modifications of the ungulates can be seen to represent logical adaptations of the blood supply to modifications of the GI tract. It is not essential for you to trace every vessel by dissection, but it is important that you be able to identify the arterial supply by its location on the GI tract.

Celiac[30] Artery: The celiac artery (Fig. 4-36) is primarily responsible for supplying the stomach, liver, spleen, and pancreas. Its three major branches are as follows:

Left Gastric Artery: The left gastric artery (Fig. 4-36) is typically the smallest branch. It goes to the area of the cardia; from there it courses distally in the lesser

[28] OK, I know most coffee doesn't come in cans anymore, so use another can.

[29] de Lahunta, A., and Habel, R.E.: *Applied Veterinary Anatomy*. W.B. Saunders, Co., Philadelphia, 1986.

[30] celiac- pertaining to the coelom or body cavity.

curvature of the stomach. In the pig, the left gastric typically arises from the splenic artery (Fig. 4-30).

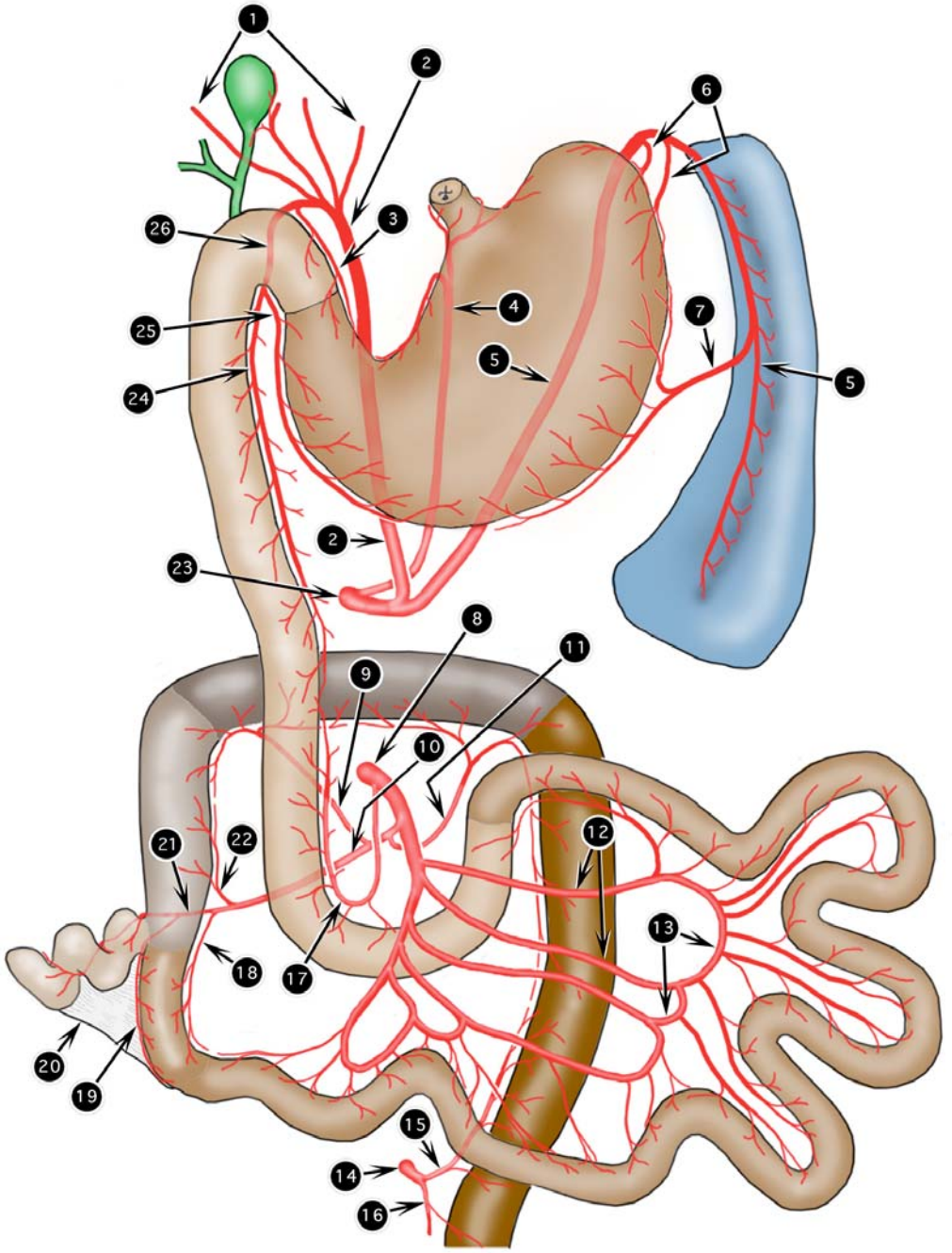


Figure 4-36. Semischematic distribution of branches of celiac, cranial mesenteric, and caudal mesenteric arteries of dog, ventral view: (1) branches of hepatic artery to liver; (2) hepatic artery; (3) right gastric artery; (4) left gastric artery; (5) splenic artery; (6) short gastric arteries; (7) left gastroepiploic artery; (8) cranial mesenteric artery; (9) right colic artery; (10) ileocolic artery; (11) middle colic artery; (12) jejunal arteries; (13) anastomotic arches between jejunal arteries; (14) caudal mesenteric artery; (15) left colic artery; (16) cranial rectal artery; (17) caudal pancreaticoduodenal artery; (18) mesenteric ileal branch of ileocolic artery; (19) antimesenteric branch of ileocolic artery; (20) ileocecal fold; (21) cecal branch of ileocolic artery; (22) colic branch of ileocolic artery; (23) celiac artery; (24) cranial pancreaticoduodenal artery; (25) right gastroepiploic artery; (26) gastroduodenal artery.

Hepatic Artery: The hepatic artery (Fig. 4-36) courses directly to the hepatic porta, gives off its **hepatic branches**, and then turns to the area of the cranial duodenal flexure. Here it gives rise to the **right gastric artery**, which courses proximally in the lesser curvature to join the left gastric artery and the **gastroduodenal artery**. The latter artery gives rise to the **right gastroepiploic artery**, which follows the greater curvature of the stomach, and continues as the **cranial pancreatico-duodenal artery**.

Splenic Artery: The splenic artery (Fig. 4-36) does more than supply the spleen. The **short gastric arteries** and the **left gastroepiploic artery** turn back to the stomach. The short gastric arteries supply the fundic area of the stomach, and the left gastroepiploic courses distally along the greater curvature to join the right gastroepiploic.[31]

Cranial Mesenteric Artery: The cranial mesenteric artery is primarily responsible for supplying the **small intestine** and most of the **large bowel**. Its major branches are distributed as follows:

Caudal Pancreaticoduodenal Artery: This artery (Fig. 4-36) arises from the cranial mesenteric and anastomoses with the cranial pancreaticoduodenal artery.

Jejunal Arteries: These arteries supply the jejunum and are interconnected to one another by anastomotic arches (Fig. 4-36); from these arches a variable number of smaller arteries continue to the jejunum. In the pig, there are literally hundreds of these secondary arteries to the gut (Fig. 4-29).

Ileocolic Artery: The ileocolic artery (Fig. 4-36), which would be more correctly termed the ileocecocolic in our domestic mammals, supplies the ileum, cecum, and through its colic branch, the proximal (ventral) part of the ascending colon. The antimesenteric branch of the ileocolic artery is not present in some species, and the use of this vessel to define the ileum is a poor choice when it is not present. The ileocecal fold is consistent (better) marker, with or without an artery.

Right Colic Artery: The right colic artery (Fig. 4-36) goes to the area of the right colic flexure and sends branches proximally and distally. Importantly, it gives the blood supply to the distal half of the ascending colon, which becomes the dorsal colon of the horse and centrifugal coils of the spiral colon of artiodactyls.

Middle Colic Artery: **The middle colic artery** (Fig. 4-36) goes to the area of the left colic flexure and sends branches proximally and distally. Each branch anastomoses with its neighbors, including the left colic from the caudal mesenteric artery.

Arterial Pattern of Horse: The celiac artery is distributed like that of the dog, a large dog perhaps, but a dog (Fig. 4-36). Modifications of the cranial mesenteric artery follow modifications of the large bowel. Enlargement of the cecum requires both **lateral** and **medial cecal arteries** from the ileocolic (Fig. 4-37).

Draw out the pelvic flexure and dissect away enough of the mesocolon to identify the major arteries. Enlargement of the ascending colon results in the **colic branch of the ileocolic artery** supplying the ventral colon (proximal part) and the **right colic artery** supplying the dorsal colon (distal part). The middle and left colic arteries

[31] gastric *vs*. gastroepiploic- shorter name, shorter curvature; longer name, longer curvature; epiploic- pertaining to the *epiploon* (omentum).

supply primarily the transverse and descending colon, respectively (Fig. 4-37).

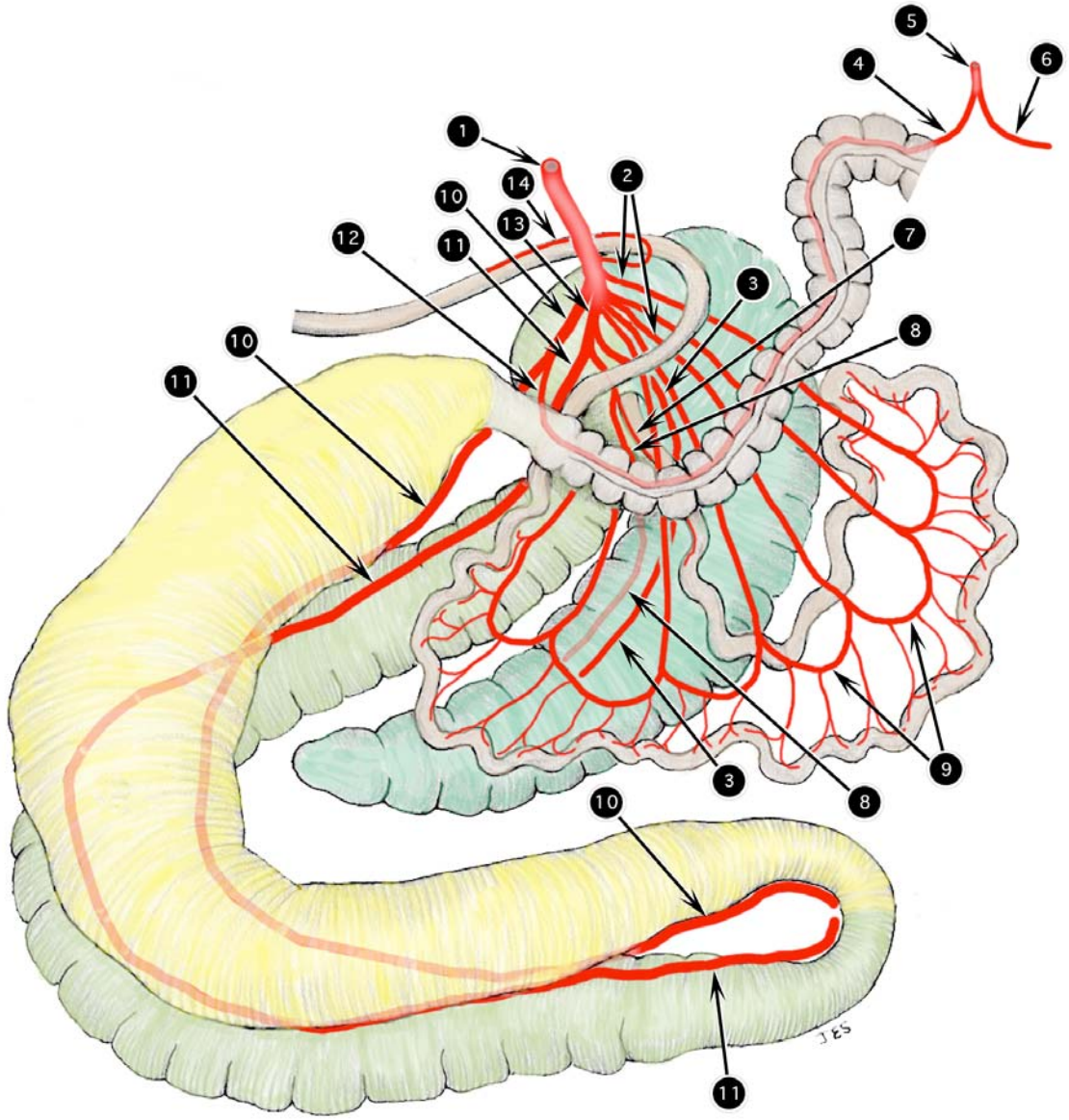


Figure 4-37: Semischematic distribution of branches of cranial mesenteric and caudal mesenteric arteries of horse, left lateral view: (1) cranial mesenteric artery; (2) jejunal arteries; (3) medial cecal artery; (4) left colic artery; (5) caudal mesenteric artery; (6) cranial rectal artery; (7) ileal branch of ileocolic artery; (8) lateral cecal artery; (9) anastomotic arches between jejunal arteries; (10) right colic artery; (11) colic branch of ileocolic artery; (12) middle colic artery; (13) ileocolic artery; (14) caudal pancreaticoduodenal artery.

Arterial Pattern of Pig: The celiac artery is distributed much like that of a dog except that the left gastric artery is a branch of the splenic (Fig. 4-30). There is also a branch of the splenic supplying the gastric diverticulum, and the short gastric arteries arise from a gastrosplenic branch of the splenic. Again, modification of the ascending colon necessitates the same for the arteries. The **colic branch of the ileocolic artery** supplies the centripetal coils (proximal part) and the **right colic artery** supplies the centrifugal coils and distal loop (Fig. 4-29).

Arterial Pattern of Ruminant: Although the branches of the ruminant celiac artery do not require detailed dissection and study, it should be noted that there are numerous similarities to the typical pattern present in simple-stomached mammals (Fig. 4-36). The celiac artery divides into the three typical branches. Refer to figure 4-38 to obtain a general understanding of the modified pattern of the **celiac branches** that is present in ruminants.

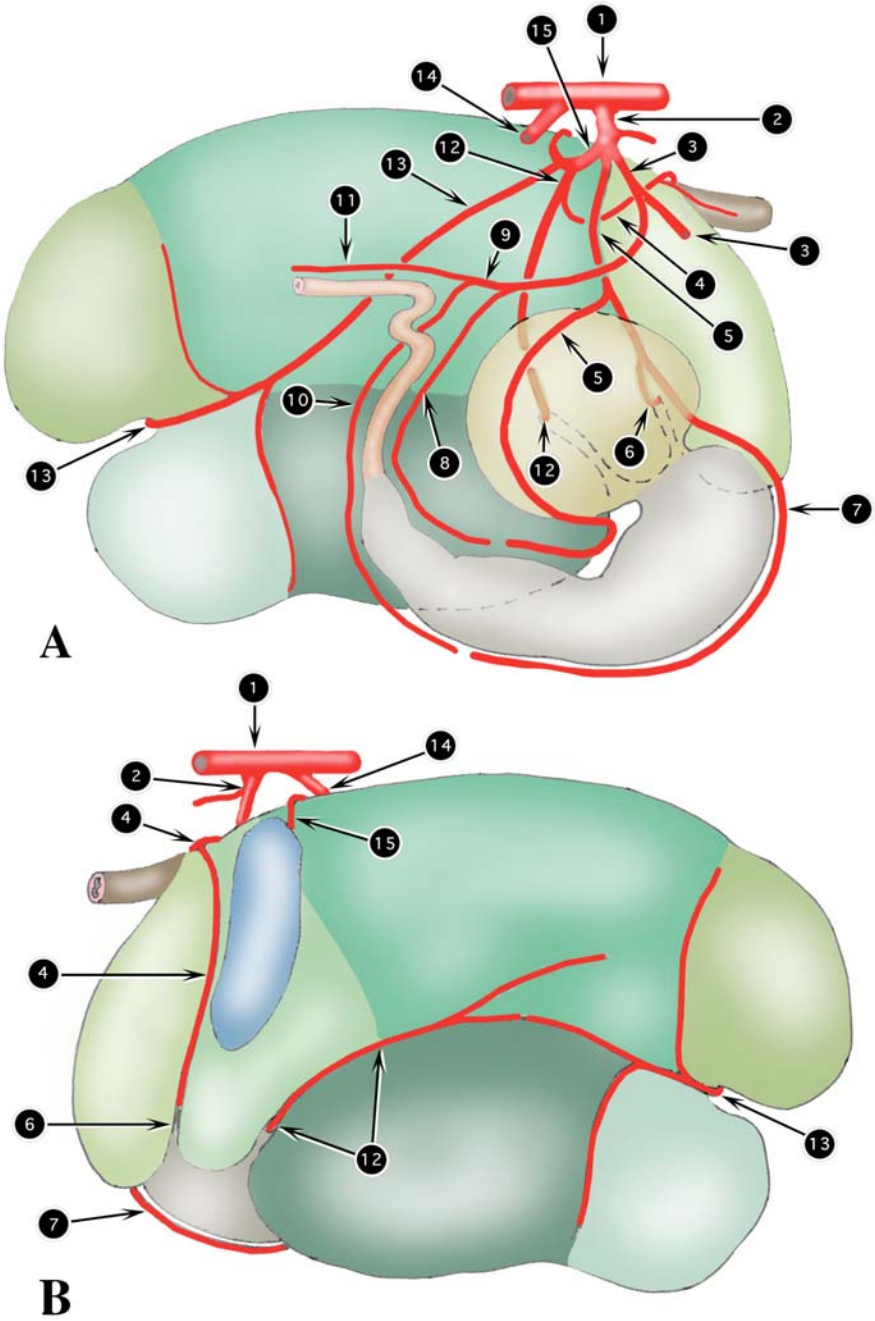


Figure 4-38. Schematic representation of major branches of celiac artery of ox; **(A)** right lateral view; **(B)** left lateral view: (1) aorta; (2) celiac artery; (3) hepatic artery; (4) reticular artery; (5) left gastric artery; (6) accessory reticular artery; (7) left gastroepiploic artery; (8) right gastric artery; (9) gastroduodenal artery; (10) right gastroepiploic artery; (11) cranial pancreaticoduodenal artery; (12) left ruminal artery; (13) right ruminal artery; (14) cranial mesenteric artery; (15) splenic artery.

The omasum and lesser curvature of the abomasum represent parts along the lesser curvature of the embryonic stomach primordium (Fig. 4-21), and these parts are supplied by the **left and right gastric arteries**. Similarly, the ruminoreticulum and greater curvature of the abomasum represent parts of the original greater curvature and are supplied primarily by branches of the **left and right gastroepiploic arteries**, and from branches of the **splenic artery**.

Note that the **right and left ruminal arteries**, which are homologous to the short gastric arteries of simple-stomached mammals, occupy their respective longitudinal grooves of the rumen. The branches are most easily followed in the calf or goat.

Modifications of the **cranial mesenteric artery** follow modifications of the large bowel. Like those of the pig, the **colic branch of the ileocolic artery** supplies the centripetal coils (proximal part) and the **right colic artery** supplies the centrifugal coils (Fig. 4-28). In the ox, but not in the small ruminants, a large **collateral branch** (Fig. 4-28) leaves the cranial mesenteric artery, crosses the right side of the spiral colon, and rejoins the main artery distally.

KIDNEYS

Although the kidneys of our domestic mammals look a bit different on the surface, they are not all that different. They are all composed of the same functional unit, the **nephron**- it's just a difference in packaging. The kidneys of cetaceans (whales and dolphins) exhibit the least amount of fusion in that their nephrons are packaged into a hundred or so small units, or reniculi. Embryologically, the kidneys of the domestic mammals undergo some fusion, and basically the differences in the degree of fusion account for the variation in their shape and structure. Let's proceed from the least amount of fusion to the most, beginning with the kidney of the ox.

Kidney of Ox: Locate the right kidney of the ox. As you recall, its cranial extremity is "caressed" by the caudate process of the liver (Figs. 4-8 & 4-9). Unless the animal is extremely emaciated, the kidneys are surrounded and cushioned by a considerable quantity of perirenal fat, or suet, typically described as the adipose capsule of the kidney. *Remove enough of this fat to expose the kidney.* The first thing you notice is that the kidney is "knobby" (Fig. 4-39).

Remove the right kidney, including the renal artery, vein, and proximal part of the ureter. Place the kidney on a cutting board, and using a large knife, section the organ longitudinally through the hilus so as to divide it into dorsal and ventral halves.

The kidney of the ox retains much of its embryonic lobation, even in the adult. Nephrons are packaged into about 20 or so units known as **lobes**, each consisting of a cortical cap over a medullary **pyramid** (Fig. 4-40). The apex of the pyramid is termed the **renal papilla**, and it is here that the large urine-collecting ducts, the **papillary ducts**, open. If you look closely, you should note that some of the larger lobes actually represent a fusion of more than one lobe that share a common renal papilla, but there is no fusion of renal papillae to form a ridge. **Thus, no renal crest is present**.

Each renal papilla projects into a funnel-like collecting chamber called a **calix**. From the calix, the urine enters one of **two major branches** (cranial and caudal) of the **ureter**. There is no central urine-collecting chamber, so no renal pelvis is present. You might

notice that I did not say that the bovine kidney was divided into distinct *lobules*. It is divided into lobules, but these are small radiating slivers of cortical tissue that are separated from one another by the **interlobular arteries**, from which the afferent arterioles arise. Thus, the divisions we see on the surface of the bovine kidney are lobes, not lobules. To say that a bovine kidney is lobulated is not really wrong, but is sort of misinformation. What you really mean to say is that the bovine kidney is distinctly lobate.

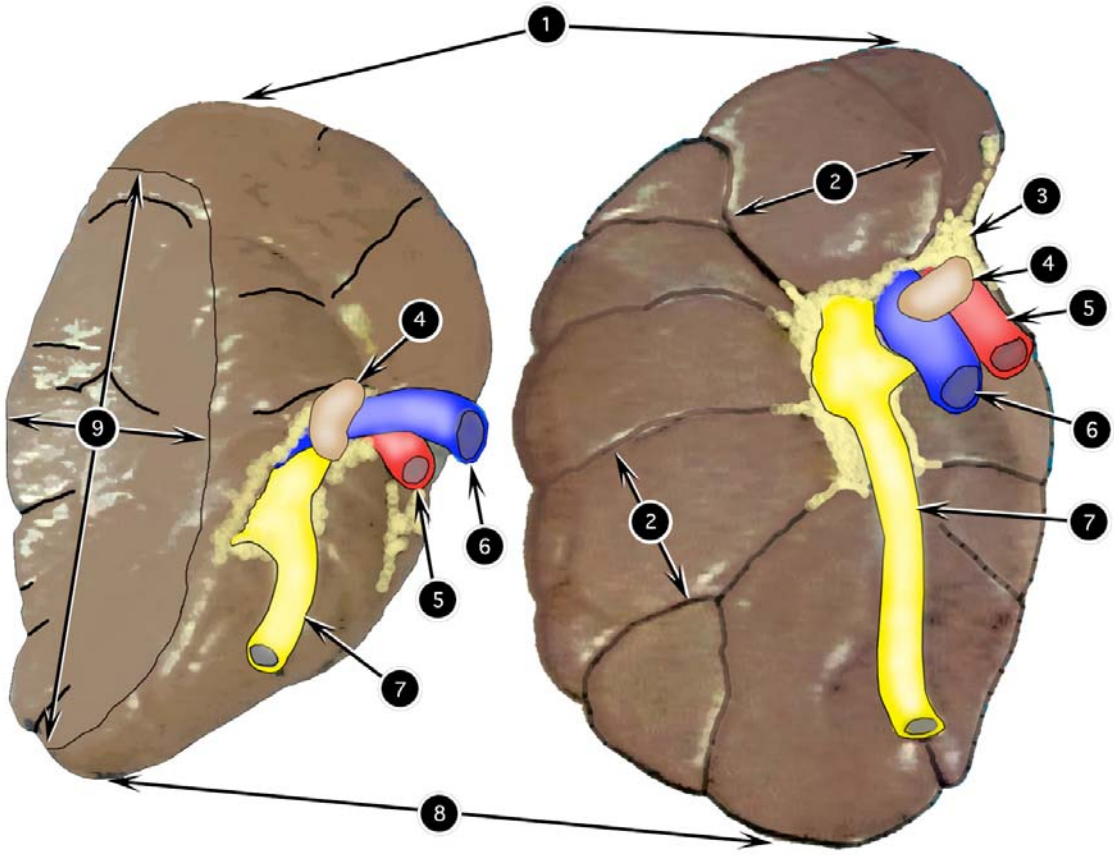


Figure 4-39. Left and right kidneys of ox: (1) cranial extremities of kidneys; (2) one lobe of kidney; (3) perihilar fat; (4) renal lymph node; (5) renal artery; (6) renal vein; (7) ureter; (8) caudal extremities of kidneys; (9) flattened surface of left kidney produced by contact with dorsal sac of rumen.

In the newborn calf, the left kidney is closely associated with the sublumbar muscles and, as expected, is located to the left of the median plane. Because of the tremendous growth of the rumen, however, the left kidney of adult ruminants is displaced toward the right side of the abdominal cavity. This displacement is accompanied by a longitudinal, pendulum-like rotation of the kidney, so that the **hilus** is directed dorsally.

The location of the pendulous left kidney varies with the fullness of the rumen, and when the dorsal sac is filled, the left kidney lies to the right of the median plane, caudoventral to the right kidney. The surface of the left kidney that is in contact with the rumen becomes flattened, so that the fixed (hardened) left and right kidneys of the adult ox can usually be differentiated after removal from the animal (Fig. 4-39).

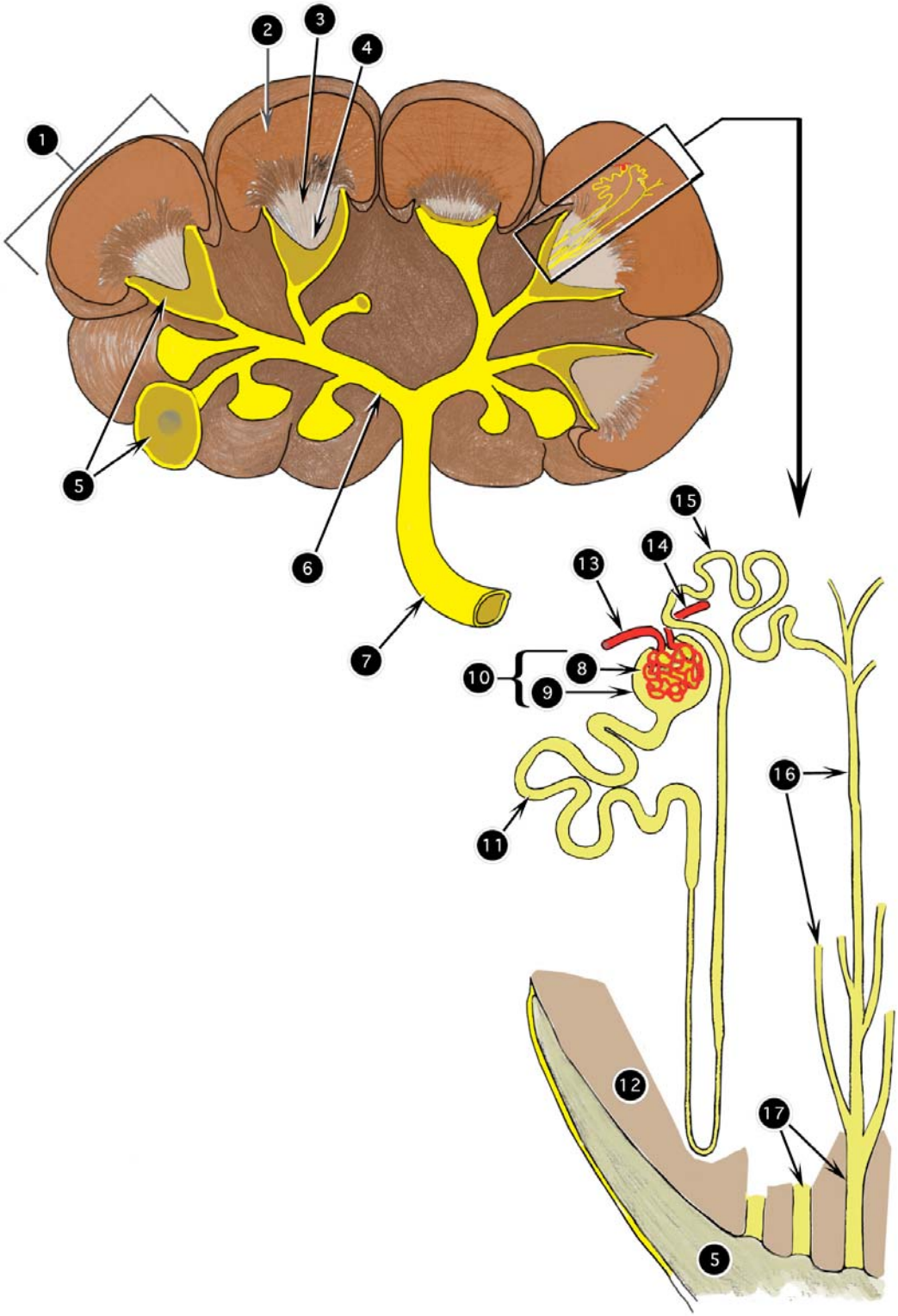


Figure 4-40. Schematic representation of bovine kidney with enlargement of nephron: (1) lobe of kidney consisting of cortical cap and medullary pyramid; (2) cortex; (3) medullary pyramid; (4) renal papilla projecting into calix; (5) calices; (6) cranial branch of ureter; (7) ureter; (8) glomerulus; (9) glomerular capsule; (10) renal corpuscle; (11) proximal convoluted tubule; (12) loop of nephron; (13) afferent arteriole; (14) efferent arteriole; (15) distal convoluted tubule; (16) collecting ducts (17) papillary ducts opening on renal papilla.

Kidney of Pig: As noted, the right kidney of the pig does not contact the liver as in other domestic mammals. *Remove enough of the perirenal fat to expose the right kidney. Remove the kidney, including the renal artery, vein, and proximal part of the ureter. Place the kidney on a cutting board, and using a large knife, section the organ longitudinally through the hilus so as to divide it into dorsal and ventral halves.*

Embryonic fusion has resulted in a smooth surface with no external indication of lobation. On cut section, however, lobation is evidenced by a lack of medullary fusion and by the retention of individual renal papillae (Fig. 4-41). Each renal papilla is surrounded by a **minor calix**. The **renal pelvis**, into which the minor calices open, consists of a **central cavity** at the origin of the ureter and two **major calices**, which extend from the central cavity toward the extremities of the kidney (Fig. 4-41). This arrangement is similar to that in the human kidney.

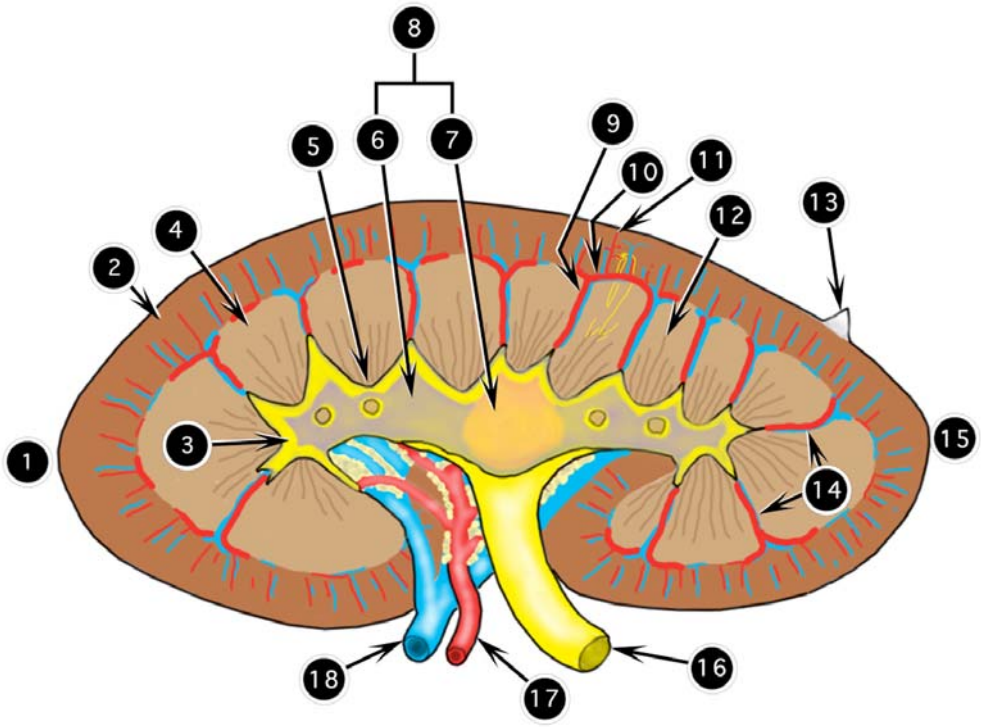


Figure 4-41. Schematic representation of porcine kidney: (1) cranial extremity; (2) renal cortex; (3) minor calix; (4) medullary pyramid; (5) renal papilla; (6) major calix; (7) central cavity; (8) renal pelvis; (9) interlobar artery; (10) arcuate artery; (11) interlobular artery; (12) papillary ducts; (13) reflected fibrous capsule; (14) renal lobe; (15) caudal extremity; (16) ureter; (17) renal artery; (18) renal vein.

Kidney of Sheep and Goat: Contrary to what might be a logical assumption, the kidneys of the small ruminants do not look like bovine kidneys, but are almost identical to those of the dog. *Remove the right kidney, including the renal artery, vein, and proximal part of the ureter. Place the kidney on a cutting board, and using a large knife, section the organ longitudinally through the hilus so as to divide it into dorsal and ventral halves.* Embryonic fusion has resulted in a smooth surface, with no external evidence of lobation.

On cut section, it can be observed that the renal papillae have aligned themselves into a neat row and have fused to form a **renal crest**, on which the papillary ducts

open. The crest is surrounded by a single collecting chamber, the **renal pelvis**, which has interlobar diverticula known as **pelvic recesses**. The pelvic recesses of the renal pelvis are closely associated with the interlobar vessels, which are the primary branches of the renal vessels.

Kidney of Horse: Locate the right kidney of the horse. *Remove enough of the perirenal fat to expose the kidney*. The first thing you notice is that the kidney is not kidney shaped, but rather is shaped more like the heart on a playing card. Unlike that of any other domestic mammal, the right kidney of a horse is compressed in a craniocaudal direction so that its craniocaudal dimension is equal to or less than its mediolateral dimension.

Compare the right and left kidneys (Fig. 4-42. Note that, because of the craniocaudal folding of the right kidney, the two kidneys can be differentiated after removal. *Remove the right kidney, including the renal artery, vein, and proximal part of the ureter. Place the kidney on a cutting board, and using a large knife, section the organ longitudinally through the hilus to divide it into dorsal and ventral halves.*

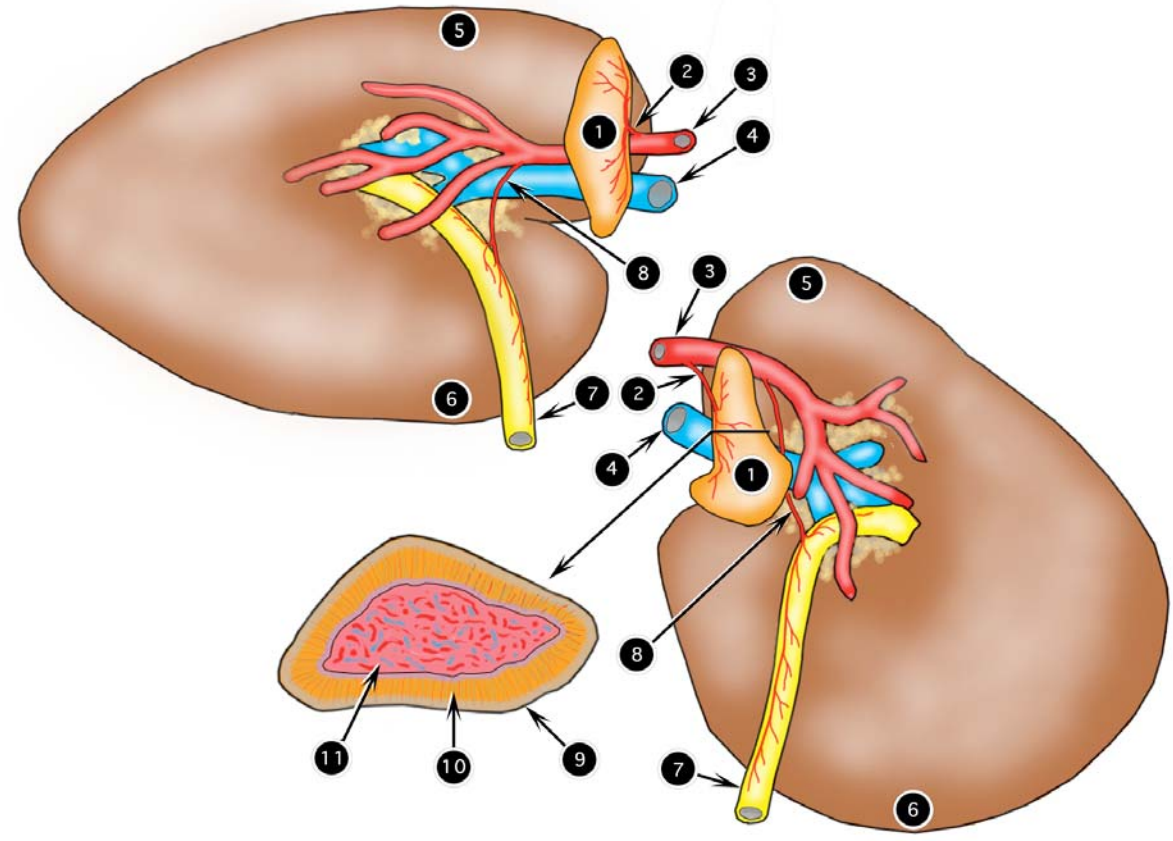


Figure 4-42. Schematic representation of equine kidneys and adrenal glands, ventral view with x-section of adrenal: (1) adrenal gland; (2) caudal adrenal branch of 3; (3) renal artery; (4) renal vein; (5) cranial extremity of kidney; (6) caudal extremity of kidney; (7) ureter; (8) ureteric branch of 3; (9) capsule of adrenal; (10) cortex of adrenal; (11) medulla of adrenal.

Embryonic fusion has resulted in a smooth surface, with little if any external evidence of lobation. Numerous branches of the renal artery that radiate from the hilus do, however, give a hint of internal lobation. On cut section, it can be observed that the

renal pelvis is represented by a small, centrally located collecting chamber (Fig. 4-43). Similarly, the **renal crest** is short and represents the fusion of the more centrally located renal papillae only.

The papillary ducts from those lobes toward the extremities cannot reach the small pelvis directly. Instead, they unite to form two large collecting ducts known as **terminal recesses**,[32] which conduct the urine from the cranial and caudal extremities to the renal pelvis.

It is virtually impossible to section the kidney so as to cut completely through both of these small and rather inconspicuous recesses (Fig. 4-43). The terminal recesses are best demonstrated by corrosion casts of the urine collection system.

Examine the cut surface carefully for portions of the terminal recesses, which do *not* have a distinct lining; the papillary ducts on the cut surface converge toward them. Do not confuse the subtle terminal recesses with the prominent branches of the renal vein. The renal pelvis and proximal part of the ureter contain mucous glands, the secretion of which accounts for the thick, mucus-like nature of equine urine.

All Kidneys: Please note the difference between the renal pelvis and the renal sinus. The **renal pelvis** is the expanded proximal end of the ureter; the **renal sinus** is a fat-filled area at the renal hilus that surrounds the ureter and renal vessels. It is outside the kidney, except that the kidney "folds" around it somewhat. I'm not sure why anatomists bothered to name this "non-entity" except perhaps to confuse matters. If it were up to me, I would drop the term renal sinus altogether.

ADRENAL GLANDS

Locate the right adrenal gland (Fig. 4-42) cranial to the stumps of the renal vessels. Although the location is relatively consistent, the shape of the gland varies considerably among different species. Therefore, *make a transverse cut through the gland* to confirm its identity and to distinguish it from one of the renal lymph nodes. Unlike the lymph nodes, the adrenal gland has a more grossly evident **cortex** and **medulla**.

As the name implies, the "ad-renal" is "ad-jacent" to the kidney. Embryologically, the adrenal gland develops from a dual origin. The cortex differentiates from celomic mesoderm, while the adrenal medulla is formed from neural crest cells that migrate and penetrate through to the center of the developing cortex. In fact, the immature adrenal medulla is similar to a sympathetic ganglion.

Chromaffin cells within the medulla are responsible for the production and release of adrenalin or epinephrine. The adrenal cortex differentiates into several zones, arranged in a laminar fashion around the medulla. Each zone of the cortex produces different hormones including androgenic steroids, mineralocorticoids, and glucocorticoids.

[32] The term terminal recesses is used to describe these unique structures of the equine kidney, which are *not* homologous to the pelvic recesses of carnivores and small ruminants.

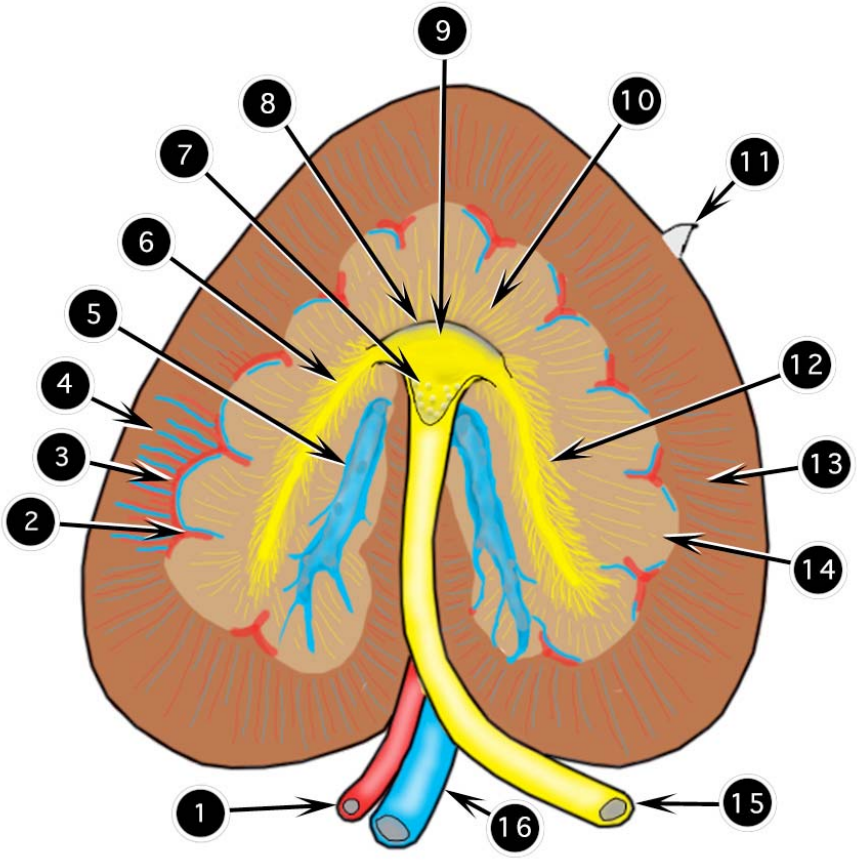


Figure 4-43. Schematic representation of longitudinal (dorsal) section of right equine kidney: (1) renal artery; (2) interlobar vessels; (3) arcuate vessels; (4) interlobular vessels; (5) large branches of renal vein; (6) terminal recess; (7) mucous glands in renal pelvis & proximal ureter; (8) renal crest; (9) renal pelvis; (10) papillary ducts from central lobes open along renal crest; (11) fibrous capsule reflected; (12) papillary ducts from non-central lobes enter terminal recess; (13) cortex; (14) medulla; (15) ureter; (16) renal vein.

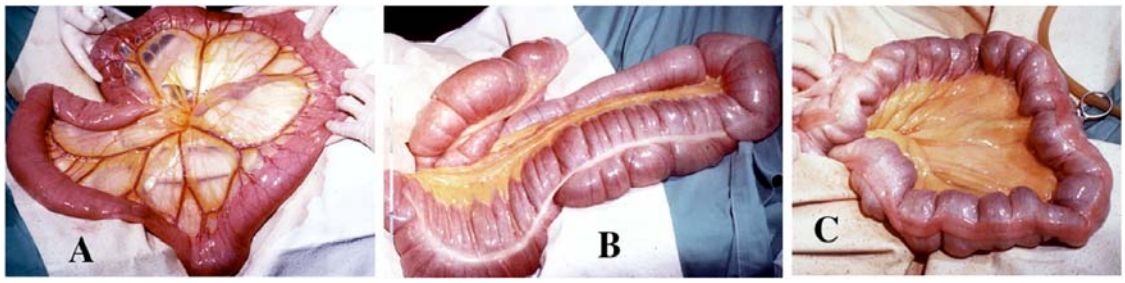
Palpation Checklist for Abdomen

Horse

1. Palpate the last rib and upper flank area; note small size of flank here.
2. Be able to identify which organ(s) would be penetrated by punctures through the abdominal wall at various sites; *i.e.*, upper right flank, ventral midline, etc.

Ox

1. Palpate and identify the tips of the transverse processes of the lumbar vertebrae.
2. Define the area of liver contact with the body wall by percussion.
3. Identify the boundaries of the paralumbar fossa.
4. Be able to identify which organ(s) would be penetrated by punctures through the abdominal wall at various sites; *i.e.*, left paralumbar fossa, upper right flank, etc.
5. Palpate ruminal contractions in the left paralumbar fossa.
6. Subiliac lymph node



Answers to Figure 4-26**:** A = jejunum; B = ascending colon and cecum; C = descending colon.

Chapter 5 • Pelvis and Reproductive Organs

Now that we have completed our study of the neck, thorax, and abdomen, it is time for us to turn our attention caudad and explore those mysterious recesses of the pelvic cavity. The problem is we still have too much stuff in the way, so let's "tidy up" the old cadaver a bit at this point.

Remove the head of the cadaver by sawing through the neck at the level of the third or fourth cervical vertebra. Be sure that the entire larynx and pharynx remain with the head. The heads are to be tagged and stored- *yes, you will need them later*.

1. *Locate the root of the mesentery, and transect the celiac and cranial mesenteric arteries near the aorta. Pull ventrally, breaking the mesenteric attachments. In the ruminant, break down any remaining attachments of the stomach to the body wall.*

2. *Locate the descending colon, and transect it at the level of the caudal extremity of the left kidney. Remove the entire gastrointestinal mass from the abdominal cavity and dispose of it.*

3. *Now, saw through the back of the cadaver at about the level of the third lumbar vertebra. Also transect the abdominal wall at this level, being careful to cut through the ventral wall cranial to the umbilicus.*

Caution: *Those of you with male specimens- please do not perform an inadvertent penectomy at this point in the dissection (and yes, it has happened). Cut up the cranial segment of the cadaver as necessary and dispose of it.*

Transverse Section of Bovine Lumbar Region: On the cut surface through the lumbar region, note the muscles that are present in the T-bone steak (Fig. 5-1). The beef carcass is split along the median plane to produce right and left halves. The loin eye is formed primarily by the **longissimus thoracis *et* lumborum muscle**, with the **multifidus lumborum** contributing to the more medial part.

Ventral to the lumbar transverse processes are located the **psoas major** and **minor muscles**, which together form the tenderloin. More caudally, where the cross section of the tenderloin increases in diameter and becomes more rounded, the steak becomes a porterhouse. The small quadratus lumborum and iliocostalis lumborum muscles are located more laterally.

Fat interspersed between individual muscle bundles or fascicles is referred to as "marbling," which is a desired characteristic, increasing flavor or improving palatability. More cranially, at the level of the thirteenth rib, similar sections produce club steaks. Cranial to rib 13, sections through the rib eye yield rib steaks.

In the other species the "homologues" of the T-bone steak of the beef carcass are pork chops and lamb chops. The small ruminants and pig typically possess six (or, in some cases, seven) lumbar vertebrae. Transverse sections through the lateral abdominal wall of the pig produce bacon;[1] the strips of lean surrounded by fat are the abdominal muscles cut in cross section (Fig. 5-2).

[1] Bacon comes from the abdominal wall; ever wonder why anyone would be interested in the price of "pork bellies?"

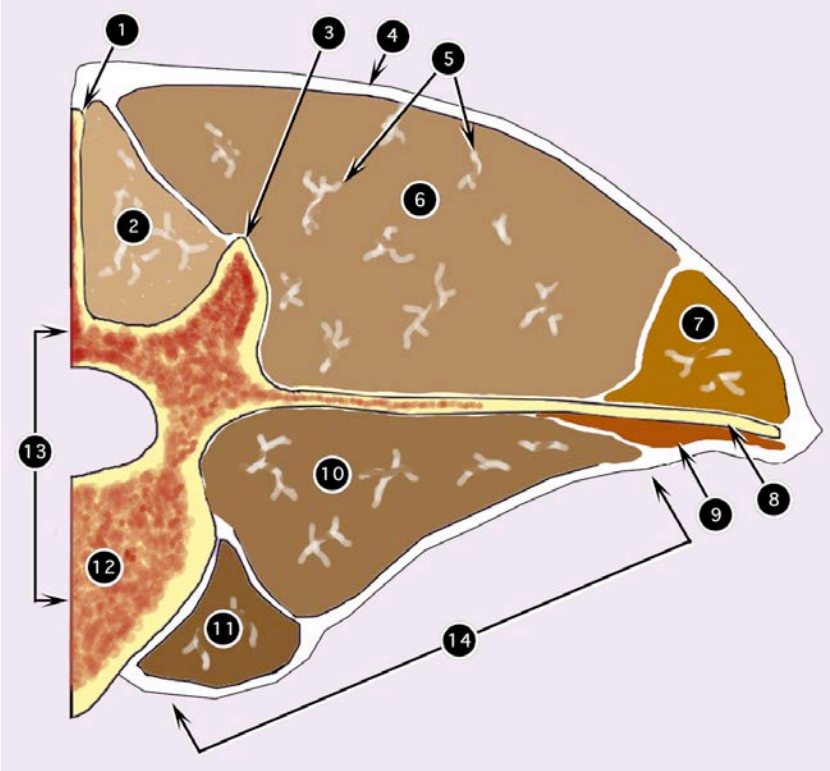


Figure 5-1. Anatomy of a T-Bone steak: (1) spinous process of lumbar vertebra; (2) multifidus lumborum muscle, part of transversospinalis system; (3) articular process; (4) fat, trimmed; (5) intramuscular (interfascicular) fat known as "marbling;" (6) longissimus lumborum muscle forming most of loin eye; (7) iliocostalis lumborum muscle; (8) transverse process; (9) quadratus lumborum muscle; (10) psoas major muscle; (11) psoas minor muscle; (12) body of vertebra; (13) median saw cut dividing carcass into right and left halves; (14) tenderloin, consisting of 10 & 11.

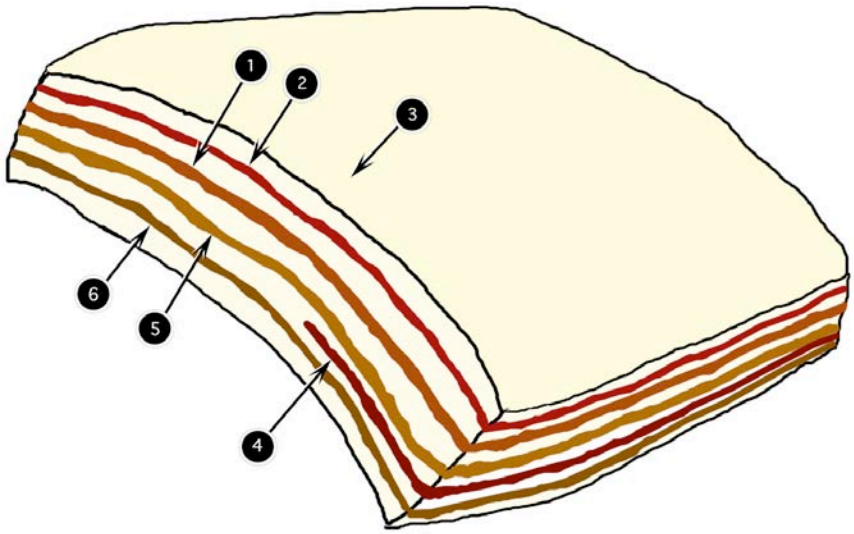


Figure 5-2. Anatomy of a slab of bacon from pork belly: (1) external abdominal oblique muscle; (2) cutaneus trunci muscle; (3) skin removed; (4) rectus abdominis muscle; (5) internal abdominal oblique muscle; (6) transverses abdominis muscle. Note that the muscles may vary depending on where the slab was taken from the pork belly; *i.e.*, the rectus abdominis would not be present in a slab taken the from upper flank.

Pass your hand caudally into the rectogenital pouch of the female, and note that the pouch extends beyond the cervix (Fig. 5-3). This is especially important in the mare. Vaginal perforations or tears can occur at the time of foaling if the foal pushes a foot through the dorsal wall of the vagina. Because of the close proximity of the vagina and rectum, and the crowded environment of the pelvic cavity, vaginal perforations may extend into the rectum.

If the perforation occurs cranial to the line of peritoneal reflection and involves the rectum, then the peritoneal cavity is obviously contaminated with fecal material, a condition that is not tolerated by the horse and may be fatal. If the vaginorectal perforation (tear) occurs more caudally (retroperitoneally), such contamination produces a messy problem that must be dealt with by the veterinarian; however, in such a case, the mare has a much better chance of survival. Vaginorectal perforations and tears are serious clinical situations that require complicated surgical repairs if the mare is to be returned to reproductive soundness.

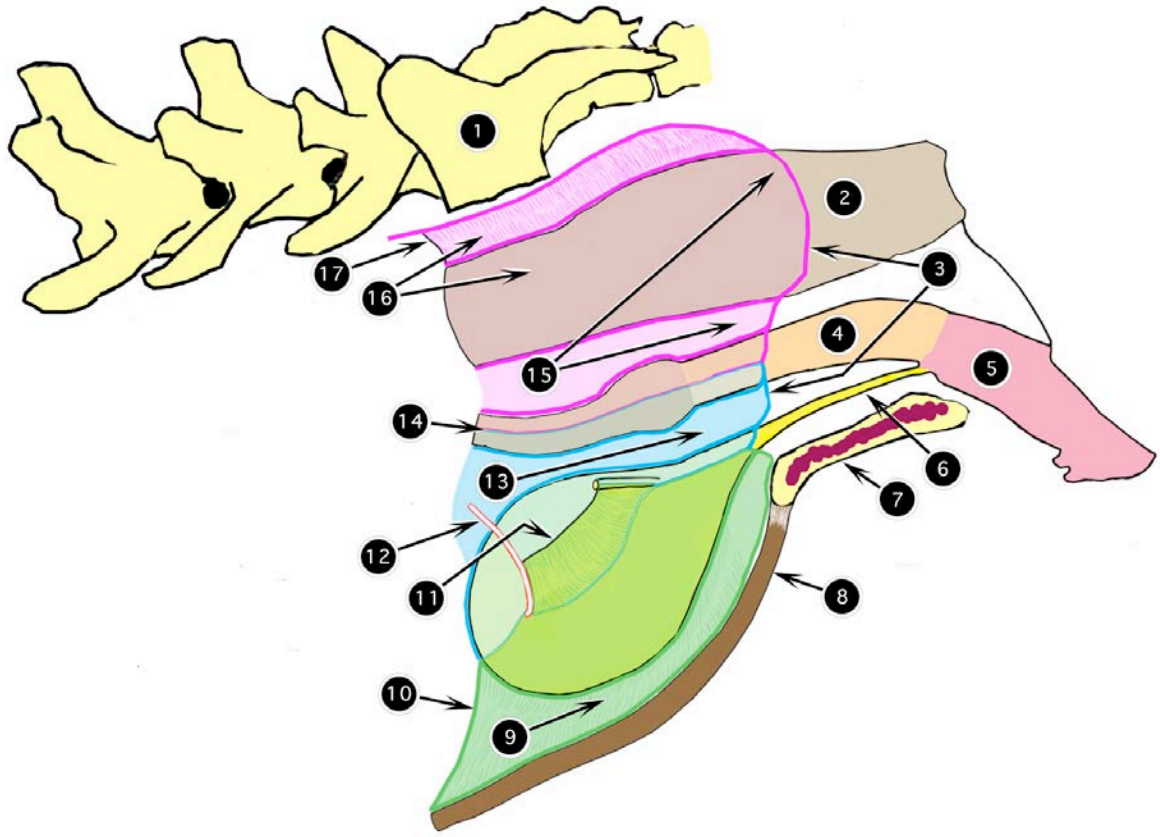


Figure 5-3. Extensions of peritoneum into pelvic cavity of bitch, left lateral view: (1) sacrum; (2) retroperitoneal part of rectum; (3) line of peritoneal reflection; (4) retroperitoneal part of vagina; (5) vestibule; (6) urethra; (7) pelvic symphysis; (8) rectus abdominis muscle; (9) pubovesical pouch; (10) median ligament of urinary bladder; (11) cut edge of left lateral ligament of urinary bladder; (12) left umbilical artery (round ligament of urinary bladder); (13) vesicogenital pouch; (14) broad ligament (mesometrium, continued as mesovagina); (15) rectogenital pouch; (16) left pararectal fossa, part of rectogenital pouch; (17) cut edge of mesocolon.

The rectogenital pouch is separated ventrally from the **vesicogenital pouch** by the **broad ligaments** in the female and by the **mesoductus-genital fold** in the male. Similarly, the vesicogenital pouch is separated ventrally from the **pubovesical pouch** by the **lateral ligaments of the urinary bladder**.

Broad Ligaments: As you recall, the broad ligaments are the two peritoneal folds that attach the female reproductive tract to the body wall (Fig. 5-4). Each ligament is divided into several parts, named according to the specific part of the internal genitalia supported by the ligament. The **mesovarium** directly supports the ovary, the **mesosalpinx** supports the uterine tube, the **mesometrium** supports the uterus, and the **mesovagina** attaches the vagina to the pelvic wall.

A separate fold leaves the main part of the broad ligament and passes laterally. In the free edge of this fold is a slightly thickened cord, the **round ligament of the uterus**, which passes to the body wall at the site where the vaginal ring would be located in the male. The round ligament of the uterus represents the female homologue of the gubernaculum testis, which guides the testis during its descent from the abdominal cavity. Only in the bitch does it typically extend through the inguinal canal, enveloped by a vaginal process. In other domestic mammals, it merely extends to the site of the vaginal ring so that there is no vaginal process formed.

Unlike that of the dog, the ovarian bursa of domestic ungulates is rather loose. That is, the mesosalpinx, which supports the uterine tube, only loosely envelops the ovary and can be easily reflected without dissection to expose the ovarian surface (Fig. 5-5). The **ovarian bursa** is thus a diverticulum, or pocket, of the peritoneal cavity that surrounds the ovary. *Fold back the mesosalpinx to expose the ovarian surface*. Within the mesovarium are the ovarian vessels and nerves. The **ovarian artery** is typically tortuous and is a direct branch of the aorta (Fig. 5-4).

INTERNAL GENITALIA

Internal Genitalia of Mare: Like those of the dog and cat, the ovaries of the mare do not migrate far from their area of development in the sublumbar region. Thus, the **ovaries** of the mare are located relatively high in the caudal part of the abdominal cavity, cranial to the ilia and at about the transverse level of the fifth lumbar vertebra (Fig. 5-5).

In the living animal, they rest on the mass of intestinal viscera unless they are drawn ventrally by the weight of a gravid uterus. Note that the ovaries of the mare are relatively large structures and, in the adult, are characterized by their unusual kidney shape. This unique shape is produced by the presence of a distinct depression, the **ovulation fossa**, which develops as the ovary matures. As the name implies, rupture of the follicle (ovulation) typically occurs at or near the ovulation fossa.

Because the ovaries of the mare are routinely palpated rectally as part of the reproductive examination, knowledge about the size and location of the ovaries is important. The **ovarian artery** of the mare typically divides into several branches before distribution to the ovary and cranial part of the uterus. The large **ovarian vein** is formed by numerous tributaries, which drain not only the ovary but also much of the uterus.

Make a longitudinal incision through one of the ovaries so as to pass through the ovulation fossa. Identify the exposed stages of follicle maturation and that may be evident, such as the corpus luteum and follicles in various stages of development or regression.

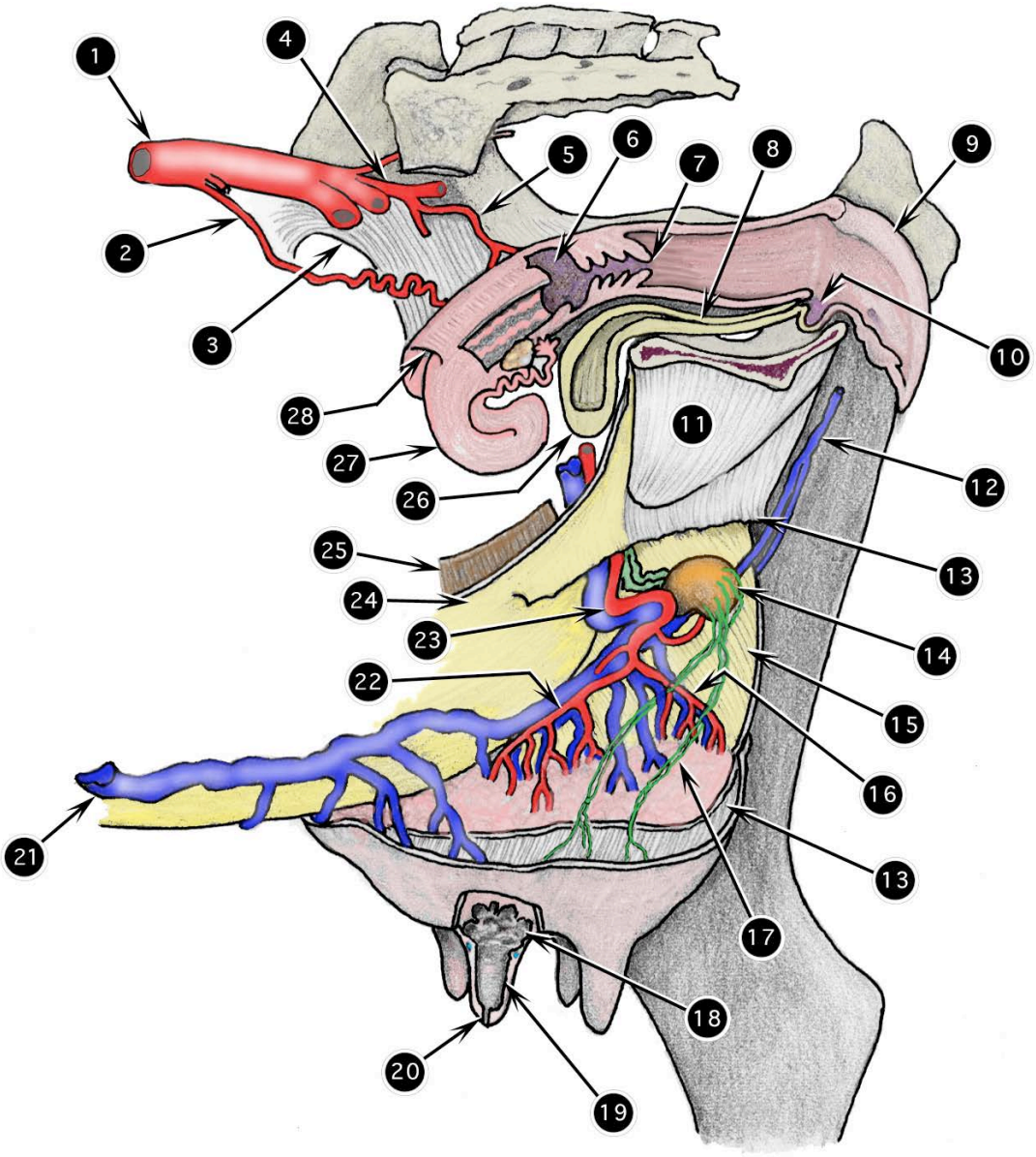


Figure 5-4. Genitalia and udder of cow with much of left wall of genitalia and udder removed, left lateral view: (1) aorta; (2) ovarian artery; (3) broad ligament; (4) internal iliac artery; (5) uterine artery arising from umbilical artery; (6) body of uterus; (7) external ostium of uterus; (8) urethra; (9) labium of vulva; (10) common opening of urethra and suburethral diverticulum in ventral wall of vestibule; (11) symphysial tendon; (12) perineal veins; (13) cut lateral lamina of suspensory apparatus of udder; (14) mammary (superficial inguinal) lymph node; (15) medial lamina of suspensory apparatus of udder; (16) caudal mammary artery; (17) subcutaneous lymphatics draining caudodorsally to mammary lymph node; (18) gland sinus; (19) teat sinus; (20) teat canal; (21) subcutaneous abdominal vein; (22) cranial mammary artery; (23) sigmoid flexure in external pudendal artery; (24) elastic abdominal tunic investing aponeurosis of external abdominal oblique muscle; (25) internal abdominal oblique muscle; (26) urinary bladder; (27) left horn of uterus; (28) dorsal part of intercornual ligament.

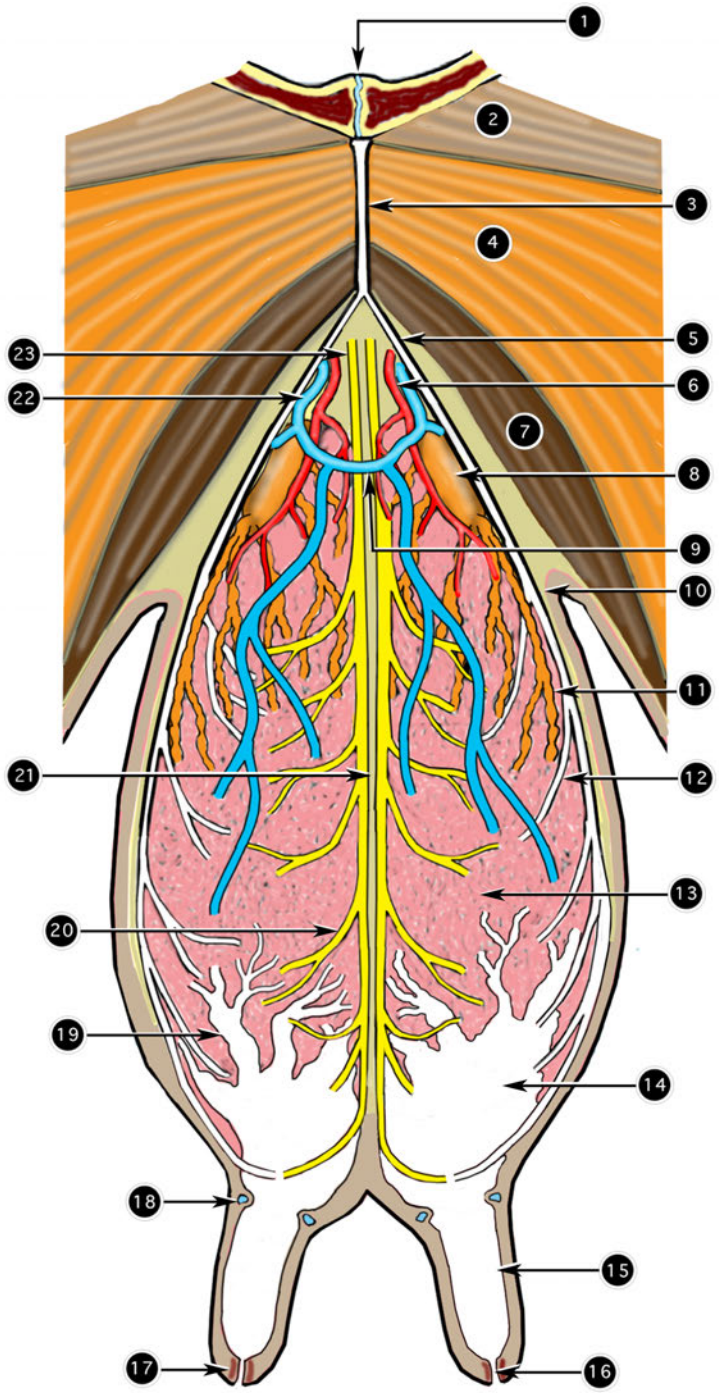


Figure 5-000. Udder of cow, transverse section through hind quarters: (1) pelvic symphysis; (2) external obturator muscle; (3) symphysial tendon; (4) adductor muscle; (5) lateral lamina of suspensory apparatus; (6) caudal mammary artery from external pudendal: (7) gracilis muscle; (8) mammary (superficial inguinal) lymph node; (9) anastomosis between caudal mammary veins; (10) reflection of lateral fascia of thigh onto 5; (11) afferent lymphatics to 8; (12) lamella from 5 blending with connective tissue stroma of mammary gland; (13) mammary tissue; (14) gland sinus; (15) teat sinus; (16) teat canal; (17) smooth muscle & elastic tissue sphincter of 16; (18) venous ring at base of teat; (19) large lactiferous duct entering 14; (20) lamella from medial lamina blending with connective tissue stroma of mammary gland; (21) loose connective tissue between medial laminae; (22) caudal mammary vein; (23) medial lamina of suspensory apparatus.

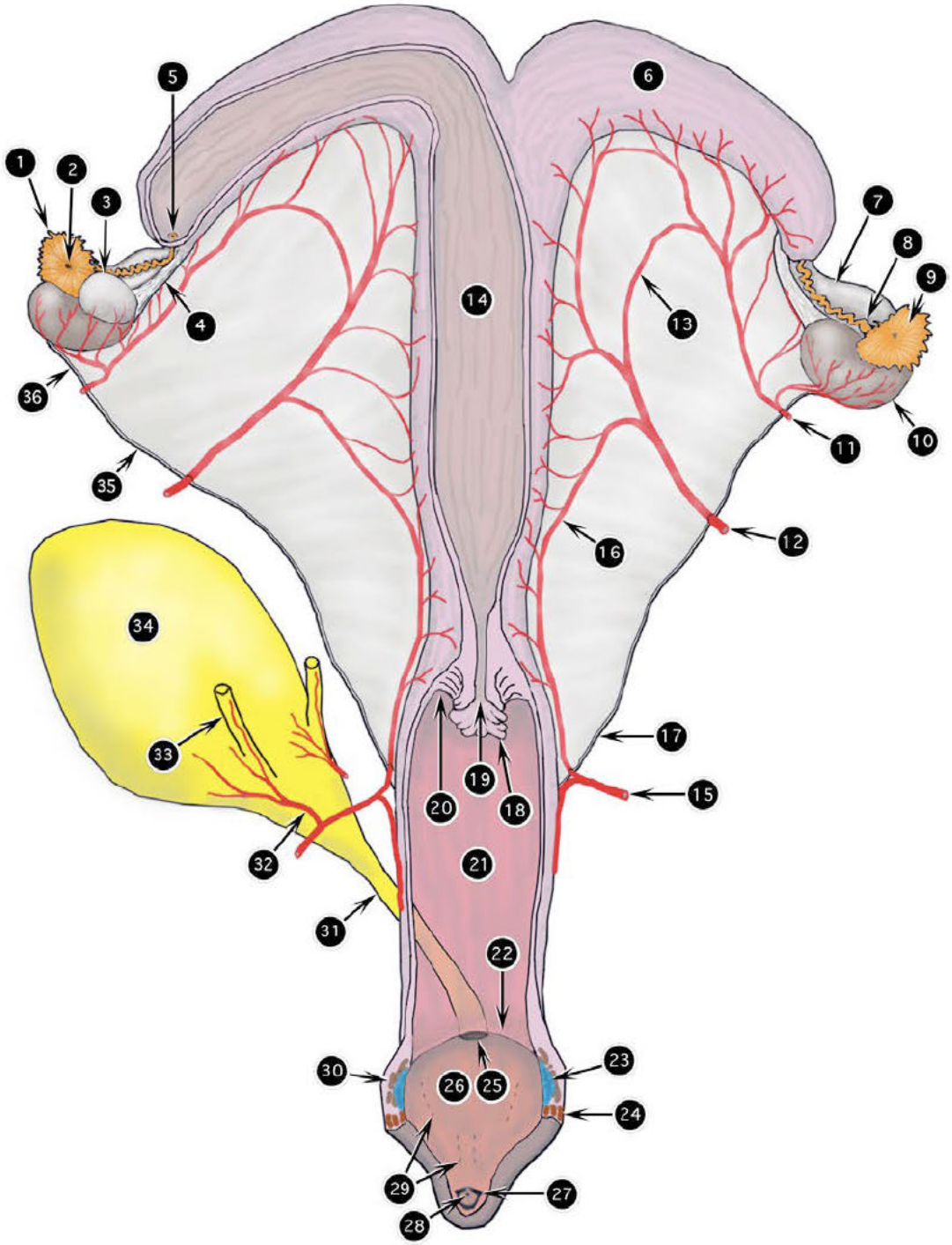


Figure 5-5. Genitalia of mare, partially dissected, dorsal view: (1) fimbriae; (2) abdominal opening of uterine tube; (3) large follicle; (4) proper ligament of ovary; (5) uterine opening of uterine tube; (6) right uterine horn; (7) mesosalpinx; (8) right uterine tube; (9) infundibulum; (10) right ovary; (11) ovarian artery; (12) uterine artery; (13) anastomosis between 11 & 12; (14) body of uterus; (15) vaginal artery; (16) anastomosis between 12 & 15; (17) mesovagina; (18) intravaginal part of cervix; (19) external uterine orifice; (20) fornix vaginae; (21) vagina; (22) transverse fold of vaginal floor; (23) vestibular bulb; (24) constrictor vulvae muscle; (25) external urethral orifice; (26) vestibule; (27) fossa clitoridis surrounding glans clitoris; (28) fossa glandis; (29) openings of minor vestibular glands; (30) constrictor vestibuli muscle; (31) urethra; (32) left caudal vesical artery; (33) left ureter; (34) urinary bladder; (35) mesometrium; (36) mesovarium.

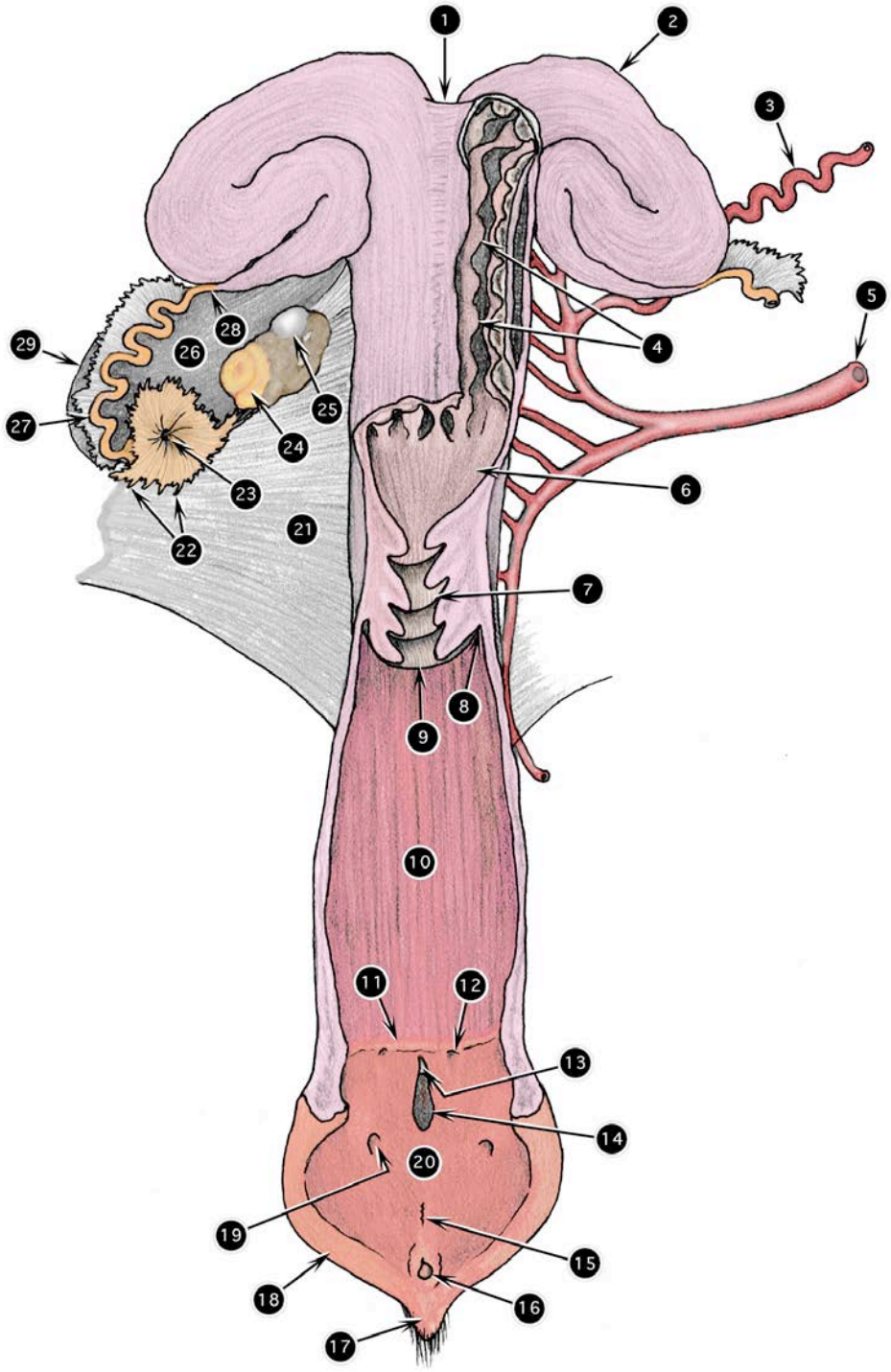


Figure 5-6. Genitalia of cow, partially dissected, dorsal view: (1) dorsal part of intercornual ligament; (2) right horn of uterus; (3) ovarian artery; (4) caruncles in right uterine horn; (5) uterine artery; (6) body of uterus; (7) cervical canal with circular folds; (8) fornix vaginae; (9) external ostium of uterus; (10) vagina; (11) location of hymen between vagina and vestibule; (12) blind opening of remnant of mesonephric duct; (13) external urethral opening; (14) suburethral diverticulum; (15) depression into which minor vestibular glands open; (16) fossa clitoridis surrounding glans clitoris; (17) ventral commissure of vulva; (18) labium of vulva; (19) opening of major vestibular gland; (20) vestibule; (21) mesometrium-mesovagina; (22) fimbriae; (23) abdominal opening of uterine tube surrounded by infundibulum; (24) corpus luteum; (25) follicle; (26) ovarian bursa; (27) ampulla of uterine tube; (28) isthmus of uterine tube; (29) mesosalpinx.

Follicles may become very large (≈ 5 cm) before they rupture and the **corpus luteum** of the equine ovary does not protrude from the ovarian surface, as it generally does in other mammals. The **uterine tube** of the mare begins near the ovulation fossa as the funnel-shaped **infundibulum**. The ragged border of the infundibulum is characterized by many finger-like projections, the **fimbriae** (Fig. 5-5).

Identify the infundibulum, and pass a probe into the **abdominal opening of the uterine tube**. The more proximal part of the uterine tube has a larger diameter, forming the **ampulla**, whereas the more distal part is narrowed, forming the **isthmus**. Unlike the smooth transition that occurs in other domestic ungulates, the isthmus of the equine uterine tube forms an abrupt junction with the blunt end of the uterine horn (Fig. 5-5).

The **horns of the equine uterus** are of uniform diameter throughout their length and diverge sharply from the uterine body. *Open one of the horns near its junction with the uterine tube*, and observe the **uterine opening of the uterine tube**, which is located on a papilla on the endometrial surface (Fig. 5-5). The mare is unique among our domestic mammals in that the body is large and forms a substantial part of the bipartite uterus.

In other domestic mammals, the uterine artery arises within the pelvic cavity as an indirect branch of the internal iliac artery; however, in the mare, the **uterine artery** is a branch of the external iliac artery. Locate the uterine artery within the mesometrium and trace it proximally to its origin from the external iliac. The relatively short **cervix** of the uterus, which can now be palpated, will be examined later, after the pelvic cavity has been opened.

Although mares do occasionally give birth to twins, the horse is considered to be a uniparous[2] species. Sometimes twins are actually conceived, but only one of the embryos develops to term; the other is resorbed relatively early in gestation. Of our domestic species, contact between dam and fetus is least intimate in the horse and pig, which have a **diffuse**, **epitheliochorial** type of **placentation**. The horse is also unique in that, for a relatively long period (5-6 weeks), the embryo is nourished by the **histotroph** (uterine milk) derived from the endometrial glands and absorbed through the **yolk sac**. This continues until the definitive **chorioallantoic placenta** has fully developed and takes over the function of nourishing the fetus. Although we consider the gestation period to be about 335 days, the horse exhibits considerable variation, ranging from 310 to over 400 days. Unfortunately, premature foals are at high risk for a multitude of problems, including self-inflicted skeletal and joint damage resulting from premature weight-bearing.

If your pony is pregnant, have an instructor assist you with opening the uterus and examining the fetal structures. We want to identify the fetal membranes (chorioallantois and amnion), and to note how the chorioallantois is attached diffusely to the endometrium. Although there are typically small areas of more concentrated attachment, microcotyledons, the entire chorionic surface of the placenta that comes in contact with the endometrium functions in placental transport.

[2] uniparous- normally gives birth to a single young per pregnancy.

As the chorioallantois is gently peeled away, the small **chorionic villi**, which project into the crypts of the endometrial surface, can be observed. Among the more interesting features that may be found floating around in the allantoic fluid of the horse are whitish-yellow to amber concretions of organic material known as **hippomanes**, which literally means- "bread of the horse." In ancient times, it was even thought that these "bread-like" bodies, which came out with foal and fluid, served as a source of nourishment for the baby *in utero*. (Fortunately, someone dispelled this old myth during my second year of veterinary school.)

Another item of interest in the equine placenta is the **cervical star**. This is a radial pattern created on the chorion that represents the part of the placenta that contacted the closed cervix of the mare.

Internal Genitalia of Female Ruminant: Note the smaller size and more caudoventral position of the ruminant ovaries as compared with those of the mare. Like those of the mare and carnivores, the ovaries develop in the sublumbar region; however, in the ruminant, the ovaries migrate caudally toward the pelvic cavity and come to lie alongside the uterus (Figs. 5-4, 5-6). As a result of this ovarian migration, the uterine horns become coiled like the horns of a ram.

The typical position of the bovine ovaries when the uterus is nongravid is illustrated in Figs. 5-4 & 5-6. This is an important mental picture to establish, because the ovaries of the cow are routinely examined by rectal palpation. *Make a longitudinal section through one of the ovaries*. Identify the exposed stages of follicle maturation and regression that may be evident, such as the corpus luteum and follicles in various stages of development. Note that both the mature follicle and **corpus luteum** project prominently from the surface of the ovary (Fig. 5-6), and can be palpated rectally.

The ovaries are drawn cranioventrally by the gravid uterus, which displaces the other abdominal viscera craniodorsally. Even the rumen is displaced by the gravid uterus. The **ovarian artery**, a direct branch of the abdominal aorta (Fig. 5-4), becomes very tortuous near the ovary, where it is intimately related to the ovarian vein; this arrangement forms a plexus similar to the pampiniform plexus of the male.

Identify the **uterine tube** within the mesosalpinx. *Open the **infundibulum,** and pass a probe into the **abdominal opening** of the uterine tube*. Follow the uterine tube to its smooth junction with the tapering end of the **uterine horn**. Continue along the uterine horn to the point where it comes into close association with the other horn. The proximal halves of the uterine horns lie close together and are connected by the **intercornual ligament** (Figs. 5-4, 5-6). In the cow, but not in the small ruminants, this ligament consists of distinct dorsal and ventral parts. During rectal palpation, the dorsal part of the intercornual ligament can be used as a *finger hold* to bring the nongravid uterus into the hand for examination.

Open the uterus as shown in figure 5-6. Note the short **body of the uterus**. Before the uterus was opened, it might have appeared that the body was much longer because of the close association of the more proximal parts of the uterine horns. Note the small **caruncles** of the nongravid ruminant uterus. These form the maternal part of the **cotyledonary ruminant placenta**. As the fetal placenta expands, **cotyledons** develop over these caruncles to

form **placentomes** (Fig. 5-7). Note the different shapes of the caruncles- convex in the cow, concave in the small ruminants.

In ruminants and the pig, the **uterine artery** typically arises as the first branch of the umbilical artery, which is a branch of the internal iliac artery (Fig. 5-4). The uterine artery of the ox is palpated rectally during a pregnancy examination.[3] It is the principal blood supply to the uterus and enlarges considerably during pregnancy, especially on the side of the gravid horn in the ox. Thus, its size can be used as an indication of the stage of gestation. Branches of the uterine artery anastomose cranially and caudally with those of the ovarian and vaginal arteries, respectively (Fig. 5-5).

Internal Genitalia of Sow: The **ovaries** of the mature female have a very irregular surface as a result of the many follicles and corpora lutea in this multiparous[4] species (Fig. 5-8). Locate the **uterine tube** within the mesosalpinx. *Pass a probe through the infundibulum and demonstrate the abdominal opening of the uterine tube*. Follow the uterine tube to its junction with the uterine horn. Note the long, tortuous **uterine horns** and the rather long, complex **cervix** of the porcine uterus (Fig. 5-8). Locate the **ovarian and uterine arteries** within the broad ligament.

Umbilical Arteries and Urinary Bladder of Newborn Calf: All students should observe the large umbilical arteries of the newborn calf. During fetal life, these vessels extended cranially through the umbilical opening and umbilical cord (Fig. 5-7). Deoxygenated blood from the fetus was carried through these arteries and their branches to the cotyledons of the placenta. The umbilical arteries are located to either side of the elongated urinary bladder and **urachus** of the fetus. The urachus extends cranially from the definitive urinary bladder to the umbilical opening, where it is continues within the umbilical cord. "Urine" from the fetus flows through the urachus to the allantoic cavity where over 9 liters of this fluid may accumulate prior to parturition.

After birth and closure of the umbilical opening, the umbilical arteries and urinary bladder begin to recede toward the pelvic cavity. The urachus should completely atrophy, leaving only a small scar at the apex of the bladder. However, the peritoneal fold that enclosed it persists as the **median ligament of the urinary bladder**. Persistent (and in some cases patent) urachus occasionally occurs. Patent urachus is more common in foals and kittens. Abscesses of the urachus have been reported in calves without external evidence of the problem. Persistent, patent, or abscessed urachus can be corrected surgically.

Similar peritoneal folds that attached the umbilical arteries to the bladder become the **lateral ligaments**, and the remnants of the umbilical arteries form the **round ligaments of the urinary bladder**. In the adult ruminant cadaver, palpate the firm umbilical arteries (round ligaments) distally from the origin of the uterine artery and note the rather abrupt termination of the vessels (Fig. 5-9). A small continuation of the lumen typically persists to the bladder as the cranial vesicular artery.

In ruminants (Fig. 5-9) and the pig, the umbilical artery arises from the **internal iliac artery**, whereas in the horse it is a branch of the **internal pudendal artery**. By definition, the internal iliac artery terminates

[3] Note: The uterine artery may be referred to in older texts as the middle uterine artery.

[4] multiparous- normally gives birth to multiple young (*i.e.*, litters).

by giving origin to the caudal gluteal artery and continuing as the internal pudendal artery. In the horse, this division occurs high- that is, close to the origin of the internal iliac artery (Fig. 5-10). Thus, in the horse, the internal iliac artery is short, and the internal pudendal artery is long. However, in the ruminants and pig the caudal gluteal artery is given off much lower- not until the internal iliac reaches the lesser sciatic notch. Thus, these species have a long internal iliac artery and a short internal pudendal artery (Fig. 5-9).

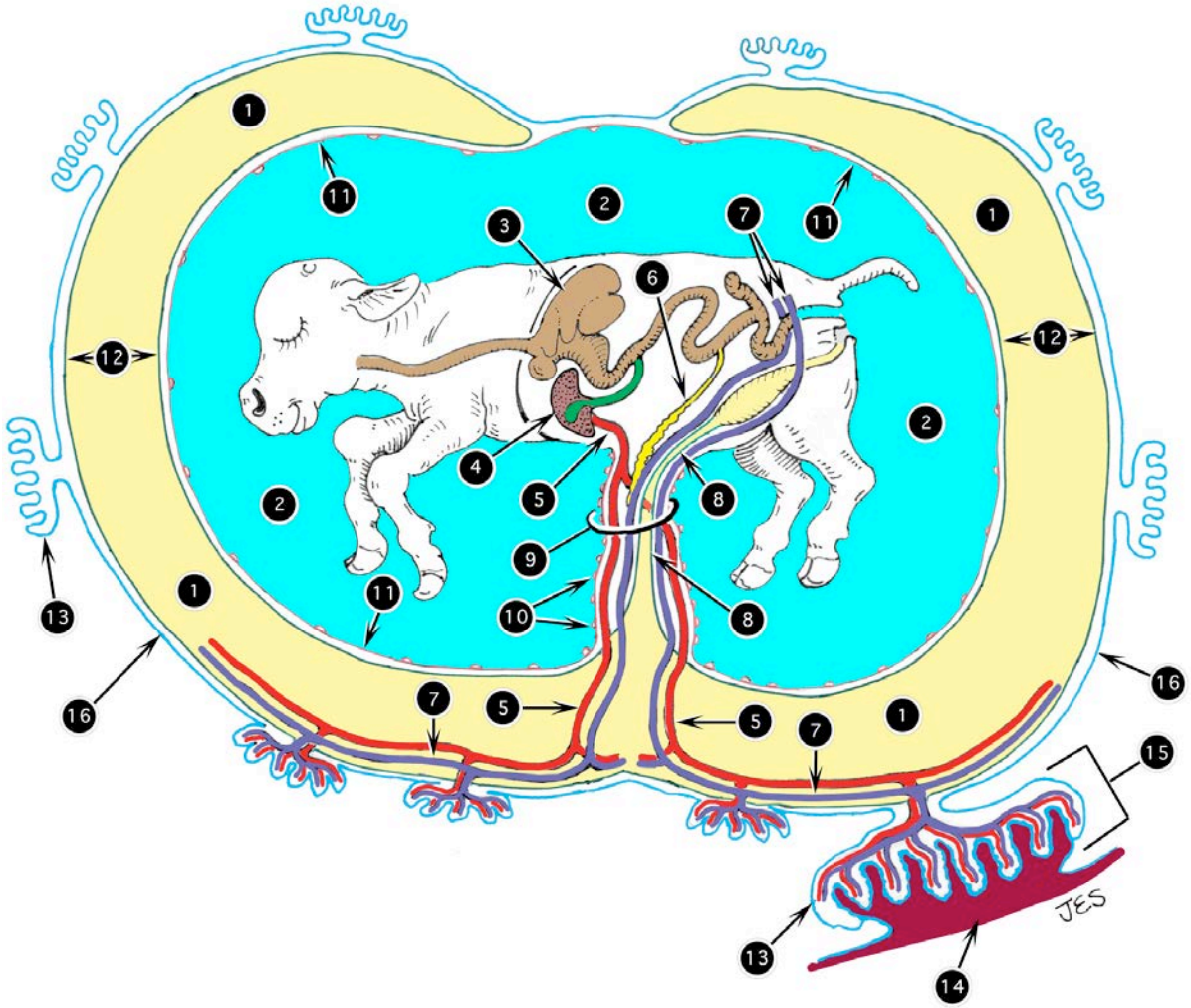


Figure 5-7. Contented bovine fetus and placenta: (1) allantoic cavity and fluid; (2) amniotic cavity and fluid; (3) stomach; (4) liver; (5) umbilical vein; (6) remnant of yolk sac; (7) umbilical arteries; (8) urachus connecting urinary bladder with allantoic cavity; (9) umbilical cord; (10) amnionic plaques; (11) amnion; (12) allantois; (13) cotyledon; (14) caruncle; (15) placentome; (16) chorion.

Lumbar and Iliac Lymph Nodes: Numerous lymph nodes are associated with the terminal part of the abdominal aorta. Those along the aorta, caudal to the kidneys, are designated **lumbar aortic nodes**, those near the origins of the iliac arteries are the **medial iliac nodes**, and those at the junction of the cranial and caudal branches of the deep circumflex iliac arteries are the **lateral iliac nodes**. In addition to the medial and lateral iliac lymph nodes, locate the large **iliofemoral lymph node** in the ox (Fig. 5-11) and pig. This lymph node, which is also present in sheep, corresponds to the **deep**

inguinal lymph nodes of the horse and goat, which are located in the femoral triangle and will be seen later.

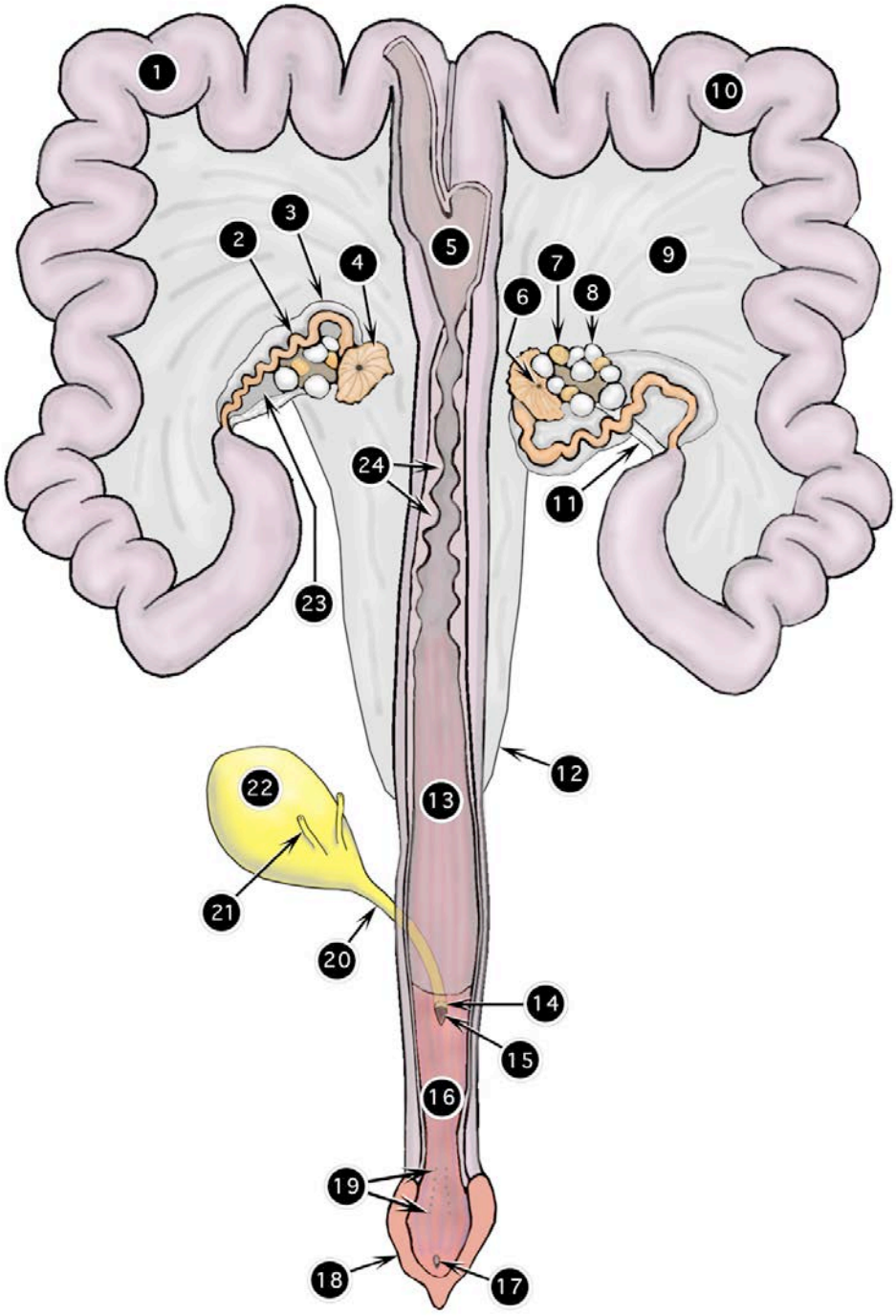


Figure 5-8. Genitalia of sow, partially dissected, dorsal view: (1) left horn of uterus; (2) left uterine tube; (3) mesosalpinx; (4) infundibulum; (5) body of uterus; (6) abdominal opening of uterine tube; (7) corpus luteum; (8) follicle; (9) mesometrium; (10) right horn of uterus; (11) proper ligament of ovary; (12) mesovagina; (13) vagina; (14) external urethral opening; (15) suburethral diverticulum; (16) vestibule; (17) glans clitoris within fossa clitoridis; (18) left labium of vulva; (19) openings of minor vestibular glands; (20) urethra; (21) left ureter; (22) urinary bladder; (23) ovarian bursa; (24) interdigitating prominences along wall of cervical canal.

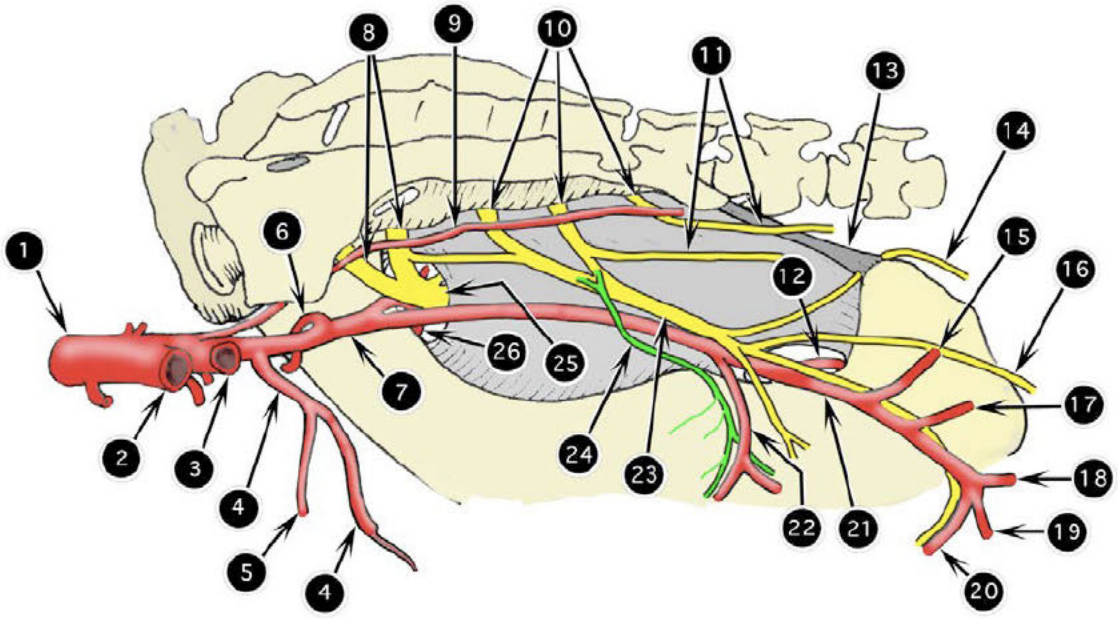


Figure 5-9. Branches of right internal iliac artery and sacral plexus nerves of ox, medial view: (1) aorta; (2) left external iliac artery; (3) left internal iliac artery; (4) umbilical artery; (5) uterine artery in female, artery of ductus deferens in male; (6) iliolumbar artery; (7) right internal iliac artery; (8) ventral branches of S1 & S2; (9) median sacral artery; (10) ventral branches of S3–S5; (11) caudal rectal nerves; (12) caudal gluteal artery passing through lesser sciatic foramen; (13) sacrotuberous ligament, continued cranially by sacrosciatic (broad sacrotuberous) ligament; (14) proximal branch of pudendal nerve; (15) caudal rectal artery; (16) distal branch of pudendal nerve; (17) ventral perineal artery; (18) artery of bulb of penis (vestibular bulb if present); (19) deep artery of penis (clitoris); (20) dorsal artery & nerve of penis (clitoris); (21) internal pudendal artery; (22) vaginal artery in female, prostatic artery in male; (23) pudendal nerve; (24) pelvic nerve (parasympathetic); (25) lumbosacral trunk passing through greater sciatic foramen; (26) cranial gluteal artery.

Genitofemoral Nerve: As the name implies, the genitofemoral nerve is distributed to parts of the external genitalia and medial surface of the thigh. It is derived from the ventral branches of several lumbar nerves and leaves the abdominal cavity through the inguinal canal (Fig. 4-3). It has special significance in the cow because of its distribution to the udder. Identify some of its roots from the lumbar nerves as they join and course retroperitoneally to the area of the deep inguinal ring.

Testicular Vessels: The testes develop in the abdominal cavity in about the same location as the ovaries, caudal to the kidneys. Then, to escape the relatively warm, uncomfortable environment and crowded conditions of the abdominal cavity, they migrate caudally and descend through the inguinal canal toward their final destination, the scrotum. Occasionally, funny things happen on the way to the scrotum, resulting in misplaced testes. (They're not lost, you understand, just misplaced.)

As the testes descend, they leave a "vapor" trail, marked by the course of the testicular vessels. That is, as you follow the course of the testicular artery from its aortic origin to the scrotum, in essence you retrace the course of testicular descent, recognizing that the animal was smaller when the testes descended. Locate the origin of the **testicular artery and vein** (Fig. 5-11) and follow them caudally, in their peritoneal fold, the **mesorchium**, to the vaginal ring.

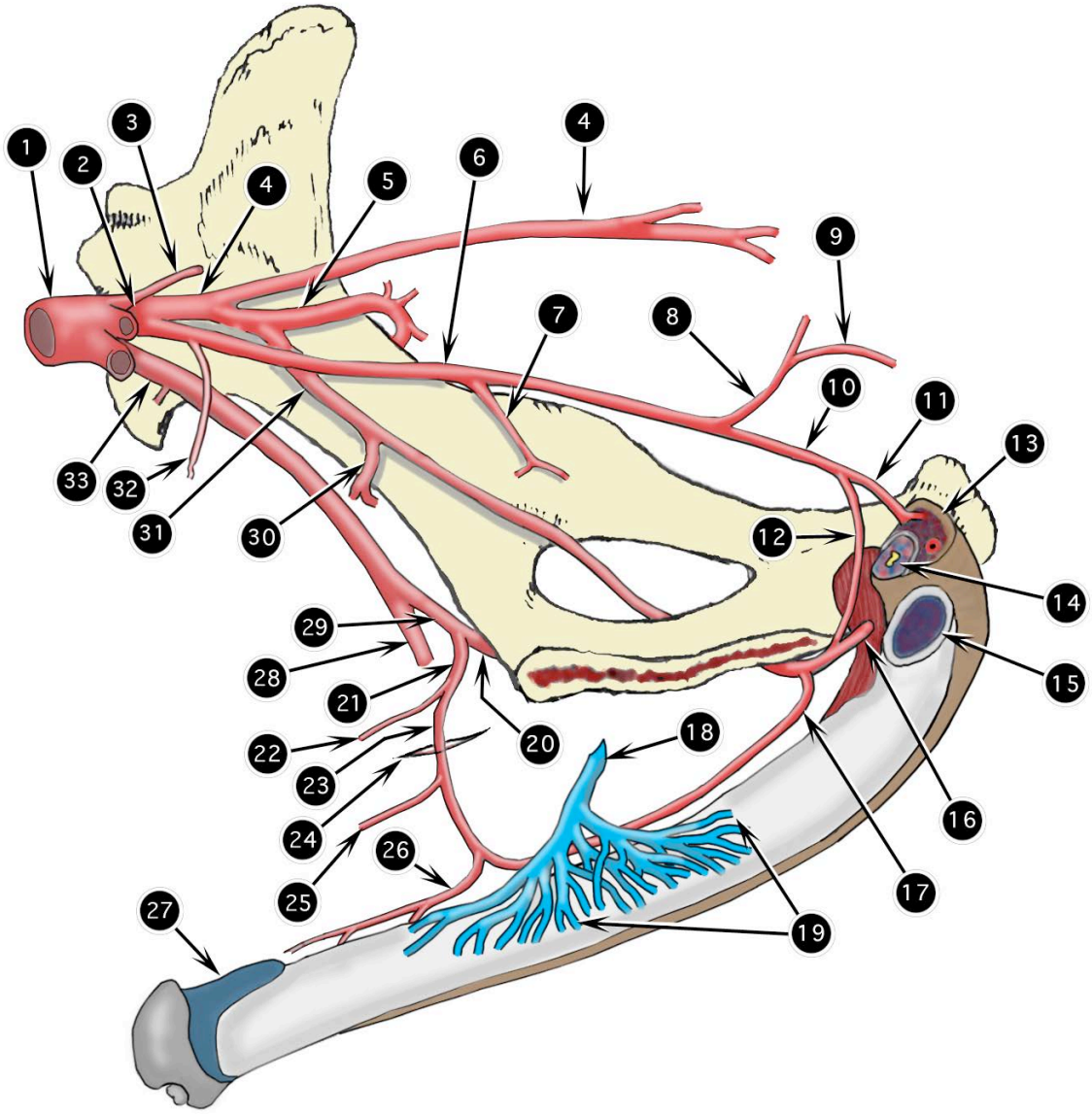


Figure 5-10. Schematic representation of blood supply to penis of horse, left lateral view: (1) aorta; (2) internal iliac artery; (3) median sacral artery; (4) caudal gluteal artery; (5) cranial gluteal artery; (6) internal pudendal artery; (7) prostatic artery; (8) caudal rectal artery; (9) ventral perineal artery; (10) artery of penis; (11) artery of bulb of penis; (12) dorsal artery of penis; (13) bulb of penis; (14) urethra; (15) cut left crus of penis; (16) deep artery of penis penetrating right crus of penis; (17) middle artery of penis; (18) external pudendal vein perforating origin of gracilis muscle to join deep femoral vein; (19) external pudendal venous plexus; (20) medial circumflex femoral artery; (21) pudendoepigastric trunk; (22) caudal (deep) epigastric artery; (23) external pudendal artery; (24) superficial inguinal ring; (25) caudal superficial epigastric artery; (26) cranial artery of penis; (27) dorsal process of glans penis; (28) femoral artery; (29) deep femoral artery; (30) iliacofemoral artery; (31) obturator artery; (32) round ligament of urinary bladder (umbilical artery); (33) external iliac artery.

Vaginal Ring: Now that you've followed the mesorchium to it, let's consider the vaginal ring. Prior to descent of the testis, a jelly-like mesenchymal cord of tissue protruded through the developing abdominal wall to the area where the scrotum was

forming. This embryonic structure was the **gubernaculum testis**, and as the abdominal wall matured, the **inguinal canal** formed around this structure. Triggered by hormonal factors, the peritoneum invaded the gubernaculum and grew out through the abdominal wall, forming a C-shaped (in cross section) **vaginal process**.

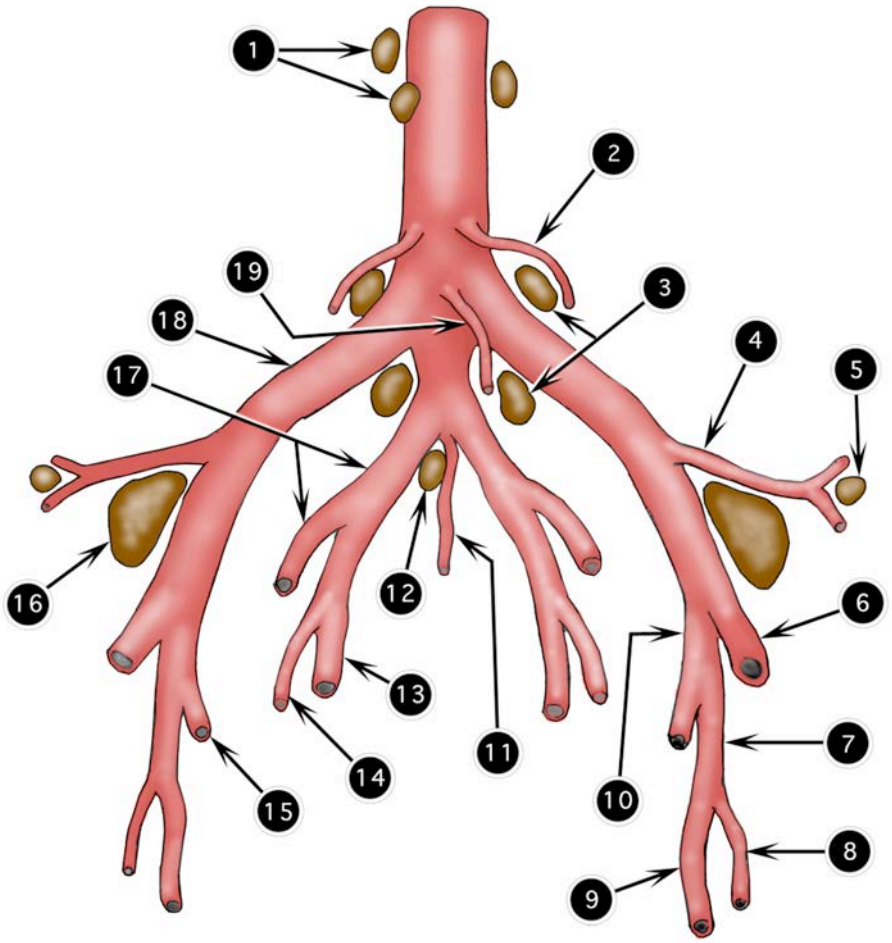


Figure 5-11. Termination of bovine aorta with associated lymph nodes, ventral view: (1) lumbar aortic nodes; (2) ovarian (testicular) artery; (3) medial iliac lymph nodes; (4) deep circumflex iliac artery; (5) lateral iliac lymph node; (6) femoral artery; (7) pudendoepigastric trunk; (8) caudal (deep) epigastric artery; (9) external pudendal artery- exits abdomen *via* inguinal canal; (10) deep femoral artery; (11) median sacral artery; (12) sacral lymph nodes; (13) uterine artery; (14) umbilical artery; (15) medial circumflex femoral artery; (16) iliofemoral (deep inguinal) lymph node; (17) internal iliac artery; (18) external iliac artery; (19) caudal mesenteric artery. (Modified from *Applied Veterinary Anatomy*, de Lahunta and Habel, W. B. Saunders, Co., 1986, p. 259.)

As the peritoneum grows out of the abdominal cavity, it forms a double-walled diverticulum. The outer (parietal) layer of peritoneum therefore forms a ring at the top of this finger-like diverticulum, the **vaginal ring** (Fig. 5-12). The inner (visceral) layer of the diverticulum surrounds and isolates a core of tissue along the axis of the gubernaculum testis. Except in the bitch, there is no vaginal ring in the female. In the male, the components of the spermatic cord (testicular vessels, nerves, lymphatics), and the ductus deferens converge and pass out through the vaginal ring.

Deep Inguinal Ring: *Carefully reflect the parietal peritoneum from one side of your specimen to expose the area outside the vaginal ring, where the structures of the spermatic cord pass through the abdominal wall.* The **deep inguinal ring** is the internal opening in the abdominal wall, through which the structures of the spermatic cord, the genitofemoral nerve, the external pudendal vessels, and lymphatics leave the abdominal cavity. It is basically a triangle (Fig. 5-12), and like most good triangles, it has three sides, each of which is formed by a different anatomic structure. The boundaries of the deep inguinal ring are the following:

1. Cranial- caudal edge of the internal abdominal oblique muscle

2. Medial- lateral edge of rectus abdominis muscle, or its **prepubic tendon**, which is how the muscle terminates on the pubis.

3. Caudolateral- thickened caudodorsal edge of the external abdominal oblique aponeurosis, known as the **inguinal ligament**.

The deep inguinal ring is *not* the same as the vaginal ring, which as previously described is only a ring of peritoneum. (Sometimes authors describe the deep inguinal ring, but refer to it as the vaginal ring; *i.e.*, they get the two confused.)

Superficial Inguinal Ring: In contrast to the triangular deep ring, the **superficial inguinal ring** is only a slit-like opening in the aponeurosis of the external abdominal oblique (Fig. 5-12). *Dissect bluntly between the external and internal abdominal oblique muscles back to the inguinal canal. If necessary, make an incision in the caudal border of the internal abdominal oblique muscle and reflect it cranially to expose the superficial inguinal ring, where the structures of the spermatic cord exit the abdominal wall.*

As the aponeurosis of the external abdominal oblique curves around the caudoventral body wall, it divides into two crura. The **medial crus** curves under the rectus abdominis muscle to attach along the linea alba; the **lateral crus** continues caudally to end in a thickened border, the **inguinal ligament**, which sweeps craniolaterally from the prepubic tendon to the tuber coxae. The superficial inguinal ring is a slit between these two crura of the aponeurosis.

Inguinal Canal: Return the internal abdominal oblique muscle to its original position. *Make a mark on the external pudendal artery where it passes behind the caudal border of this muscle-- that is, where it enters the deep ring. Now, reflect the muscle again, and note the distance between your mark on the vessel and the point where it passes out of sight through the superficial ring.* The segment of the vessel between these points is located within the **inguinal canal**, which is the oblique passage through the abdominal wall between the deep and superficial rings. Note that the superficial and deep inguinal rings are closer together medially than laterally, so the inguinal canal is longer laterally than medially.

In both sexes, the inguinal canal transmits the external pudendal vessels, the genitofemoral nerve, and some rather large lymphatic channels. In addition, it transmits the structures of the spermatic cord in the male. Associated with the parietal vaginal tunic in the male is the **cremaster muscle**, which is derived as a slip off the caudal edge of the internal abdominal oblique muscle.

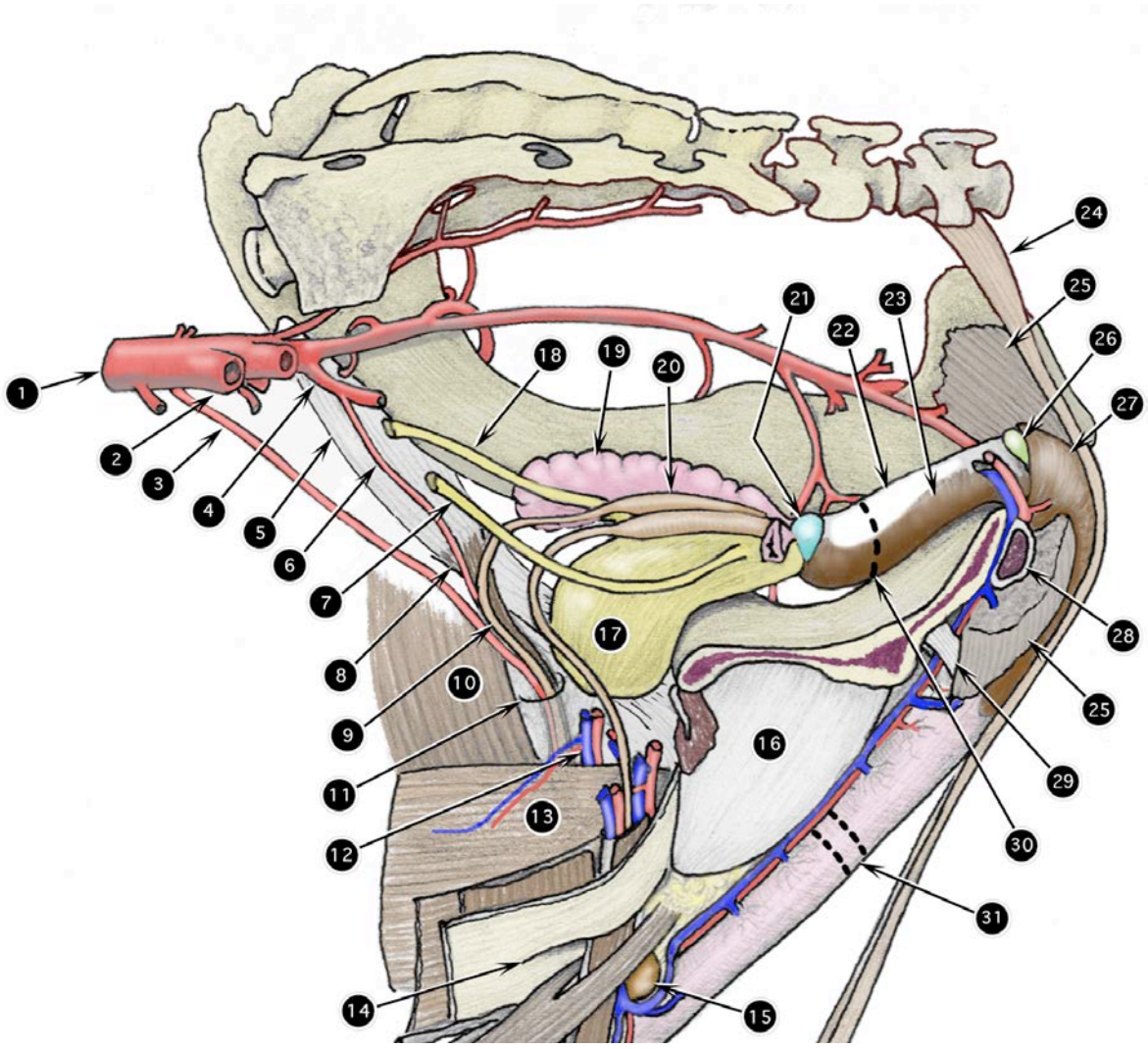


Figure 5-12. Pelvic viscera of bull, left lateral view: (1) aorta; (2) left external iliac artery; (3) testicular artery; (4) umbilical artery; (5) inguinal ligament forming caudolateral boundary of deep inguinal ring; (6) artery of ductus deferens; (7) left ureter; (8) cremaster muscle; (9) ductus deferens; (10) internal abdominal oblique muscle forming cranial boundary of deep inguinal ring; (11) vaginal ring (peritoneal structure); (12) external pudendal vessels entering deep inguinal ring; (13) rectus abdominis muscle forming medial boundary of deep inguinal ring; (14) left superficial inguinal ring (slit in aponeurosis of external abdominal oblique); (15) left superficial inguinal lymph node; (16) symphysial tendon; (17) urinary bladder; (18) right ureter; (19) right vesicular gland (left gland removed); (20) ampulla of ductus deferens; (21) compact part of prostate; (22) location of disseminate part of prostate (indicated by white area); (23) urethralis muscle surrounding pelvic urethra; (24) retractor penis muscles; (25) ischiocavernosus muscle surrounding crus of penis; (26) bulbourethral gland; (27) bulbospongiosus muscle surrounding bulb of penis; (28) left crus of penis (cut) as ischium was removed; (29) suspensory ligament of penis; (30) dotted line indicating level for transection of pelvic urethra to produce cross-section; (31) dotted lines to indicate level of sectioning body of penis to produce cross-section.

Anatomy of the inguinal canal is particularly important in the male horse because of the need for surgical intervention in some cases of *cryptorchidism*. In the male pig, this area also deserves some attention because young male pigs are

predisposed to inguinal hernias. *All students should concentrate their study of the inguinal canal on the male equine and porcine specimens but should also examine this area in the other species.*

In the pig, note that the caudal border of the internal abdominal oblique is more cranial than in the horse. Thus, the deep inguinal ring is large, and the superficial inguinal ring can be seen from the abdominal cavity. Note also that the vaginal ring is also large and is located within the deep inguinal ring. These factors are thought to be related to the occurrence of hernias in young male pigs, in which a loop of intestine descends into the cavity of the vaginal tunic. Another factor in the high incidence of inguinal/scrotal hernias in pigs is thought to be due to the habit of young piglets to pile up for warmth. The piglet(s) on the bottom of the pile is thus "smushed", causing increased abdominal pressure.

External Pudendal Vessels of Ox: These vessels are particularly important in the dairy cow because the arteries are essentially the sole blood supply to the udder, and the veins are a major route of venous return. It has been estimated that approximately 400 units of blood must flow through the udder for each unit of milk produced. When well developed, these vessels form a **sigmoid flexure** just outside the superficial inguinal ring (Fig. 5-4). Also, note that the efferent lymphatics from the large **mammary (superficial inguinal) lymph nodes** pass through the inguinal canal to the **iliofemoral lymph node** (Fig. 5-11).

REMOVAL OF ONE PELVIC LIMB

To continue our study of the reproductive organs, we need to remove the pelvic limb on one side. At this time, we will not carry out a proper dissection of the gluteal region, but the structures of this region will be considered in some detail as we dissect the other side of the specimen. The objective here is just to remove one limb and get down to the pelvic wall.

Continue the dorsal midline incision caudally onto the tail to just beyond the level of the anus. Now, make a transverse incision from the caudal end of that incision, laterally over the tail. Continue to the anus, and carefully incise the skin around it. In the female, continue around the vulva. Bring the skin incision back to the midline and continue ventrally for several centimeters beyond the level of the ischial arch. Now, reflect the skin from the lateral surface of the gluteal and perineal regions, and from the thigh to the level of the stifle.

The lateral wall of the pelvic cavity is formed primarily by the ilium, ischium, and sacrosciatic ligament (Fig. 5-9). The objective here is to reflect the overlying gluteal muscle mass to expose the lateral surface of the ligament. *Remove the large muscles from the ilium, sacrum, and sacrotuberous ligament to the femur; dissect down to the sacrosciatic ligament.*

Sacrosciatic (Broad Sacrotuberous) Ligament: *Continue cleaning away the muscles until the lateral surface of the ligament is completely exposed.* Although broad sacrotuberous ligament is the official name, the shorter **sacrosciatic ligament** is more commonly used to describe this sheet of connective tissue in the ungulates (Fig. 5-9). The dog had a sacrotuberous ligament, but the cat did not. Ungulates have a sacrosciatic ligament, with a sacrotuberous ligament as its caudal border.

The latter is a prominent, palpable structure in the ruminant but is covered by the origins of the semimembranosus and semitendinosus muscles in the horse and pig. As you can see, the sacrosciatic ligament almost completely fills in the space between the sacrum and pelvic bones and forms much of the lateral wall of the pelvic cavity. It converts the greater and lesser sciatic notches of the pelvis into greater and lesser sciatic foramina, which allow for vessels and nerves to exit the pelvic canal and enter the pelvic limb (Fig. 5-9). Relaxation of the ligament prior to and during parturition allows for some widening of the pelvic canal.

Greater and Lesser Sciatic Foramina: The **greater sciatic foramen** is formed by the sacrosciatic ligament and the greater sciatic notch of the ilium. The **lumbosacral trunk**, which gives rise to the sciatic nerve, cranial and caudal gluteal nerves, and to the caudal cutaneous femoral nerve, emerges through this foramen (Fig. 5-9). In addition, the **cranial gluteal vessels** pass out through the greater sciatic foramen. The **lesser sciatic foramen** is formed between the sacrosciatic ligament and the lesser sciatic notch of the ischium. In the ruminants, the **caudal gluteal vessels** pass out through this foramen (Fig. 5-9); however, in the horse, these vessels penetrate the dorsal part of the sacrosciatic ligament, near the lateral border of the sacrum (Fig. 5-10). In the ox, identify the **ischiatic lymph node** near the lesser sciatic foramen.

Pudendal Nerve: Of the numerous nerves that are closely associated with the sacrosciatic ligament, we are primarily interested here in the **pudendal nerve**, which is distributed to the genitalia and associated muscles. Most of the other nerves are distributed to the pelvic limb, and will be studied in more detail on the other side of your cadaver. In the horse, the pudendal nerve is intimately associated with the sacrosciatic ligament and should be preserved as the ligament is reflected (Fig. 5-13).

In the ox, locate the proximal cutaneous branch of the pudendal nerve, which emerges cranial to the dorsal process of the tuber ischiadicum (Fig. 5-9). The distal cutaneous branch of the pudendal nerve emerges through the **ischiorectal fossa**, medial to the tuber ischiadicum. This branch can be palpated in the living ox. Preserve these branches of the pudendal nerve as the sacrosciatic ligament is reflected. The proximal cutaneous branch should be traced proximally as the sacrosciatic ligament is carefully reflected to expose the main trunk of the pudendal nerve (Fig. 5-9).

Once the gluteal muscles have been reflected and the sacrosciatic ligament studied, the pelvic limb is to be removed by cutting through the coxal (hip) joint. *Place the specimen on a table, and abduct the pelvic limb to be removed as far as possible. Beginning in the inguinal region, cut through the skin and medial thigh muscles. Continue applying abduction pressure to the limb as the incision is deepened to enter the coxal joint; be careful not to damage the udder or the external genitalia of the male. Open the coxal joint, and transect the ligamentous attachments to the femoral head; cut any remaining attachments, and remove the pelvic limb*. Tag the limb and store it for study later.

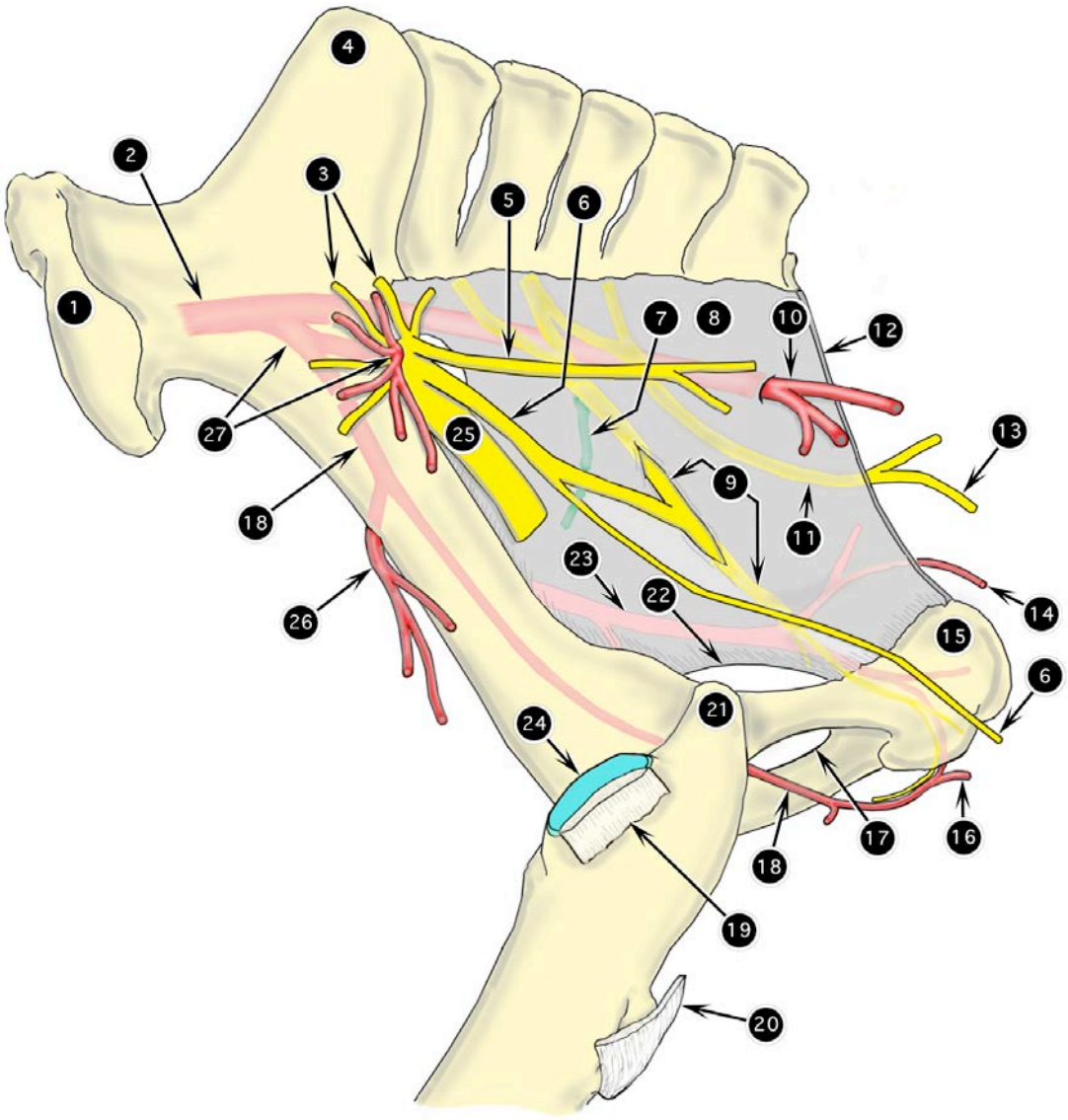


Figure 5-13. Pelvic wall of horse, lateral view: (1) tuber coxae; (2) caudal gluteal artery (from internal iliac); (3) numerous branches of cranial gluteal nerve emerging from greater sciatic foramen; (4) tuber sacrale; (5) caudal gluteal nerve to superficial gluteal muscle; (6) caudal cutaneus femoral nerve; (7) pelvic nerve from pudendal nerve, which is embedded in sacrosciatic ligament; (8) sacrosciatic (broad sacrotuberous) ligament; (9) pudendal nerve; (10) caudal gluteal artery emerging through opening in 8; (11) caudal rectal nerve; (12) sacrotuberous ligament (caudal border of 8); (13) perineal nerve; (14) ventral perineal artery; (15) tuber ischiadicum; (16) deep artery of penis; (17) obturator foramen; (18) obturator artery; (19) tendon of accessory gluteal muscle; (20) tendon of superficial gluteal muscle terminating on third trochanter; (21) caudal part of greater trochanter; (22) lesser sciatic foramen; (23) internal pudendal artery; (24) trochanteric bursa between 19 and cranial part of greater trochanter; (25) sciatic nerve; (26) iliacofemoral artery; (27) cranial gluteal artery.

Coccygeus and Levator Ani Muscles: The bovine levator ani originates from the ischiatic spine, medial to the coccygeus, and is less complex than that of the horse, which has numerous slips that attach to the anus with the external anal sphincter. The coccygeus and levator ani muscles, with the associated pelvic fascia, form the **pelvic diaphragm**, which closes the pelvic cavity dorsolaterally. In quadrupeds, the weight of

the pelvic viscera is supported principally by the osseous pelvic floor. However, the pelvic diaphragm functions to contain the pelvic viscera during abdominal press. Sustained periods of abdominal press, such as during parturition, difficult urination, or defecation, can overpower the pelvic diaphragm, especially if it is inherently weak. This can result in *perineal herniation* or prolapse of the pelvic or abdominal viscera, including the rectum, vagina, urinary bladder, uterus, and intestines.

Retractor Penis Muscles: A loop of the retractor penis muscles under the anus is well developed only in the horse. In the pig, the rectal and penile parts of the muscle arise independently and are not connected. Note the pale color of the retractor penis muscles (smooth muscle) as compared with that of the other penile muscles (skeletal muscles). In the pig and ruminants (fibroelastic penis), the retractor penis muscles insert in the **tunica albuginea penis**, distal to the sigmoid flexure (Fig. 5-14). The homologous **retractor clitoridis muscle** is present in all the common domestic mammals except the bitch.

Preserving the pudendal nerve, carefully incise the sacrosciatic ligament along the lateral border of the sacrum, and reflect it to expose the structures of the pelvic cavity. To gain more exposure, it is necessary to remove part of the osseous pelvic wall. *Using a wire saw, cut through the body of the ilium at the level of the greater sciatic foramen. Now, place the wire through the lesser sciatic foramen and obturator foramen, and cut laterally through the ischium just cranial to the tuber ischiadicum. Pull laterally on the isolated bone segment to break it loose at the pelvic symphysis; cut any remaining attachments and remove it*.

This should expose the pelvic viscera, which are usually surrounded by fat. Carefully clean away this fat, preserving the nerves and vessels that are located medial to the sacrosciatic ligament (Figs. 5-9 & 5-13).

Sacral Plexus: The nerves of the lumbosacral plexus can be divided into two groups: (1) those more cranial nerves to the pelvic limb; and (2) those more caudal nerves that are supplied to the pelvic viscera and perineal region (Fig. 5-15). For now, we shall direct our attention to the latter group. The **pudendal nerve** is derived primarily from S2 to S4 and courses caudoventrally on the medial surface of the broad sacrotuberous ligament, where it can be palpated rectally in the ox (Fig. 5-15). There is some variation in the sacral plexus, so the arrangement in your cadaver may not conform exactly to the pattern shown in the illustrations.

The pudendal nerve gives rise to the deep perineal nerve and continues as the **dorsal nerve of the penis** (clitoris). Typically, the **caudal rectal nerve**(s) parallels the pudendal nerve in a more dorsal location (Fig. 5-15). Locate the **pelvic nerve**, which lies medial to the pudendal nerve and carries parasympathetic fibers from the sacral segments of the spinal cord to the **pelvic plexus**, from which they are distributed to the pelvic viscera.

Internal Iliac and Pudendal Arteries: As previously noted, the internal iliac artery terminates high in the horse, giving rise to the caudal gluteal artery and continuing as the **internal pudendal artery** (Fig. 5-10). In the artiodactyls, this division does not occur until the internal iliac reaches the level of the lesser sciatic foramen (Fig. 5-9). Follow the internal iliac artery caudally, and identify its branches. The **umbilical artery** gives rise to the **uterine artery** (artery of

ductus deferens in male) in the artiodactyls (Fig. 5-9) and then continues toward the urinary bladder.

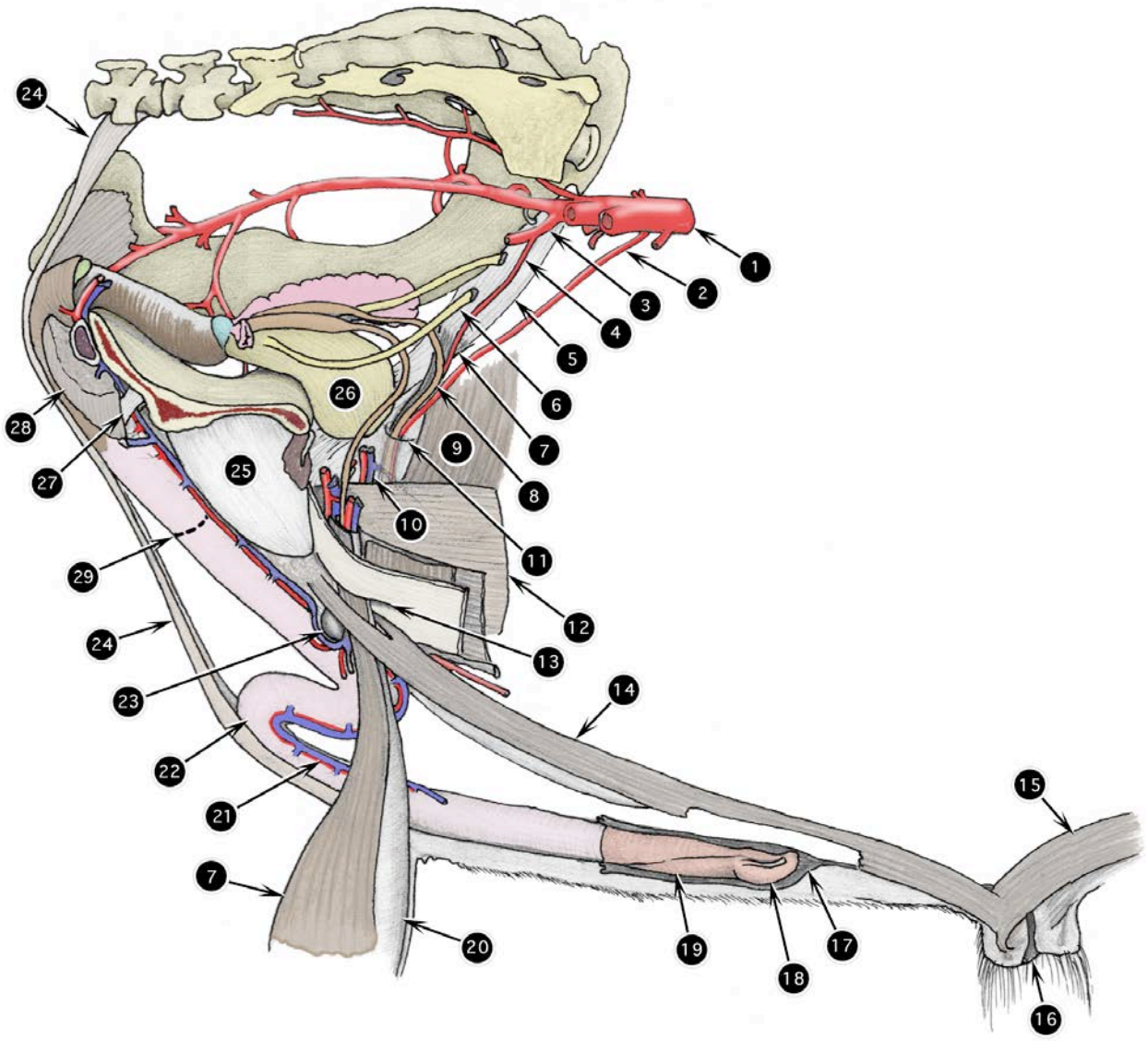


Figure 5-14. Genitalia of bull, right lateral view: (1) aorta; (2) testicular artery; (3) umbilical artery; (4) artery of ductus deferens; (5) inguinal ligament; (6) ureter; (7) cremaster muscle; (8) ductus deferens; (9) internal abdominal oblique muscle; (10) external pudendal vessels; (11) vaginal ring; (12) rectus abdominis muscle; (13) superficial inguinal ring; (14) caudal preputial muscle; (15) cranial preputial muscle; (16) preputial orifice; (17) preputial cavity; (18) glans penis; (19) free part of penis; (20) parietal vaginal tunic; (21) dorsal vessels of penis; (22) sigmoid flexure of penis; (23) superficial inguinal lymph node; (24) retractor penis muscles; (25) symphysial tendon; (26) urinary bladder; (27) suspensory ligament of penis; (28) ischiocavernosus muscle.

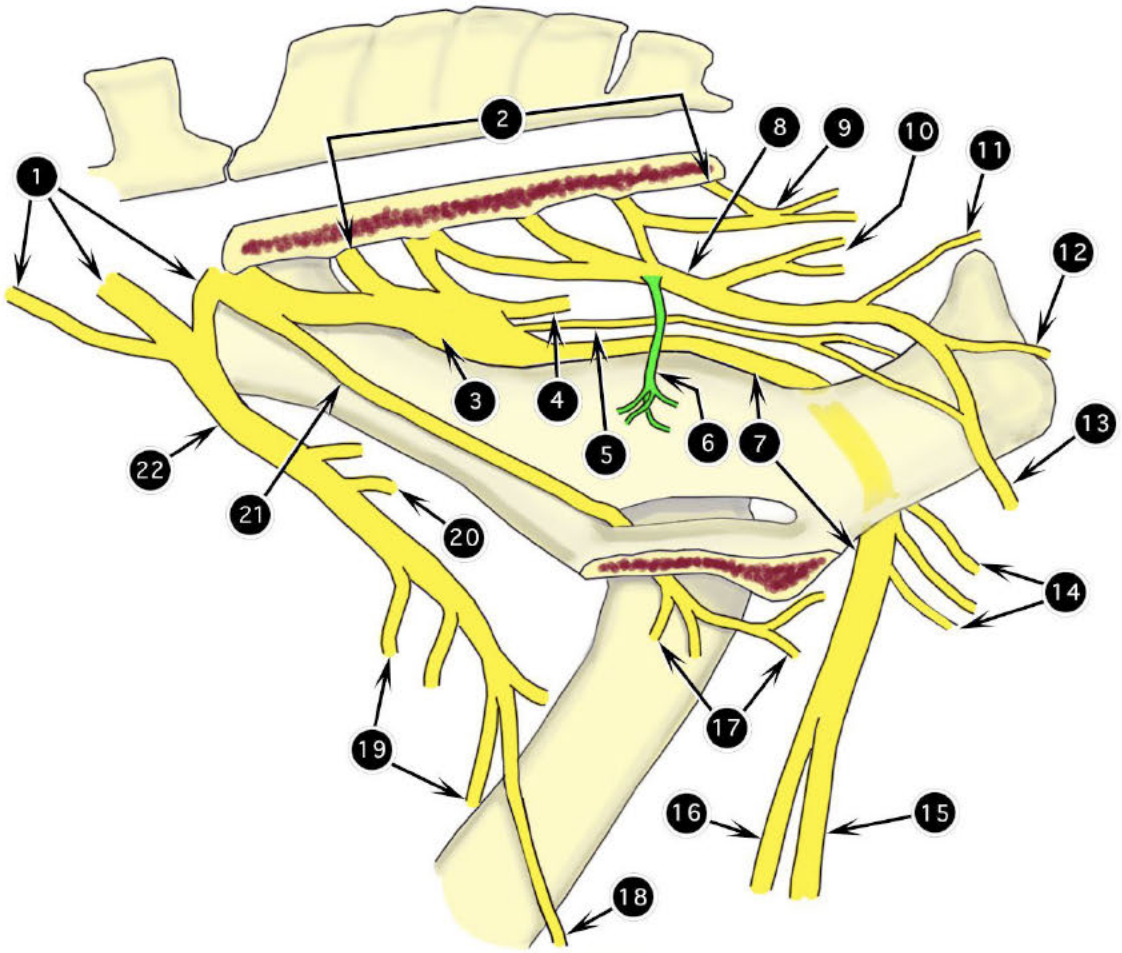


Figure 5-15. Nerves of bovine lumbosacral plexus, medial view: (1) roots of lumbosacral plexus derived from ventral branches of L4-L6; (2) roots of lumbosacral plexus derived from ventral branches of S1-S5; (3) lumbosacral trunk; (4) caudal gluteal nerve to superficial gluteal component of gluteobiceps muscle; (5) caudal cutaneous femoral nerve; (6) pelvic nerve- parasympathetic fibers to pelvic viscera; (7) sciatic nerve; (8) pudendal nerve; (9) caudal rectal nerve to external anal sphincter & retractor penis (clitoridis) muscles; (10) muscular branches of 8 to levator ani and coccygeus muscles; (11) proximal cutaneous branch of pudendal nerve; (12) distal cutaneous branch of pudendal nerve; (13) dorsal nerve of penis (clitoris); (14) branches of sciatic nerve to biceps femoris (gluteobiceps), semitendinosus, & semimembranosus muscles; (15) tibial nerve; (16) common peroneal (fibular) nerve; (17) branches of obturator nerve to pectineus, gracilis, adductor, and external obturator muscles; (18) saphenous nerve; (19) branches of femoral nerve to quadriceps femoris & sartorius muscles; (20) branches of femoral nerve to psoas minor and iliopsoas muscles; (21) obturator nerve coursing along body of ilium; (22) femoral nerve.

The pig is unique in that the internal iliac artery exits the pelvic cavity *via* the greater sciatic foramen and continues along the *lateral* surface of the sacrosciatic ligament. As it reaches the lesser sciatic foramen, the caudal gluteal continues to supply the pelvic limb, while the internal pudendal branches off medially and re-enters the pelvic cavity *via* the lesser sciatic foramen (Fig. 5-16).

The primary branch to the pelvic part of the reproductive tract is the **prostatic** or **vaginal artery**. The term, urogenital artery, was formerly used as a collective term to describe the homologous vaginal and

prostatic arteries, but because you invariably deal with either a male or female animal, the specific names are more appropriate. After giving off branches to the perineal region (ventral perineal arteries) and to the area of the external anal sphincter (caudal rectal artery), the main continuation of the internal pudendal artery is distributed to the genitalia, accompanied by the pudendal nerve.

Only the mare and bitch have **vestibular bulbs** or arteries of same. The cow does have vestibular and labial branches, and the continuation of the artery is a mammary branch, which typically provides an insignificant amount of blood to the udder but could represent a potentially important collateral supply to the udder if the external pudendal artery were to become obstructed. The tortuous perineal veins (Fig. 5-4), which accompany the mammary branches, do not usually serve to drain the udder. The valves in these veins normally dictate flow toward the udder rather than away from it.

To examine the pelvic part of the genitalia *in situ*, the rectum and anus need to be removed. *After all groups have had the opportunity to appreciate the relationships of the rectum to the other pelvic viscera, carefully incise around the anus, and detach the retractor penis (clitoridis) muscles from the area of the external anal sphincter. Preserving the nerves of the sacral plexus as much as possible, remove the rectum and anus. Cut through the dorsal commissure of the vulva, and extend the mid-dorsal incision cranially through the vestibule and vagina to the level of the cervix.*

FEMALE INTERNAL GENITALIA AND URINARY BLADDER

Pelvic Viscera of Mare: The **labia** of the equine **vulva** are rounded, and the **vulvar cleft** is unique in that the ventral commissure is rounded and the dorsal commissure pointed, just the opposite of the other domestic mammals. The **clitoris** of the mare is large and arises by two crura from the ischia; its body lies in the floor of the vestibule and contains a considerable quantity of erectile tissue. Like its male homologue, the **glans clitoris** of the horse (Fig. 5-5) is better developed than that of the other species.

Locate the glans clitoridis within the **fossa clitoridis**. Note that it has its own prepuce (preputium clitoridis) to which it is attached by a wide, dorsally located frenulum. Although the urethra is not associated with the clitoris, a **fossa glandis** is present in the well-developed glans clitoris of the mare (Fig. 5-5). This dead-end fossa serves no apparent purpose, but it has been shown to harbor the infectious organism responsible for contagious equine metritis. During estrus or following urination, mares can voluntarily contract their ischiocavernosus muscles and expose the glans clitoris, a phenomenon that, for lack of a more appropriate term, is known as "winking."

Like the deep artery of the penis in the stallion, the **artery of the clitoris** comes from the obturator artery in the mare, whereas in the other species, it is a branch of the internal pudendal artery.

Similar to the arrangement in the bitch, the erectile tissue in the lateral walls of the vestibule is consolidated to form right and left **vestibular bulbs** in the mare (Fig. 5-5). Although erectile tissue is present in the other domestic ungulates, it is more diffuse, and definitive vestibular bulbs are typically not recognized. Also in the dorsal and ventral walls of the vestibule are numerous

small, crater-like openings of the **minor vestibular glands**. The mare does not have major vestibular glands. Note the well-developed **constrictor vulvae** and **constrictor vestibuli muscles** of the mare (Fig. 5-5).

The relationship of the vulva and vestibule to the ischial arch is important. As a mare ages, muscle tone in the perineal region decreases, and there is often less perivulvar fat to help support the vulva. In these mares, the vulva tends to sink in at the top as if it were falling into the pelvic cavity, a situation that obviously predisposes it to fecal contamination. To compound matters, the vulva tends to fall in and out of the pelvic outlet as the mare walks. This to-and-fro motion tends to pump air into the vestibule and vagina, carrying contamination with it, a condition known as *pneumovagina*. Mares that exhibit this problem are affectionately known around the barn as "wind suckers." Breeding or foaling injuries can also result in pneumovagina because the labia become malformed and do not seal properly.

To prevent this condition from contaminating the reproductive tract and producing chronic genital tract infection, many brood mares undergo surgery, a procedure known as a Caslick's operation. In essence, the vulvar cleft is sewn shut, except for an opening at the ventral commissure to allow for urination. Under local infiltration anesthesia, a narrow ribbon of tissue is excised from the edges of the labia about one-half to two-thirds of the way down on each side, including the dorsal commissure. The raw edges are then sutured together to close the vulvar cleft (except ventrally). Some mares have the procedure performed more than once, but this becomes more difficult as scar tissue builds up. In these mares, the only two times when their vulva isn't sewn shut is when they are being bred and when they are foaling.

Note the large **external urethral orifice** of the mare, just caudal to an overhanging transverse fold of tissue (remnant of the hymen) that marks the junction of the vagina and vestibule (Fig. 5-5). Note also the short and relatively large **urethra**, which predisposes the mare to prolapse of the urinary bladder out through the urethra. In some older mares, the transverse fold that lies cranial to the urethral orifice sags cranially and allows urine to pool in the vagina, resulting in vaginitis and possibly in metritis. In these mares, surgical relocation of the transverse fold to a more caudal position may be performed to create a shelf of tissue over the urethral orifice, which diverts the urine caudally and prevents pooling of urine in the vagina.

Review the extent of the rectogenital pouch (Fig. 5-3), and identify the **line of peritoneal reflection** onto the vagina. It is possible to enter the peritoneal cavity of the mare by a longitudinal incision in the dorsal wall of the vagina, just caudal to the cervix. Although not frequently performed any more, this approach can be used for ovariectomy. Note the projection of the cervix into the vagina. The appearance of the cervix varies considerably and, when viewed through a vaginal speculum, can be used to evaluate the stage of the reproductive cycle in the mare. The **external ostium of the uterus** is located at the apex of the cervical projection, and the recess around the cervix is known as the fornix vaginae (Fig. 5-5).

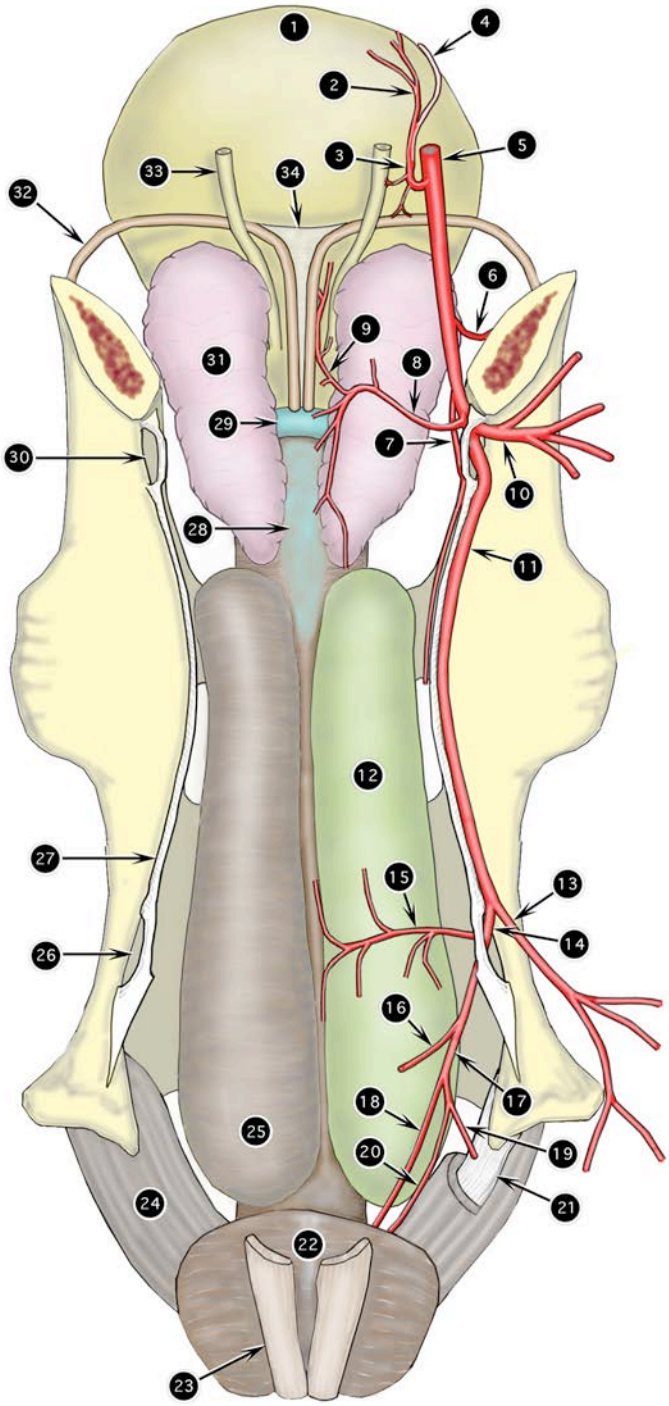


Figure 5-16. Pelvic viscera of boar, dorsal view: (1) urinary bladder; (2) cranial vesical artery; (3) umbilical artery; (4) round ligament of urinary bladder; (5) internal iliac artery; (6) iliolumbar artery; (7) obturator artery; (8) prostatic artery; (9) caudal vesical artery; (10) cranial gluteal artery; (11) internal iliac artery, lateral to sacrosciatic ligament; (12) bulbourethral gland; (13) caudal gluteal artery; (14) internal pudendal artery; (15) urethral branch of 14; (16) caudal rectal artery; (17) artery of penis; (18) artery of bulb of penis; (19) deep artery of penis; (20) dorsal artery of penis; (21) crus of penis; (22) bulbospongiosus muscle covering bulb of penis; (23) retractor penis muscle; (24) ischiocavernosus muscle; (25) bulboglandularis muscle covering 12; (26) lesser sciatic foramen; (27) sacrosciatic ligament; (28) disseminate part of prostate covered by urethralis muscle; (29) body of prostate; (30) greater sciatic foramen; (31) vesicular gland; (32) ductus deferens; (33) ureter; (34) genital fold.

Open the cervical canal dorsally from the external ostium into the uterine body. The cervical canal of the horse is relatively short, but as you can see, the body of the equine uterus is large, which is unique among domestic mammals (Fig. 5-5).

As previously noted, the vagina of the mare is subject to serious injury (*e.g.*, laceration, perforation) during foaling. Such injuries occur most often in *primiparous* mares, especially when there is some malpositioning of the foal. When only the mucosa of the vagina and vestibule is involved, these tears are termed first-degree lacerations. Second-degree injuries are deeper penetrations that involve the submucosa and muscular layer of the vagina.

The most serious tears are classified as third-degree lacerations. These involve the full thickness of the vaginal wall, penetration of the perineal body,[5] and tearing of the rectum, which results in a rectovaginal fistula. It is hard to believe the amount of damage that can result from the strong expulsive efforts of the mare, following penetration of these structures by the foal. Sometimes the tear breaks completely through the cutaneous bridge between the anus and vulva. Obviously, third-degree lacerations result in continuous contamination of the vagina with fecal material, and reconstructive surgery is required if the mare is to be returned to breeding soundness.

As is intuitively obvious, even to the more casual observer, the size and position of the **urinary bladder** vary significantly with the amount of urine contained therein. Because most ungulates are not housebroken, they tend not to let themselves get too uncomfortable, unless there is some impediment to urination. When relatively empty, the bladder of the horse resides entirely within the pelvic cavity, with only its more cranial part being covered by peritoneum (Fig. 5-3). As the bladder fills, it descends over the pubis and along the caudoventral abdominal wall. It is gently restrained by the **lateral and median ligaments of the urinary bladder**, which among other things prevent the bladder from twisting on its urethral attachment when the horse rolls over.

The urethra of the mare is short. If a mare strains too vigorously, she can actually evert (prolapse) her bladder, wrong-side-out, through the urethra. **Patent urachus** is not an uncommon condition in foals. It is characterized by seepage of urine at the umbilicus, which unfortunately may be accompanied by leakage into the peritoneal cavity. This condition can be corrected surgically.

Pelvic Viscera of Female Ruminant: In the cow, note the tuft of hair that is associated with the ventral commissure of the vulva (Fig. 5-6). As a tip to the examining veterinarian, external evidence of any vaginal discharge is often present on these hairs. Note the small glans and prepuce of the **clitoris** just inside the ventral commissure. Identify the **suburethral diverticulum** of the cow (also present in the sow), which opens in common with the urethra in the floor of the vestibule (Fig. 5-6). This pocket serves no apparent purpose, except perhaps to retain a small quantity of urine, which may be useful to the bull when he comes sniffing around sampling for pheromone content.

The suburethral diverticulum must be taken into account, however, whenever we attempt to catheterize the urinary bladder of

[5] perineal body- the firm, fibromuscular connection between the anal canal and the vagina-vestibule or bulb of the penis.

the cow or sow. The catheter, once inserted into the common opening, must be directed dorsally to enter the urethra and avoid the dead end of the diverticulum. Note the openings of the **major vestibular glands**[6] (Fig. 5-6), which are present in the cow, queen, and occasionally in the ewe. These glands represent the female homologues of the bulbourethral glands of the male. Also examine along the junction of vagina and vestibule for two small openings lateral to the suburethral diverticulum. These are the openings of the vestigial mesonephric ducts, and are sometimes referred to as Gartner's canals. Occasionally, these vestigial ducts may contain cysts.

The **fornix vaginae** surrounds the intravaginal part of the cervix and must be avoided when attempting to insert an insemination pipette into the external ostium of the uterus. Note that the fornix is deeper dorsally.

In the small ruminants, the intravaginal part of the cervix lies in a ventral depression so that the external ostium is more on a level with the ventral wall of the vagina. *Open the cervical canal dorsally from the external ostium into the uterine body*. The **cervix** of the cow is firm and thick-walled, which allows it to be easily identified during rectal palpation of the genital tract. Note that it has three or four prominent **circular folds** that project into the lumen of the cervical canal (Fig. 5-6). When the cervix is closed, these folds interdigitate with one another and make passage of an insemination pipette virtually impossible. During pregnancy, the canal is completely sealed with a tight-fitting mucous plug. The cervical canal of the small ruminants has more circular folds than that of the cow.

When only moderately full, the **urinary bladder** of the ruminant extends over the pubis into the abdominal cavity (Fig. 5-4). The neck of the bladder and urethra are firmly anchored by connective tissue to the vagina. If you have not already done so, be sure to examine the urinary bladder of the newborn calf. As is characteristic of the neonate, the bladder is elongated and extends cranially toward the umbilicus. As it recedes toward the pelvic cavity, it assumes its more characteristic pear shape, and the peritoneal fold that contained the urachus persists as the **median ligament of the bladder** (Fig. 5-3).

Pelvic Viscera of Sow: Similar to that of the ruminant, the **glans clitoris** is rather poorly developed in the sow and is concealed in its small fossa, just inside the ventral commissure of the vulva (Fig. 5-8). **Minor vestibular glands** open individually in the floor of the vestibule, but no major vestibular glands are present. The vestibule of the pig is long, so the **external urethral orifice** is located relatively far cranially, and, like that of the cow, opens in common with the **suburethral diverticulum** (Fig. 5-8).

In the gilt[7] a prominent annular fold (remnant of hymen) marks the junction of the vagina and vestibule. The vagina of the sow is also long and is characterized by prominent longitudinal folds (Fig. 5-8). Unlike the other ungulates, the sow has no intravaginal portion of the cervix, and therefore no fornix vaginae. *Open the cervical canal dorsally from the external ostium into the uterine body*. The **cervix** is especially long, and the canal is closed by the interdigitation of a series of prominences (tubercles) from the cervical wall into the

[6] major vestibular glands- also known by the eponym Bartholin's glands.

[7] gilt- a young female pig that has not yet had a litter.

lumen (Fig. 5-8). Like most everything else in the female urogenital tract of the pig, the **urethra** is long, so that only the neck of the **urinary bladder** is located within the pelvic cavity.

MAMMARY GLANDS

Before we study the male urogenital apparatus, let's examine those female structures involved with nursing the progeny. Although the mammae are skin modifications and are not technically part of the genital system, they are typically involved in the postpartum life of domestic mammals. Thus, functionally, if not morphologically, this seems a good time to consider these structures. As the mammary glands of the different species are examined, special emphasis should be placed on those of the cow and goat. The first point to be made is that mammary glands are nothing more than modified sweat glands.[8]

Udder of Cow: The mammary glands of the cow are closely applied to one another, forming the **udder**. The udder typically consists of four mammae, with each possessing a single **teat** (mammary papilla); however, accessory (supernumerary) teats may be present. *Carefully clean the stumps of the gracilis and adductor muscles away to expose the* ***symphysial tendon*** (Fig. 5-4). In addition to providing a common origin for the gracilis and adductor muscles of each limb, the symphysial tendon also gives rise to part of the **suspensory apparatus of the udder**. The **lateral laminae** leave the symphysial tendon and pass to the right and left lateral aspects of the udder (Fig. 5-17). These laminae are primarily collagenous and are reinforced by fascia from the medial aspects of the thighs. The cranial part of the lateral lamina of each side originates from the elastic abdominal tunic lateral to the superficial inguinal ring (Fig. 5-17).

Isolate the lateral lamina and carefully transect it in a horizontal manner dorsal to the udder. Reflect the lateral lamina to expose the mammary tissue of that side. Dorsal to the mammary tissue identify the **external pudendal artery and vein** and the **mammary (superficial inguinal) lymph node** (Fig. 5-17). The external pudendal artery passes through the inguinal canal and is the primary arterial supply to each half of the udder. It typically divides into cranial and caudal mammary arteries, but there is some variation in the branching pattern. The large external pudendal vein is a major route of venous return from the mammary tissue (Fig. 5-17).

A **venous ring** is present at the base of the udder and receives the blood returning from the glands (Fig. 5-17). In addition to the external pudendal veins, a large **subcutaneous abdominal vein** (milk vein) leaves the ring on each side. Each of these vessels follows a tortuous course along the abdomen until it penetrates the abdominal wall at the so-called "milk well." From here, the blood continues through the internal thoracic vein to the cranial vena cava.

The subcutaneous abdominal vein develops during the first pregnancy as an anastomosis between the cranial and caudal superficial epigastric veins. As the demand for venous return increases, the veins enlarge and the valves become incompetent, allowing blood to flow cranially away from the udder, forming a sort of “physiologic varicose vein. The flow of blood in the small perineal veins, which enter the caudal aspect of the venous ring at the base of the udder, is toward the udder. Thus, under

[8] Does that mean that milk is "modified sweat?" Oh, sorry I brought that up. Why do I think of such questions?

normal circumstances, the perineal veins do not serve as a route of venous drainage for the udder.

Numerous large, superficial lymphatics drain the mammary tissue to the mammary lymph node (Fig. 5-17). Efferent lymphatics then continue through the inguinal canal, to the iliofemoral lymph node. The superficial lymphatics of the udder can be observed in the living animal, and their direction is primarily caudodorsal. These lymphatics can be distinguished from the superficial veins, which course in a more craniodorsal direction (Fig. 5-17).

Blunt dissection caudodorsal to the mammary glands should expose a deeper plate of supporting tissue, the **medial lamina**. Together with its adjacent counterpart on the other side, this lamina forms the other major part of the suspensory apparatus of the udder (Fig. 5-17). In contrast to the fibrous lateral laminae, the medial laminae are *elastic* structures, which are derived primarily from the elastic abdominal tunic along the caudal part of the linea alba.

Beginning caudally, bluntly separate between the adjacent medial laminae to observe that the right and left halves of the udder can be cleanly divided (Fig. 5-9). The position of this division is marked externally by the **intermammary groove**. Thus, each half of the udder is supported by a separate sling, or basket of connective tissue formed by the medial and lateral laminae of that side. Many lamellae of connective tissue leave each lamina at various levels and join the stroma of intramammary connective tissue.

Each teat possesses a single teat orifice at its apex, which is the termination of that mammary gland (Fig. 5-17). *Locate one of these openings, and incise the wall of the teat in a cranial to caudal direction to pass through it. Continue this incision along the cranial and caudal sides of the teat to its base, and then connect the two ends by a transverse lateral incision.* This should allow for removal of the lateral half of the teat wall to expose the **teat sinus**. The teat sinus is continuous dorsally with an irregular cavity in the lower part of that quarter (Fig. 5-17). *Remove enough of the glandular tissue to expose adequately this* **gland sinus**. The combined teat sinus and gland sinus form a single reservoir, the **lactiferous sinus** (Fig. 5-17).

The branching duct system of each mammary gland is completely separate from the others, and each terminates in numerous **lactiferous ducts** that empty into the gland sinus. The openings of these large ducts can be observed entering the sinus. If a lactiferous duct could be followed away from the sinus (against the flow of milk), it would be found to be formed by the unions of progressively smaller ducts that finally lead to the mammary alveoli. The arrangement is similar to that of the respiratory tree.

As observed, the right and left halves of the udder are neatly separated by connective tissue. From a surgical standpoint, it is unfortunate that this is not the case with the two quarters (cranial and caudal) on the same side. Although the duct systems are separate, the two branching glands intermesh with each other like two dense bushes growing close together with their branches all intertwined with one another. Because of this complex entanglement of the adjacent duct systems, a clean surgical division is not possible.

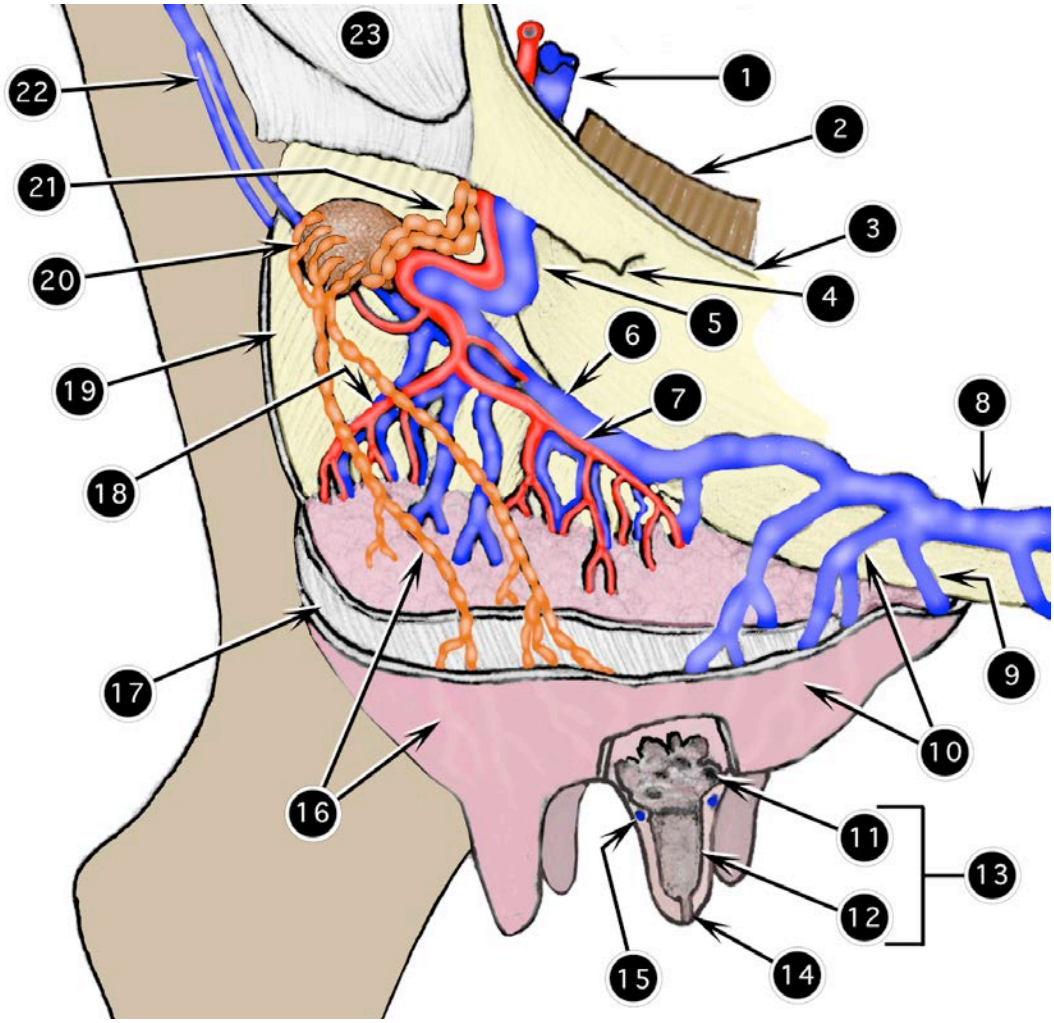


Figure 5-17. Udder of cow, right lateral view: (1) external pudendal vessels entering inguinal canal; (2) internal abdominal oblique muscle; (3) aponeurosis of external abdominal oblique muscle; (4) cut lateral lamina of suspensory apparatus of udder; (5) external pudendal vessels exiting superficial inguinal ring; (6) lateral part of venous circle at base of udder; (7) cranial mammary artery; (8) subcutaneous abdominal vein; (9) right-left anastomosis forming cranial part of venous ring at base of udder; (10) superficial veins draining blood away from udder in craniodorsal direction; (11) gland sinus; (12) teat sinus; (13) lactiferous sinus; (14) teat canal; (15) venous ring at base of teat; (16) large superficial lymphatics carrying lymph away in a caudodorsal direction to mammary lymph node; (17) lateral lamina of suspensory apparatus of udder; (18) caudal mammary artery; (19) medial lamina of suspensory apparatus of udder; (20) mammary (superficial inguinal) lymph node; (21) large efferent lymphatics carrying lymph through inguinal canal to iliofemoral lymph node; (22) perineal veins (23) symphysial tendon.

Return to the orifice at the apex of the teat. Note that the teat sinus does not extend entirely to this opening but that a short duct, the **teat canal**, continues to the outside (Fig. 5-17). The teat canal (papillary duct) is usually closed by longitudinal mucosal folds with the aid of a sphincter of smooth muscle and elastic tissue. This serves as an *important barrier* against external contamination and infection of the mammary tissue (mastitis). *The folds that help close the teat canal can be best appreciated by sectioning another teat transversely about 2 cm from its apex*. This

opens the teat sinus, and the internal orifice of the teat canal can be observed. The radial pattern created by the converging mucosal folds at the internal orifice is sometimes referred to as Furstenberg's rosette.

In addition to the large venous ring at the base of the udder, a smaller venous ring is present at the base of each teat (Fig. 5-17). This latter ring, which is associated with a circular constriction at the base of the teat, receives its blood from a rich, erectile tissue plexus of longitudinal veins in the wall of the teat.

The udder of the cow is supplied by sensory and autonomic nerves. The *sensory innervation* is derived from the ventral cutaneous branches of L1 and L2, the genitofemoral nerve (L3 and L4), and the mammary (superficial perineal) branch of the pudendal nerve (Fig. 4-3). Of these, the **genitofemoral nerve** is of major importance, because it innervates much of the skin, the teats, and most of the glandular tissue.

The *autonomic innervation* is supplied by sympathetic fibers from the caudal mesenteric ganglion, which accompany the genitofemoral nerve through the inguinal canal. These fibers supply the **myoepithelial cells** and the smooth muscle fibers of blood vessels. It is interesting to note that no parasympathetic fibers have been demonstrated in the bovine udder. This seems curious, but as previously noted, *mammary glands are just modified sweat glands*.

As you might appreciate from the above description, making milk is hard work, and it requires a great deal of energy. To meet those high energy requirements, dairy cattle must eat a lot of high-energy feed to maximize milk production. And after all those nutrients have been absorbed *via* their efficient digestive system, those nutrients must be transported through the udder by a substantial circulatory network. It has been estimated that for every unit of milk a cow produces, some 400 units of blood must flow through her udder. Now let's see. If a cow produces 8 gallons (≈ 64 lbs) of milk in 24 hours, that would mean some 3200 (8 x 400) gallons of blood would have to flow through her udder. No wonder those external pudendal vessels and subcutaneous abdominal veins are so large in lactating dairy cows.

Udder of Doe ("Nanny"): The caprine udder consists of two mammary glands. In the young nanny (doe), there is a fairly distinct demarcation between the teat and body of each gland, but after several lactations, this demarcation is lost. Also, in the older doe, the lactiferous sinus expands caudodorsally in a subcutaneous location, where it can be palpated.

Identify one of the teat openings, and incise the wall of the teat in a cranial-caudal direction to pass through it. Continue this incision along the cranial and caudal sides of the teat to its base, and then connect the two ends by a lateral transverse incision. This should allow for removal of half of the teat wall and expose the teat sinus. The **teat sinus** is continuous dorsally with an irregular cavity in the lower part of the gland. *Remove enough of the glandular tissue to expose adequately this* **gland sinus**. The teat sinus is large, and the teat canal is less than 1 cm long. The wall of the teat, like that of the cow, contains a plexus of thick-walled veins.

There are numerous sebaceous and coiled scent glands in the skin of the udder,

and small accessory teats are often present. The arterial supply is through the external pudendal artery, which has considerable variation in its branching. The principal venous drainage is through the external pudendal vein, and the innervation and lymph drainage are similar to those of the cow.

Udder of Ewe: The ovine udder is similar to that of the nanny, only smaller, and both the teat and gland sinuses are much smaller than those of the doe. *There is no smooth muscle in the sphincter of the teat canal*. Closure of this canal is accomplished by a dense network of elastic fibers. Accessory teats are not common in the ewe, but do occur typically in the male. Between the udder (or scrotum) and the medial surfaces of the thighs are the **inguinal pouches**, which contain an oily secretion. The sebaceous and tubular glands associated with these pouches are thought to produce a unique marker scent, which is thought to help the ewe in identifying her own lamb(s).

Udder of Mare: There seems to be some unnecessary confusion about how many mammae (two or four) are present in the mare. When you look at the udder of a mare, how many teats do you see- two, right? It's true that each mamma usually has two (occasionally three) papillary ducts and orifices, each associated with a separate duct system. But using that logic, each mammary papilla of the dog may have 10 or more separate duct systems associated with it, but we don't go around saying a dog has 100 mammae (10 x 10); do we? Let's get straight on this point: the mare has **two mammae** (Fig. 5-18).

Identify the two teat orifices on one mamma. Make a cranial-caudal incision in the teat and gland so as to pass through these two openings. Remove the lateral half of the gland and teat. Now, you can appreciate that each mamma consists of two separate duct systems that converge to share a common papilla (Fig. 5-18). Although less developed than that of the cow, the suspensory apparatus consists of elastic medial and fibrous lateral laminae that support the udder.

There is no smooth muscle in the sphincter of the teat canal; however, there are numerous sweat glands and sebaceous glands associated with the teat. The *sebaceous glands* are especially large near the teat canals, and it is the product of these large glands that is responsible for the phenomenon of "waxing" in the pregnant mare just prior to parturition. Horsepersons use this signal as an indicator of foaling time, and they tend to get excited when they see the mare "waxing up."

Mammary Glands of Sow: The mammae of the sow usually consist of seven or eight pairs, including thoracic, abdominal, and inguinal glands). These glands are suspended by an elastic, supporting apparatus. Each mamma, like that of the horse, consists of two separate glandular complexes that are drained by separate lactiferous sinuses and teat canals. Occasionally, three glandular complexes are present in one mamma, but the third usually ends blindly at the base of the teat.

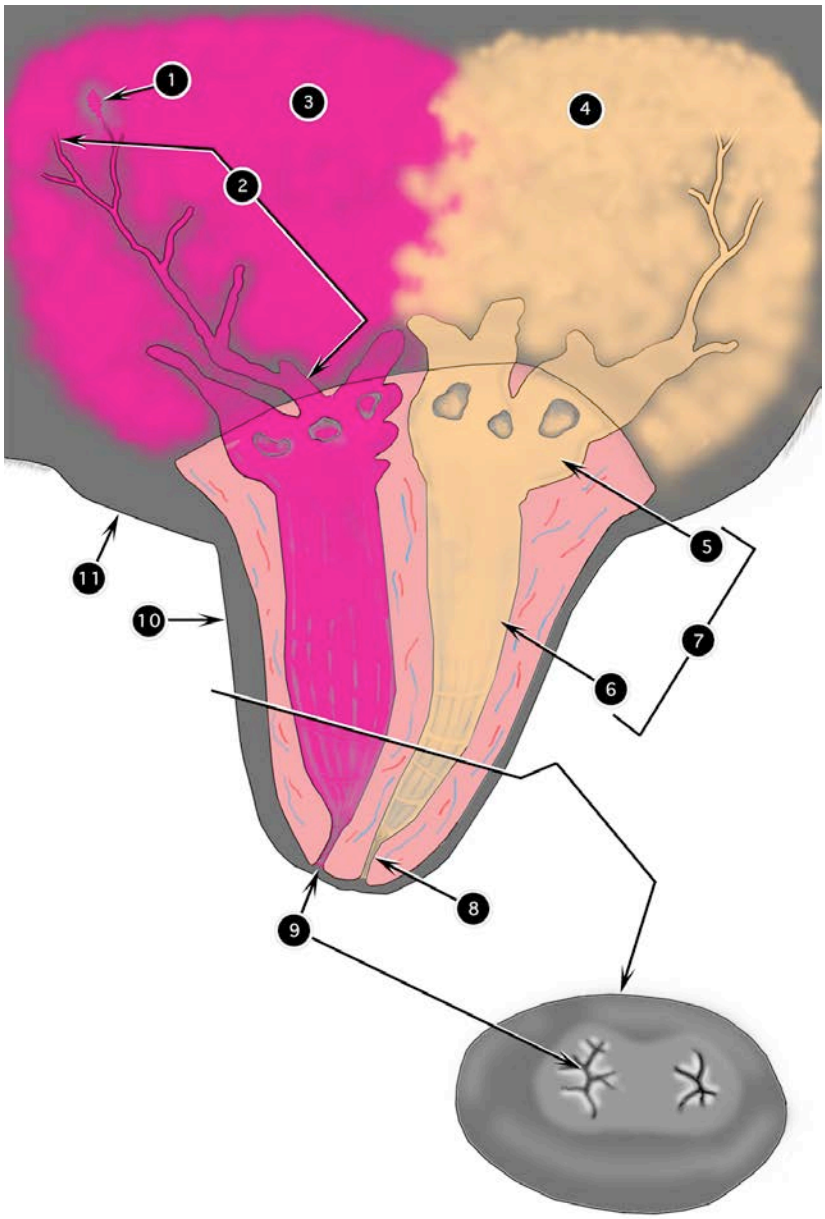


Figure 5-18. Semischematic of mammary gland (mamma) of mare, lateral view with section through distal teat: (1) mammary lobule (cluster of alveoli secreting into central ductule); (2) various orders of lactiferous ducts from cranial gland complex; (3) cranial gland complex; (4) caudal gland complex; (5) caudal gland sinus, receiving largest lactiferous ducts; (6) caudal teat sinus; (7) caudal lactiferous sinus; (8) caudal teat canal (papillary duct); (9) cranial teat orifice; (10) teat; (11) body of mamma.

As in the horse and sheep, there is no smooth muscle in the sphincter of the teat canal, which is closed by elastic fibers. Accessory teats are sometimes associated with the abdominal mammae and are often found on the caudal aspect of the inguinal mammary glands.[9]

[9] In gilts kept for breeding, it is important that they have at least 14 mammae; otherwise they won't be able to nurse enough piglets. You see, baby pigs each identify their own "spigot" and will go back to

Because the mammary glands of the sow are spread along most of the ventral body wall, the blood supply and lymphatic drainage vary with the region. The thoracic mammae are supplied by the lateral and internal thoracic arteries and by the cranial epigastric vessels. The abdominal and inguinal mammae are supplied by the epigastric and external pudendal vessels. The lymphatic drainage from the thoracic mammae is through the sternal[10] and ventral superficial cervical lymph nodes, and the abdominal and inguinal glands drain to the superficial inguinal nodes. The cranial abdominal mammary glands may drain to all of these lymph nodes.

MALE INTERNAL GENITALIA AND URINARY BLADDER

Pelvic Viscera of Male Horse: *After the rectum has been removed, carefully clean the pelvic fascia and fat away to expose the pelvic part of the urogenital tract* (Fig. 5-19). The distal part of each ductus deferens is noticeably thickened because of the presence of glands in its wall that form the **ampulla of the ductus deferens**. Between the ampullae, and within the substance of the genital fold, there is sometimes a recognizable remnant of the paramesonephric ducts, the **uterus masculinus**[11] (Fig. 5-19). Lateral to the ampullae identify the **vesicular glands**. Because of their bladder-like structure in the horse, these glands are sometimes called *seminal vesicles*. Unfortunately, this is a misleading name because it *implies that semen is stored in them*; actually, only the secretion of the vesicular glands accumulates here. If the term *vesicular gland* is good enough for the pig and ruminants, I see no reason to call it something different in the horse.

The **prostate** of the horse is distinctly bilobed, complete with a connecting isthmus, and consists entirely of a **compact part** that flanks the junction of bladder and urethra (Fig. 5-19). It is mostly retroperitoneal and palpable rectally. As you might have guessed, the prostatic artery arrives at the urogenital tract in this region.

The **pelvic urethra** is surrounded by the thick **urethralis muscle** (Fig. 5-19). As the pelvic urethra approaches the ischial arch, it is flanked dorsolaterally by the **bulbourethral glands**, the size and prominence of which vary considerably according to the available testosterone level. They are conspicuous, structures in the stallion, less imposing in the mild-mannered gelding. Like those of the pig, the bulbourethral glands of the horse are covered by the bulboglandularis muscles (Fig. 5-19). Just beyond the level of the bulbourethral glands, the pelvic urethra curves around the ischial arch and continues into the **root of the penis** as the **penile part** of the urethra.

Here the urethralis muscle is replaced by the **bulbospongiosus muscle**, which as the name implies surrounds the **bulb of the penis**. This expanded, bilobed bulb of erectile tissue is contiguous with the *vascular layer* of tissue that surrounds the pelvic part of the urethra. Identify the **artery of the bulb**, which is given off from the artery of the penis (Fig. 5-19). The obturator artery also plays an important part in supplying blood to the penis in the horse. Before discussing the penis in detail, let's back-up and look at some additional internal structures.

---

the same nipple at each feeding. Yes, somebody ends up suckling the most "caudad mamma."

[10] Sternal lymph nodes are those in the cranial mediastinal group located ventrally, just dorsal to the sternum.

[11] uterus masculinus- male homologue of uterus

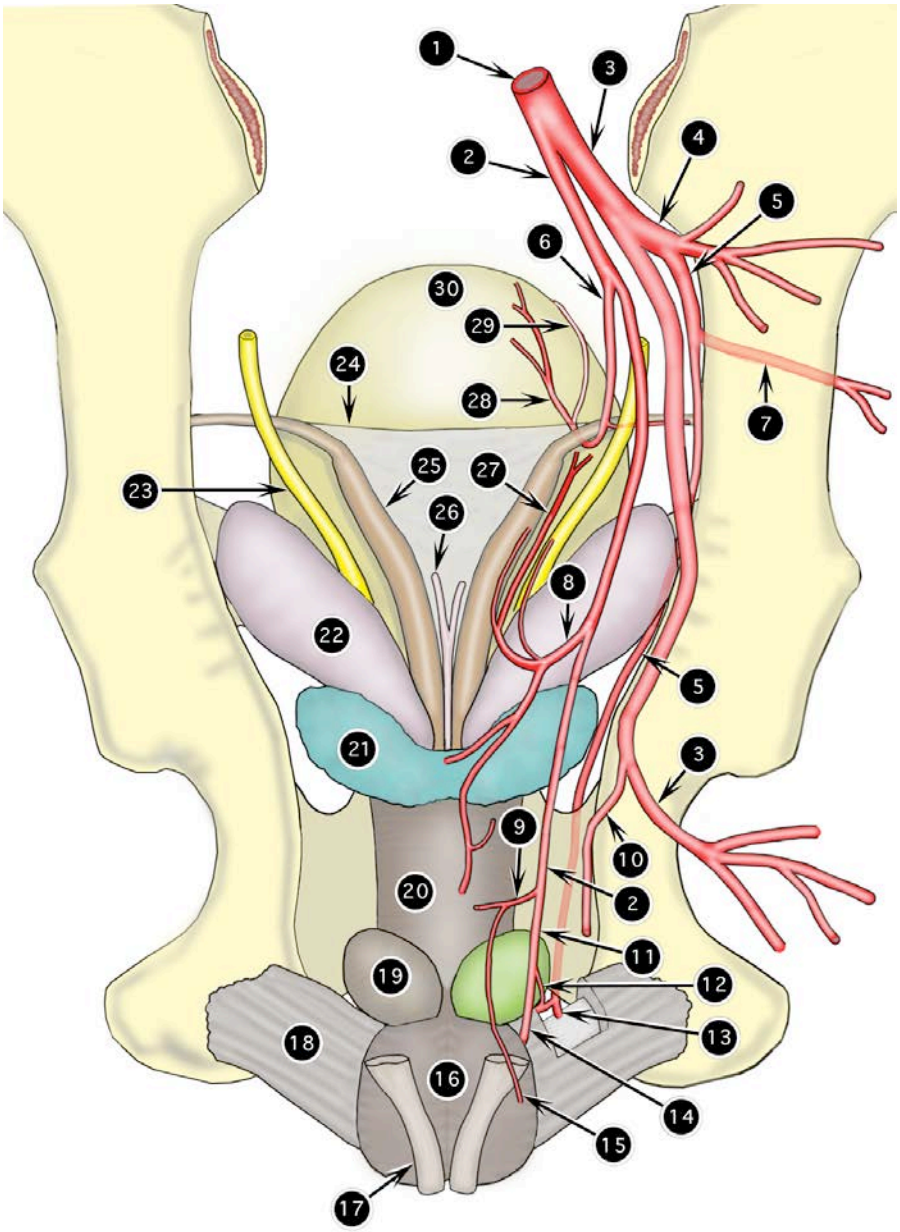


Figure 5-19: Pelvic viscera of stallion, dorsal view: (1) internal iliac artery; (2) internal pudendal artery; (3) caudal gluteal artery; (4) cranial gluteal artery; (5) obturator artery; (6) umbilical artery; (7) iliacofemoral artery; (8) prostatic artery; (9) caudal rectal artery; (10) median caudal artery (unilateral); (11) artery of penis; (12) dorsal artery of penis; (13) deep artery of penis entering crus of penis; (14) artery of bulb of penis; (15) ventral perineal artery; (16) bulb of penis covered by bulbospongiosus muscle; (17) retractor penis muscle; (18) ischiocavernosus muscle covering crus of penis; (19) bulboglandularis muscle covering bulbourethral gland; (20) urethralis muscle surrounding pelvic urethra; (21) prostate; (22) vesicular gland; (23) ureter; (24) genital fold; (25) ampulla of ductus deferens (26) uterus masculinus (remnant of paramesonephric ducts; (27) caudal vesical artery; (28) cranial vesical artery; (29) round ligament of urinary bladder; (30) apex of urinary bladder.

*Open the **urinary bladder** through a lateral incision that is continued through the pelvic urethra to the level of the ischial arch*. The **ureteric orifices** are located in the dorsal wall of the bladder neck, which tapers to the **internal urethral orifice**. Note

that the ureter actually enters the bladder wall some distance proximal to its termination inside the bladder at the ureteric orifice. Thus, the terminal part of the ureter is located within the bladder wall itself.

Physiologically, this *intramural portion* of the ureter is important in that the muscular tone of the bladder wall, assisted by the pressure created by the expanding bladder, compresses the terminal ureter and helps prevent urine reflux back into the ureter. This arrangement creates a natural barrier to ascending urinary tract infection, which sometimes occurs in spite of this obstacle. Young, growing animals are predisposed to *vesicoureteral reflux* because the intramural segment may be shorter due to differences in growth rates between the ureter and bladder. The three openings (two ureteric, one urethral) define an area in the dorsal wall of the bladder neck known as the **vesicular trigone**.

A dorsal ridge of tissue, the **urethral crest**, leads caudally through the urethral orifice to a mound known as the **colliculus seminalis**, on which are located the **ejaculatory orifices**. These are the openings of the **ejaculatory ducts**, which are formed by the union of the ductus deferens and the duct of the vesicular gland in the horse. On the lateral sides of the colliculus seminalis, try to identify the numerous openings of the **prostatic ducts**. More caudally, in the dorsal urethral wall, look for the multiple openings of the bulbourethral glands.

Pelvic Viscera of Male Ruminant: *After the rectum has been removed, carefully clean the pelvic fascia and fat away to expose the pelvic part of the urogenital tract* (Fig. 5-12). As in the horse, the terminal part of each ductus deferens is thickened to form **ampullary glands**. A *uterus masculinis* (remnant of the paramesonephric ducts) may occasionally be identified in the genital fold of the ruminant, between the two ampullae.

Unlike those of the horse, the **vesicular glands** consist of firm, highly folded tubular structures that appear to be lobulated (Fig. 5-20). The bovine **prostate** consists of both a compact part (body) and a disseminate part. The **body** is not divided into distinct lobes, but is represented by a transverse ridge of tissue across the dorsal junction of bladder and urethra. As the name implies, the **disseminate part** is spread along the **pelvic urethra** (Fig. 5-20). *The latter part can be identified by making a transverse section through the urethra about 2-3 cm caudal to the body of the prostate* (Figs. 5-12, 5-20). Although there is no disseminate prostate in the horse, this is the only part of the prostate present in the small ruminants.

In the male goat, the disseminate prostate completely surrounds the pelvic urethra, whereas in the ram, it is limited to the dorsal and lateral aspects. As the pelvic urethra, surrounded by the circular **urethralis muscle**, approaches the ischial arch, it becomes associated with the bilobed **bulb of the penis**, which is surrounded by the **bulbospongiosus muscle** (Fig. 5-12). At this level locate the **bulbourethral glands**, which are partly covered by the bulbospongiosus (bulboglandularis) muscle. Identify the **artery of the bulb**, which is given off the **artery of the penis**, the continuation of the internal pudendal artery. *It may be helpful at this point to clean the ischiocavernosus muscle from the medial side of the tuber ischiadicum and to remove the latter.*

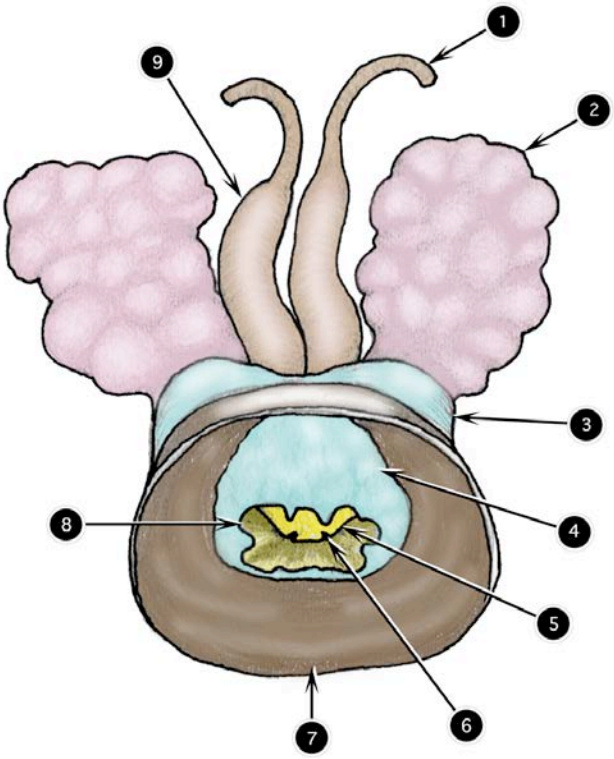


Figure 5-20. Cross section through pelvic urethra of bull at level indicated in figure 5-12, caudal view: (1) ductus deferens; (2) vesicular gland; (3) compact part (body) of prostate; (4) disseminate part of prostate; (5) colliculus seminalis; (6) ejaculatory orifice; (7) urethralis muscle; (8) urethral lumen; (9) ampulla of ductus deferens.

Complete development and maintenance of the accessory genital glands are *androgen-dependent* in the domestic mammalian species. Prepubertal castration markedly retards their development and postpubertal castration results in rapid atrophy of these glands.

Retained testes typically produce testosterone, even though spermatogenesis is usually inhibited by the increased temperature of the testis. In general, *cryptorchidism* is rare in domestic ruminants, which may be related to the relatively early embryonic descent of the testes through the inguinal canal in these species. Of the domestic ruminant species, cryptorchidism is most common in sheep. Based on external features, cryptorchid lambs can be confused with *wethers* (castrated male sheep), but rectal palpation of the bulbourethral glands can be used to differentiate them. In the cryptorchid lamb (4-6 months old), these glands are about 1.25 cm in diameter, whereas those of the wether are much smaller and are difficult to identify by rectal palpation.[12]

Open the urinary bladder and urethra using a lateral incision, and identify the ureteric and urethral orifices. In the ruminant, the vesicular gland and ductus deferens of each side enter the pelvic urethra through a common opening, the **ejaculatory orifice**, on the **colliculus seminalis** (Fig. 5-20).

[12] de Lahunta, A. and Habel R. E., *Applied Veterinary Anatomy*, W. B. Saunders, Co., Philadelphia, 1986, p. 289.

Continue the lateral incision in the urethra through the bulbospongiosus muscle to open the penile urethra to about 10 cm distal to the ischial arch. Examine the urethral lumen in this area and identify a mucosal fold associated with the ducts of the bulbourethral glands. Probe the **urethral recess** formed behind this fold, and consider the complications to urinary catheterization created by this diverticulum. Because of the curvature of the urethra through this area, the catheter tip may well lodge in the recess, which causes considerable difficulty in catheterization of the male ruminant. The urethral recess has been demonstrated in male cattle, sheep, goats, pigs, Dromedary camels, and llamas.[13]

Open the urethra again by a caudal midline incision distal to this mucosal fold. Because this part of the penis is subcutaneous, such an approach can be used in perineal urethrostomy. Feedlot steers on high-concentrate rations are subject to developing urinary calculi. These calculi typically lodge further distally at the level of the sigmoid flexure of the penis and may cause complete urinary obstruction. Urethrostomy allows for urination through this newly created opening for the remainder of the feeding period. If the operation is not performed, the animal can die from uremia or from rupture of the urethra or urinary bladder. Because of postsurgical problems (*e.g.*, urine scalding of the skin) with this "high" urethrostomy, some surgeons prefer a more distal site for the operation.

Pelvic Viscera of Boar: *After the rectum has been removed, carefully clean the pelvic fascia and fat away and expose the pelvic part of the urogenital tract* (Fig. 5-16). There is a marked difference in size of the accessory genital glands between the boar and barrow.[14] Although a few glands are present in the terminal part of the **ductus deferens**, no grossly evident ampulla is formed. In the mature boar, the **vesicular glands** are represented by two large, pyramid-shaped masses that almost completely conceal the underlying prostate (Fig. 5-16). The body of the **prostate** is small, with most of the gland being formed by the disseminate part.

The **bulbourethral glands** of the intact boar are very large, cigar-shaped structures that almost completely cover the pelvic urethra (Fig. 5-16). As with the other accessory genital glands, they are greatly reduced in the barrow.

Although the large bulbourethral glands might appear to be a major factor in the large volume of semen ejaculated by the boar (average, about 200 ml), studies indicate that only about 10 to 25% of the ejaculate comes from these glands. Another 15 to 20% is produced by the vesicular glands, but most (55 to 75%) is believed to come from the small prostate and urethral glands.[15] Barrows can be differentiated from cryptorchid males by rectal palpation of the bulbourethral glands. In the pig, the vesicular gland typically opens separately into the pelvic urethra, but it may open in common with the ductus deferens. *Open the urinary bladder and pelvic urethra by a lateral incision and identify those structures forming the vesicular trigone, and the colliculus seminalis*.

PENIS

[13] Timm, K. L., Watrous, B. J. Urethral recess in two male llamas. JAVMA 192 (1988): 937-938.

[14] barrow- a pig that has been castrated before reaching sexual maturity

[15] Pond, W. G., Houpt, G. K. *The Biology of the Pig*. Cornell University Press, Ithaca, NY, 1978.

For descriptive purposes, the penis can be divided into three segments- the root, the body, and the glans. The **root of the penis** consists of a triad of converging structures, the bulb, and the two crura (Fig. 5-19). As the urethra curves around the ischial arch, it becomes closely associated with the **bulb of the penis**, which is supplied by the right and left arteries of the bulb and is surrounded by the bulbospongiosus muscle. The **right and left crura of the penis** consist of fibrous sleeves containing erectile tissue, which originate directly from the ischial arch of the pelvis. Each crus is closely associated with the ischiocavernosus muscle and is penetrated near its origin by the deep artery of the penis.

Distal to the ischial arch, the two crura converge to form the **corpus cavernosum penis**, and the bulb tapers to form the **corpus spongiosum penis**. Once the three erectile bodies have come together, the cylindrical **body of the penis** is formed. The **free part of the penis** is that part of the body that lies within the preputial cavity and is covered by skin. The **glans penis** is the head of the penis, containing the corpus spongiosum glandis.

Owing to its highly fibrous structure, the penis of the pig and ruminant is classified as a **fibroelastic type**. It is firm, even in the quiescent state, and the body is characterized by the presence of a **sigmoid flexure**. During erection, the sigmoid flexure straightens out, and the fully extended penis becomes more rigid; however, there is little actual enlargement of the organ, either in length or diameter. In contrast, the penis of the horse is of the **musculocavernous type**. This type of penis contains more smooth muscle in its wall and is soft in the quiescent state. During erection, there is engorgement of the cavernous spaces with blood, and in addition to increased rigidity, there is significant enlargement of the organ both in diameter and length.

Muscles of Penis: The **bulbospongiosus muscle** is homologous to the constrictor vestibuli and vulvae muscles of the female. It surrounds the bulb of the penis and extends cranially to cover the bulbourethral glands (Fig. 5-12). The term **bulboglandularis muscle** is used to designate the muscular coverings of these glands in the pig and horse (Figs. 5-16 & 5-19). The bulbospongiosus muscle of the ruminant and pig does not continue very far distally onto the body of the penis (Fig. 5-12); however, in the horse, it extends much further distally to the free part of the penis (Fig. 5-10).

The *ischiourethralis muscles* impede venous outflow from the erect penis in the dog. They do not serve this function in the ungulates. In the female ungulate, these muscles pass to the vicinity of the external urethral orifice and facilitate micturition.

The paired **ischiocavernosus muscles** surround the crura of the penis (Figs. 5-16 & 5-19), and contraction of these muscles forces blood in the crura distally to produce a high-pressure engorgement of the corpus cavernosum penis. In effect, these muscles serve as the "booster pumps" that produce the increased rigidity and extension of the fibroelastic penis, as well as enlargement of the musculocavernous penis.

The paired **retractor penis muscles** originate from one or more caudal vertebrae (Fig. 5-12 & 5-14) and pass around the rectum, where in the horse they form a distinct suspensory loop around the anus. They then converge and continue down the

caudal surface of the bulbospongiosus muscle (Figs. 5-16 & 5&19). In the pig and ruminant, these muscles diverge and terminate in the *tunica albuginea penis*, distal to the sigmoid flexure (Fig. 5-14). In the horse, they eventually pass through the bulbospongiosus muscle to reach the tunica albuginea penis.

Crura of Penis: *Transect the crus of the penis on one side near the ischial arch*. The stump of the crus, which remains on the ischium ("aitch-bone") of the ruminant or pig carcass, is the *pizzle eye* of *abattoir jargon*. Its presence (absence) is sometimes used as a criterion to differentiate steer from heifer carcasses. (Another difference is the presence of so-called "cod fat" in the scrotal area of the steer carcass.)

Arterial Supply to Penis: In the ruminant and pig, blood supply to the penis is similar to that of the dog (Figs. 5-9 & 5-16). The continuation of the internal pudendal artery is the **artery of the penis**, which gives rise to the **artery of the bulb** and the **deep artery of the penis**, and then continues as the **dorsal artery of the penis**. Identify the deep artery of the penis as it penetrates the proximal part of the crus, and note the continuation as the dorsal artery of the penis.

While the artiodactyls (fibroelastic penis) get along just fine with a little blood under a lot of pressure, the horse chooses a completely different strategy (musculo-cavernous), which requires a lot more blood to achieve erection.

The penis of the horse is supplied with blood from three major sources (Fig. 5-10):

1. The **internal pudendal artery** continues as the **artery of the penis**, which gives rise to the **artery of the bulb** and continues as the small **dorsal artery of the penis** (Fig. 5-10).

2. The **obturator artery**, a branch of the cranial gluteal artery, courses with the obturator nerve along the body of the ilium, exits the pelvic canal through the obturator foramen (Fig. 5-10 & 5-19), and supplies the **deep artery of the penis**. Locate the obturator artery and the deep artery of the penis in the horse. In addition to supplying the deep artery, the obturator artery forms an anastomosis with the dorsal artery of the penis and gives rise to the **middle artery of the penis**, which continues cranially along the dorsolateral aspect of the penis (Fig. 5-10).

3. The **external pudendal artery** passes out through the inguinal canal and gives rise to the **cranial artery of the penis**, which forms an anastomosis with the middle artery and continues cranially along the penis (Fig. 5-10). These vessels are difficult to identify at this point because of the presence of a large venous plexus that covers the dorsolateral surfaces of the penis.

External Pudendal Venous Plexus of Male Horse (Fig. 5-10): Because of the great engorgement of the penis during erection, this venous plexus serves to receive blood from the cavernous spaces of the penis immediately following dismounting of the stallion. Thus, the fully erect penis, which because of its size and rigidity is especially subject to injury, can drain rapidly and reduce its period of vulnerability. Note that the venous plexus is drained by the **external pudendal vein**, which does not return through the inguinal canal in the horse. Instead, it perforates the origin of the gracilis muscle and joins the deep femoral vein (Fig. 5-10).

While the stallion is breeding the mare, he has his pelvic limbs in an abducted position, which stretches the gracilis muscle and constricts the external pudendal vein. Once dismounted, tension on the gracilis muscle relaxes, the external pudendal vein opens, and blood can leave the venous plexus easily, allowing blood from the penis to escape quickly into the venous plexus. The external pudendal vein does not drain the penis of the other species and does accompany the artery back through the inguinal canal.

Dorsal Nerves and Arteries of Penis: In all species these nerves are the principal continuations of the right and left pudendal nerves (Fig. 5-9). Because the horse has middle and cranial arteries of the penis, its dorsal artery is small. In the other species, the dorsal artery continues distally along the entire body of the penis without anastomoses (assistance) from the obturator and external pudendal arteries.

Body of Penis: The body of the penis extends cranially from the ischial arch. It is anchored to the pelvis by a pair of short ligaments, the **suspensory ligaments of penis** (Figs. 5-12 & 5-14). Note the **sigmoid flexure** in the pig and ruminants. Because the fibroelastic penis does not enlarge significantly during erection, the length of penis involved in the formation of this flexure represents approximately that length available for extension during erection, that is, the *reserve capacity*. The sigmoid flexure is partially maintained by the retractor penis muscles; however, it is also an inherent shape that results from the fibrous configuration within the tunica albuginea penis.

To study the body of the penis in cross section, *remove a 1-cm section of the penis* at the level indicated in figure 5-12 and shown in figure 5-21. Place the cross sections of the different species together on the table. Compare the consistency of the **corpus cavernosum** in the fibroelastic penis of the pig and ruminant with that of the musculocavernous equine penis (Fig. 5-21). It should be obvious from the consistency of the corpus cavernosum that there is little room for vascular engorgement in the fibroelastic type, whereas the musculocavernous type provides for significant filling and enlargement.

Note the thick, unyielding **tunica albuginea penis** of the ruminant and pig and its much softer counterpart in the horse. During erection, tremendous pressures are created within the penis by the pumping action of the ischiocavernosus muscles, which rhythmically compress the crura and force blood distally through vascular channels (Fig. 5-12) within the corpus cavernosum. Note that the thick tunica albuginea penis in the pig surrounds the corpus spongiosum penis as well as the corpus cavernosum penis.

In the bull, pressures in the corpus cavernosum may be 60 times greater than the arterial pressure. If the penis is misdirected and kinked in this condition, there may be partial tearing of the tunica albuginea, with bleeding into its wall. Sometimes complete rupture occurs, with the formation of a large parapenile hematoma. Although some of these hematomas can be repaired, such an accident may mark the end of the bull's reproductive capability. Note that the corpus spongiosum of the fibroelastic penis is more erectile than the corpus cavernosum penis.

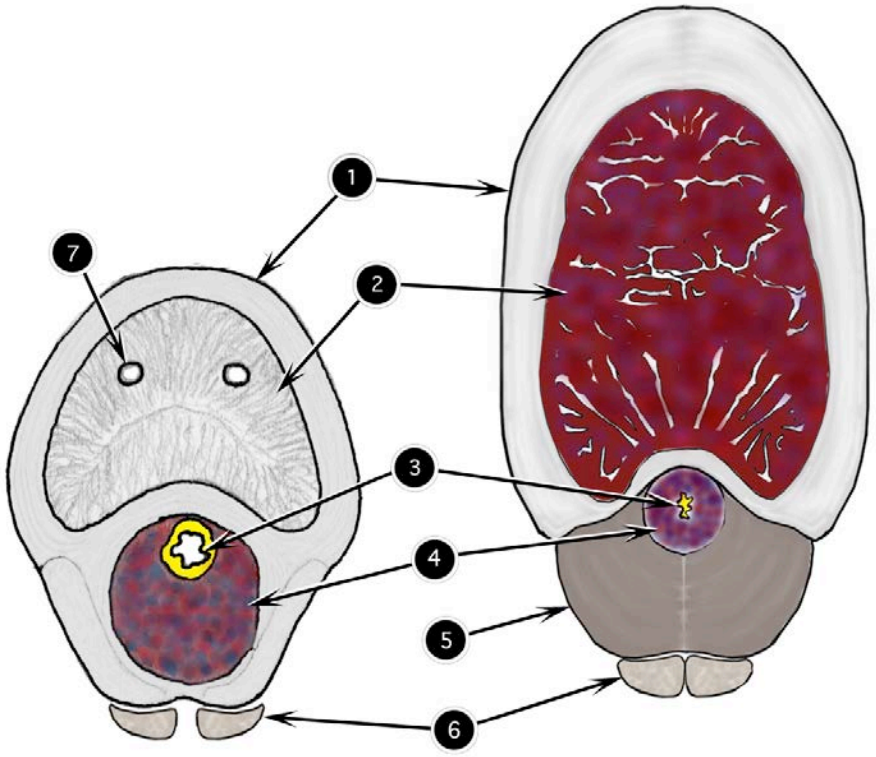


Figure 5-21: Cross section through body of penis of bull (left) & stallion at level indicated in figure 5-12, showing comparison of fibroelastic (bull) and musculocavernous (stallion) types: (1) tunica albuginea penis surrounding corpus cavernosum penis; (2) corpus cavernosum penis; (3) urethra; (4) corpus spongiosum penis; (5) bulbospongiosus muscle; (6) retractor penis muscles; (7) longitudinal vascular canal. (Not drawn to scale.)

Free Part of Penis and Prepuce: Unfortunately, there is some confusion about what constitutes the various laminae of the prepuce. The **external lamina** of the prepuce is what you see on the outside of the animal- it is hair-covered skin (Fig. 5-22). At the **preputial orifice**, it is continuous with the **internal lamina** of the prepuce (hairless skin that lines the preputial cavity). The internal lamina continues caudally to a **preputial fornix**, where, except in the horse, it immediately reflects back onto the penis for a short distance. Here it is loosely attached to the underlying penis.

In the horse, the internal lamina forms the **preputial fold**, and then does the same thing that it does in the other species. During erection, the internal lamina of the prepuce rolls onto the body of the extended penis as it moves forward out of the preputial orifice. Thus, the internal lamina of the prepuce represents the reserve skin necessary to cover the fully erect penis.

The free part of the penis is covered by tightly adherent skin, *which is not part of the prepuce*. Although unnecessary in the horse, *in the ruminant and pig you will need to open the preputial cavity. Beginning at the preputial orifice, open the preputial cavity using a lateral incision to expose the free part of the penis* (Figs. 5-22). In the newborn calf and in males that were castrated prior to puberty, the internal lamina of the prepuce typically adheres to the skin of the free part of the penis. In the bull, note the **frenulum of the prepuce**, which is continuous with the **raphe of the penis** (Fig. 5-22).

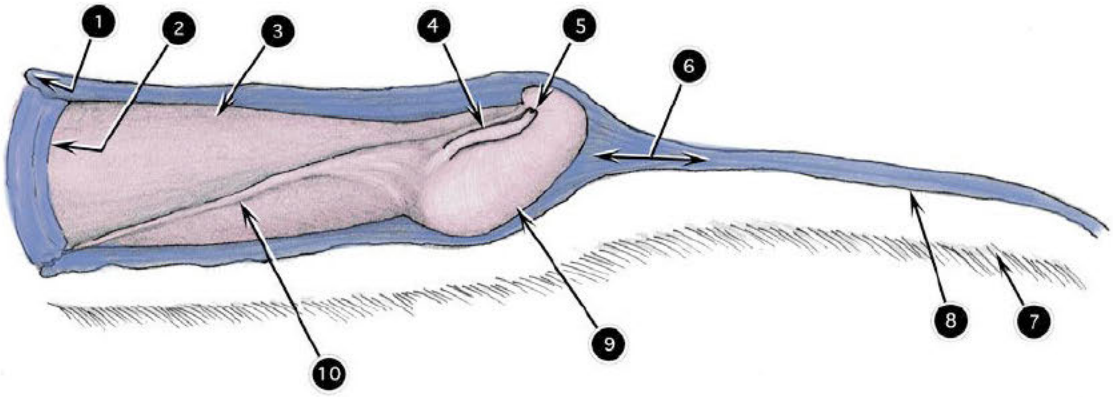
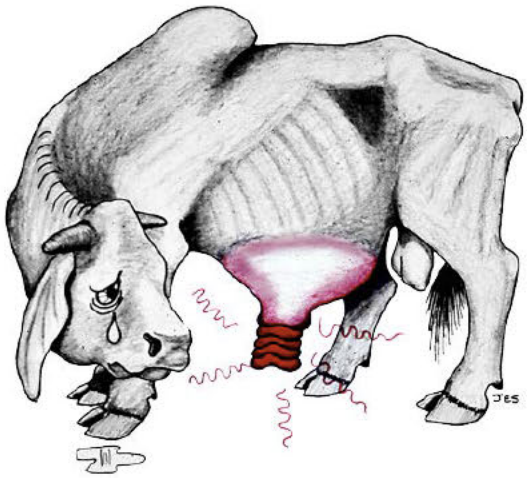


Figure 5-22. Free part of bovine penis in preputial cavity, right lateral view: (1) fornix of prepuce; (2) junction of prepuce with skin of free part of penis; (3) free part of penis; (4) urethral process; (5) external urethral orifice; (6) preputial cavity; (7) external lamina of prepuce; (8) internal lamina of prepuce; (9) glans penis; (10) raphe of penis- indicates original ventral midline, rotated to right side by normal left-hand spiral.

Separation of the skin of the free part of the penis and the internal lamina of the prepuce partially depends on the sexual maturation of the animal. Prepubertal castration interferes with this process, and the skin of the penis remains variably adherent to the internal lamina of the prepuce. Even in an intact bull, this separation may be incomplete. The frenulum-to-raphe penis connection may not completely separate, resulting in a persistent penile frenulum. When a persistent frenulum occurs, there is often a blood vessel within the frenulum, and this area is thickened. A persistent penile frenulum results in the penis being anchored to the prepuce and, upon erection, the penis is strongly deviated by this tie. Surgical correction is necessary if the bull is to be used for breeding.

Another problem is that the prepuce of some bulls has too much reserve skin (internal lamina). This is more common in Brahman and Brahman crossbreeds that naturally have a more pendulous prepuce. The internal lamina everts out through the preputial orifice, where it is subjected to trauma (*e.g.*, laceration, being stepped on when lying down; Fig. 5-23). Correction of this problem involves surgical removal of the excess internal lamina- sort of a *circumcision*. Removal of just enough, but not too much, is obviously important (Fig. 5-24).

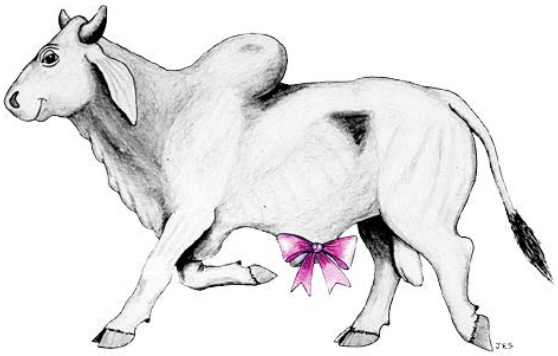


"And you think you've got troubles"

Figure 5-23. Brahman bull with prepuce problem- temporarily out of commission; needs veterinary attention to remove excessive prepuce.

Telescopic Prepuce of Horse: Because of the significant elongation of the equine penis during erection, more reserve skin is needed to cover the fully extended organ than can be provided by a single reflection of internal lamina. To solve this problem, the horse has

a second fold of internal lamina, the **preputial fold** (Fig. 5-25). This arrangement forms a *telescopic prepuce*. On reaching an outer fornix, the internal lamina is reflected cranially almost back to the preputial orifice; it then turns caudally again to form a thickened free border, the **preputial ring**. From here it continues caudally to an inner fornix and then reflects cranially for a short distance before becoming continuous with the more tightly adherent skin of the free part of the penis. When male horses are standing around, relaxed, the preputial ring often "peeks out" through the preputial orifice. During erection, the entire preputial fold and initial part of the internal lamina reflect onto the body of the extended penis (Fig. 5-26).



"Happy days are here again."

Figure 5-24. Same bull as shown in figure 5-23, but much happier now that circumcision has been performed successfully by competent veterinarian.

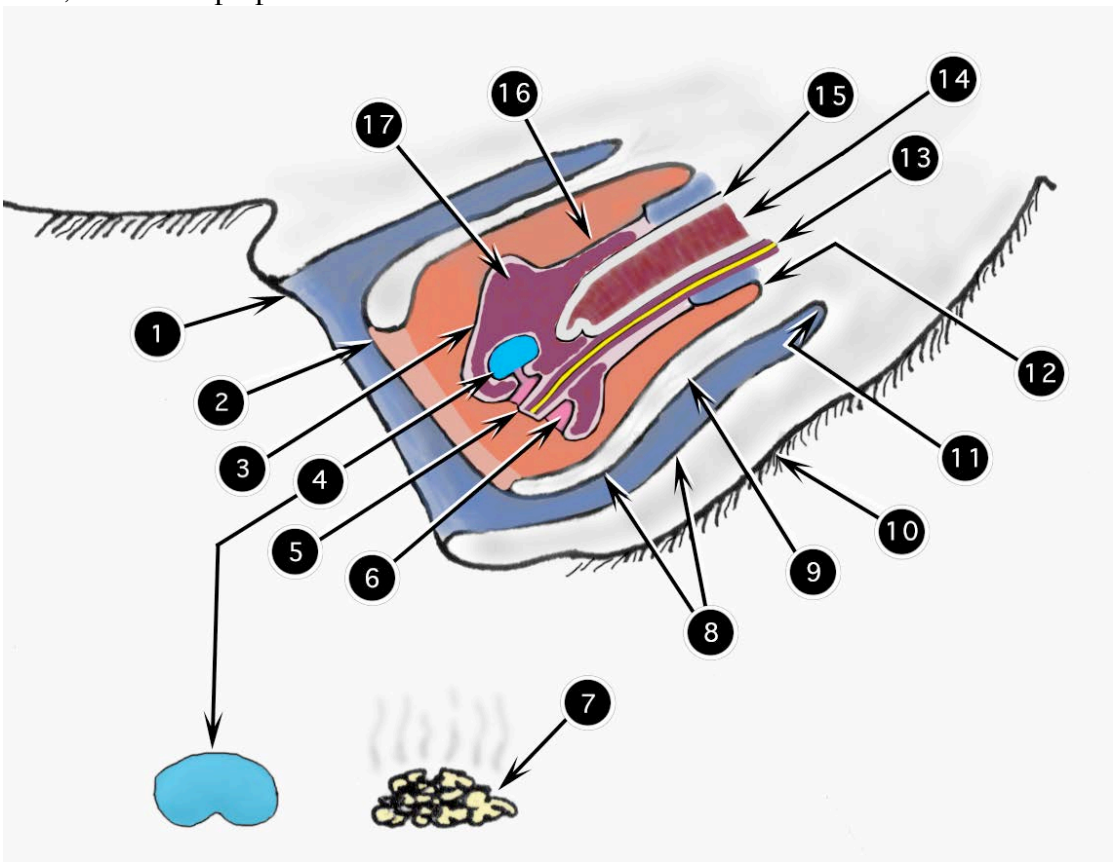


Figure 5-25. Schematic representation of telescopic prepuce of horse, left lateral view with accessories included at no extra charge: (1) preputial orifice; (2) preputial ring- thickened free border of preputial fold; (3) glans penis; (4) urethral sinus with "bean" removed; (5) urethral process; (6) fossa glandis- depression surrounding urethral process; (7) smegma- removed from preputial cavity (may well be only artistic rendering of smegma in existence); (8) internal lamina of prepuce; (9) preputial fold formed by internal lamina of prepuce; (10) external lamina of prepuce; (11) outer preputial fornix; (12) inner preputial fornix; (13) urethra, surrounded by corpus spongiosum penis; (14) corpus cavernosum penis; (15) tunica albuginea penis surrounding 14; (16) skin of free part of penis; (17) corpus spongiosum glandis- erectile tissue of glans penis applied to end of 15.

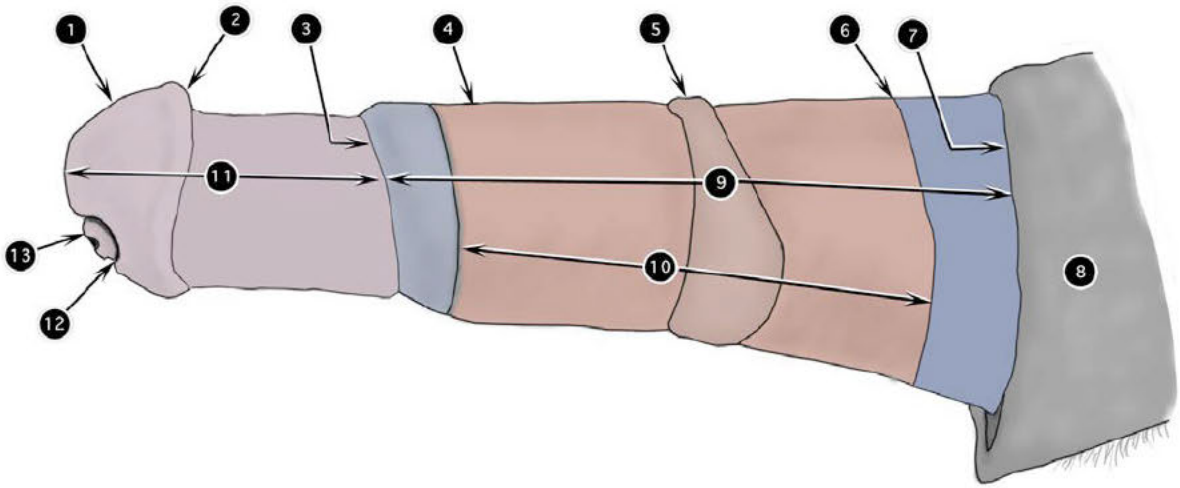


Figure 5-26. Extended equine penis to illustrate how individual parts of prepuce roll onto body of extended penis, left lateral view: (1) glans penis; (2) corona glandis; (3) junction of skin of penis with prepuce; (4) approximate location of inner fornix; (5) preputial ring- thickened free border of preputial fold; (6) approximate location of outer fornix; (7) preputial orifice; (8) external lamina of prepuce; (9) internal lamina of prepuce; (10) preputial fold; (11) free part of penis; (12) fossa glandis; (13) urethral process. (Modified from Nickel, Schummer, Sieferle. and Sack, *The Viscera of the Domestic Mammals*, 2nd ed., Springer-Verlag, New York, 1979, p. 345.)

One last thing before we leave the prepuce of the horse. Any of you who have ever ridden geldings very much have probably been annoyed by a rather curious sort of "honking-grunt" sound coming from somewhere down there, especially at the trot. What the heck is that anyway? Well, this "socially impolite" sound is produced by the back-and-forth, plunger action of the penis within his telescopic prepuce. Air is apparently sucked in on the "back-stroke" and then "blown-out" on the "fore-stroke", producing this rather obnoxious "gelding grunt" sound. (And now you know.)

Preputial Muscles of Pig and Ruminant: Note the paired **cranial preputial muscles**, which are present in the pig and ruminants (Fig. 5-14). These muscles represent modified parts of the cutaneus trunci and are innervated by the lateral thoracic nerve. The cranial preputial muscles loop around the preputial orifice and serve to re-sheath the penis as it is retracted following erection. The **caudal preputial muscles** are not present in carnivores and are occasionally absent in the pig. These muscles are consistently present in ruminants and serve to unsheath the penis by retracting the prepuce during erection. Although I do not know what functional significance there might be, if any, it is interesting to note that the caudal preputial muscle of the bull divides into two limbs, which encircle the spermatic cord (Fig. 5-14).

Preputial Diverticulum of Pig: In the dorsal wall of the porcine preputial cavity is the opening to the preputial diverticulum (Fig. 5-27). This cavity is small in the barrow, but becomes large in the adult boar. The diverticulum is partially divided by a septum and lies over the dorsolateral aspect of the prepuce. It is partially covered by the cranial preputial muscles. Prior to copulation, these muscles empty the diverticulum, which apparently lubricates the penis.

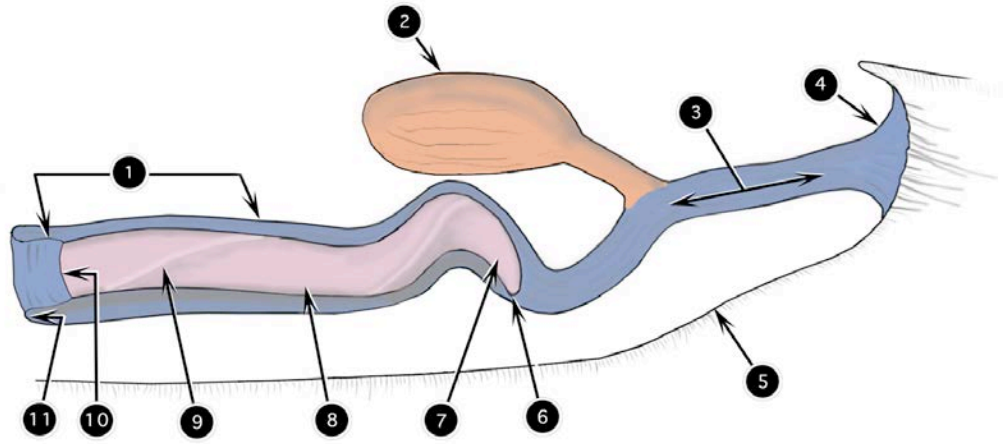


Figure 5-27. Free part of porcine penis in preputial cavity, right lateral view: (1) internal lamina of prepuce; (2) preputial diverticulum; (3) preputial cavity; (4) preputial orifice; (5) external lamina of prepuce; (6) external urethral orifice; (7) glans penis; (8) free part of penis; (9) raphe of penis- indicates original ventral midline, rotated to right side by normal left-hand spiral; (10) junction of prepuce with skin of free part of penis; (11) fornix of prepuce. (Modified from Nickel, Schummer, Sieferle. and Sack, *The Viscera of the Domestic Mammals*, 2nd ed., Springer-Verlag, New York, 1979, p. 332.)

The preputial diverticulum may become infected and can be opened laterally for drainage. The combined debris (*e.g.*, urine, desquamated epithelial cells) that accumulates in this diverticulum is thought to be responsible for the strong odor associated with the adult boar. An excessive accumulation of material in the diverticulum may be mistaken for an umbilical hernia. Surgical removal of the preputial diverticulum has been used to reduce the odor and semen contamination in boars used for artificial insemination. Removal of the diverticulum has also been done in pot-bellied pigs kept as pets to reduce odor and to reduce urine pooling and dribbling.[16]

Glans Penis: The first thing we need to understand is that the glans penis is not the same thing as the free part of the penis. The free part of the penis is the entire part of the organ that resides within the preputial cavity during the quiescent state. The glans penis is the portion of the free part of the penis that is not enclosed by the heavy tunica albuginea penis. It consists of an erectile tissue body, the **corpus spongiosum glandis** and is applied over the distal part of the corpus cavernosum penis (Fig. 5-10). It is large in the horse (Fig. 5-25) and dog, but relatively small in the cat, pig, and ruminant (Figs. 5-22 & 5-27).

Glans Penis of Horse: The glans penis of the horse consists of a large erectile cushion that completely caps the distal part of the corpus cavernosum (Figs. 5-10 & 5-25). The glans forms a blunt tip and is surrounded by a ridge, the **corona glandis** (Fig. 5-26). In older stallions, there may be numerous papillae associated with this ridge. Immediately proximal to the corona, the glans is constricted to form the collum glandis.

Make a transverse incision through the dorsal part of the glans about 3 cm proximal to the corona and down to the firm tunica albuginea penis enclosing the corpus cavernosum. This will demonstrate the soft, erectile nature of the glans penis and, specifically at this location, its prominent

[16] Lawhorn, B., Jarrett, P. D., *et al*. Removal of the preputial diverticulum in swine. JAVMA 205 (1994): 92-96.

dorsal process, which projects caudally along the dorsal surface of the corpus cavernosum (Figs. 5-10 & 5-25).

The **urethral process** is surrounded by a circular recess in the glans penis known as the **fossa glandis** (Figs. 5-25 & 5-26). *Deflect the urethral process ventrally, and locate an opening in the dorsal wall of the fossa glandis*. This is the entrance into a bean-shaped diverticulum known as the **urethral sinus** (Fig. 5-25). ***Smegma*** is the polite name applied to the *potpourri*[17] of urine, semen, sebaceous and sweat gland secretions, desquamated epithelial cells, and other material that accumulates in the fossa glandis and the urethral sinus. It may become very dry and hard, forming the "**bean**" of the horse penis (Fig. 5-25). When a large bean is present in the urethral sinus, it compresses the urethral process and interferes with urination; it is one cause of dysuria in the male horse. In some cases removal of a large bean requires general anesthesia.

Glans Penis of Ruminant: The glans penis is a relatively small cushion of tissue on the distal end of the free part of the penis (Fig. 5-22). Note the characteristic twisting of the bovine penis. Although the bovine urethral process is actually on the left side of the penis, it is seen from the right side of the animal because of this normal left-hand spiral. Some illustrations show this incorrectly. Note the long **urethral process** in the small ruminants and the **tuberculum spongiosum** of the ram penis (Fig. 5-28).

Spiral Deviation of Bovine Penis: Studies using a transparent artificial vagina have shown that a left-hand spiral deviation of the bovine penis frequently occurs after intromission. Factors that are believed to produce this spiral include the fiber orientation of the dense subcutaneous tissue and tunica albuginea of the free part of the penis. Premature spiraling of the penis can prevent intromission and is a recognized clinical problem known as *spiral or corkscrew deviation*. Some controversy exists as to whether this problem should be corrected because there is some evidence of inheritance, particularly in polled Herefords.[18]

Free Part of Porcine Penis: Like that of the ruminant, the penis of the pig is of the fibroelastic type, and the glans penis is small (Fig. 5-27. Note that the free part is naturally twisted in a left-hand spiral, similar to that which occurs in the bovine penis after intromission. This spiral becomes more distinct during erection. Occasionally, the penis may become lodged in the preputial diverticulum during erection, which inhibits protrusion of the penis. This is another reason why the preputial diverticulum is sometimes removed in boars used for artificial insemination.

Superficial Inguinal Ring and Spermatic Cord: Now that we've worked our way out of the pelvic cavity and down the penis to the preputial cavity, let's return to the superficial inguinal ring- this time from the outside, looking in. You remember that we left the spermatic cord back there, and we can't just leave it dangling, so let's go back and pick up some loose ends while we're in the neighborhood.

---

[17] *potpourri* (Fr. *pot pourri*)- literally means a *rotten pot*.

[18] Ashdown, R. R., Pearson, H. Studies on "corkscrew penis" in the bull. Vet. Record 93 (1973): 30-35.

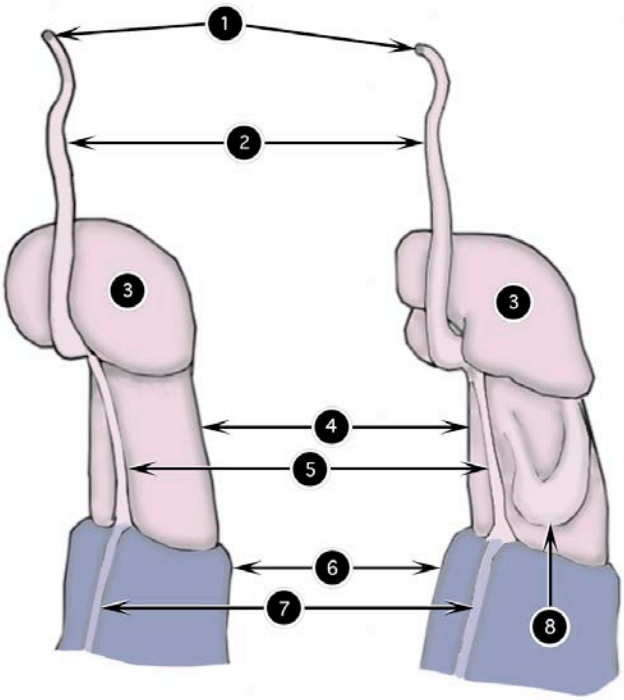


Figure 5-28. Free part of caprine penis (left) and ovine penis (right), left ventral view: (1) external urethral orifice; (2) urethral process: (3) glans penis; (4) free part of penis; (5) raphe of penis; (6) internal lamina of prepuce (reflected over body of penis); (7) frenulum of prepuce (8) tuberculum spongiosum of ram. (Modified from Nickel, Schummer, Sieferle. and Sack, *The Viscera of the Domestic Mammals*, 2nd ed., Springer-Verlag, New York, 1979, p. 338.)

From the inside, the superficial inguinal ring was seen as a slit-like separation between the medial and lateral crura of the external abdominal oblique aponeurosis. Now locate it from the outside- not so easy, right? That's because the abdominal fascia was reflected from around the margin of the ring onto the parietal lamina of the vaginal process as it came through the abdominal wall.

Thus, the superficial inguinal ring does not have as well-defined borders on the outside as it does internally. Note that the medial fascia of the thigh also blends with the abdominal fascia in this area, which has one clinically important ramification. When the animal abducts its pelvic limb, tension on the fascia tends to dilate the inguinal canal; or to turn this around, if you want to dilate and examine the inguinal canal in the anesthetized patient, abduct the pelvic limb.

Testicular Descent: Before we dissect the scrotum and its contents, let's first consider how things got to the scrotum in the first place. As previously noted, the testis formed in the sublumbar region of the embryo and subsequently moved out of the abdominal cavity to a cooler, more comfortable location, away from the hot and crowded conditions of the abdomen. This process is known as *testicular descent*, and one of the key actors in this delivery is the **gubernaculum testis** (Fig. 5-29).

Descent of the testis is accomplished by a series of sequential events that are hormonally influenced and involve specific parts of the gubernaculum testis. Both the timing of these events and the correct location of these responses along the length of the gubernaculum are important if the process of testicular descent is to succeed.

The first thing to understand is that the gubernaculum testis forms as a condensation of mesenchyme relatively early in embryonic life. It extends from the level of the testis, through the developing abdominal wall, and out to the future site of the scrotum (Fig. 5-29A). In other words, it defines the course that the testis needs to take to get from *point A* (origin) to *point B* (scrotum).

Next, the peritoneum invades the gubernaculum and grows outward within it as the **vaginal process**. Hormonal factors really get going as the gonad differentiates into a definitive testis, not an ovary. The extra-abdominal part of the gubernaculum begins to swell, like a balloon being blown up outside the abdominal wall (Fig. 5-29B). As this occurs, pressure naturally builds up against the abdominal wall, and tension is applied to that part of the gubernaculum still within the abdomen. Thus, this intra-abdominal part is drawn out through the inguinal canal, bringing with it the testis to which it is attached (Fig. 5-29C).

That gets the testis through the inguinal canal, but now we have a new problem- the expanded gubernaculum stands in the way of progress. Thus, for the testis to complete its journey to the scrotum, the gubernaculum must now get out of the way. Therefore, the second phase of testicular descent involves regression of the gubernaculum testis, which at this stage is represented by the **gubernacular bulb** (Fig. 5-29C). Again, triggered by hormonal factors, the gubernacular bulb degenerates and allows the testis to assume its final position within the scrotum (Fig. 5-29D). Remnants of the gubernaculum testis persist in the adult as the **proper ligament of the testis**, the **ligament of the tail of the epididymis**, and the **scrotal ligament**.

As you can see, successful testicular descent depends on a sequence of events that must occur at the right time and in the right place. Failure can result if: (1) the gubernaculum fails to respond; (2) the swelling reaction is not sufficient to draw the testis out of the abdomen; and (3) the swelling reaction is sufficient, but in the wrong location (*i.e.*, it involves the intra-abdominal or intrainguinal part of the gubernaculum, perhaps the most common cause of failure). These failures result in **cryptorchidism**, a condition in which one or both testes (orchids) are retained in an intra-abdominal or intrainguinal location, that is, still within the "crypt" of the abdomen.

Among our common domestic mammals, cryptorchidism is most common in horses and dogs. The horse has two strikes against it here. First, the testes descend late in gestation, entering the inguinal canal between 270-300 days gestation (out of 335 days average gestation period). Secondly, the testes of the horse fetus must actually shrink to get through. The testes of equine fetuses get enormous, growing to about 5 cm in diameter and weighing about 50 grams at 250 days gestation.[19]

[19] Bergin, W. C., Gier, H. T., *et al*. A Developmental concept of equine cryptorchidism. Biol. of Reproduction 3 (1970): 82-92

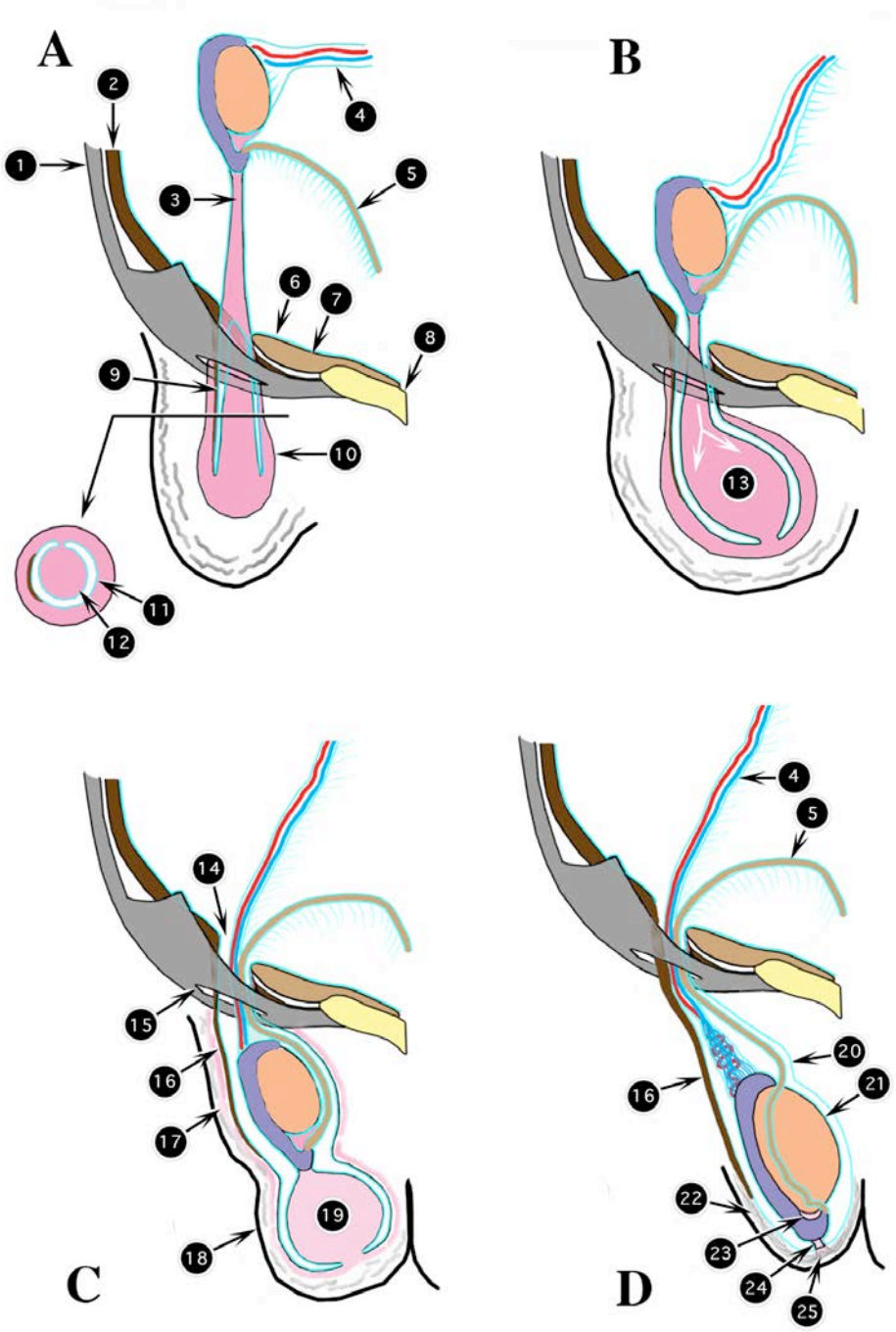


Figure 5-29. Schematic representation of testicular descent in domestic mammal, sequence A-D: (1) external abdominal oblique aponeurosis; (2) internal abdominal oblique muscle; (3) intra-abdominal part of gubernaculum testis; (4) testicular vessels within by mesorchium; (5) ductus deferens within mesoductus; (6) parietal peritoneum; (7) rectus abdominis muscle; (8) pubis; (9) evagination of peritoneum into gubernaculum forming vaginal process; (10) extra-abdominal part of gubernaculum testis; (11) cross-section of vaginal process; (12) central core of gubernaculum isolated by 9; (13) expansion of extra-abdominal gubernaculum, drawing out intra-abdominal part and testis; (14) vaginal ring, overlying deep inguinal ring; (15) superficial inguinal ring; (16) cremaster muscle, from 2; (17) degeneration of peripheral part of gubernaculum; (18) scrotum; (19) gubernacular bulb; (20) parietal vaginal tunic; (21) visceral vaginal tunic; (22) spermatic fascia; (23) proper ligament of testis; (24) ligament of tail of epididymis; (25) scrotal ligament. (After Wensing, 1973)

These testes are just too large to get through the inguinal canal, and must "slim down" to squeeze through. By 270-300 days gestation, when they start through the inguinal canal, they have shrunk to about 30 grams, mainly through the loss of interstitial (Leydig) cells. Their shape has also changed from plump, kidney-shaped structures to a more streamlined torpedo shape for passage through the inguinal canal. As if the testes of the horse needed any more complications, if they fail to shrink, they fail to pass.

Scrotum and Spermatic Fascia: Carefully incise the skin of the scrotum over one of the testes, and bluntly separate the parietal vaginal tunic away from the scrotal wall. You are now working in the **external spermatic fascia**, which is continuous proximally with the fascia of the abdominal wall. This relatively loose fascia is what allows the vaginal tunic (and enveloped testis and epididymis) to move within the scrotum (Fig. 5-30).

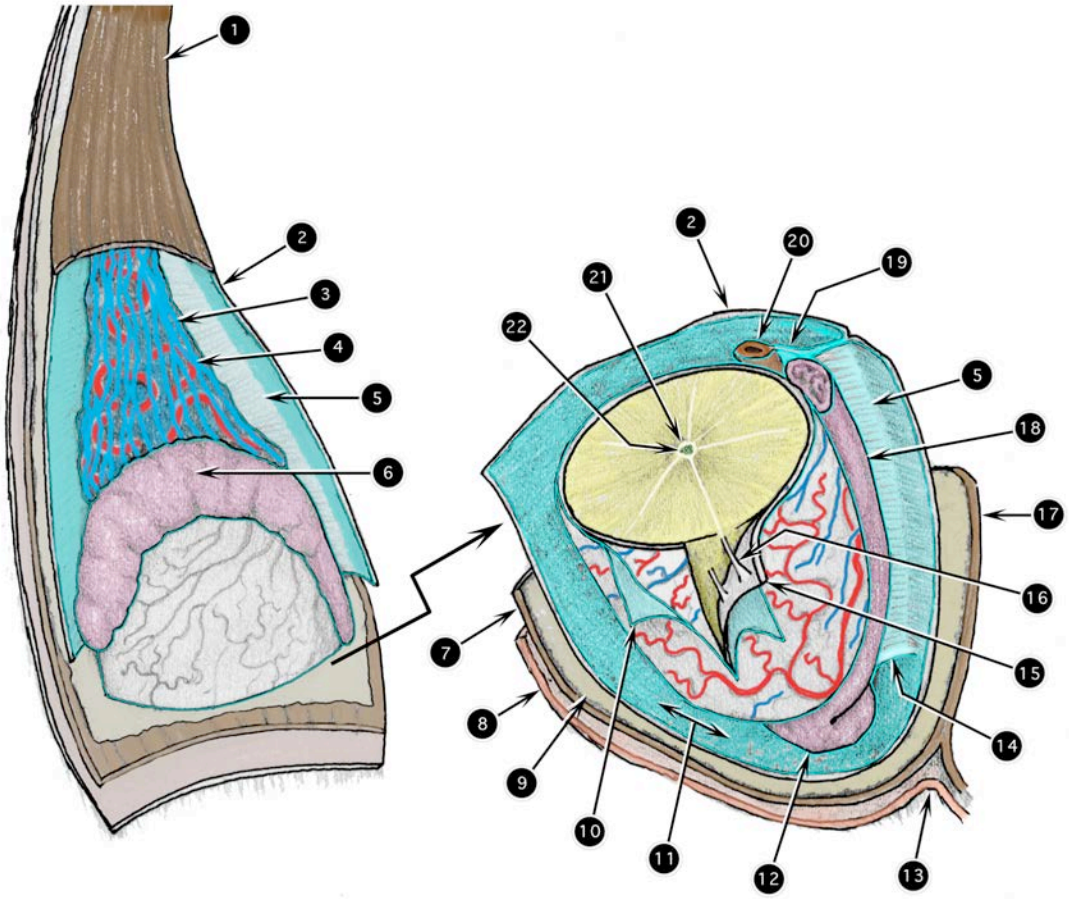


Figure 5-30. Sectioned left testis and associated structures of bull, caudolateral view: (1) cremaster muscle; (2) parietal vaginal tunic with adherent internal spermatic fascia; (3) pampiniform plexus formed by testicular vein; (4) highly tortuous testicular artery weaving through venous plexus; (5) mesorchium; (6) head of epididymis; (7) tunica dartos; (8) skin of scrotum; (9) external spermatic fascia; (10) visceral vaginal tunic being reflected; (11) cavity of vaginal tunic- continuous above with peritoneal cavity; (12) tail of epididymis; (13) raphe of scrotum; (14) ligament of tail of epididymis in distal border of mesorchium; (15) tunica albuginea testis being reflected from parenchyma; (16) septula testis connecting 15 with 21; (17) septum of scrotum formed by tunica dartos; (18) body of epididymis; (19) mesoductus deferens; (20) ductus deferens; (21) mediastinum testis; (22) rete testis within 21.

In the horse (and dog), a variably developed condensation of this fascia near the tail of the epididymis forms the "scrotal ligament," which results from regression of the most distal part of the gubernaculum testis (Fig. 5-29). When the vaginal tunic is bluntly dissected from the scrotum, such as in a closed castration,[20] the separation occurs within the external spermatic fascia. The **internal spermatic fascia** is continuous proximally with the transverse fascia of the abdomen and closely adheres to the parietal vaginal tunic and cremaster muscle. It accounts for the toughness and opacity of the parietal tunic. (The relationship is similar to that between the fibrous pericardium and the parietal lamina of the serous pericardium.)

The skin of the scrotum is thin and relatively hairless, a modification that allows for better heat dissipation. Heavy wool around the scrotum can create problems with spermatogenesis in the ram. Intimately adhered to the dermis is a modification of the subcutaneous tissue layer known as the **tunica dartos** (Fig. 5-30), which consists of smooth muscle bundles mixed with elastic and collagenous fibers. Because it blends with the dermis, it cannot be easily separated from the skin.

During cold conditions, sexual arousal, and fright, contraction of the tunica dartos wrinkles (shrivels) the scrotal skin, thereby reducing the exposed surface area of the scrotum and reducing heat loss. Contraction of the tunica dartos holds the testes closer in to the body wall, where they are warmer and/or safer, depending on the precipitating stimulus for the contraction. The tunica dartos also forms the **septum of the scrotum**, which separates the right and left testes (Fig. 5-30). The location of the septum is indicated externally by the **raphe of the scrotum**.

Rudimentary teats are typically found at the neck of the scrotum in the bull, buck, ram, and jack. They are rarely if ever present in the male horse. The wall of the scrotum, formed by the skin, the tunica dartos, and the external spermatic fascia, drains to the **superficial inguinal lymph nodes**, which are located just outside the superficial inguinal ring (Fig. 5-12). Following castration, the remnant of the scrotum typically fills with fat, the so-called "cod fat" of the steer carcass.

Orientation of Testes in Horse: The orientation of the equine testes is shown in figure 5-31. The testes are positioned somewhat obliquely, so that their long axes are oriented slightly caudoventrally.

Pretend you're a surgeon performing an open castration, and *incise the parietal vaginal tunic along the free border of the testis*. You should observe that the cremaster muscle is outside the parietal vaginal tunic (Fig. 5-32). The epididymis is attached to the testis cranially at the head and again caudally by the **proper ligament of the testis**. The body of the epididymis is only attached along the medial side, leaving a space between the epididymis and testis, the **testicular bursa**, which is open laterally (Fig. 5-32).

[20] *closed castration*- the parietal vaginal tunic is *not* opened prior to removal of the testis. Rather the testis and epididymis, still enclosed by the entire vaginal tunic, are removed as a unit. In an *open castration*, the parietal tunic is incised *(opened)* and the testis and epididymis are exposed, dissected free, and removed.

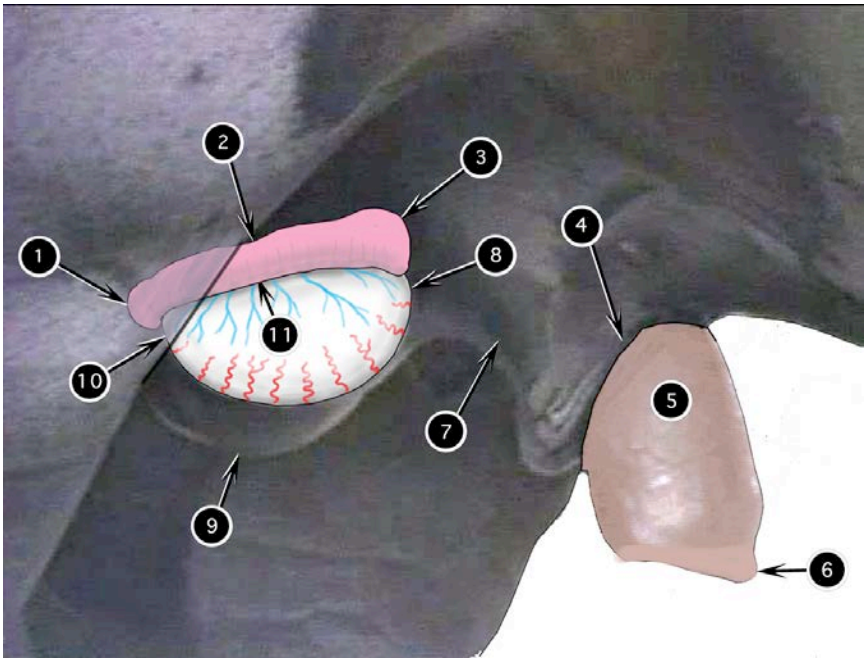


Figure 5-31. Orientation of equine testes, right lateral view: (1) tail of epididymis; (2) body of epididymis; (3) head of epididymis; (4) preputial orifice; (5) preputial fold (part of internal lamina of prepuce); (6) preputial ring; (7) external lamina of prepuce; (8) cranial extremity of right testis; (9) left testis within scrotum; (10) caudal extremity of right testis; (11) testicular bursa.

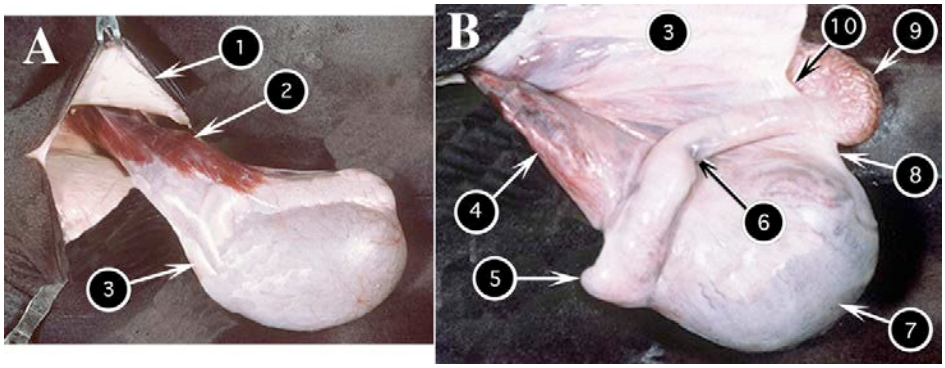


Figure 5-32. Surgical exposure of left testis of stallion, left lateral view: **(A)** scrotal skin incised with testis still enclosed in parietal tunic and exteriorized by blunt dissection in external spermatic fascia- ligation and removal at this point would accomplish a *closed castration*; **(B)** parietal tunic incised to open cavity of vaginal tunic as in an *open castration*; (1) skin incision; (2) cremaster muscle attaching to lateral surface of parietal vaginal tunic; (3) parietal vaginal tunic and adherent internal spermatic fascia, incised and reflected in B; (4) pampiniform plexus enveloped by mesorchium; (5) head of epididymis attached to capital extremity of testis; (6) testicular bursa between testis and epididymis- open laterally; (7) testis covered by visceral vaginal tunic; (8) proper ligament of testis attaching tail of epididymis to caudal extremity of testis; (9) tail of epididymis; (10) ligament of tail of epididymis in distal border of mesorchium and attaching tail of epididymis to parietal vaginal tunic. (Modified from slide set, *The Dissected Horse*, by W. O. Sack and L. L. Sadler, Cornell University.)

This loose attachment is less obvious in the embalmed specimen but is more evident at surgery (Fig. 5-32). The significance of this loose attachment is that, during castration of the horse, it is important that the testis and entire epididymis be removed. Although not the only explanation, leaving part of the epididymis in the horse has been

associated with what is popularly called a "proud cut" horse (*i.e.*, he's a gelding, but still thinks and acts like he's a stallion). Sometimes, going back in on these geldings and removing additional tissue (residual epididymis) from the stump of the cord corrects such behavior problems. Obviously, it's better to get it all the first time. (Old-time horsemen refer to the epididymis of the horse as the "squealer," based on their belief that if you leave any of it behind, that's what the horse will do when he gets around mares.)

The **ductus epididymidis** of the stallion is very long, measuring some 75 m (225 feet) when unraveled.[21] The epididymis is attached to the parietal vaginal tunic by the **ligament of the tail of the epididymis** (Fig. 5-32). At the tail of the epididymis the ductus epididymidis becomes continuous with the **ductus deferens**, which, enclosed in its separate peritoneal fold, the **mesoductus deferens**, ascends along the medial side of the mesorchium to enter the spermatic cord.

Orientation of Testes in Ruminant: The large testes of sexually mature ruminants are positioned in the scrotum with their long axes in a dorsoventral orientation. *Incise the parietal vaginal tunic along the free border of the testis*. You should observe that the **body of the epididymis** lies along the caudomedial aspect of the testis (Fig. 5-30). The epididymis is attached to the testis at the head, where the efferent ductules are located and again at the tail by the **proper ligament of the testis**. Between these attachments is the **testicular bursa**, which opens caudolaterally.

When straightened out, the **ductus epididymidis** of the ruminant measures about 40 to 50 m.[21] The epididymis is attached to the parietal vaginal tunic by the **ligament of the tail of the epididymis**, and here the ductus epididymidis becomes continuous with the **ductus deferens** (Fig. 5-30). The latter remains enclosed in its separate peritoneal fold, the **mesoductus deferens**, and ascends along the cranial side of the mesorchium to enter the spermatic cord. The tail of the epididymis is so prominent in the bull and buck (billy goat) that its outline can be noted in the living animal. By the way, if you're ever asked if you would like to try some “calf fries” or “mountain oysters,” you might be interested to know (before you order a full plate) that these are cooked calf testes.

Orientation of Testes in Pig: The testes of the pig migrate well beyond the inguinal region and, like those of the tomcat, continue caudally to the perineal region. They are positioned in the scrotum with their long axes in a somewhat dorsoventral orientation, but with their heads down, that is, the tail of the epididymis is dorsal.

Incise the parietal vaginal tunic along the free border of the testis. You should observe that the **body of the epididymis** lies along the craniolateral aspect of the testis. The epididymis is attached to the testis at the head, where the efferent ductules are located, and again at the tail by the **proper ligament of the testis**. Between these attachments is the **testicular bursa**. When straightened out, the **ductus epididymidis** of the boar measures about 17 to 18 m.[21]

The epididymis is attached to the parietal vaginal tunic by the **ligament of the tail of the epididymis**. Here the ductus epididymidis becomes continuous with the **ductus deferens**, which, enclosed in its

[21] Nickel, R., Schummer, A., Sieferle, E., and Sack, W. O. *The Viscera of the Domestic Mammals*, 2nd ed., Springer -Verlag, New York, 1979.

separate peritoneal fold, the **mesoductus deferens**, ascends along the medial side of the mesorchium to enter the spermatic cord.

Internal Structure of Testis: *Now pretend you are a pathologist, and make a transverse cut through the testis to expose the parenchyma and supporting tissues* (Fig. 5-30). The testis and epididymis are invested by peritoneum, the **visceral lamina of the vaginal tunic**. Deep to this thin layer is the more substantial capsule of the testis, the **tunica albuginea testis**. Many superficial vessels, which vary in size and configuration according to the species, are located within the capsule. In the living animal, the internal tissue of the testes is under pressure, so that when the tunica albuginea is incised, the parenchyma bulges or everts out through the incised capsule.

Incise the capsule, and peel back the tunica albuginea for a short distance (Fig. 5-30). Note the presence of numerous **septula testis**, which extend from the capsule into the parenchyma. These septula converge to form an axial strand of connective tissue through the center of the testis, the **mediastinum testis**. The interconnected tunica albuginea testis, septula testis, and mediastinum testis form a supporting connective tissue framework for the testis (Fig. 5-30).

The septula divide the parenchyma into indistinct lobules, each of which houses several **seminiferous tubules**. Within the substance of the mediastinum testis, except in the horse, is a network of tubules that forms the **rete testis**, which accounts for the sponge-like appearance of the mediastinum on cut surface (Fig. 5-30). Unlike that of other domestic mammals, the rete testis of the stallion is not associated with the mediastinum testis, but is concentrated near the head of the testis.

Regardless of how it gets there, the rete testis reaches the cranial extremity of the testis and continues through the tunica albuginea testis for a short distance as the extratesticular rete. From this portion of the rete, arise about 15 to 17 **efferent ductules**, located within the head of the epididymis. The efferent ductules unite with one another to form the **ductus epididymidis**. It is important to understand that, to this point, there have been alternative avenues of egress for the spermatozoa. Once united to form the ductus epididymidis, however, there is only one way out. Any obstruction (*e.g.*, fibrosis, surgical ligation, transection) beyond this union effectively renders that testis incapable of delivering spermatozoa to the outside world. Bilateral obstructions, whether intentional ("vasectomy") or accidental, would thus result in sterility.

Spermatic Cord: As the **testicular artery** approaches the testis, it becomes highly tortuous, forming a spring-like configuration (Fig. 5-30). Surrounding that part of the artery, the testicular vein forms an elaborate, mesh-like plexus, the **pampiniform plexus**.[22] For many years, the pampiniform plexus was assigned two functions: (1) cooling of arterial blood by the absorption of heat into the cooler venous blood that surrounds the artery; and (2) absorption of the pulsating (systolic-diastolic) pressures in the artery prior to reaching the sensitive tissues of the testis (*i.e.,* the spring-like configuration of the artery dampens the pulse and results in a more constant perfusion pressure to the testis).

[22] pampiniform- shaped like a tendril (a long thin thing)

More recently, normal arteriovenous interconnections (anastomoses) have been demonstrated in this region of intimate arteriovenous contact. These connections are believed to function in a type of hormonal feedback mechanism. Although not typically described as a pampiniform plexus, this same type of relationship is present between the ovarian artery and vein. The ductus deferens has its own blood supply, the **artery and vein of the ductus deferens** (Fig. 5-33), which closely accompany the duct within the mesoductus deferens and are homologous to the uterine artery and vein of the female.

The spermatic cord consists of a collection of structures, including the ductus deferens and its deferent vessels, the testicular artery and vein, smooth muscle fibers, lymphatic channels that drain to the medial iliac lymph nodes, and testicular (sympathetic) nerves. Because these structures are intimately invested by peritoneum, the mesorchium, and mesoductus deferens, these coverings are frequently included in surgical descriptions of the spermatic cord. Note, however, that the cremaster muscle lies outside the parietal lamina of the vaginal tunic and is thus not technically part of the spermatic cord.

While together in the spermatic cord, the mesorchium and ductus share a common connection to the parietal vaginal tunic, which is termed the mesofuniculum[23] (Fig. 5-33). Just inside the vaginal ring, the mesoductus and mesorchium part company and go their separate ways (Fig. 5-29).

There is no lymphatic drainage of the testis or epididymis to the superficial inguinal nodes; they drain directly *via* the testicular lymphatics to the medial iliac lymph nodes. Therefore, unless there is concurrent involvement of the scrotum, orchitis[24] does not produce enlargement of the superficial inguinal nodes.

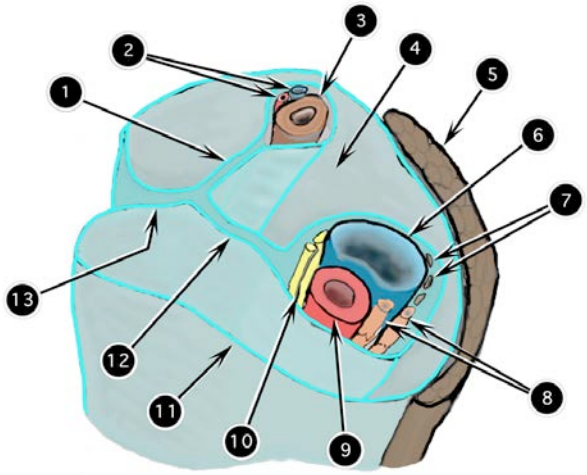


Figure 5-33. Schematic representation of transverse section through left spermatic cord of bull, caudoproximal view: (1) mesoductus deferens; (2) artery and vein of ductus deferens; (3) ductus deferens; (4) cavity of vaginal tunic, continuous above with peritoneal cavity; (5) cremaster muscle; (6) testicular vein; (7) smooth muscle fibers; (8) testicular lymphatics draining to medial iliac nodes; (9) testicular artery; (10) testicular nerves; (11) parietal vaginal tunic; (12) mesorchium; (13) mesofuniculum.

[23] funiculus- a cord-like structure or part

[24] orchis (Greek)- the testis. *Orchitis is an inflammation of the testis*; it has nothing to do with a disease of flowers.

Chapter 6 • Tail, Pelvic Wall, and Pelvic Limb

Because of differences in the relative growth of the vertebral column and spinal cord, the level of termination of the spinal cord varies among species. In some species, this difference is great and the spinal cord is relatively short (*e.g.*, in the dog, where it ends at L6-L7). The spinal cord of the adult horse, ruminant, and pig typically ends between the last lumbar and second sacral vertebra.

TAIL

Caudal Epidural Anesthesia: Caudal epidural anesthesia is routinely employed in the horse and ox for obstetric procedures and for standing surgery in the perineal and pararectal regions. By raising the tail of the live animal, a distinct "dimpling" can usually be seen over the dorsal interspace between caudal (Cd) vertebrae 1 and 2, which is a common site for caudal epidural anesthesia in the horse and ox. The needle is usually inserted in a cranioventral direction at about a 45° angle to enter the vertebral canal between Cd1 and Cd2. A local anesthetic, such as 2% lidocaine, is injected into the epidural fat that surrounds the caudal nerves at this level. Depending on the volume injected, it flows cranially to affect the nerves that contribute to the sacral plexus.

One of the primary benefits of using an epidural during obstetric manipulation of a malpositioned fetus is that the sensory nerves from the pelvic cavity are blocked. Thus, the dam no longer senses the pressure and discomfort in her pelvic canal and stops straining (by abdominal press) to expel the fetus. Although the uterus still contracts around the fetus, cessation of abdominal straining is often sufficient to allow the veterinarian to repel the fetus and bring it into proper position for an assisted delivery. One disadvantage is that if too much anesthetic is injected at one time, it may flow cranially and block the motor nerves of the pelvic limbs. The animal will go down if the femoral nerves (L4-L6) are affected. Although less commonly performed, epidural anesthesia can also be used in the ox at L1-L2 in lieu of paravertebral anesthesia for surgery in the flank. In the sheep and pig, epidural anesthesia is more often performed at the lumbosacral interspace, where it is useful in cesarean section.

Transverse Section of Tail: In the horse and ox cadavers (not the live animals), palpate the tail and, using a large knife, *make a transverse cut completely through the tail between Cd3 and Cd4* (that's right, cut it off). On the transverse section of the bovine tail, identify the **median caudal artery and vein** ventral to the vertebra (Fig. 6-1). The median caudal vein, which may be double, is a frequent site for blood sample collection in the ox ("tail bleeding"). Access to the vein using a midventral approach is intermittently obstructed by the presence of **hemal arches**, which are usually present on the second and third caudal vertebrae.

The tails of the horse and ox are natural “fly swatters.” Anyone who has ever been swatted in the face by a cow's tail, especially when the switch is adorned with a few cockleburs, knows that it is most effective in discouraging annoying stimuli that fall within its range of motion. The highly accurate swatting motion of the tail is

primarily accomplished by the coordinated contraction of the **sacrocaudalis muscles**. There are eight of these muscles, which encircle the cylindrical caudal vertebrae like directions on a compass face. As the name implies, they all originate on the sacrum and terminate on the caudal vertebrae. Although the names of these muscles sound complicated, they simply locate the muscle on the compass.

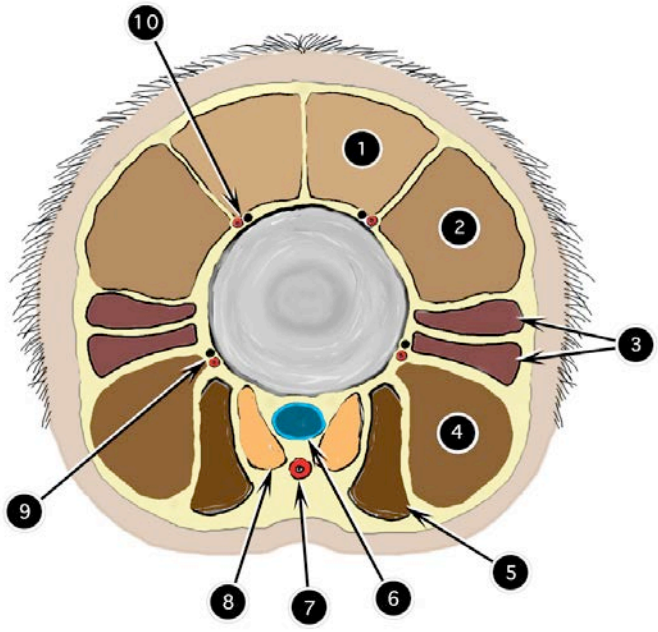


Figure 6-1. Transverse section through tail of horse at about Cd3-Cd4 intervertebral space, caudal view: (1) sacrocaudalis dorsalis medialis muscle; (2) sacrocaudalis dorsalis lateralis muscle; (3) dorsal and ventral intertransversarii caudalis muscles; (4) sacrocaudalis ventralis lateralis muscle; (5) sacrocaudalis ventralis medialis muscle; (6) median caudal vein; (7) median caudal artery; (8) rectococcygeus muscle; (9) ventrolateral caudal vessels; (10) dorsolateral caudal vessels.

Beginning at the dorsal midline (Fig. 6-1), identify the **sacrocaudalis dorsalis medialis**, then the **sacrocaudalis dorsalis lateralis**, the **dorsal and ventral intertransversarii caudalis** (slipped that one in on you), the **sacrocaudalis ventralis lateralis**, and finally the **sacrocaudalis ventralis medialis**. In the more proximal part of the tail, you will also find the pale **rectococcygeus muscles** flanking the median caudal vessels on each side.

The rectococcygeus muscles are smooth muscle continuations of the outer longitudinal layer of the rectal wall that extend beyond the anus and attach to caudal vertebrae. When the animal raises its tail for defecation, the rectococcygeus muscles tense, applying traction to the dorsal rectal wall and providing support for the peristaltic contractions that push out the feces and resist the tendency for the rectum to be pushed back into the abdomen.[1]

Other than "tail bleeding" in cattle, another reason for looking at this region in the horse is because of the controversial "tail set operation", which is sometimes performed in gaited show horses.[2] The

[1] Remember: For every action, there is an equal and opposite reaction (principle of physics).

[2] Why veterinarians continue to perform such purely cosmetic surgeries is unclear, but until we decide to stop doing such mutilations to please owners and show judges, we should look at the structures involved. I have absolutely no problem with this operation if the horse (not the owner) personally requests it- *in writing*.

surgery involves cutting the ventral sacrocaudalis muscles on each side of the median caudal vessels with a special "nicking knife."

The horse's tail is then placed in a harness-like apparatus known as a "tail set" until the scar tissue resulting from the surgery has matured and more or less fixes the tail in this deformed position. Continued use of the "tail set" maintains the tail in this "kinked" configuration.

Horsepeople also talk veterinarians into "blocking" some of the nerves to the sacrocaudalis muscles to prevent their show horses from the ever so unsightly acts of tail swishing or tail wringing in the show ring.[3]

Tail amputations (docking) are routinely performed in lambs for sanitation purposes and in piglets to prevent tail biting when they are confined for feeding. Tails may also be docked in draft horses, supposedly to prevent the long tail from becoming entangled in the rigging. These short tails may also be braided, tied in a bun, and ribbons can be added as part of "accessorizing" the well-dressed draft horse.

PELVIC WALL

Now that we've studied the pelvic viscera, let's turn our attention to those structures associated with the pelvic wall on the side of the cadaver that has not been dissected. The nerves of the lumbosacral plexus and vessels that supply the pelvic limb are now considered in more detail. Clean the medial surface of the pelvic wall, and identify the vessels and nerves of this area (Figs. 5-9, 5-10, 5-13, & 5-15).

As previously noted, the pudendal, pelvic, and caudal rectal nerves form the more caudal (sacral) division of the **lumbosacral plexus**. The **lumbosacral trunk** exits through the **greater sciatic foramen**. Its primary continuation is the sciatic nerve, but the cranial and caudal gluteal nerves and the caudal cutaneous femoral nerve also arise from this trunk. The **obturator nerve** courses along the medial surface of the ilium to exit the pelvic canal through the **obturator foramen**. In the horse, it is accompanied by the **obturator artery**; as previously seen, this vessel gives rise to the deep and middle arteries of the penis (clitoris). In addition, the obturator artery, a branch of the cranial gluteal artery, gives origin to the **iliacofemoral artery** (Figs. 5-13 & 5-19), which courses laterally, cranial to the ilium, to help supply the large quadriceps femoris muscle.

Let's pause for a moment and consider the osseous confinement of the pelvic canal. Examine the bovine and equine skeletons, and note the boundaries of their pelvic canals. The **terminal line** (entrance of the pelvic canal) is formed by the **sacral promontory** and wings dorsally, by the iliopectineal lines of the ilia laterally, and by the cranial border of the pubis ventrally.

It would appear that the bovine pelvis was designed with the veterinarian in mind, that is, one may well be needed when a large calf tries to get through it. The floor of the canal is distinctly concave and rises sharply to the **ischial arch** (Fig. 5-4). Thus, the lateral osseous walls are very high and are unyielding to expansion. The **sacrosciatic ligament**, which forms the more dorsal part of the lateral wall, relaxes under the hormonal influences of preparturition, and the **sacroiliac joint** becomes more compliant.

[3] Smallwood's First Law of Horses: Whatever can possibly be done to a horse has already been done- at least once.

This allows the sacrum and first few caudal vertebrae to move dorsally, which accounts for the "high tail head" of the preparturient cow. Except in the first-calf heifer, in which the pelvic symphysis may not be completely fused, there is no possibility of lateral expansion of the pelvic canal, regardless of hormonal changes. Thus, the bovine pelvis has plenty of room, but only for improvement in its design. When big calf meets small, poorly designed pelvis, veterinarians are occupationally predisposed to an untimely notification of the "blessed event." It's another one of those "economic opportunities."

In contrast, the pelvis of the mare has a much better design for passage of the foal. Her main problem is getting a live foal to the pelvic canal, not through it. Once through the terminal line, the foal is basically "home free." The osseous walls are low and wide, and the sacrosciatic ligament can provide for considerable expansion for the foal (Fig. 5-13). Most obstetric complications in the mare are related to some type of malpositioning of the foal rather than to a foal-pelvis size problem.

Note the difference in the area of the **lesser sciatic notch** between the artiodactyl and equine pelves. The horse has a low, smooth border to accommodate the tendon of the internal obturator muscle. Artiodactyls have a high, sharp ridge that would cut the tendon if it passed over it. To avoid this hazard, artiodactyls have no internal obturator muscle. Through evolutionary translocation, the tendon has redirected itself through the obturator foramen. In the artiodactyls, the muscle that looks like it should be the internal obturator is actually the intrapelvic part of the **external obturator muscle**.

Because things can get pretty tight through the pelvic canal of the cow during parturition, those structures that are related to the unyielding osseous boundaries of the canal can find themselves caught between a bone and hard calf. Among those structures is the **obturator nerve**. Note that this nerve lies along the medial aspect of the ilium, where it is vulnerable to damage during parturition (Fig. 5-15). Injury to this nerve during dystocia (difficult parturition) has long been incriminated in the obturator paralysis syndrome of the cow.

Postparturient paresis is actually related to a number of varied factors that may include, but is certainly not limited to, obturator nerve damage. Research involving the artificial production of the "downer cow syndrome" by long-term (up to 12 hours) anesthesia indicates that ischemic necrosis of the caudal thigh muscles and inflammation of the sciatic and/or peroneal nerves may be major factors.

This is thought to be due to a compartmental crush syndrome, which has also been found in the limbs of clinical downer cows. The final verdict may still be out, but note the vulnerability of the bovine obturator nerve. In addition, note that the contribution from L6 to the lumbosacral trunk must pass over the terminal line to reach the greater sciatic foramen (Fig. 5-15). Here it is vulnerable to damage during dystocia. Many of the nerve fibers in the ventral branch of L6 are destined for the **common peroneal nerve**, which correlates with the incidence of peroneal paresis in postparturient cows.

PELVIC LIMB

Before you lose it, let's look at that bony segment you removed from the other side of the pelvis to expose the pelvic viscera.

When you removed the limb, you cut through the **coxal joint**,[4] which is the correct name for what almost everyone but anatomists call the hip joint. The **acetabulum**[5] is deeper than you might think, that is, if you're basing your estimate on the skeleton, not the cadaver. Deepening of the socket is accomplished by a fibrocartilaginous lip, the **labrum acetabulare**, which extends the bony rim of the acetabulum (Fig. 6-2). Thus, luxation of the coxal joint is not as probable as one might assume by studying the skeleton.

When you disarticulated the joint, you cut through the **ligament of the femoral head**, which originates from the acetabular fossa, passes through the acetabular notch (Fig. 6-2), and terminates in the **fovea capitis femoris**. This ligament anchors the femoral head in the socket and resists luxation of the joint. As usual, the horse has an extra added attraction, the **accessory ligament of the femoral head**. This accessory ligament originates from the prepubic tendon, passes through the origin of the pectineus muscle, and terminates in the more caudal part of the large fovea capitis femoris (Fig. 6-2. If you look on the ventral surface of the equine pubis, you should find a groove for this ligament.

One function attributed to the accessory ligament is that, during flexion of the joint, the caudal part of the fovea rotates caudally, thus tensing the ligament. Its resistance rotates the femur outward (supinates the joint), which automatically (passively) directs the stifle joint along the lateral aspect of the abdominal wall (*i.e.*, the horse doesn't knee himself in the belly).

Rump *vs.* Croup: The gluteal region of artiodactyls is called the rump, whereas that of the horse is known as the croup. The highest point of the rump (croup) is formed by the **tubera sacrale** of the ilia (Fig. 6-2). These structures serve as palpable landmarks for locating the lumbosacral space in the horse. Lumbosacral cerebrospinal fluid (CSF) collection in the horse is performed by inserting a spinal needle on the midline between the cranial edges of the tubera sacrale and passing it through the yellow ligament, dura mater, arachnoid, and conus medullaris of the spinal cord to the ventral part of the subarachnoid space.

As noted previously, epidural anesthesia can be administered at the lumbosacral space in the dog, pig, and sheep. Compared with the pelvis of the carnivore, there is a variable degree of outward rotation of the ilial wings, so that the **tuber coxae** of ungulates are directed more laterally (Fig. 6-3). This is most conspicuous in the horse and ox, where the tuber coxae forms a prominent, laterally projecting landmark (Figs. 6-2 & 6-3). The tuber coxae of the ox is commonly referred to as the "hook bone."

Also, compared with that of carnivores, the **tuber ischiadicum** (ischiatic tuberosity) is more prominent in ruminants, particularly in the ox. The prominent tuber ischiadicum of the ox is commonly referred to as the "pin bone." Although palpable in the horse, the tuber ischiadicum is much less conspicuous because it is blunted and is covered by parts of the semitendinosus and semimembranosus muscles, which originate not only from it, but also from sacral vertebrae.

---

[4] coxa (Latin)- the hip joint; inflammation of the joint is properly termed *coxitis*.

[5] acetabulum (Latin)- literally means *vinegar cup*.

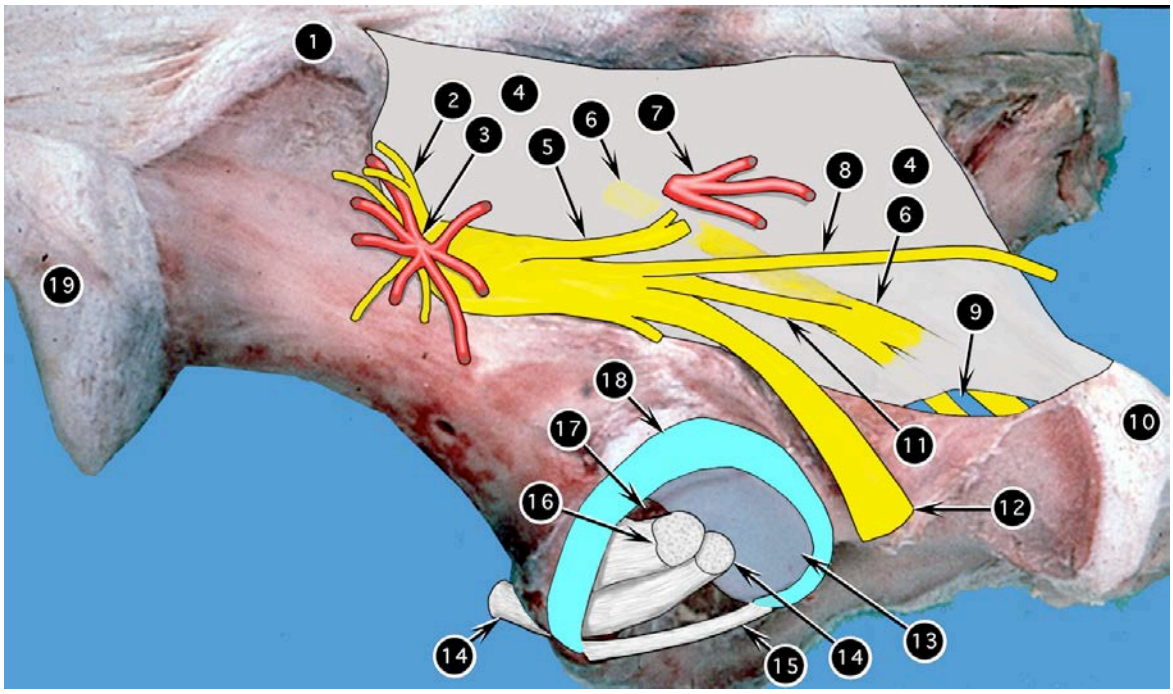


Figure 6-2. Pelvic area of foal, right lateral view: (1) tuber sacrale; (2) cranial gluteal nerve, to middle & deep gluteal muscles, & tensor fasciae latae muscle; (3) cranial gluteal artery, exiting greater sciatic foramen; (4) sacrosciatic ligament; (5) caudal gluteal nerve to superficial gluteal muscle; (6) pudendal nerve, partially embedded in 4; (7) caudal gluteal artery passing through 4; (8) caudal cutaneus femoral nerve; (9) lesser sciatic foramen; (10) tuber ischiadicum; (11) communicating branch from 8 to 6; (12) sciatic nerve; (13) lunate surface of acetabulum; (14) accessory ligament of femoral head, from prepubic tendon; (15) transverse acetabular ligament, crossing acetabular notch; (16) ligament of femoral head, from acetabular fossa; (17) acetabular fossa; (18) labrum acetabulare, fibrocartilaginous rim that deepens acetabulum; (19) tuber coxae.

These additional sacral attachments are also present in the pig and account for the rounded contour of this region in pig and horse as compared with its more angular shape in ruminants. Because the tuber ischiadicum develops as a secondary ossification center, it is subject to avulsion fracture.[6] This type of injury is of particular importance in young sows. Although pigs are pushed nutritionally for rapid growth and slaughter at an early age (about 6 months), they actually mature rather slowly. Many secondary ossification centers require years to fuse (if ever), and breeding swine can grow to a large size (over 800 lb.) if they are allowed to mature.

Reflect the skin from the gluteal region, thigh, and crus (Fig. 6-4). Don't forget- you have another pelvic limb in storage that should now be retrieved and used as needed. Most students prefer to use the detached limb for deeper, more invasive dissections, and preserve the attached limb for studying more superficial structures.

As we begin our study of the limbs, I cannot overemphasize the importance of making frequent reference to the skeletons to identify osseous landmarks and tuberosities that serve as points of muscle and ligament attachments. As a note to the wise, major muscle attachments are given more attention on the limbs, and you are expected to become familiar with these

[6] avulsion- the tearing away of part of a structure

attachment sites. It does little good to dissect a structure of the limb if you don't understand how that structure relates to the limb as a whole.

Carefully clean away the deep fascia over the rump (croup) and caudal part of the thigh so that the individual muscles can be defined and identified. At this time, ***do not remove the fascia lata over the craniolateral surface of the thigh*** (Fig. 6-4).

Superficial Gluteal Muscle: The deep gluteal fascia covers the surface of the middle gluteal muscle and provides partial attachment for the superficial gluteal. This is a V-shaped muscle in the horse that originates over the middle gluteal and more caudally from the sacrum (Fig. 6-5). It terminates on the prominent **third trochanter** of the femur (see skeleton), which, with some practice and caution, can be palpated in the live horse. In the ruminants and pig, the superficial gluteal muscle fuses to the cranial edge of the biceps femoris muscle, and in these species the combined unit is referred to as the biceps femoris or the **gluteobiceps muscle** (Fig. 6-4). Because the superficial gluteal fuses with the biceps femoris rather than terminating separately on the femur, the third trochanter of these species is absent.

Middle Gluteal Muscle: Note how far cranially this large muscle extends in the horse (Fig. 6-5) and ox (Fig. 6-4), where it originates partly from the heavy thoracolumbar fascia over the longissimus muscle. *Carefully cut the attachments of the superficial gluteal (gluteobiceps) from the sacrum and reflect it to expose the termination of the middle gluteal muscle on the* ***greater trochanter*** *of the femur* (Fig. 6-6). The middle gluteal is one of the most powerful extensor muscles of the coxal joint because of its attachment to the lever provided by the greater trochanter. Not only does it function in thrusting the pelvic limb caudally during propulsion (and kicking), but also assists the animal in rearing up on its hind limbs.

Biceps Femoris Muscle: The largest of the caudal thigh muscles is the biceps femoris, which is fused with the superficial gluteal in the ruminant and to a lesser degree in the pig. *Isolate and identify the borders of this powerful muscle* (Figs. 6-4 & 6-5). It originates from the sacrum, sacrotuberous ligament, and tuber ischiadicum, and has a broad termination over the lateral surface of the thigh, stifle, and crus and, through a minor contribution to the common calcanean tendon, to the tuber calcanei. In the horse, the distal part of the biceps femoris is divided into three distinct divisions- cranial, middle, and caudal, which can be appreciated in the live animal (Fig. 6-5). In the ruminant and pig, the gluteobiceps muscle is divided into cranial and caudal divisions (Fig. 6-4).

Semitendinosus and Semimembranosus Muscles: As noted previously, these muscles have additional vertebral (sacral) origins in the horse and pig, whereas in the ruminant, they originate entirely from the ischium. This difference accounts for the more rounded caudal contour to the junction of croup and thigh in the horse and for the smooth transition from rump to ham in the pig.

Isolate and identify the borders of these caudal thigh muscles, which can be used as a site for *intramuscular injections*. Note that the muscle with the m (membranosus) is medial (Fig. 6-4 & 6-6). The semitendinosus terminates on the tibia, and, by way of a minor contribution to the *common calcanean tendon*, on the tuber calcanei.

Termination of the semimembranosus can be better appreciated after the medial muscles of the thigh have been dissected.

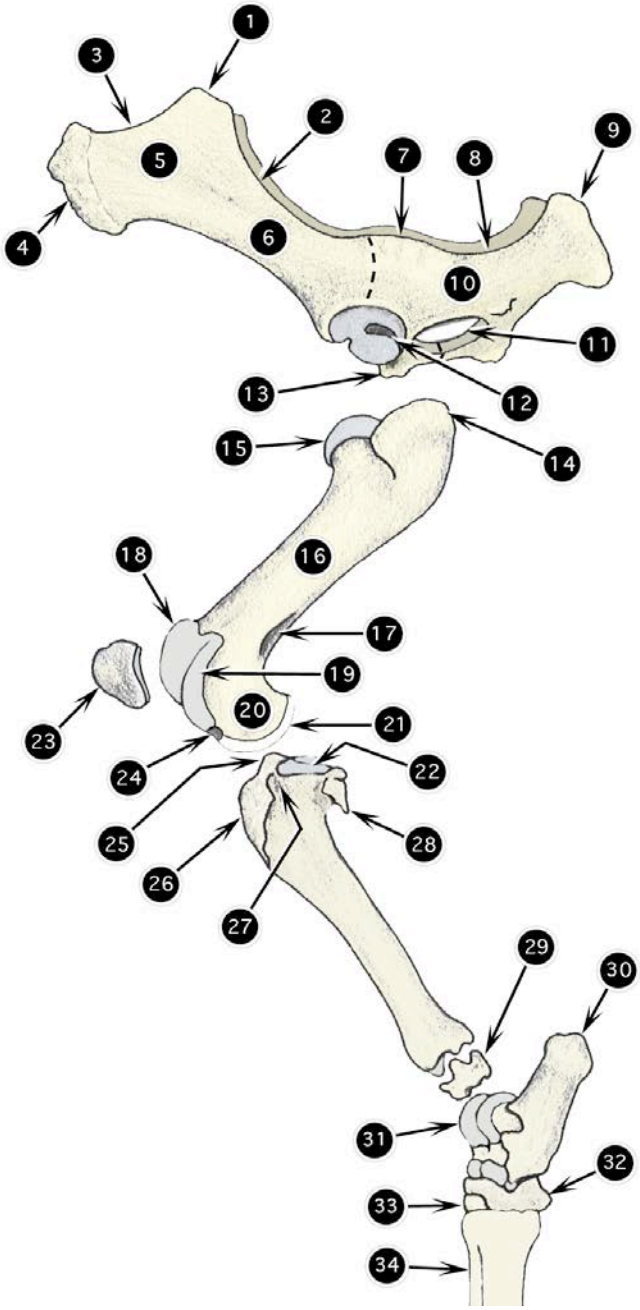


Figure 6-3. Bones of left pelvic limb of ox, lateral view: (1) tuber sacrale; (2) greater sciatic notch; (3) iliac crest; (4) tuber coxae; (5) wing of ilium; (6) body of ilium; (7) ischiatic spine; (8) lesser sciatic notch; (9) tuber ischiadicum; (10) body of ischium; (11) obturator foramen; (12) acetabular fossa; (13) body of pubis; (14) greater trochanter; (15) head of femur; (16) body of femur; (17) supracondylar fossa for origin of superficial digital flexor muscle; (18) medial ridge of femoral trochlea; (19) lateral ridge of femoral trochlea; (20) lateral epicondyle of femur; (21) lateral condyle of femur; (22) lateral condyle of tibia; (23) patella; (24) extensor fossa of femur for origin of long digital extensor and peroneus tertius muscles; (25) intercondylar eminence of tibia; (26) tibial tuberosity; (27) extensor groove of tibia; (28) head of fibula fused to tibia; (29) lateral malleolus of fibula; (30) tuber calcanei; (31) talus; (32) fused central and 4th tarsal bones; (33) fused 2nd and 3rd tarsal bones; (34) fused 3rd and 4th metatarsal bones.

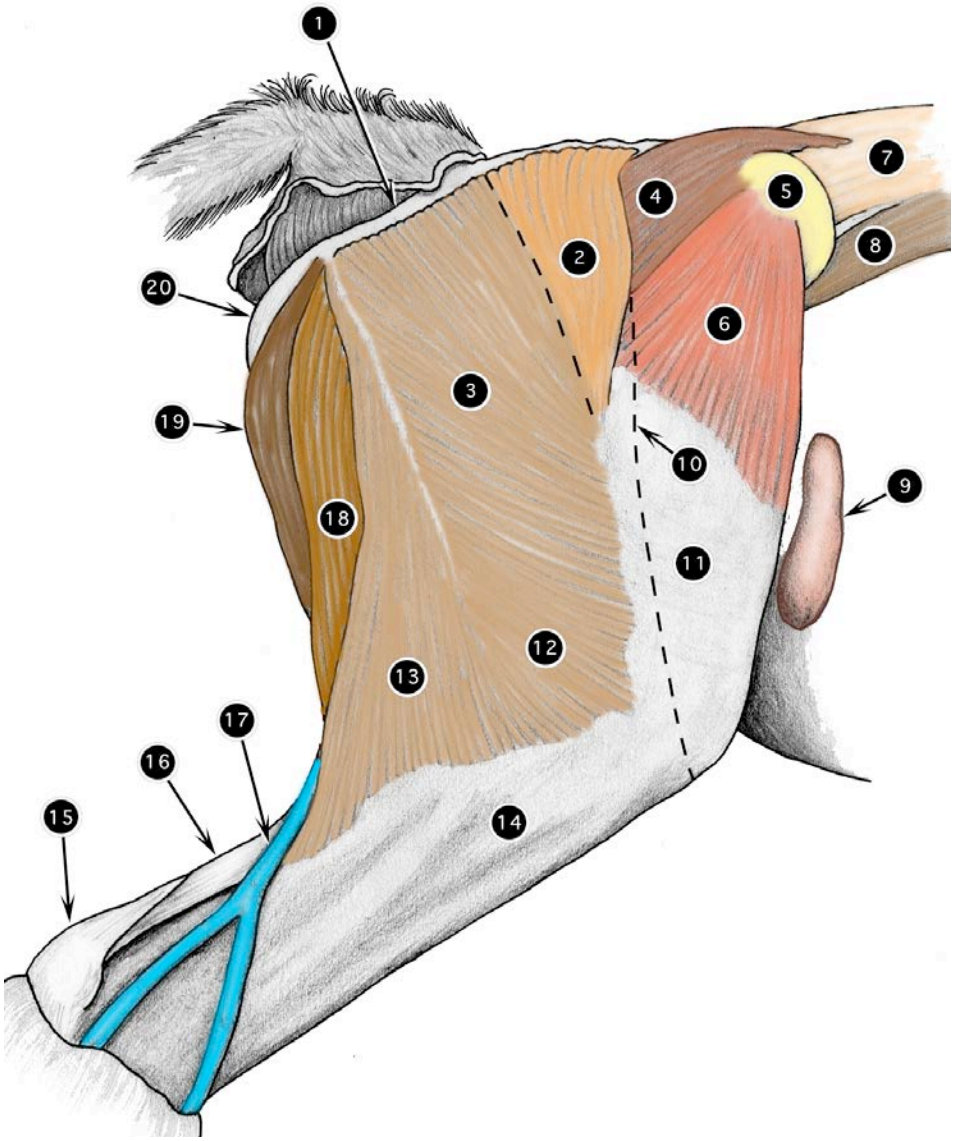


Figure 6-4. Superficial structures of rump, thigh, and leg of newborn calf, right lateral view: (1) sacrotuberous ligament; (2) superficial gluteal muscle- fused with biceps femoris at about broken line; (3) biceps femoris (gluteobiceps) muscle; (4) middle gluteal muscle; (5) tuber coxae; (6) tensor fasciae latae muscle; (7) thoracolumbar fascia covering longissimus muscle; (8) psoas major muscle; (9) subiliac lymph node; (10) broken line indicating incision through fascia lata; (11) fascia lata; (12) cranial division of biceps femoris muscle; (13) caudal division of biceps femoris muscle; (14) crural fascia covering muscles of leg; (15) superficial digital flexor tendon covering tuber calcanei; (16) common calcanean tendon; (17) lateral saphenous vein; (18) semitendinosus muscle; (19) semimembranosus muscle; (20) tuber ischiadicum.

Tensor Fasciae Latae: The tensor fasciae latae is a triangular muscle that originates from the tuber coxae and terminates by a double-layered aponeurosis, the **fascia lata** (Figs. 6-4 & 6-5). This aponeurosis fans out over the craniolateral surface of the thigh, partially enveloping the quadriceps femoris and providing an attachment for the biceps femoris muscle.

Carefully incise the tensor fasciae latae as indicated in figure 6-4, and reflect it cranially to its origin. As the tensor fasciae latae muscle is transected and reflected, a branch of the **cranial gluteal nerve** should

be seen entering its deep surface. The **iliacofemoral artery** (Fig. 5-13) is present only in the horse, whereas in the other species, branches of the **lateral circumflex femoral** are primarily responsible for supplying this area.

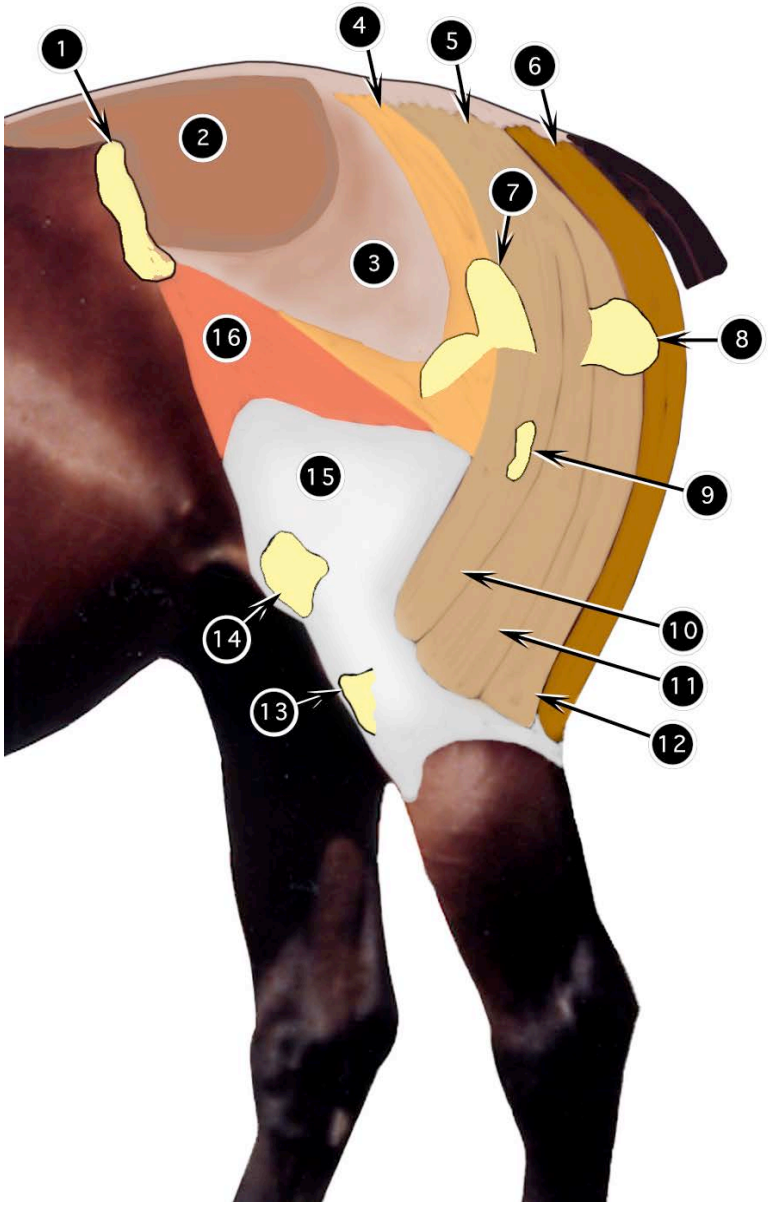


Figure 6-5. Superficial structures of croup, thigh, and leg of horse, left lateral view: (1) tuber coxae; (2) middle gluteal muscle; (3) gluteal fascia covering 2; (4) superficial gluteal muscle; (5) biceps femoris muscle; (6) semitendinosus muscle; (7) caudal part of greater trochanter; (8) tuber ischiadicum; (9) third trochanter; (10) cranial division of 5; (11) middle division of 5; (12) caudal division of 5; (13) tibial tuberosity; (14) patella; (15) fascia lata; (16) tensor fasciae latae muscle.

Detach the biceps femoris muscle from its proximal attachments, and carefully reflect it to expose the sacrosciatic ligament. Reflection of the biceps femoris muscle also exposes the termination of the middle gluteal muscle on the greater trochanter of the femur (Figs. 6-6 & 6-7). Refer to the skeletons, and note that the greater

trochanter of the horse is more complex than that of the other species. In the horse, the **greater trochanter** is divided into distinct **cranial and caudal parts**, separated by a notch (Fig. 6-5).

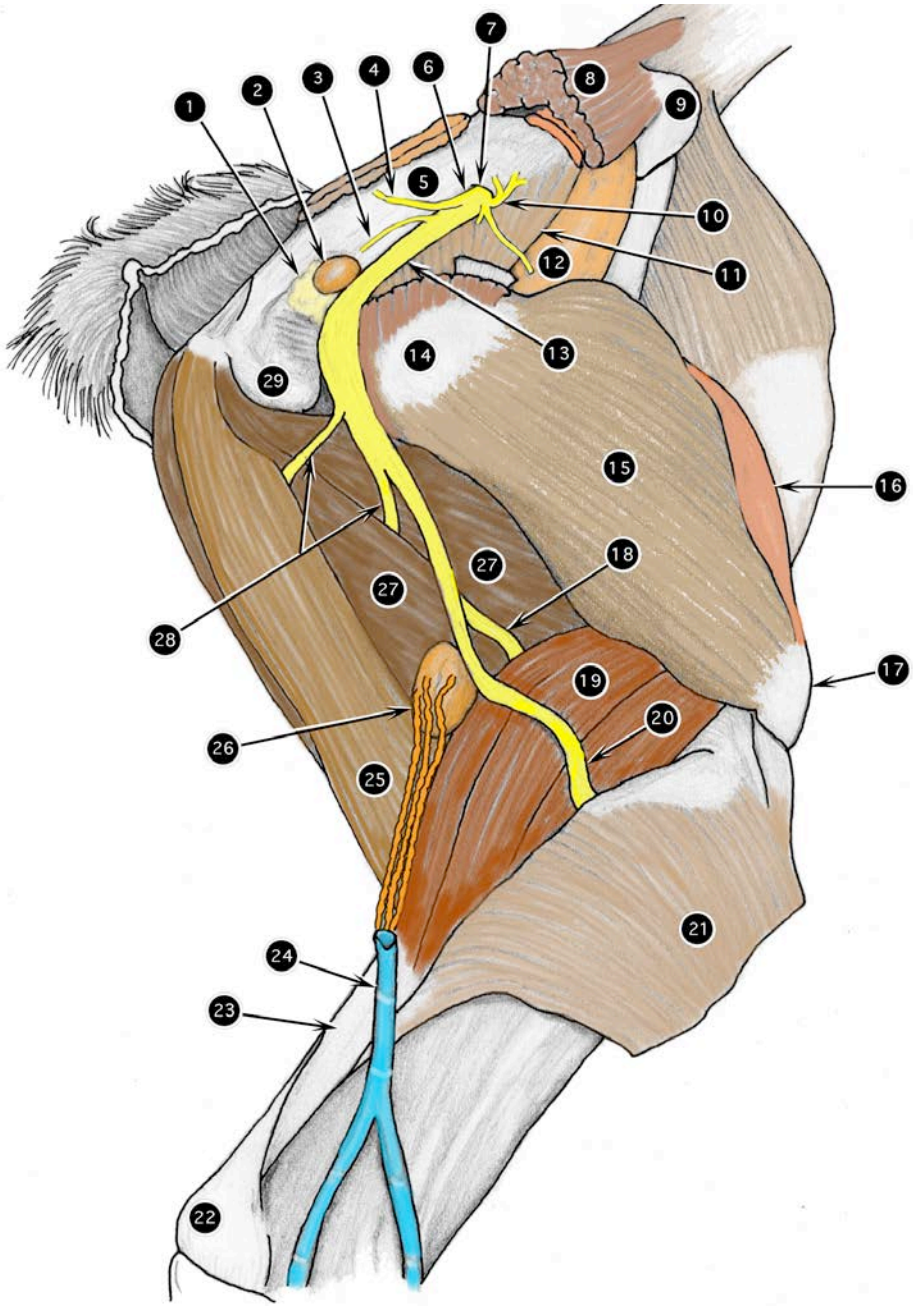


Figure 6-6. Deeper structures of rump, thigh, and leg of newborn calf, lateral view: (1) fat covering lesser sciatic foramen; (2) ischiatic lymph node; (3) caudal cutaneous femoral nerve; (4) caudal gluteal nerve to superficial gluteal muscle; (5) sacrosciatic ligament; (6) lumbosacral trunk; (7) greater sciatic foramen; (8) middle gluteal muscle; (9) tuber coxae; (10) cranial gluteal nerve to middle and deep gluteal and tensor fasciae latae muscles; (11) deep gluteal muscle; (12) iliacus muscle; (13) sciatic nerve; (14) greater trochanter; (15) vastus lateralis muscle; (16) rectus femoris muscle; (17) patella; (18) tibial nerve; (19) lateral head of gastrocnemius muscle; (20) common peroneal nerve; (21) reflected biceps femoris (gluteobiceps) muscle; (22) superficial digital flexor tendon covering tuber calcanei; (23) gastrocnemius tendon; (24) lateral saphenous vein; (25) semitendinosus muscle; (26) popliteal lymph node; (27) semimembranosus muscle; (28) branches of sciatic nerve to 25 and 27; (29) tuber ischiadicum.

Carefully work under the middle gluteal, and transect it at the level of the ilial wing. Reflect the muscle to its termination on the greater trochanter. The major component of the **middle gluteal muscle** terminates on the longer, more caudal part (summit) of the trochanter in the horse, but a deeper part, the **accessory gluteal**, terminates over the more rounded cranial part (convexity) of the trochanter (Fig. 6-7). The accessory gluteal muscle can be distinguished by its fibrous convergence to a definitive tendon, as opposed to the more fleshy attachment of the major part of the middle gluteal.

Trochanteric Bursa of Horse: *Transect the accessory gluteal muscle through its middle, and carefully reflect its tendon distally over the trochanter.* As this is done, you should open the large **trochanteric bursa**, which lies between the tendon of the accessory gluteal muscle and the cranial part of the greater trochanter (Fig. 6-7).

Trochanteric bursitis (whorlbone lameness) is an inflammation of this bursa. In an attempt to reduce pressure of the tendon over the bursa, an affected horse may stand with the sore limb in an abducted and pronated position. Also, a horse with trochanteric bursitis tends to trot sort of sideways like a dog, that is, the caudal part of the body is shifted toward the sound side. Thus, the horse breaks over the medial part of the toe of the affected limb, and greater hoof wear can be noted in this area.

The greater trochanter of the horse is an important palpable landmark. Refer to the skeleton, and note that it is much closer to the tuber ischiadicum than you might have thought (Fig. 6-5). Horses with trochanteric bursitis are usually hypersensitive to pressure (bumping) over the area. Although there is no trochanteric bursa, the accessory gluteal muscle is also present in the other ungulates.

Palpate the greater trochanter in the live horse. The notch between the two parts of the trochanter is used as the avenue of needle insertion for arthrocentesis of the coxal joint in the horse. With reference to the skeleton, consider the angle at which, and depth that, a needle would need to be inserted to enter the dorsal part of the joint capsule, which lies under the deep gluteal muscle.

Immediately after exiting the greater sciatic foramen, the **lumbosacral trunk** gives rise to the multiple branches of the **cranial gluteal nerve** that are distributed with the **cranial gluteal vessels** to the middle and deep gluteal muscles and the tensor fasciae latae (Fig. 6-2). The **caudal gluteal nerve**, destined for the superficial gluteal muscle, leaves the lumbosacral trunk. The **caudal cutaneous femoral nerve**, which arises just distal to the caudal gluteal, passes along the lateral surface of the sacrosciatic ligament, communicates with the pudendal nerve near the lesser sciatic foramen, and supplies branches to the skin over the caudal surface of the thigh (Figs. 6-2 & 6-6).

The **sciatic nerve** courses over the caudodorsal aspect of the coxal joint between the middle and deep gluteal muscles (Fig. 6-6). The **deep gluteal muscle** also terminates on the greater trochanter of the femur. The sciatic nerve sends branches to the caudal thigh muscles and continues distally caudal to the femur, between the biceps femoris laterally and semimembranosus medially (Fig. 6-8).

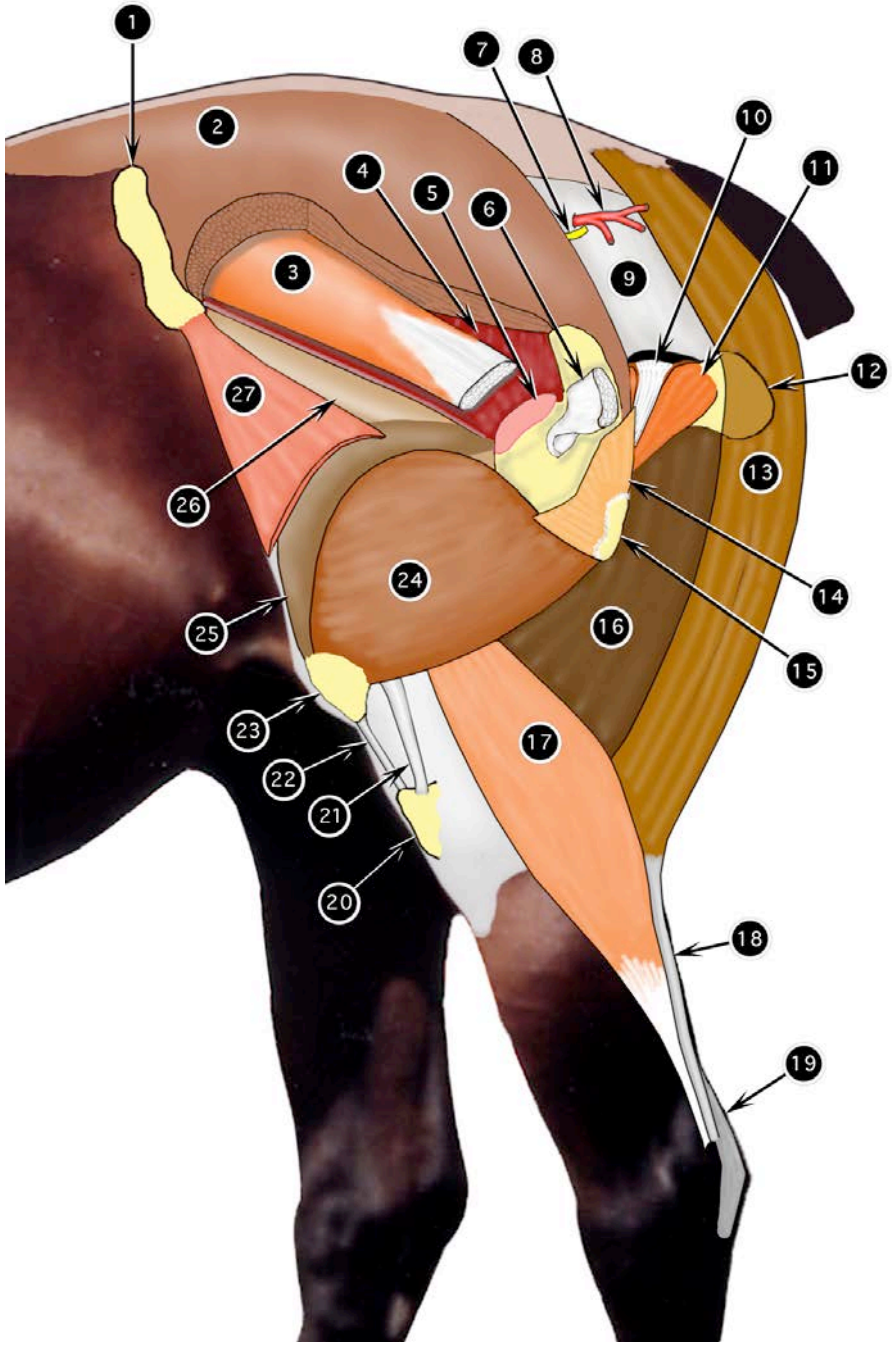


Figure 6-7. Deeper structures of croup, thigh, and leg of horse, lateral view: (1) tuber coxae; (2) middle gluteal muscle (partially removed); (3) accessory gluteal muscle; (4) deep gluteal muscle; (5) trochanteric bursa covering cranial part of greater trochanter; (6) reflected tendon of 3; (7) caudal gluteal nerve to 14; (8) caudal gluteal artery; (9) sacrosciatic ligament; (10) tendon of internal obturator muscle; (11) caudal gemellus muscle; (12) tuber ischiadicum; (13) semitendinosus muscle; (14) superficial gluteal muscle; (15) third trochanter; (16) semimembranosus muscle; (17) lateral head of gastrocnemius muscle; (18) contribution of 13 to common calcanean tendon; (19) tendon of superficial digital flexor; (20) tibial tuberosity; (21) lateral patellar ligament; (22) intermediate patellar ligament; (23) patella; (24) vastus lateralis of quadriceps femoris muscle; (25) rectus femoris of quadriceps femoris muscle; (26) iliacus muscle; (27) tensor fasciae latae muscle (partially removed).

Continue reflecting the biceps femoris muscle to its terminations. In the distal half of the thigh, the sciatic nerve divides into its two major branches, the **common peroneal and tibial nerves**. Locate this division, and identify these two branches (Figs. 6-6, 6-8, 6-9). The **popliteal lymph node** is located caudal to the stifle joint, between the biceps femoris and semitendinosus (Fig. 6-6). Unlike those of the dog and cat, these nodes are more deeply located and cannot normally be palpated in the domestic ungulates.

Rotator Muscles of Coxal Joint: Although they need not be dissected in detail, we should recall that a group of muscles originates primarily from the ischium and terminates in or near the **trochanteric fossa** of the femur. These muscles assist in extension and adduction of the joint but are primarily rotators or supinators of the coxal joint, that is, they rotate the limb such that the toe rotates laterally and the tuber calcanei medially. This "pelvic association" includes the **internal and external obturator muscles**, the **gemelli**,[7] and the **quadratus femoris** (not to be confused with the quadriceps femoris). The internal obturator muscle of the horse has a large ilial head and, as in the dog, there is a bursa under the tendon as it emerges through the lesser sciatic foramen (Fig. 6-7). As previously noted, artiodactyls do not have an internal obturator muscle, but have instead an intrapelvic part of the external obturator.

Quadriceps Femoris Muscle: The quadriceps femoris is the primary extensor muscle of the stifle joint, and when it is paralyzed because of femoral nerve damage or anesthesia, the limb cannot support weight. As you know, the muscle consists of four named heads- the three vastus brothers (lateral, intermediate, and medial), and the straight man of the group, rectus femoris. The **vastus lateralis** was exposed by reflection of the fascia lata (Figs. 6-6 & 6-7).

Beginning proximally, define the separation between the vastus lateralis and the rectus femoris. The **rectus femoris** is the only head of the muscle that originates from the pelvis; all other heads originate from the proximal part of the femur. Thus, in addition to extension of the stifle joint, the rectus femoris can assist in flexion of the coxal joint.

On the detached limb, separate between the vastus medialis and rectus femoris (Fig. 6-10). Transect the rectus femoris near its middle, and reflect the stumps to expose the **vastus intermedius**, which lies against the femur, deep to the rectus femoris. Locate the stump of the large **femoral nerve** near the proximal part of the vastus medialis, and trace it a short distance to observe its distribution to the individual heads of the muscle. In the horse, branches of the **iliacofemoral artery** can be found in this area (Fig. 5-10), and in all species the **lateral circumflex femoral artery** provides branches to the quadriceps femoris.

The femoral nerve also sends a branch to the **sartorius muscle**, which, unlike that of the dog, is not divided into distinct cranial and caudal parts. The only superficial (sensory) branch of the femoral nerve is the **saphenous nerve**, which continues distally with the **saphenous artery** along the medial surface of the limb. This nerve provides sensory innervation to the overlying skin, down to the level of the fetlock joint (Figs. 6-8 & 6-9). Testing for cutaneous sensation in the area supplied by this nerve can provide diagnostic information about a suspected femoral nerve injury.

[7] gemelli (from the Latin gemini) - the twins; in this case two Italian girls- *the Gemelli sisters*.

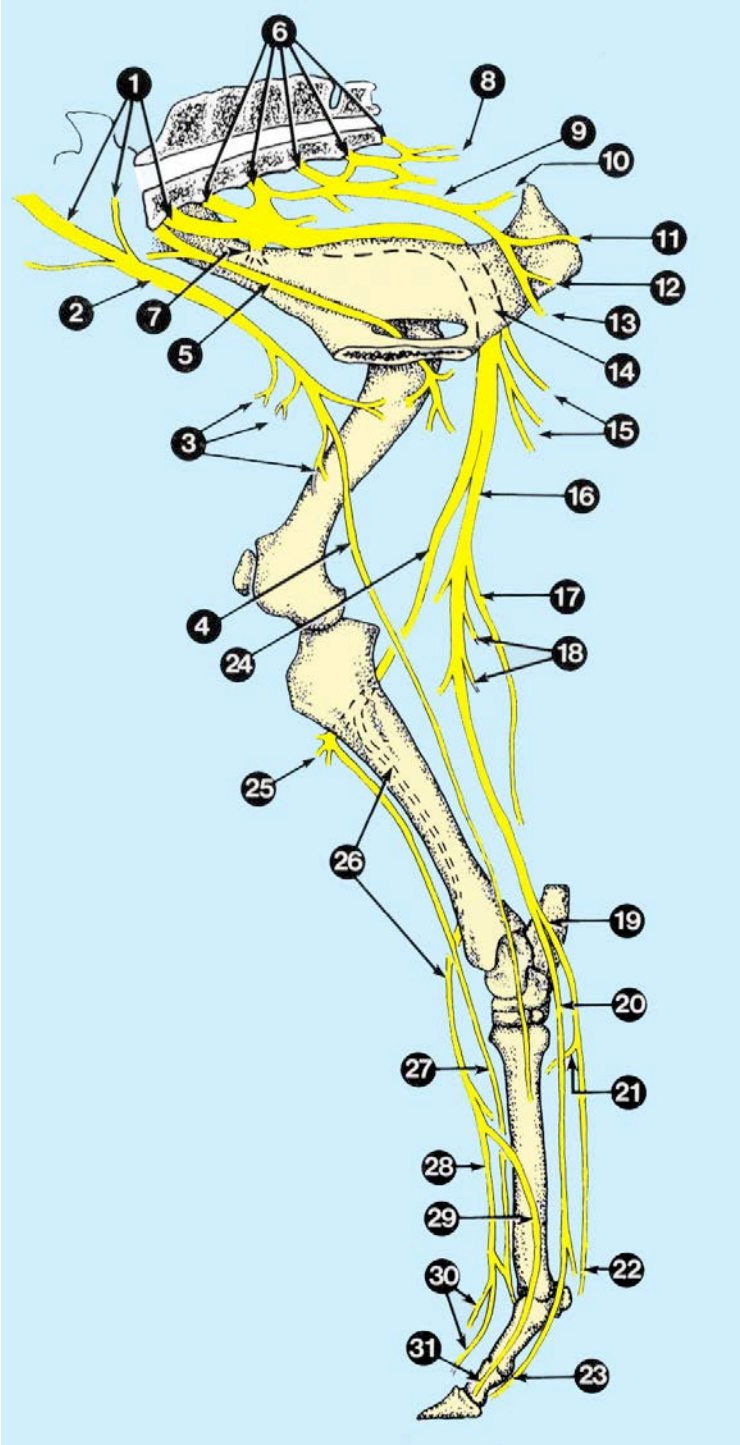


Figure 6-8. Nerves of bovine pelvic limb, medial view: (1) roots of lumbosacral plexus derived from L4-L6; (2) femoral nerve; (3) branches of femoral nerve to quadriceps femoris and sartorius muscles; (4) saphenous nerve; (5) obturator nerve- to pectineus, gracilis, adductor, and external obturator muscles; (6) roots of sacral plexus derived from ventral branches of S1-S5; (7) cranial gluteal nerve- to middle gluteal, deep gluteal, and tensor fasciae latae muscles; (8) caudal rectal nerves- to external anal sphincter and retractor penis (clitoridis) muscles; (9) pudendal nerve; (10) proximal cutaneous branch of 9; (11) distal cutaneous branch of 9; (12) deep perineal nerve; (13) dorsal nerve of penis (clitoris): (14) sciatic nerve; (15) branches of sciatic nerve to biceps femoris, semitendinosus, and semimembranosus muscles; (16) tibial nerve; (17) caudal cutaneous sural nerve; (18) branches of tibial nerve to gastrocnemius, popliteus, and superficial and deep digital flexor muscles; (19) lateral plantar nerve; (20) medial plantar nerve; (21) deep branch of lateral plantar nerve; (22) plantar common digital nerves 2, 3, and 4; (23) abaxial plantar nerve of digit 3; (24) common peroneal nerve; (25) deep peroneal nerve- to cranial tibial, peroneus tertius, peroneus longus, and long digital extensor muscles; (26) superficial peroneal nerve- innervates lateral digital extensor muscle; (27) dorsal metatarsal nerve 3; (28) dorsal common digital nerve 3; (29) dorsal common digital nerve 2; (30) axial dorsal nerves of digits 3 and 4; (31) abaxial dorsal nerve of digit 3.

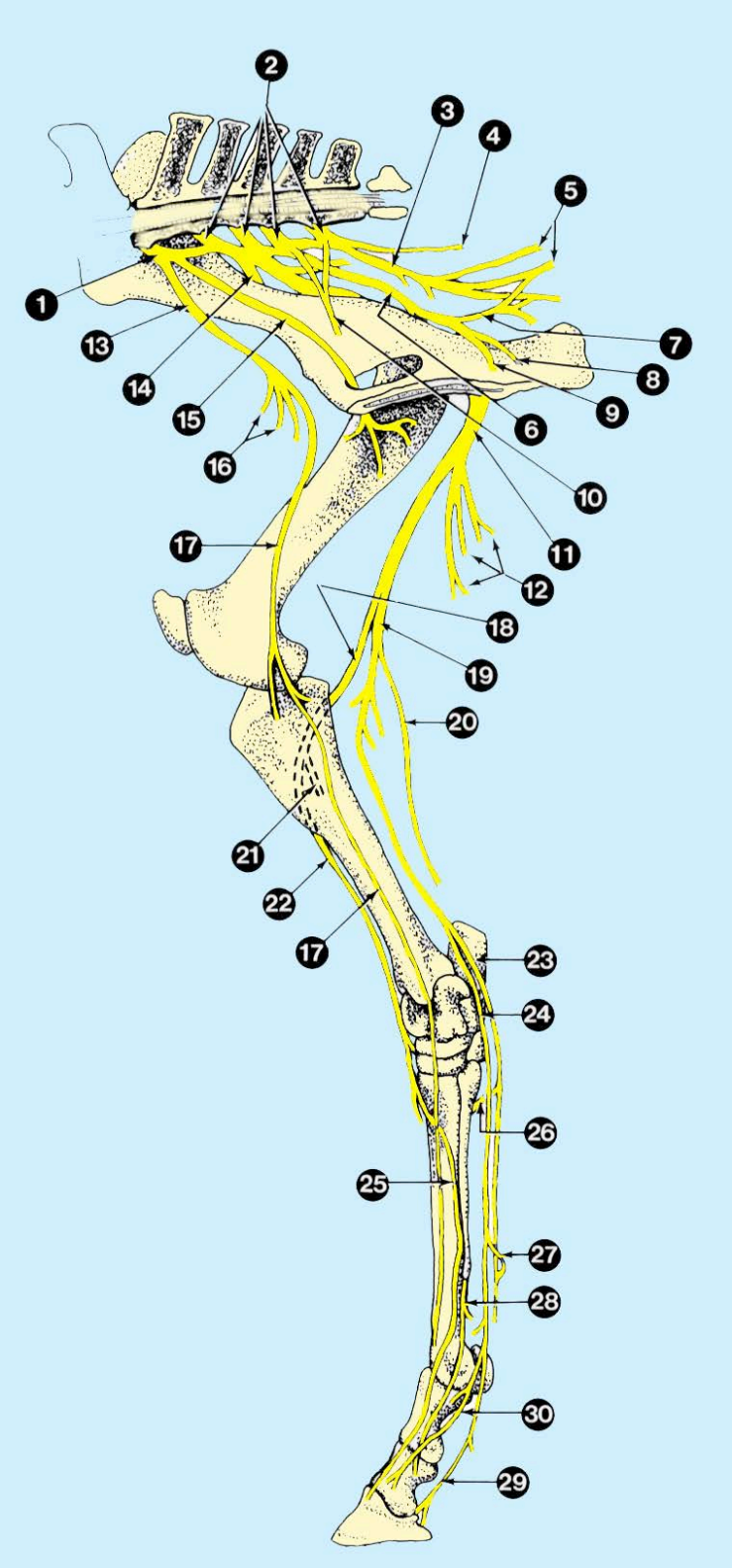


Figure 6-9. Nerves of equine pelvic limb, medial view: (1) ventral branch of L6; (2) ventral branches of S1- S4; (3) caudal rectal nerve; (4) cutaneous branch of 3; (5) branches to anal sphincter muscles; (6) pudendal nerve; (7) deep perineal nerve; (8) dorsal nerve of penis (clitoris); (9) preputial (mammary) branch of pudendal nerve; (10) pelvic nerve; (11) sciatic nerve; (12) branches of sciatic nerve to biceps femoris, semitendinosus, and semimembranosus muscles; (13) femoral nerve; (14) cranial gluteal nerve; (15) obturator nerve; (16) branches of femoral nerve to quadriceps femoris muscle; (17) saphenous nerve; (18) common peroneal nerve; (19) tibial nerve; (20) caudal cutaneous sural nerve; (21) superficial peroneal nerve; (22) deep peroneal nerve- gives rise to dorsal metatarsal nerves 2 and 3; (23) lateral plantar nerve (plantar common digital nerve 3); (24) medial plantar nerve (plantar common digital nerve 2); (25) dorsal metatarsal nerve 2- continues as medial dorsal digital nerve; (26) deep branch of lateral plantar nerve; (27) communicating branch between medial and lateral plantar nerves; (28) medial plantar metatarsal nerve (plantar metatarsal nerve 2); (29) medial plantar digital nerve; (30) dorsal branch of medial plantar digital nerve.

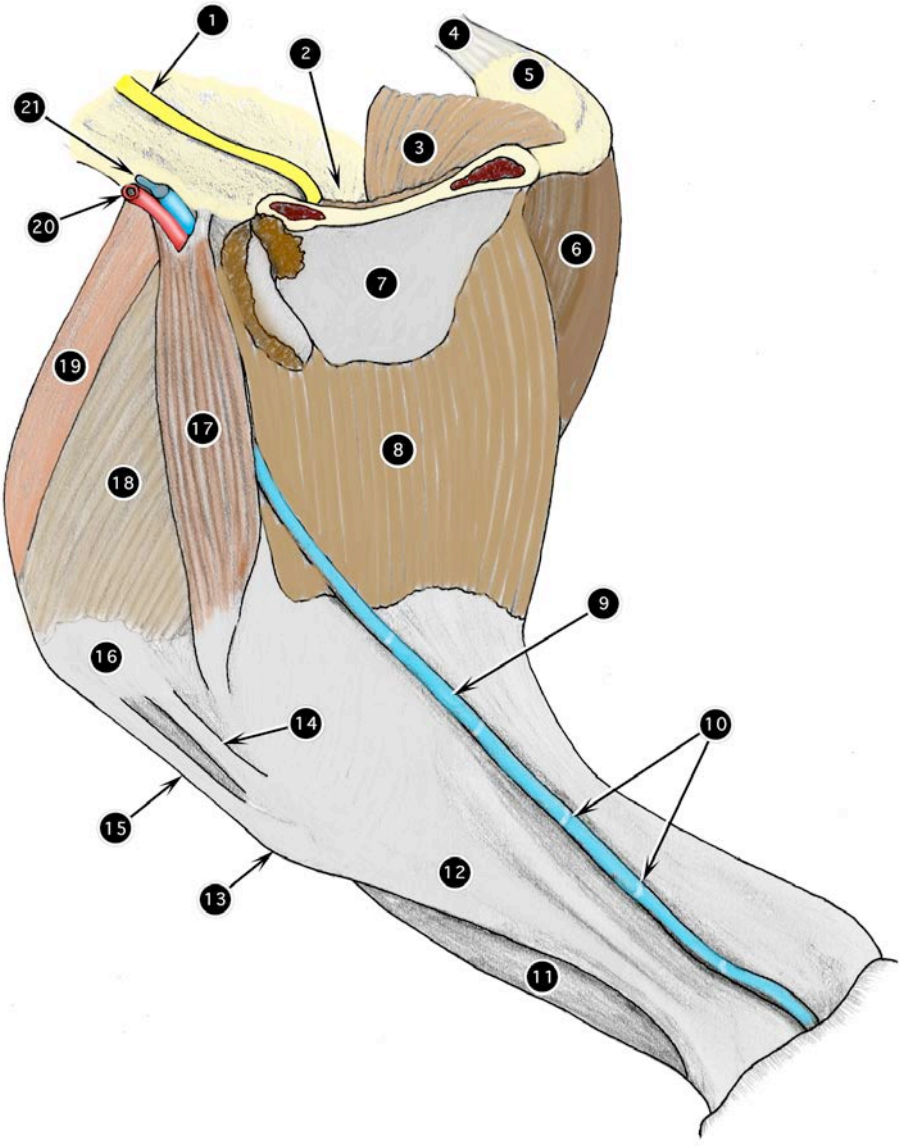


Figure 6-10. Superficial structures of thigh and leg of newborn calf, medial view: (1) obturator nerve; (2) obturator foramen; (3) intrapelvic part of external obturator muscle; (4) sacrotuberous ligament; (5) tuber ischiadicum; (6) semimembranosus muscle; (7) symphysial tendon; (8) gracilis muscle; (9) medial saphenous vein; (10) valves in vein; (11) peroneus tertius muscle; (12) tibia; (13) tibial tuberosity; (14) medial patellar ligament; (15) intermediate patellar ligament; (16) patella; (17) sartorius muscle; (18) vastus medialis muscle; (19) rectus femoris muscle; (20) femoral artery; (21) femoral vein.

The **femoral artery and vein** should be located at the proximal end of the sartorius, where they pass between the two parts of the divided origin of this muscle (Fig. 6-10). Emerging near the division between the sartorius and gracilis muscles is the **medial saphenous vein.** This is an especially large and prominent vein in the horse and *can be easily observed in the live animal*. In the horse, it divides into **cranial and caudal branches** (Fig. 6-11), whereas in domestic ruminants, the vein corresponds to the caudal branch of the horse (Figs. 6-10 & 6-12). In the pig, the cranial branch is formed by medial and lateral branches.

The **saphenous artery**, a branch of the femoral artery, emerges with the medial saphenous vein and continues with it (caudal branch in horse). This artery contributes to the blood supply of the distal limb. In the pig, it is a more important arterial channel of the limb, whereas in the other species, it is a relatively small artery (Fig. 6-13). Its continuation will be followed later.

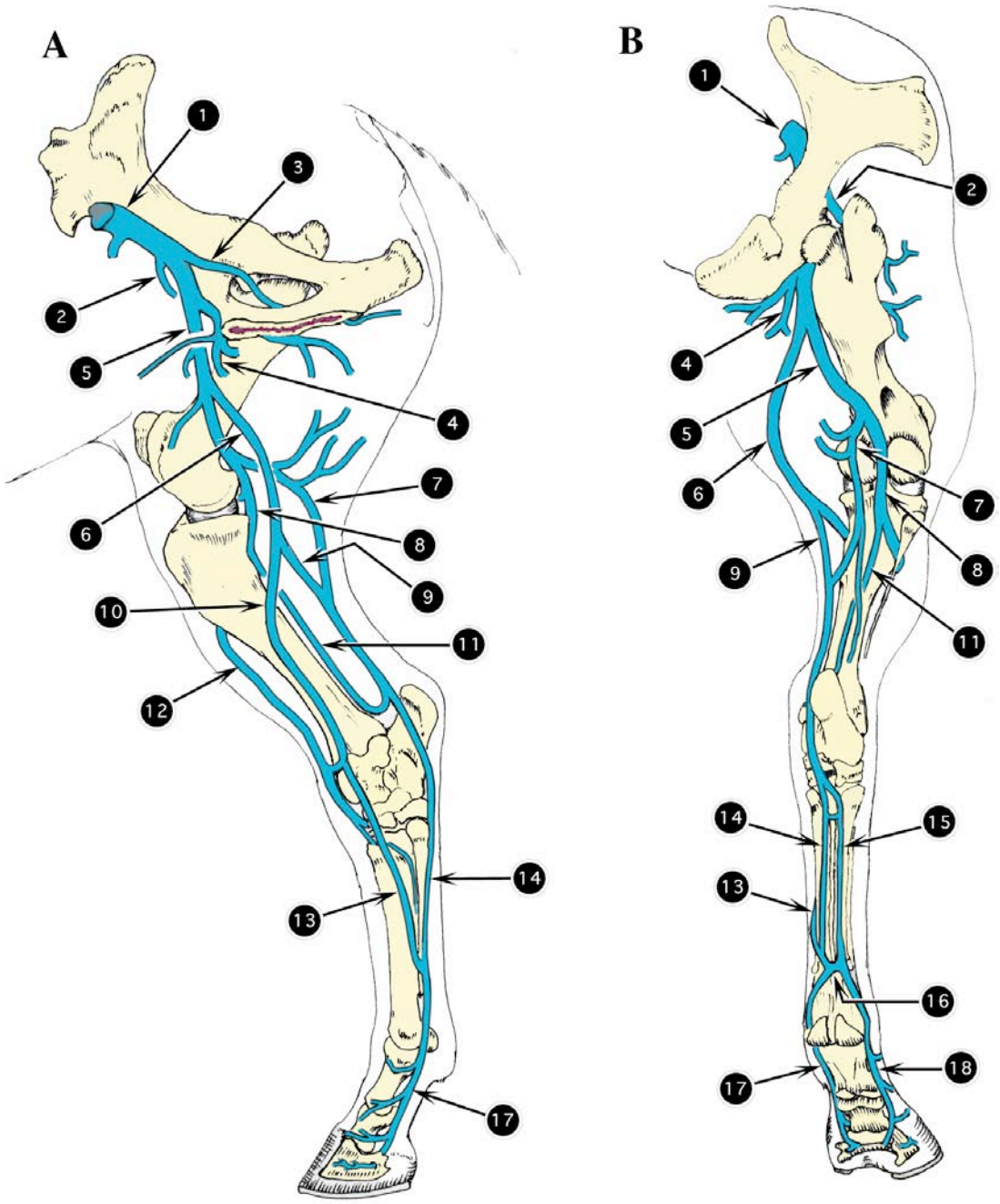


Figure 6-11. Branches of external iliac vein of horse, **(A)** medial view; **(B)** caudal view: (1) external iliac vein; (2) iliacofemoral vein; (3) obturator vein; (4) external pudendal vein - passes through gracilis muscle; (5) femoral vein; (6) medial saphenous vein; (7) caudal femoral vein; (8) popliteal vein; (9) caudal branch of 6; (10) cranial branch of 6; (11) caudal tibial vein; (12) cranial tibial vein; (13) dorsal common digital vein 2; (14) medial plantar vein; (15) lateral plantar vein; (16) distal deep plantar arch; (17) medial digital vein; (18) lateral digital vein.

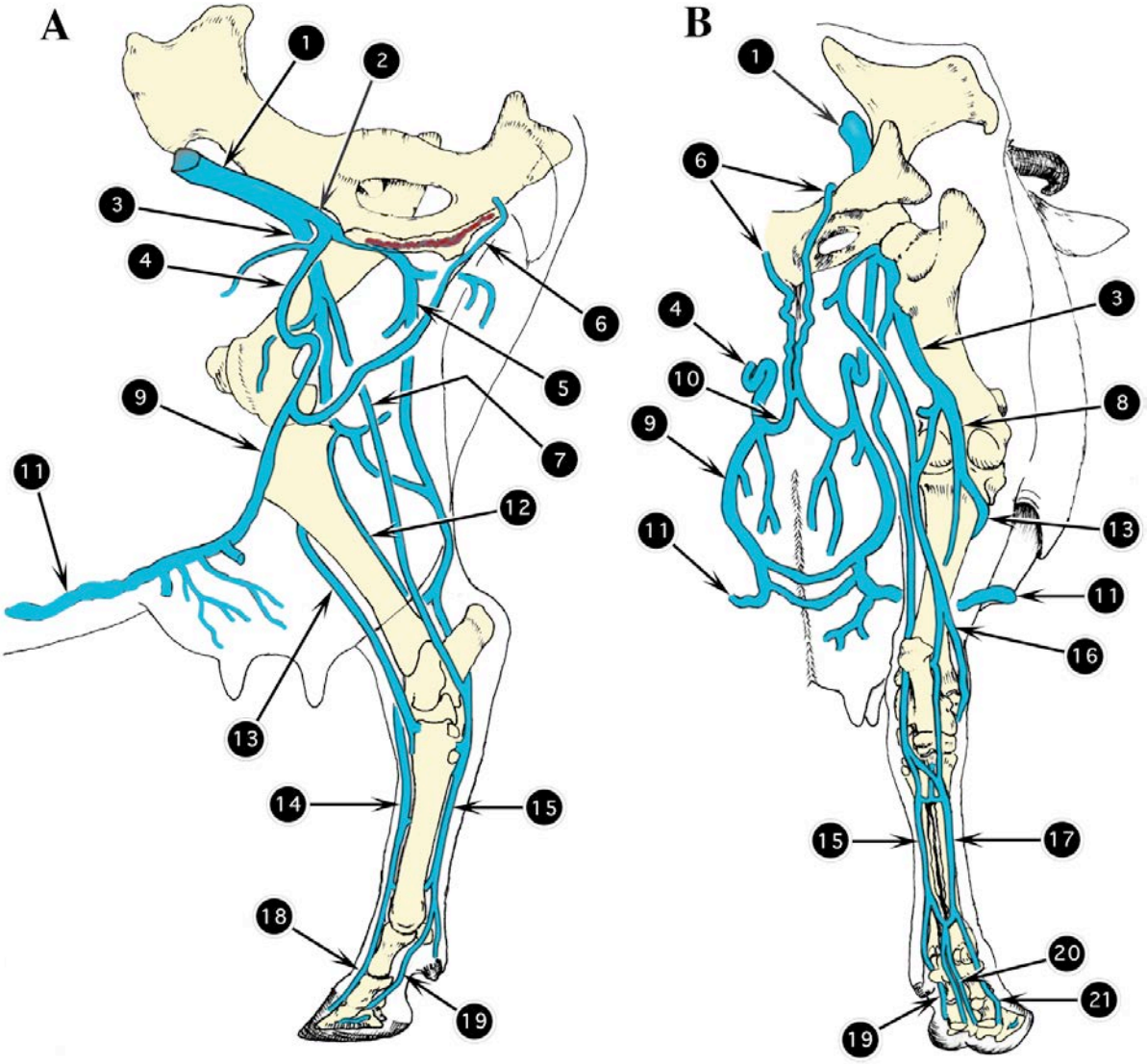


Figure 6-12. Branches of external iliac vein of cow, **(A)** medial view; **(B)** caudal view: (1) external iliac vein; (2) deep femoral vein; (3) femoral vein; (4) external pudendal vein- passes through inguinal canal; (5) medial circumflex femoral vein; (6) perineal veins; (7) medial saphenous vein; (8) popliteal vein; (9) cranial mammary vein; (10) caudal mammary vein; (11) subcutaneous abdominal vein; (12) caudal tibial vein; (13) cranial tibial vein; (14) dorsal common digital vein 3; (15) medial plantar vein; (16) lateral saphenous vein; (17) lateral plantar vein; (18) dorsal (proper) digital veins; (19) abaxial plantar (proper) digital vein 3; (20) axial plantar (proper) digital veins 3 and 4; (21) abaxial plantar (proper) digital vein 4.

Gracilis Muscle: The gracilis[8] muscle is a wide, thin muscle that forms the most medial part of the thigh (Fig. 6-10). It arises from the more ventral part of the symphysial tendon and terminates on the medial surface of the leg.

On the detached limb, reflect the gracilis and sartorius muscles to expose the deeper structures of the medial thigh (Fig. 6-14). As the gracilis is reflected look for the branch of the obturator nerve that innervates this muscle. In the horse, the external pudendal vein passes through this muscle near its origin (Fig. 5-10). As noted

[8] gracilis (Latin)- slender or delicate

previously, abduction of the limb tenses the muscle and impedes flow through the vein in the horse.

Adductor Muscle: Cranial to the semimembranosus muscle is the thick, triangular adductor (*magnus et brevis*) muscle (Fig. 6-14). The division between adductor and semimembranosus is indistinct, but can be located distally and established by proximal separation between the muscles. Like the gracilis, the adductor muscle originates from the symphysial tendon and is innervated by the obturator nerve. It attaches primarily along the caudal surface of the femur. The femoral artery and vein of the horse penetrate the distal part of the adductor muscle. Transect the part of the muscle that passes medial to these vessels so that they can be traced distally to their continuation as the popliteal artery and vein.

Pectineus Muscle: Cranial to the adductor is the pectineus muscle, which is also innervated by the obturator nerve. The pectineus originates from the pelvis, and in the horse, the accessory ligament of the femoral head passes through its origin. The pectineus muscle forms the caudal boundary of the **femoral triangle**, which accommodates the femoral vessels. In the horse and goat, the femoral triangle also houses the **deep inguinal lymph nodes**, homologues of the iliofemoral nodes of the other species. Other boundaries of the femoral triangle include the sartorius muscle craniomedially and the vastus medialis laterally.

Femoral Vessels: The **femoral artery** is the direct continuation of the **external iliac artery**, after giving off the **deep femoral artery** (Fig. 6-13). The latter almost immediately gives off the pudendoepigastric trunk and is continued as the large **medial circumflex femoral artery**, which supplies the medial thigh muscles and passes just ventral to the coxal joint. The femoral vessels pass over the caudodorsal border of the external abdominal oblique with the psoas major muscle to exit the abdominal cavity through an opening referred to as the **vascular lacuna**. Shortly thereafter the femoral artery gives rise to the **lateral circumflex femoral artery**, which supplies the quadriceps femoris muscle and continues in the femoral triangle (Fig. 6-13). It then gives rise to the **saphenous artery** and the **descending genicular artery**, which help supply the medial aspect of the stifle joint.

Iliopsoas Muscle: If the adductor and pectineus muscles are reflected distally, the termination of the **psoas major and iliacus** muscles can be observed as they unite to form the **iliopsoas** and attach to the **lesser trochanter** of the femur. The iliopsoas functions in flexion and supination of the coxal joint. Identify the lesser trochanter of the femur on the skeleton. Also, in this area, ventral to the coxal joint, you may note the **medial circumflex femoral artery**, which is the continuation of the deep femoral artery after it gives rise to the pudendoepigastric trunk (Fig. 6-13).

STIFLE JOINT

Patellar Ligaments: In the carnivores, small ruminants, and pig, there is only one ligament that attaches the patella to the tibial tuberosity, a structure known as the **patellar ligament**. Functionally, the patellar ligament is the continuation of the quadriceps femoris muscle. Although this powerful extensor muscle terminates on the patella, drawing the patella proximally is not a particularly useful function in terms of stifle joint extension and locomotion.

Functionally, the patella is nothing more than a large sesamoid bone that changes the direction of pull, absorbs pressure, and transmits the traction of the quadriceps to the tibial tuberosity through the patellar ligament(s).

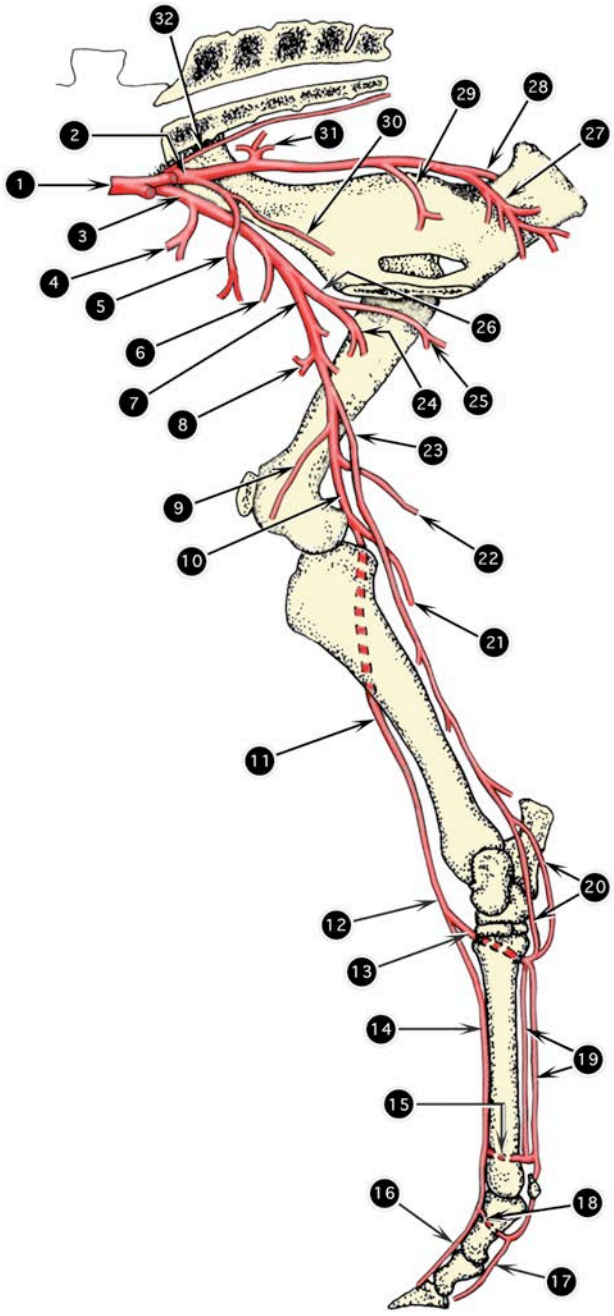


Figure 6-13. Major branches of internal and external iliac arteries of cow, medial view: (1) aorta; (2) internal iliac artery; (3) external iliac artery; (4) deep circumflex iliac artery; (5) uterine artery; (6) caudal abdominal artery; (7) femoral artery; (8) lateral circumflex femoral artery; (9) descending genicular artery; (10) popliteal artery; (11) cranial tibial artery; (12) dorsal pedal artery; (13) perforating tarsal artery; (14) dorsal metatarsal artery 3; (15) distal perforating branch; (16) dorsal proper digital arteries; (17) plantar proper digital arteries; (18) interdigital artery; (19) plantar common digital and metatarsal arteries; (20) medial and lateral plantar arteries; (21) caudal tibial artery; (22) caudal femoral artery; (23) saphenous artery; (24) pudendoepigastric trunk; (25) medial circumflex femoral artery; (26) deep femoral artery; (27) internal pudendal artery; (28) caudal gluteal artery; (29) vaginal artery; (30) umbilical artery (round ligament of urinary bladder); (31) cranial gluteal artery; (32) median sacral artery.

The following structures are to be dissected on the detached limb only. *Dissect away the deep retinacular fascia of the stifle area as necessary to expose and define the patellar ligament(s)*. Three separate ligaments attach the patella to the tibial tuberosity in the horse and ox and are named according to their relative location as the **medial**, **intermediate**, **and lateral patellar ligaments** (Figs. 6-7 & 6-10).

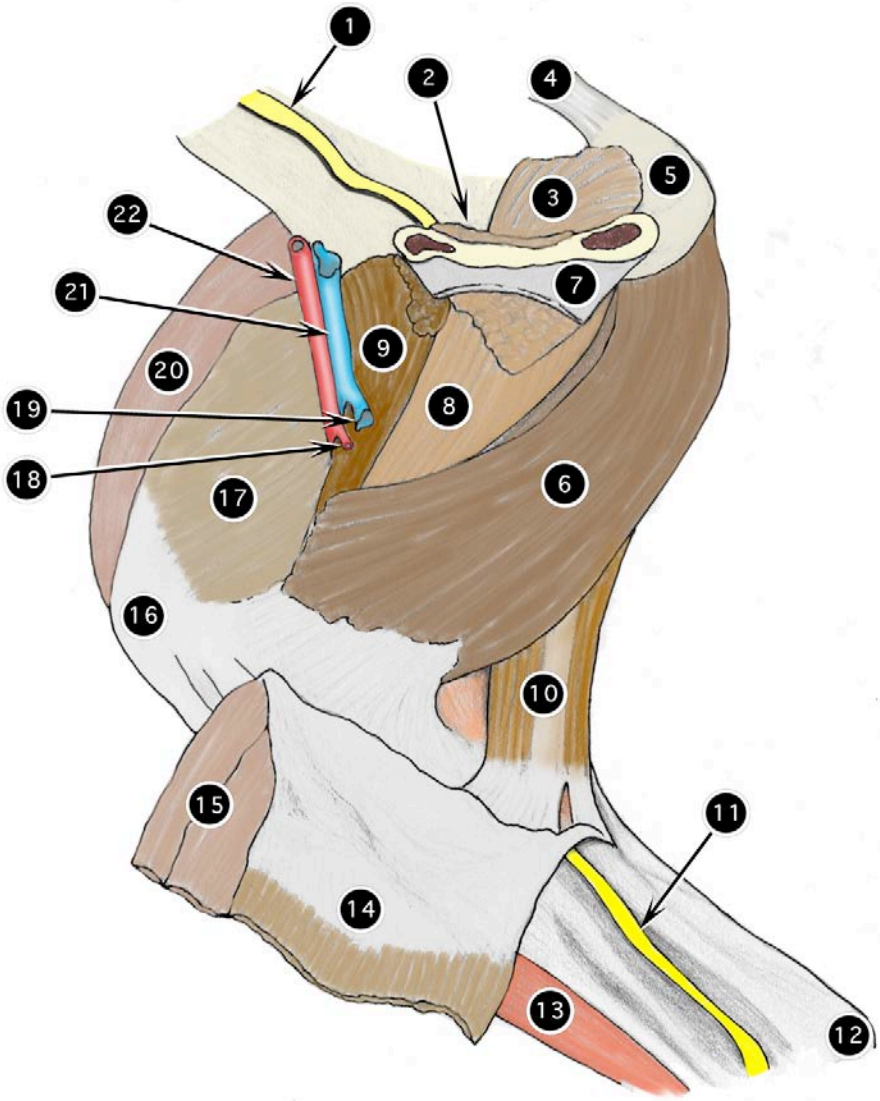


Figure 6-14. Deeper structures of thigh and leg of newborn calf, medial view: (1) obturator nerve; (2) obturator foramen; (3) intrapelvic part of external obturator muscle; (4) sacrotuberous ligament; (5) tuber ischiadicum; (6) semimembranosus muscle; (7) symphysial tendon (partially removed); (8) adductor (*magnes et brevis*) muscle; (9) pectineus muscle; (10) semitendinosus muscle; (11) tibial nerve; (12) tuber calcanei; (13) peroneus tertius muscle; (14) reflected gracilis muscle; (15) reflected sartorius muscle; (16) patella; (17) vastus medialis muscle; (18) stump of saphenous artery; (19) stump of medial saphenous vein; (20) rectus femoris muscle; (21) femoral vein; (22) femoral artery.

Continue reflection of the biceps femoris muscle to define its attachment to the lateral patellar ligament. In the ox, there is typically a large bursa present under the craniodistal part of the biceps femoris as it approaches the lateral patellar ligament. This bursa lies over the lateral epicondyle of the femur and may communicate directly with the lateral femorotibial sac of the stifle joint. Its location can be appreciated by reference to the skeleton, where a circumscribed "articular" surface can be noted on the lateral epicondyle.

The patella is also attached to the medial and lateral epicondyles of the femur by the **medial and lateral femoropatellar ligaments**, respectively. These ligaments

allow for the normal proximodistal excursion of the patella in the femoral trochlea and help maintain it in the groove formed between the two ridges of the trochlea.[9]

Now, transect all heads of the quadriceps muscle about 6 cm proximal to the patella. Reflect the patella and attached quadriceps termination distally by cutting the femoropatellar ligaments. This should expose the articular surfaces of the femoral trochlea and patella. In the ox, reflect the vastus medialis muscle, and identify a deeper tendon of termination on the medial aspect of the patella.

There is a considerable quantity of fat, the **infrapatellar fat body**, located distal to the patella and caudal to the patellar ligaments. *Remove this fat to expose the deeper structures of the joint* (Fig. 6-15).

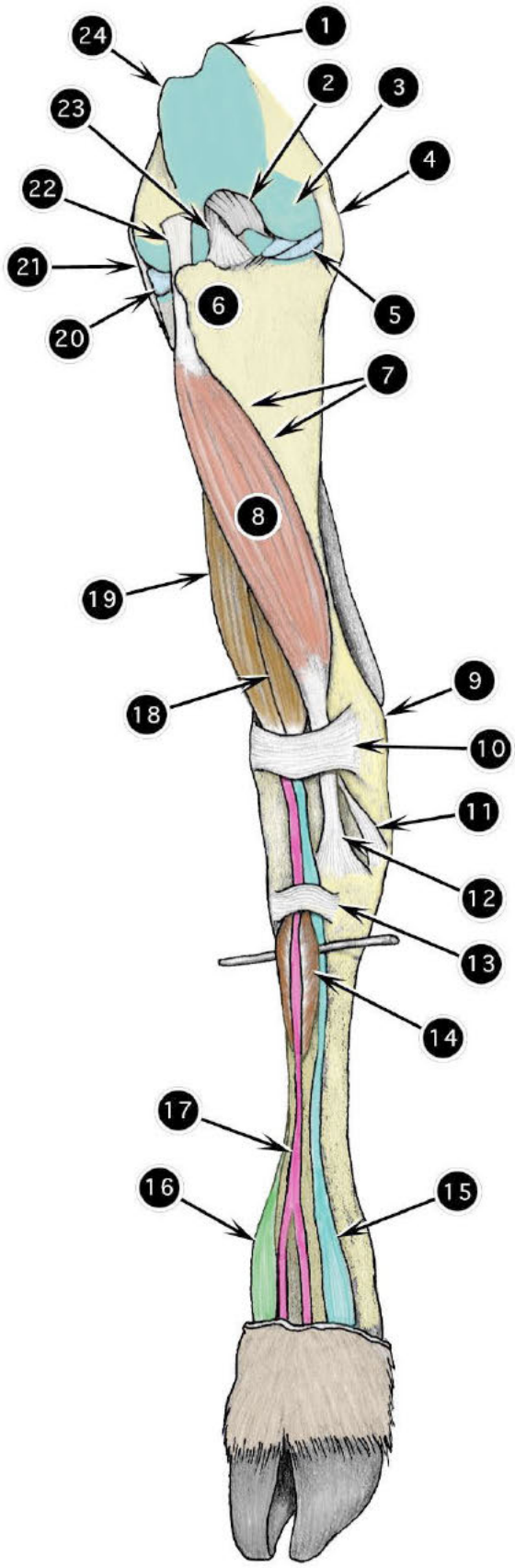


Figure 6-15. Structures of stifle, leg, and pes of newborn calf, cranial view: (1) medial ridge of femoral trochlea: (2) caudal cruciate ligament; (3) medial condyle of femur; (4) medial collateral ligament of stifle joint; (5.medial meniscus; (6) tibial tuberosity; (7) cranial border of tibia; (8) peroneus tertius muscle; (9) medial malleolus of tibia; (10) proximal extensor retinaculum of tarsus; (11) tendon of cranial tibial muscle; (12) tendon of peroneus tertius muscle; (13) distal extensor retinaculum of tarsus; (14) short digital extensor muscle; (15) tendon of medial digital extensor; (16) tendon of lateral digital extensor muscle; (17) tendon of long digital extensor muscle; (18) medial digital extensor, part of long digital extensor muscle; (19) long digital extensor muscle; (20) lateral meniscus; (21) lateral collateral ligament of stifle joint; (22) common tendon of origin of peroneus tertius and long digital extensor muscles from extensor fossa of femur; (23 cranial cruciate ligament; (24) lateral ridge of femoral trochlea.

[9] Primary stability of the patella within the femoral trochlea is not provided by these relatively weak ligaments. Rather it is the straight-line orientation of the trochlear groove with the tibial tuberosity, which allows the quadriceps to pull the patella straight up the groove.

Flex the joint, and observe the articular surfaces of the femoral trochlea, patella, and femoral condyles. In those species with a single patellar ligament (pig and small ruminants), the ridges of the femoral trochlea are approximately equal in size. In the horse and ox, however, the medial ridge is much larger than the lateral one (Fig. 6-15).

Note the articular surfaces of the patella and the femoral trochlea in the horse. Extending from the medial aspect of the patella is a hook-shaped **parapatellar fibrocartilage** that is continuous with the medial patellar ligament (Fig. 6-16). Careful inspection of the articular surfaces of the patella and trochlea should reveal two distinct areas of engagement on each surface. During flexion and extension of the joint, the large **gliding surfaces** are in contact. If you inspect the distal aspect of the patella and its fibrocartilage, and the proximal aspect of the medial ridge of the femoral trochlea, you can see a second, smaller pair of **resting surfaces** that are engaged only when the patella is pulled proximally and rotated medially to lock over the ridge in a resting position. This is part of the *normal* **patellar locking mechanism** of the horse.

Most of you have undoubtedly noticed that when horses are just standing around, taking it easy, they tend to stand with all their weight on one pelvic limb, with the other one relaxed and sort of half-cocked, resting on the toe of the hoof. When they do this, they lock the patella of the supporting limb over the medial ridge of the femoral trochlea (*i.e.*, they "put it in park"). Fixation of the stifle joint by the patellar locking mechanism is the key to converting the pelvic limb into a passive stay for support of the body weight. We'll come back to this later, after examining the other components of the *stay apparatus*.

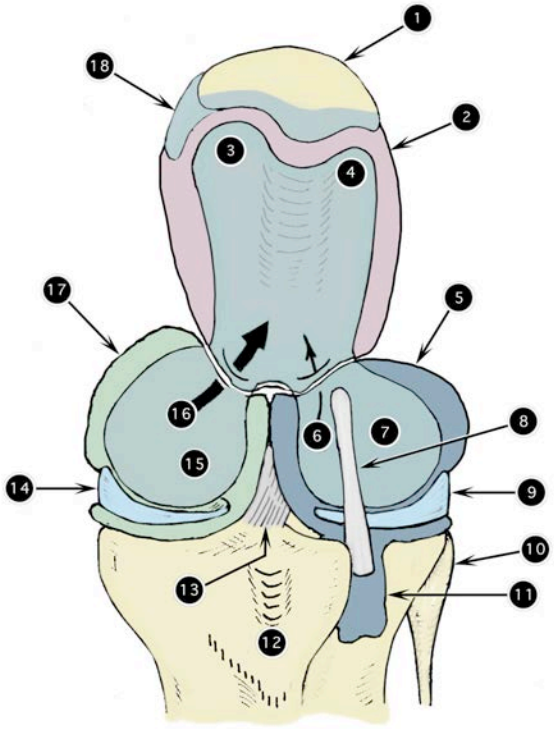


Figure 6-16. Schematic representation of left equine stifle joint, maximally flexed, cranial view: (1) patella; (2) femoropatellar joint capsule (sac); (3) medial ridge of femoral trochlea; (4) lateral ridge of femoral trochlea; (5) lateral femorotibial joint capsule (sac); (6) potential communication between 5 and 2; (7) lateral condyle of femur; (8) combined tendon of peroneus tertius & long digital extensor muscles originating from extensor fossa of femur; (9) lateral meniscus; (10) fibula; (11) distal pouch of 5 for lubrication of 8 through extensor groove of tibia; (12) tibial tuberosity; (13) cranial cruciate ligament; (14) medial meniscus; (15) medial condyle of femur; (16) more consistent communication between 17 and 2; (17) medial femorotibial joint capsule (sac); (18) parapatellar fibrocartilage.

Refer to the skeleton, and note the relationship of the patella, ridges of the femoral trochlea, and the tibial tuberosity. *Locate, by palpation, the **tibial tuberosity** on the live horse*. It is further distal than you might have thought. *Now palpate proximally to identify the **patellar ligaments***. When a horse is bearing weight on the limb, these ligaments are very tense and firm.

Place your thumb and index finger on either side of the intermediate ligament, and define the edges of the medial and lateral ligaments. Follow the intermediate ligament proximally, and palpate the ***medial ridge of the femoral trochlea and the patella****. While keeping one hand on the patella, push the horse to make it move to one side. Feel the movement of the patella as the stifle is flexed.* Return to the tibial tuberosity, my preferred "home base" when palpating the stifle. *Now move your fingertips laterally, and locate* ***the head of the fibula*** (rounded prominence). *Palpate proximally along* ***the lateral collateral ligament of the stifle*** *and then distally in search of the* ***common peroneal nerve*** *that crosses the proximal part of the fibula in a craniodistal direction- bump, that's it.*

Synovial Capsules of Stifle Joint: There are three major articulations in the stifle joint complex- the **femoropatellar joint**, the **medial femorotibial joint**, and the **lateral femorotibial joint** (Fig. 6-16). In the dog and cat, these three joints communicate freely, and no special consideration is necessary. In the ungulates, however, at least the potential exists that these joints do not communicate. The reason that this variation is important is that, if an infection is present in one joint, it may involve the other joints. Also, if you want to inject a specific part of the joint complex, it may be necessary to enter that part selectively, because it might not communicate with the other parts. By the way, the correct anatomic name of the stifle joint is the **genual joint** (but only anatomists ever call it that). Inflammation of the stifle joint is known as **gonitis** (which has nothing to do with a swollen gonad).

As noted above, three potentially separate joint capsules (sacs) are associated with the stifle joint complex, and their *communications are variable*. To simplify this situation, the first thing to mention is that, in the pig and ruminants, all three typically do communicate. This brings us to the horse, in which this information is most important. In the horse, the medial femorotibial joint typically communicates with the femoropatellar joint (Fig. 6-16), but only occasionally (≈20%?) with the lateral femorotibial (FT) joint.

Because of the variability of these communications in the horse, to be safe one must consider the worst-case scenario. In other words, when infection is present in any sac, all three should be considered involved. Conversely, when injecting the joint, each sac should be injected separately to ensure that the entire joint receives the medication. Personally, I have observed that contrast medium injected into the femoropatellar (FP) capsule does not usually flow into the medial femorotibial (MFT) sac, even though they apparently do communicate. Identify the small, slit-like opening between the FP and MFT capsules (Fig. 6-16). Note that it is protected by a valve-like flap, which makes flow from the FP sac difficult, even when the opening is present.

On demonstration specimens, review the ligaments of the stifle joint, including the cruciate and meniscal ligaments (Figs. 6-15 & 6-16). With the minor exception that there is no transverse ligament in the horse, these ligaments are the same as those studied in the dog. Recall that the **cranial cruciate ligament** lies lateral to the **caudal cruciate ligament**, and that these ligaments are named according to their tibial attachments.

CRUS AND DISTAL PART OF LIMB

Tibia and Fibula: Refer to the skeletons and compare the tibia and fibula of the

various species (Fig. 6-3). As with the carnivores, the fibula of the pig is a complete and separate bone of the crus. This is not true, however, in the horse and ruminant, in which only the proximal and distal parts of the bone ossify, and part of the fibula fuses to the tibia. Note that the **lateral malleolus** (distal end of fibula) is fused to the tibia in the horse, but remains as a separate bone in the ruminant. Just the opposite is true with regard to the proximal part of the fibula; *i. e.* it is fused to the tibia of the ruminant, but is a separate bone in the horse.

There is wide variation in the ossification of the proximal part of the fibular body in the horse and ruminants, but particularly in the horse. The fibula is more or less a vestigial bone in the horse, and vestiges vary. Ossification defects in the equine fibula can be easily mistaken for fractures. The **tibial tuberosity** and the **medial and lateral malleoli** are important palpable landmarks in the horse.

External Features: Before the skin is reflected from the more distal part of the limb, a few external features should be recognized. In the horse, note the presence of the **chestnut** (torus tarseus[10]) on the plantaromedial aspect of the tarsus. This epidermal modification is not a vestige of the first digit (as is sometimes stated), but represents the evolutionary remnant of the tarsal pad, which is a well-developed structure in plantigrade mammals such as the rat and raccoon. The chestnut of the pelvic limb is usually absent in the donkey and reduced in size in the mule.

Although, to my knowledge, there is no scientific evidence that these structures in any way enhance nocturnal vision, they are commonly referred to around the racetrack as "night eyes." Like fingerprints, chestnuts vary considerably in shape and size from one horse to another and are therefore used for identification purposes. Close-up photographs of the four chestnuts (two pelvic, two thoracic) are included as part of the Universal Horse Identification System used by the Jockey Club.[11]

Buried within the tuft of hair on the plantar aspect of the equine metatarsophalangeal (fetlock) joint, locate another much smaller epidermal modification, the **ergot**. Again, this structure does not represent any missing digits but rather is a vestige of the metatarsal pad.

Domestic artiodactyls do not have chestnuts or ergots, but they do possess **dewclaws**, which represent vestigial second and fifth digits in the ruminant. In the pig, digits 2 and 5 include complete skeletal components, while in domestic ruminants, there are no metatarsal components, and the phalanges are seen only as osseous opacities that can be a source of confusion in radiographs.

Craniolateral Structures: *Continue the skin reflection to the level of the hoof.* The muscles of the lower limb are compartmentalized into distinct functional groups by their collective and individual envelopments of deep fascia. Intermuscular septa retain most of the muscles into distinct tunnels of connective tissue. The craniolateral muscles of the leg consist of

[10] Nobody but an anatomist would ever call it the *torus tarseus*, but FYI that is its *NAV* designation.

[11] This is the system used to identify horses to make sure they are the horse they are supposed to be. Prior to a race, photographs of these identification features are checked against those of the horse entered under that name as a prevention against the "ringer scam," in which a fast horse is slipped in as a "dead ringer" for a slower horse, usually at very good odds.

the flexors of the tarsus and the extensors of the digital joints.

Common Peroneal Nerve: The common peroneal nerve separates from the tibial nerve, passes over the lateral head of the gastrocnemius muscle, courses just distal to the head of the fibula, and divides into the superficial and deep peroneal nerves (Figs. 6-8 & 6-9). *The common peroneal nerve can be palpated in the live horse as it crosses the fibula* (refer to the skeleton and live horse). The first branch of the common peroneal nerve is the lateral cutaneous sural nerve, which penetrates the distal part of the biceps femoris muscle and provides sensory innervation to the skin on the lateral surface of the crus.

The **superficial peroneal nerve** innervates the lateral digital extensor muscle and continues distally in a superficial location just caudal to the intermuscular septum, between the long and lateral digital extensors. The **deep peroneal nerve** provides motor innervation to the remaining craniolateral muscles of the leg. It then joins company with the cranial tibial vessels and continues distally with them, between the muscles and the tibia, cranial to the intermuscular septum between the lateral and long digital extensor muscles.

In the horse, dissect over this intermuscular septum about 10 cm proximal to the tarsocrural joint. Locate the superficial peroneal nerve caudal to the septum, and locate the deep peroneal nerve, along with the cranial tibial vessels, cranial to the septum. These nerves can be blocked by injecting a local anesthetic on either side of the septum at this level (≈ 4 inches) proximal to the tarsus. Two injections are necessary because the anesthetic solution cannot diffuse easily through the tough intermuscular septum.

As the common peroneal nerve of the artiodactyls is traced distally, it passes deep to the **peroneus longus muscle** (Fig. 6-17), which is not present in the horse. Retract the peroneus longus caudally and continue following the common peroneal nerve. Locate the division of the common peroneal nerve into the superficial and deep peroneal nerves. The deep peroneal nerve can now be traced distally in association with the cranial tibial vessels.

The craniolateral muscles of the crus form the outer "gaskin muscle" of the horse. The largest muscle of this group in the horse is the **long digital extensor**, which originates from the **extensor fossa of the femur** and terminates primarily on the **extensor process of the distal phalanx**. Because it crosses three major joint complexes, this powerful muscle can therefore extend the stifle, flex the tarsus, and extend the **digital joints**.[12] As the tendon of the muscle is followed toward the tarsus, it becomes enveloped by a tendon sheath and is held in position by several connective tissue bands, the **extensor retinacula of the tarsus** (Figs. 6-17).

In the artiodactyls, the large **peroneus tertius** and the **long and medial digital extensors** originate as a common tendon from the extensor fossa of the femur (Fig. 6-15)). The medial digital extensor of these species is part of the long digital extensor, but in some texts it is listed as a separate muscle. In the ruminants, it terminates on the medial (third) digit, while in the pig, it divides to send separate tendons to both the third and second digits. The peroneus tertius of the artiodactyls terminates on the dorsomedial aspect of the proximal metatarsus and on the tarsus (Fig. 6-15).

[12] The digital joints include the metatarsophalangeal, and the proximal and distal interphalangeal joints.

The peroneus tertius of the horse, which also originates in common with the long digital extensor, is deep to the extensor muscle, and will be seen later. It is not a fleshy muscle in the horse as in the other species. As you undoubtedly recall, the peroneus tertius is not present in the domestic carnivores.

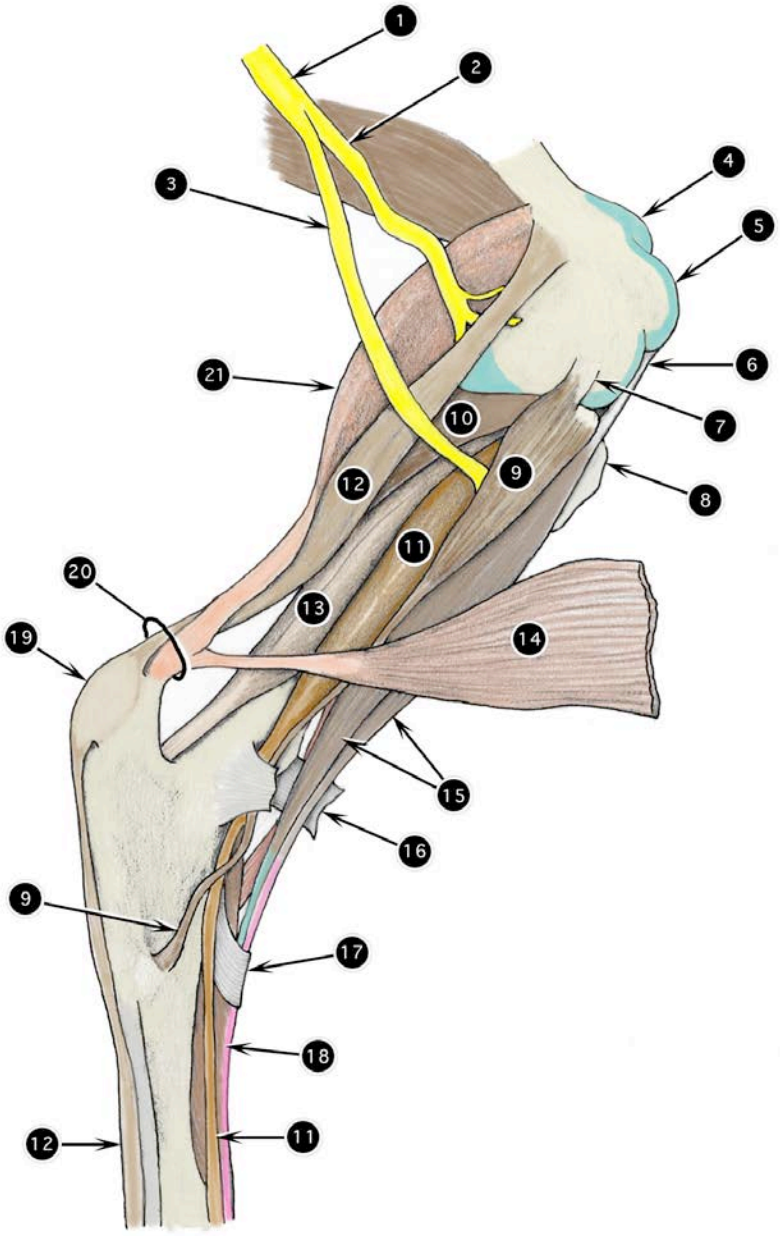


Figure 6-17. Crus of newborn calf, lateral view: (1) sciatic nerve; (2) tibial nerve; (3) common peroneal nerve; (4) medial ridge of femoral trochlea; (5) lateral ridge of femoral trochlea; (6) common tendon of origin of peroneus tertius and long digital extensor muscles; (7) lateral collateral ligament of stifle joint; (8) tibial tuberosity; (9) peroneus longus muscle; (10) popliteus muscle; (11) lateral digital extensor muscle; (12) superficial digital flexor muscle; (13) lateral head of deep digital flexor muscle; (14) reflected lateral head of gastrocnemius muscle; (15) long digital extensor muscle; (16) opened proximal extensor retinaculum of tarsus; (17) distal extensor retinaculum of tarsus; (18) short digital extensor muscle; (19) superficial digital flexor tendon covering tuber calcanei; (20) common calcanean tendon; (21) medial head of gastrocnemius muscle.

The **lateral digital extensor** originates from the head of the fibula and the lateral collateral ligament of the stifle (Figs. 6-17 & 6-18). As it traverses the tarsus, the lateral digital extensor is enveloped by a tendon sheath and is held in position by an extensor retinaculum. In the artiodactyls, its tendon is crossed by that of the peroneus longus, and then continues to the lateral (fourth) digit (Fig. 6-15). In the pig, it divides to send separate tendons to both the fourth and fifth digits.

In the horse, the lateral digital extensor muscle has a peculiar significance (Fig. 6-18). For reasons that are not completely understood, this muscle sometimes contracts involuntarily as the horse steps forward, resulting in a sharp, spastic flexion of the tarsus. This clinical problem has been recognized for many years as **stringhalt**. Refer to the equine skeleton, and locate the groove in the lateral malleolus that accommodates the lateral digital extensor tendon. *Palpate the tendon of the lateral digital extensor in the live horse proximal to the lateral malleolus, and follow it distally as it passes through this groove and continues dorsodistally to join that of the long extensor.*

In the surgical correction for stringhalt, a longitudinal incision is made over the distal part of the muscle belly, and the muscle is isolated and brought out through the incision. This tenses its tendon, and a second, smaller incision is made over its junction with the long extensor. The lateral digital extensor tendon is isolated here and transected. Then the tendon is pulled up and out through the proximal incision, after which the entire tendon and a liberal amount of the distal muscle belly are removed. (Although I've never seen it tried, I've often wondered if cutting the branch of the superficial peroneal nerve that enters the proximal part of the muscle belly wouldn't be just as effective, and a lot less traumatic.)

Peroneus Tertius of Horse: In contrast to the more muscular and superficial peroneus tertius muscle of the artiodactyls, that of the horse has undergone an "evolutionary translocation and modification." Not only has it rotated around behind the long extensor, it has lost its muscular character and become a fibrous band. Thus, it has been reduced to a mechanical connector between the extensor fossa of the femur and its termination on the dorsal and lateral aspects of the proximal metatarsus (Fig. 6-19).

Emerging from between the bifid termination of the peroneus tertius is the bifid termination of the cranial tibial muscle, which is adherent to the deep surface of the peroneus tertius. As a fibrous and relatively inelastic[13] band that crosses both the stifle and the tarsal joints, the peroneus tertius of the horse dictates that flexion of the stifle is accompanied by an obligatory flexion of the tarsus, that is, a normal horse cannot flex its stifle and extend its tarsus at the same time. With the possible exception of a trained Lipizzaner, if you can flex the stifle and extend the tarsus simultaneously, then the peroneus tertius has been torn- you have a diagnosis of ruptured peroneus tertius.

[13] This brings up a common misconception that I have observed to run rampant among first-year veterinary students. Although I'm sure that engineers have a quantitative definition of what constitutes elasticity, as anatomists, we can lead our students' minds astray when we say flatly that one structure is elastic and another is collagenous (implied nonelastic). Well, there is elasticity and there is elasticity. Almost all anatomic structures are somewhat elastic- it's just a matter of degree. Fibrous (collagenous) tendons and ligaments stretch and then return the energy as recoil, even the peroneus tertius.

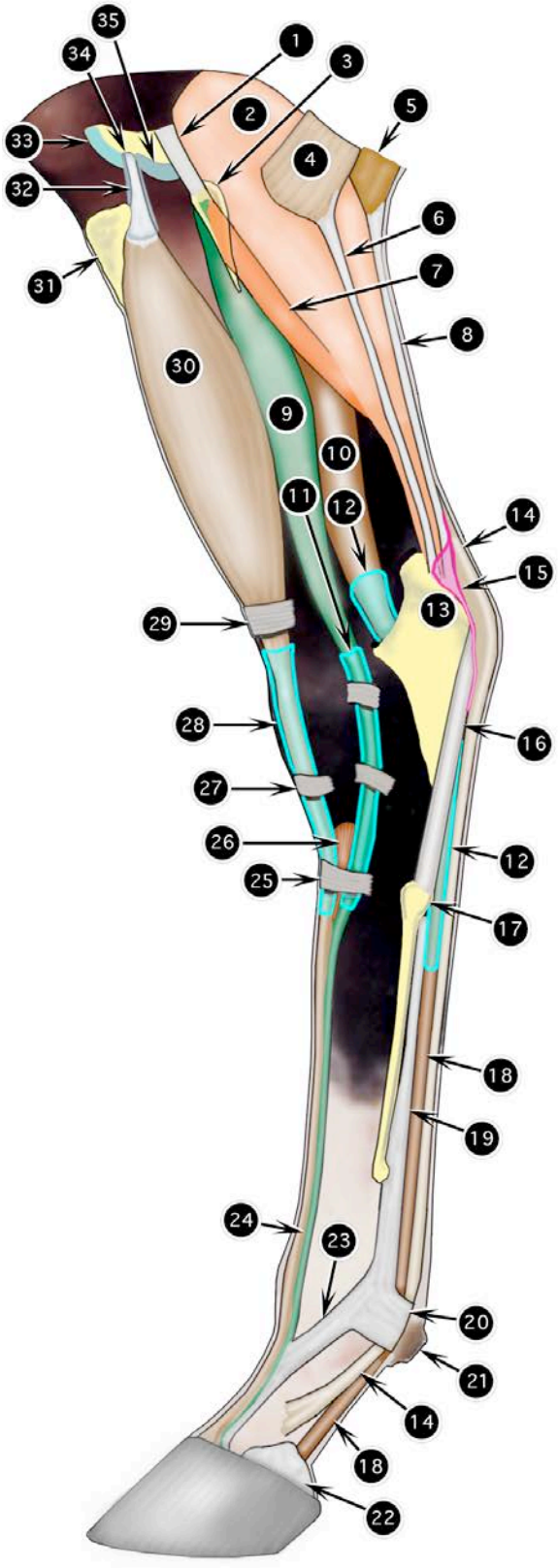


Figure 6-18. Crus and pes of horse, lateral view: (1) lateral collateral ligament of stifle; (2) lateral head of gastrocnemius muscle; (3) head of fibula; (4) caudal division of biceps femoris muscle; (5) semitendinosus muscle; (6) contribution of 4 to common calcanean tendon; (7) soleus muscle; (8) contribution of 5 to common calcanean tendon; (9) lateral digital extensor muscle; (10) lateral head of deep digital flexor muscle; (11) tendon sheath of 9; (12) tendon sheath of 10; (13) tuber calcanei; (14) tendon of superficial digital flexor; (15) subtendinous calcaneal bursa; (16) long plantar ligament; (17) base of metatarsal bone 4; (18) tendon of deep digital flexor; (19) interosseus 3 (suspensory ligament); (20) plantar annular ligament of fetlock; (21) ergot (metatarsal pad); (22) cartilage of hoof (lateral); (23) lateral extensor branch of 19; (24) combined tendon of long, short, & lateral digital extensors; (25) distal extensor retinaculum of tarsus; (26) short digital extensor muscle; (27) middle extensor retinaculum of tarsus; (28) tendon sheath of long digital extensor; (29) proximal extensor retinaculum of tarsus; (30) long digital extensor muscle; (31) tibial tuberosity; (32) common tendon of origin of 30 & peroneus tertius, enveloped by synovial extension (distal pouch) of lateral femorotibial sac; (33) lateral ridge of femoral trochlea; (34) extensor fossa of femur; (35) lateral condyle of femur.

Cranial Tibial Muscle: Although this is a superficial muscle in carnivores, it has been rotated to a deeper location in ungulates. It originates from the proximal part of the tibia and spirals around the peroneus tertius-long digital extensor unit to lie along the cranial surface of the tibia. In the horse, it is intimately adhered to the deep surface of the fibrous peroneus tertius. In the distal part of the crus, its tendon of termination reappears. In the ox, its tendon passes through a canal in the tendon of the peroneus tertius and then emerges to terminate on the tarsus and proximomedial aspect of the fused third and fourth metatarsals (Fig. 6-19).

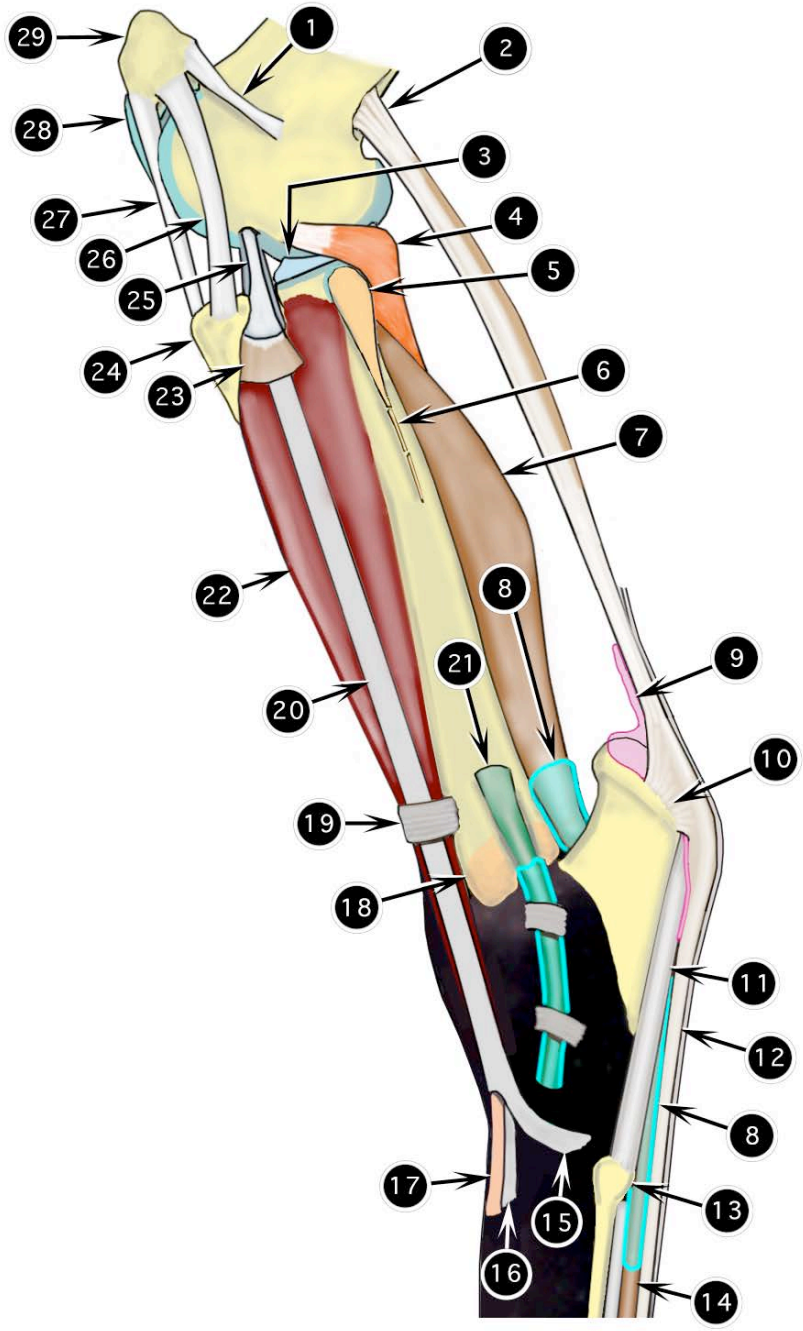


Figure 6-19. Crus of horse, lateral view: (1) lateral femoropatellar ligament; (2) origin of superficial digital flexor from supracondylar fossa of femur; (3) lateral meniscus; (4) popliteus muscle; (5) head of fibula; (6) irregularly ossified body of fibula (highly variable); (7) lateral head of deep digital flexor muscle; (8) tarsal sheath; (9) subtendinous calcaneal bursa; (10) lateral attachment of superficial digital flexor to tuber calcanei; (11) long plantar ligament; (12) superficial digital flexor tendon; (13) base of metatarsal bone 4; (14) deep digital flexor tendon; (15) lateral tendon of peroneus tertius; (16) dorsal tendon of peroneus tertius; (17) dorsal tendon of cranial tibial muscle; (18) lateral malleolus (distal part of fibula); (19) proximal extensor retinaculum of tarsus; (20) peroneus tertius; (21) lateral digital extensor tendon; (22) cranial tibial muscle; (23) long digital extensor muscle (mostly removed); (24) tibial tuberosity; (25) common tendon of origin of 20 & 23 from extensor fossa of femur; (26) lateral patellar ligament; (27) intermediate patellar ligament; (28) medial ridge of femoral trochlea; (29) patella resting at proximal aspect of femoral trochlea.

In the horse, the tendons of the cranial tibial muscle emerge between the divided termination of the peroneus tertius and then divides into **dorsal and medial branches** (Fig. 6-20)). The dorsal tendon terminates on the proximal aspect of Mt3, and the medial branch curves around to terminate on the fused first and second tarsal bones (T1+2; "cuneiform bones"). Thus, this medial tendon is referred to clinically as the **cunean tendon.** *Isolate this tendon, and transect it as close as possible to its termination. Reflect it proximally to expose the* ***cunean bursa****, located between the tendon and the dorsomedial aspect of the tarsus* (Fig. 6-20).

The cunean bursa is subject to inflammation, and pressure exerted over the dorsomedial aspects of the central and third tarsal bones and the medial collateral ligament. Although the cunean tendon has historically been incriminated in the stimulation of new bone production (exostosis), resulting in a condition known as **bone spavin**, it has now been established that this tendon has nothing to do with the problem, which is a form of degenerative joint disease. Sometimes, injection of a local anesthetic solution into the bursa can relieve the pain and result in a temporary return to soundness of the limb. In these cases, some surgeons recommend and perform a cunean tenectomy, which involves cutting the tendon near its termination and removing a section of it.

The cunean tendon should be palpated in the live horse as it curves around the dorsodistomedial aspect of the tarsocrural joint capsule (Fig. 6-20). Hint: it is usually directed toward the distal aspect of the chestnut.

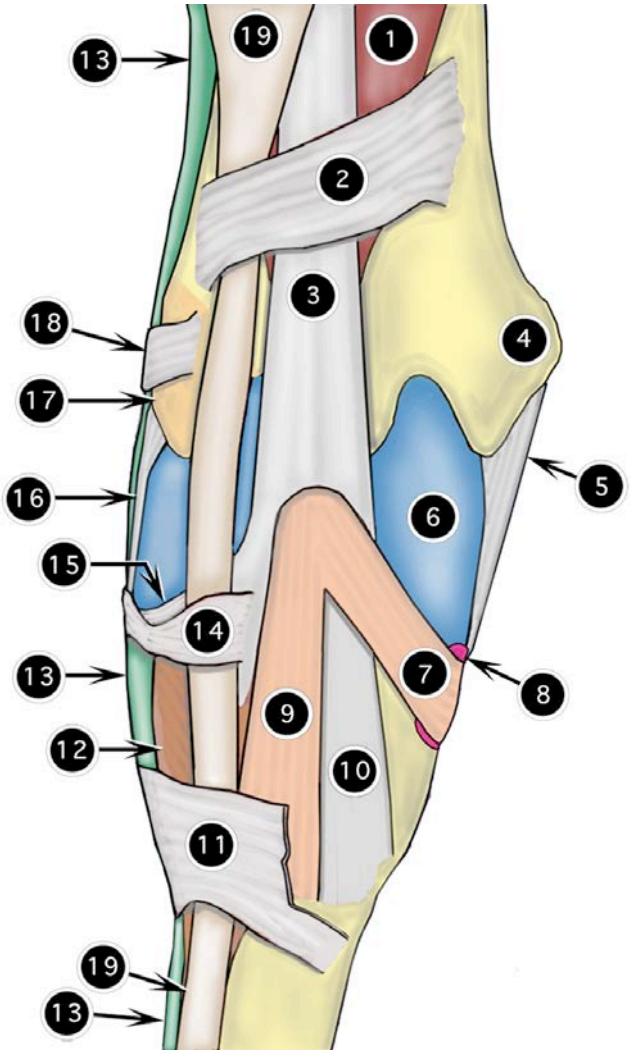


Figure 6-20. Tarsus of horse, dorsal view: (1) cranial tibial muscle; (2) proximal extensor retinaculum of tarsus; (3) peroneus tertius; (4) medial malleolus of tibia; (5) medial collateral ligament of tarsus; (6) dorsal pouch of tarsocrural joint; (7) medial tendon of 1 (cunean tendon); (8) bursa under 7 (cunean bursa) (9) dorsal tendon of 1; (10) dorsal tendon of 3; (11) distal extensor retinaculum of tarsus; (12) short digital extensor muscle; (13) lateral digital extensor tendon; (14) middle extensor retinaculum of tarsus; (15) lateral tendon of 3; (16) lateral collateral ligament of tarsus; (17) lateral malleolus of fibula; (18) extensor retinaculum of 13; (19) long digital extensor muscle & tendon.

Popliteal Artery: Return to the femoral artery, and follow it distally (Fig. 6-13). After giving off the saphenous and descending genicular arteries, it gives rise to

the **caudal femoral artery** and continues as the principal arterial channel, the **popliteal**[14] artery. In the pig, the **saphenous artery** is a more substantial arterial channel and should be followed.

Lateral Saphenous Vein: The medial saphenous vein is large in the horse (Fig. 6-11) and cat, whereas in the ruminant and dog, the lateral saphenous vein is more prominent (Figs. 6-4). Rather than joining the caudal femoral vein, its major continuation in the ox ascends between the caudal thigh muscles to join the medial circumflex femoral vein (Fig. 6-12).

Tibial Nerve: The common peroneal nerve was followed to the craniolateral muscle group. The other major branch of the sciatic nerve is the tibial nerve, which supplies the caudal muscles of the leg and sensory innervation to the caudal (plantar) surface of the limb, distal to the stifle (Figs. 6-8 & 6-9). The first branch of the tibial nerve is the caudal cutaneous sural nerve, which courses along the craniolateral aspect of the common calcanean tendon. It provides sensory innervation to the skin over the caudolateral surface of the crus.

The tibial nerve continues between the heads of the gastrocnemius muscle along with the popliteal vessels. Much of the nerve is distributed to the caudal muscles of the leg, but the major sensory component continues distally along the deep digital flexor muscle (Figs. 6-8 & 6-9). This continuation of the tibial nerve joins the saphenous artery and *is palpable in the distal part of the leg*. When performing diagnostic nerve blocks for lameness localization, this nerve can be blocked where it is palpable, about 10 cm (4 inches) proximal to the tarsus.

[14] popliteal (Latin)- ham; pertaining to the back of the knee.

Caudal Muscles of Crus: The largest muscle of the caudal group is the triceps surae muscle, which consists of the **medial and lateral heads of the gastrocnemius** and the **soleus muscles** (Figs. 6-18 & 6-21). The combined tendon, which terminates on the tuber calcanei, forms a major component of the **common calcanean tendon** (Fig. 6-21). As previously noted, minor contributions to this tendon are provided by the biceps femoris and semitendinosus muscles (Fig. 6-18). Locate the primary division in the tendon, which passes obliquely across its caudal surface in a laterodistal direction. *Separate between this division* and note that the superficial digital flexor tendon comes from deep to superficial by spiraling around the tendon of the gastrocnemius (Figs. 6-18 & 6-21). As it is in the cat, the soleus muscle is well developed in the pig.

On the detached limb, carefully transect the lateral head of the gastrocnemius and soleus muscles near their origins, and reflect them to expose the deeper muscles. Now you can follow the other major component of the common calcanean tendon proximally to confirm that it is the tendon of the **superficial digital flexor muscle** (Figs. 6-17 &6-19). In the horse, and to a lesser degree in the ox, the superficial digital flexor has lost most of its muscular tissue and has been converted to a predominantly fibrous structure.

As a "reciprocal" to the peroneus tertius, this muscle has been reduced to another mechanical connector between the stifle and tarsus. Whenever the stifle of a horse is extended, tension on the fibrous superficial digital flexor results in an obligatory (mechanical) extension of the tarsus. Thus, the stifle and tarsus work in unison because of their mechanical connections, which make up the **reciprocal apparatus** of the

horse.[15] Also, when the stifle is locked in extension by the patellar locking mechanism, the tarsus is fixed in extension

Reflection of the lateral head of the gastrocnemius should also expose the **popliteus muscle** and the lateral head of the deep digital flexor muscle (Figs. 6-17,6-19 & 6-21). The popliteus muscle originates by a tendon from the lateral epicondyle of the femur, spirals around the caudolateral aspect of the lateral meniscus and then fans out to terminate as a triangular fleshy muscle on the caudomedial surface of the tibia. It primarily serves to stabilize the stifle and counteract the twisting forces that are exerted on this joint during weight-bearing.[16]

As the superficial digital flexor (SDF) spirals around the gastrocnemius tendon, it becomes superficial and passes over the tuber calcanei. It is attached to the medial and lateral sides of the calcaneus, but is free to move proximally and distally over the tuber as the tarsus is flexed and extended.

Cut the medial attachment of the tendon to the calcaneus, and carefully reflect it laterally off the tuber calcanei. This should open the large **subtendinous calcaneal bursa** (Figs. 6-18 &6-19), which lubricates this tendon's movement over the tuber. This is a constant bursa, and like any other bursa, it is subject to inflammation (bursitis). However, in most cases of **calcaneal bursitis** ("capped hock"), this deeper bursa is not involved. In the horse, the large subtendinous bursa extends around the lateral aspect of the gastrocnemius tendon to lubricate the pressure of the latter over the tuber calcanei.

Bursae are generally divided into two types, constant and inconstant. **Constant bursae** are usually subtendinous and can be found in 99.99% of all animals examined. **Inconstant bursae** are generally subcutaneous and are only present when needed. These bursae (sort of like blisters) form in response to excess pressure and/or friction, which is what occurs in "capped hock." In response to abnormal pressure or repeated trauma, a subcutaneous calcaneal bursa develops between the SDF tendon and the skin (Fig. 6-22). In such cases, the bursa can be drained and injected with anti-inflammatory medication, or it can be surgically opened and excised. Most importantly, for long-term correction, the initiating cause must be identified and alleviated; otherwise, the condition will likely recur.

The tendon of the superficial flexor muscle continues distally along the plantar aspect of the limb to terminate on the middle phalanx of each digit. In the horse, it attaches to both proximal and middle phalanges (Fig. 6-18. Because its

---

[15] How goes the stifle, so goes the tarsus of the horse. When the stifle flexes, the peroneus tertius mechanically flexes the tarsus; when the stifle extends, the superficial digital flexor mechanically extends the tarsus.

[16] This brings us to another misunderstanding that frequently permeates the cranial cavity of first-year veterinary students. You see, they always want to ascribe a particular action to each and every muscle- flexion of this, extension of that- it makes for a neater chart no doubt. Well, that's all well and good, but one of the most important actions that muscles perform is passive vs. active. One of the most important actions performed by muscles is the prevention of an unwanted effect, like falling down for example. Muscles resist and counteract forces that are exerted on joints by gravity and forces created by the contraction of antagonistic muscle groups. True, the quadriceps femoris is an extensor of the stifle joint, but it more frequently functions as an "antiflexor"- that is, it supports the weight of the body by resisting flexion of the stifle and collapse of the limb. No quadriceps, no weight-bearing- a pretty important "non-action" don't you think.

termination is the same in the thoracic limb, it will be studied later.

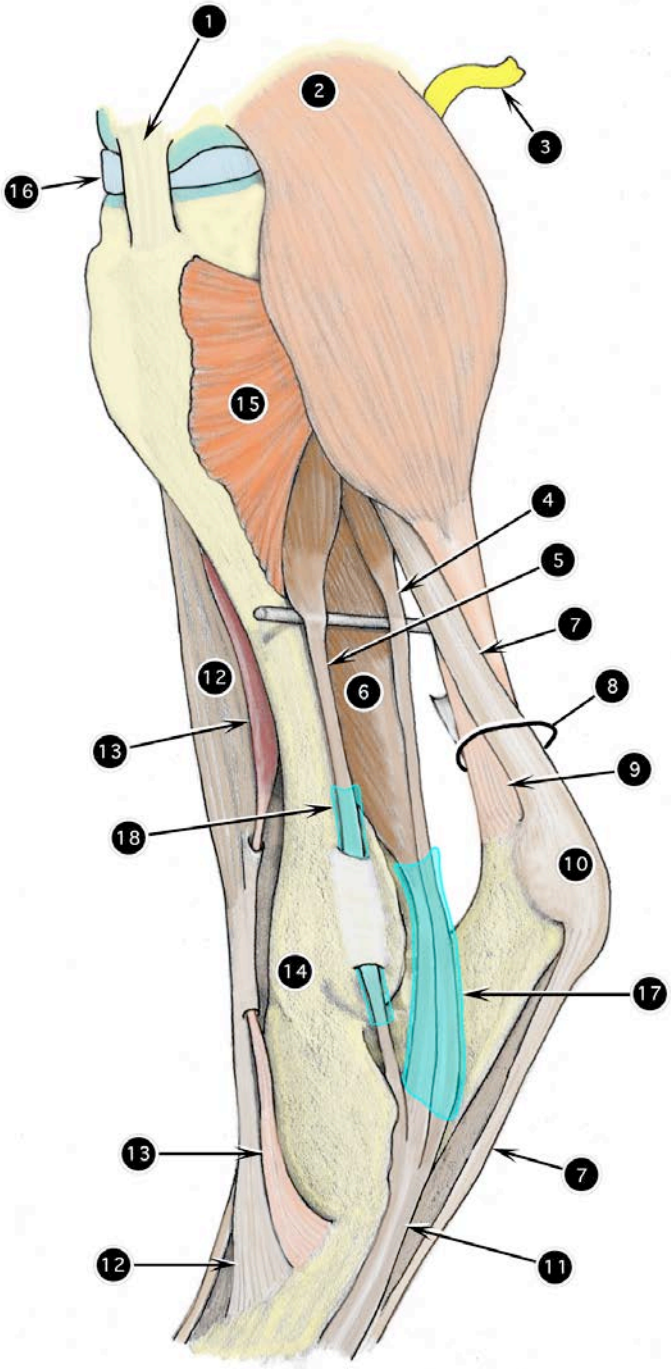


Figure 6-21. Crus of newborn calf, caudomedial view: (1) medial collateral ligament of stifle joint; (2) medial head of gastrocnemius muscle; (3) tibial nerve; (4) caudal tibial muscle- part of deep digital flexor; (5) medial head of deep digital flexor muscle; (6) lateral head of deep digital flexor muscle; (7) superficial digital flexor tendon; (8) common calcanean tendon; (9) gastrocnemius tendon; (10) tendon of superficial digital flexor covering tuber calcanei; (11) tendon of deep digital flexor; (12) peroneus tertius muscle; (13) cranial tibial muscle; (14) medial malleolus; (15) popliteus muscle; (16) medial meniscus (17) tarsal synovial sheath surrounding tendons of 4 & 6; (18) tendon sheath surrounding 5.



Figure 6-22. Tarsus of horse with calcaneal bursitis ("capped hock"), caudolateral view. This bursitis does not typically involve the deeper subtendinous calcaneal bursa between the superficial digital flexor tendon & the tuber calcanei. The extent of a large subcutaneous bursa is indicated.

The **deep digital flexor** extends the tarsus, flexes the digital joints, and is composed of three heads. The largest of these is the **lateral head** (flexor hallucis longus),[17] which originates from the caudoproximal part of the tibia and passes distally over the **sustentaculum tali** of the calcaneus, through the **flexor canal of the tarsus** (Fig. 6-21). It can be seen from the lateral side, just caudal to the lateral digital extensor (Fig. 6-18). The lateral head is "piggybacked" by the smallest component, the **caudal tibial muscle**, the tendon of which joins that of the lateral head at the level of the flexor canal (Fig. 6-21). The third component is the **medial head** (long digital flexor), which also originates on the caudal surface of the tibia near the popliteus muscle. The tendon of the medial head takes a more medial course and does not descend through the flexor canal; distal to the tarsus, it joins the other two components to form the definitive tendon of the deep digital flexor (Fig. 6-21).

As the tendons of the lateral head and the caudal tibial muscle are followed distally, they pass medial to the body of the calcaneus and through the flexor canal of the tarsus. Here they are held in place by the **flexor retinaculum of the tarsus**, which passes from the calcaneus to the medial aspect of the distal tibia and tarsus, thus enclosing the canal. *Transect the flexor retinaculum to follow these tendons through the flexor canal*. As the tendons pass through the canal, they are lubricated by synovial fluid contained within a large tendon sheath, the **tarsal sheath** (Fig. 6-21). As is the case with many synovial structures, the tarsal sheath is subject to inflammation and distention- **tarsal tendosynovitis**.

Actually, there are three classifications of inflammatory disease associated with tendons: (1) **tendinitis**- inflammation of a tendon and/or its attachments; (2) **tenosynovitis** (tenovaginitis)[18]- inflammation of a tendon sheath; and (3) **tendosynovitis** (tendovaginitis)- inflammation of the tendon and its tendon sheath. Inflammation of nonsheathed portions of tendons results in tendinitis. A tendon sheath can become inflamed in the absence of tendon inflammation, but the most common form of the disease in sheathed tendons is the concurrent inflammation of both the tendon and its sheath-- tendosynovitis. Tarsal tendosynovitis is just one example of the inflammatory disease associated with tendons and their sheaths throughout the body. It is basic to understanding the process, regardless of the specific location (*e.g.,* tarsal sheath, carpal sheath, digital sheath).

It is important you understand that the fluid within a tendon sheath, as with bursae and synovial joints, is not static, but is continually being produced and resorbed. We refer to this as a state of **dynamic equilibrium**- that is, the rate of production is approximately equal to the rate of resorption, and thus the volume of fluid remains relatively constant. (Actually, the amount tends to increase with exercise and to decrease with rest.) Whenever we have an insult (*e.g.*, trauma, infection), to one of these synovial structures, the most common response is a shift away from this equilibrium, so that the rate of production is greater than the rate of resorption. This results in excess fluid accumulation, which

[17] Although NAV refers to this part of the DDF as the lateral digital flexor, this terminology leads to confusion. It is much better to have medial, and lateral digital extensors and deep and superficial digital flexors.

[18] vagina (Latin)- a sheath or sheath-like structure.

leads to distention (puffiness) of synovial structures.

When the tarsal sheath becomes distended with excess synovial fluid, it presents as a swelling of that structure. The part of the sheath proximal to the tarsus is less confined by a surrounding connective tissue wrapper, so that the swelling is most obvious proximal to the flexor canal (*i.e.,* in the caudodistomedial part of the leg). When you press on the swelling on one side of the tendons, it distends on the opposite side like pushing a pin back and forth. Thus, the common name for tarsal tendosynovitis is **thoroughpin**.[19]

To this point, we have examined several **synovial structures**, and it's now time for us to be sure that we understand what these structures are all about. Basically, we have three types of synovial structures to deal with as veterinarians: **bursae**, **tendon sheaths**, and **joint capsules** (Figs. 6-23, 6-24, 6-25). They all share a common feature, the presence of a **synovial membrane**. This is a membrane capable of regulating the production and resorption of synovial fluid, a specialized type of extracellular fluid associated with lubrication.

In basic terms, whenever two structures must rub on one another, we need lubrication to reduce friction, which causes wear and heat production. Most body parts are "factory installed" and are designed to last for the lifetime of the unit. Having them replaced is not only expensive but often yields less than optimal results, regardless of the skill of the surgeon.

Let's talk about pressure. Whenever two body parts rub against one another repeatedly, there is the potential for fatigue of one or both parts. Rather than thinking of each of these pressure absorbers as a separate entity, it is better to consider them as a progression of the law of demand and supply.[20]

First, we have the situation in which one structure rubs on another over a single contact surface, such as the accessory gluteal tendon over the greater trochanter- the need for lubrication is limited to one side and a short distance. The problem is friction- one side, short distance, and the solution is the formation of a **bursa** (Fig. 6-23). Next, we have a tunnel to deal with. The problem is friction on all sides over a variable length- a bursa is not sufficient, so a more elaborate set-up is needed; the solution is a **tendon sheath** (Fig. 6-24).

Another problem is that of extreme pressure over a localized area of the tendon; this requires not only lubrication, but strengthening of the tendon to withstand the pressure. One solution is a **fibrocartilage pad** in the tendon; another solution is ossification of fibrocartilage- that is, a **sesamoid bone** (Fig. 6-25). The body is basically stingy when it comes to passing out these pressure absorbers; it doesn't use a tendon sheath if a bursa will do.[21]

---

[19] If you are going to deal with horses, which have been kept and prized by humans for hundreds of years, you are going to have to become familiar with the jargon of the horseperson. For example, they refer to the carpus as the knee, which it is not, and to the fetlock as the ankle, which it is not.

[20] I've never understood why they call it the law of supply and demand in the first place. In most cases, demand precedes supply; *i.e.,* the body is more responsive than proactive. It's really a type of problem solving- here's the problem, what's the solution? With the exception of duplication for back-up needs (*e.g.,* two kidneys), rarely does the solution greatly exceed the problem.

[21] And speaking of sesamoid bones, kangaroos (macropodia) don't have osseous patellae; fibrocartilage apparently works better for them.

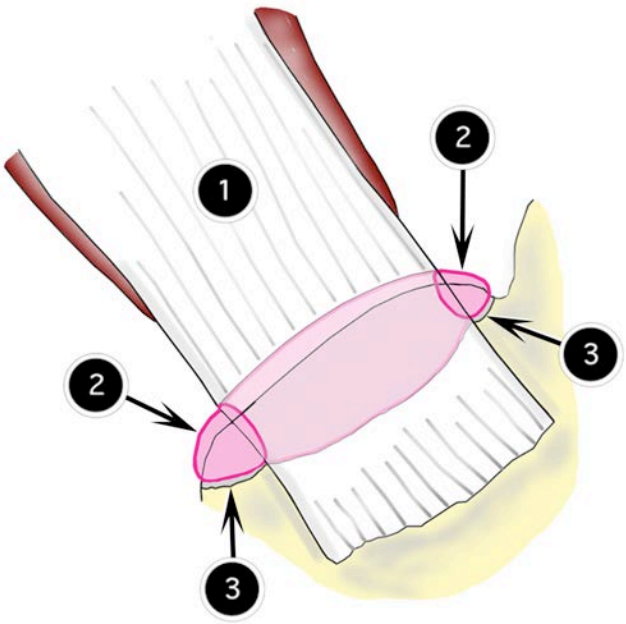


Figure 6-23. Anatomy of a bursa (equine trochanteric): (1) tendon of accessory gluteal muscle; (2) trochanteric bursa; (3) fibrocartilage covering cranial part of greater trochanter.

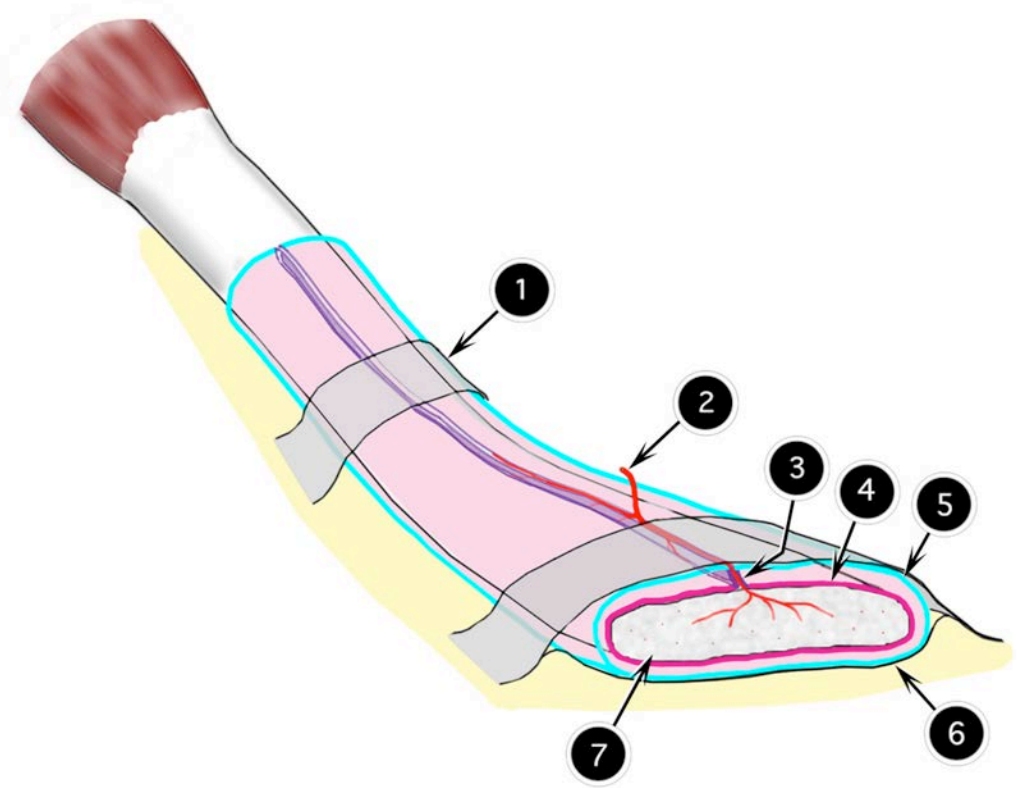


Figure 6-24. Anatomy of a tendon sheath: (1) retinaculum; (2) vessel entering tendon *via* mesotendon; (3) mesotendon; (4) inner (visceral) layer of synovial sheath; (5) outer (parietal) layer of sheath; (6) groove in bone to accommodate tendon; (7) cross section of tendon.

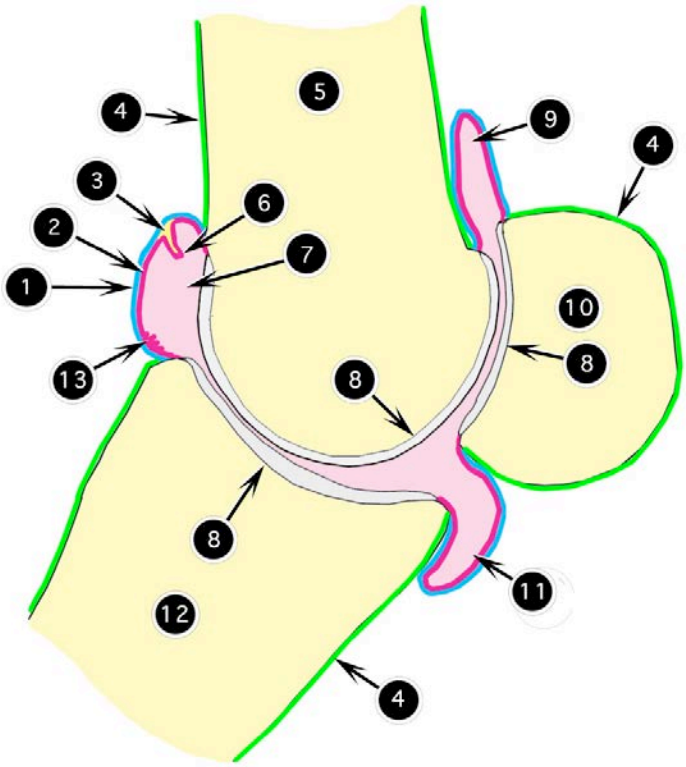


Figure 6-25. Anatomy of a synovial joint (equine fetlock): (1) fibrous layer of joint capsule; (2) synovial membrane; (3) fat between 1 & 2; (4) periosteum; (5) metacarpal 3; (6) synovial fold; (7) dorsal pouch of fetlock joint; (8) articular (hyaline) cartilage; (9) proximal part of palmar pouch; (10) proximal sesamoid bone; (11) distal part of palmar pouch; (12) proximal phalanx; (13) synovial villi.

Now let's consider the tendon sheath for what it really is (Fig. 6-23). It is a linear structure that lubricates a tendon as it passes through a tight place (tunnel). The tendon is not within the sheath, but is enveloped by it, much like the heart is enveloped by the pericardial sac. The outer layer is attached to the walls of the tunnel and remains stationary as the tendon does its thing; the inner layer is adhered to the tendon and moves with it. Thus, we have two slick surfaces gliding on one another as the tendon moves back and forth.

Incise the extensor retinaculum over the lateral digital extensor, and carefully reflect the tendon from its bed. You should observe that there is a linear connecting fold between the outer and inner layers of the tendon sheath. This is the **mesotendon**, which, like the mesentery, provides an avenue for vessels and nerves to enter and leave the tendon. It does not typically extend the entire length of the sheath, but has enough slack in it to allow for the normal excursion of the tendon (Fig. 6-23).

Deep Digital Flexor of Horse: As the deep digital flexor (DDF) tendon of the horse is followed distally into the metatarsus, it is usually joined by another fibrous structure that originates from the plantar surface of the tarsometatarsal junction. This structure, which may be small or even absent, is the **accessory ligament of the deep digital flexor** (Fig. 6-26). It joins the tendon of the DDF in the midmetatarsus. Because it is a fibrous connection, it provides for a stop or

"check" for the DDF tendon as it is pulled distally by the pressure (weight) of the descending fetlock. Hence, it is frequently referred to as a **check ligament**.

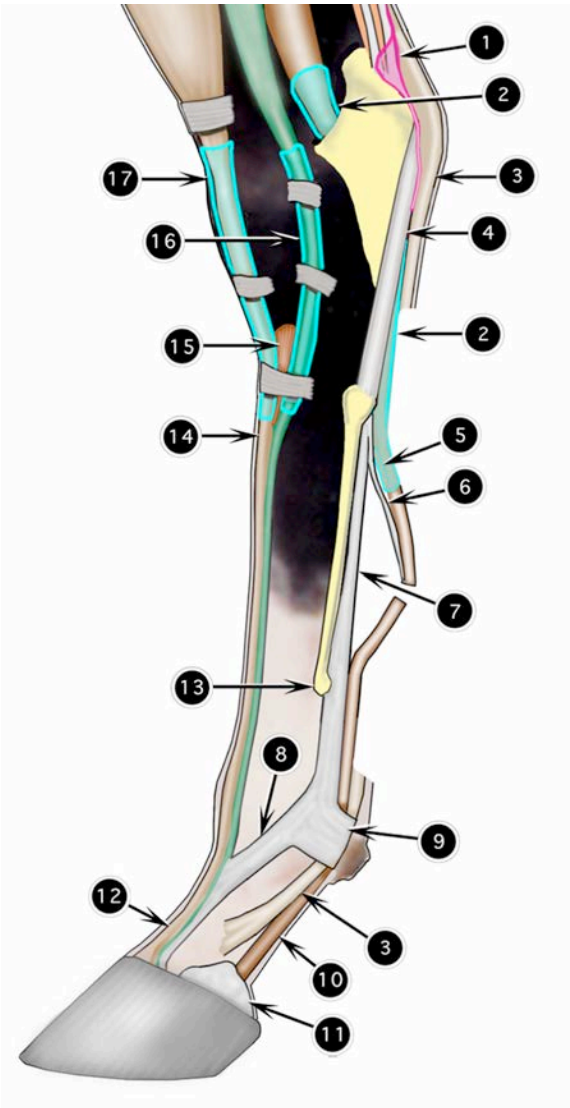


Figure 6-26. Distal limb of horse, lateral view: (1) subtendinous calcaneal bursa; (2) tarsal sheath; (3) superficial digital flexor tendon; (4) long plantar ligament; (5) tendon of medial head of deep digital flexor; (6) accessory ligament of deep digital flexor (check ligament); (7) interosseus 3 (suspensory ligament; (8) lateral extensor branch of 7; (9) plantar annular ligament of fetlock joint; (10) deep digital flexor tendon; (11) cartilage of hoof (lateral); (12) combined tendon of long, short & lateral digital extensors; (13) head of metatarsal 4; (14) tendon of long digital extensor; (15) short digital extensor muscle; (16) tendon sheath of lateral digital extensor; (17) tendon sheath of long digital extensor.

Interosseus: Deep to the DDF tendon in the metatarsus is another fibrous structure, which arises from the plantar surface of the proximal metatarsus. In the horse, it is a single structure representing the **third interosseus muscle**; in the ruminants, it represents the **fused third and fourth interossei** and is not as fibrous as in the horse. This structure attaches distally to the proximal sesamoid bones and through branches that join the digital extensor tendons to the phalanges.

Because the proximal sesamoid bones are anchored distally to the phalanges by a set of strong ligaments, the interosseus forms part of a fibro-osseous sling or **suspensory apparatus** across the plantar surface of the fetlock joint (Fig. 6-26). The interosseus of the horse is therefore usually referred to by horsepersons as the **suspensory ligament**. We shall consider its distal attachments with the forelimb.

Pelvic-Limb Stay Apparatus of Horse: It should be obvious to you by now that the horse has devised a set of fibrous support structures that can convert the limb into a passive, weight-bearing stilt. These structures make up the stay apparatus (Fig. 6-27). Horses spend much of their adult life standing, and as long as they have to do it, why not be comfortable? Being the "efficiency experts" that they are, horses only have to lock the patella over the medial ridge of the femoral trochlea, engaging their resting surfaces, and what do you know, they've "put the limb in park." If the stifle can't flex, neither can the tarsus (fibrous SDF). The lower joints are passively supported by the fibrous SDF, the DDF with its fibrous accessory ligament, and the fibro-osseous sling formed by the interosseus muscle, the proximal sesamoid bones, and their distal ligaments.

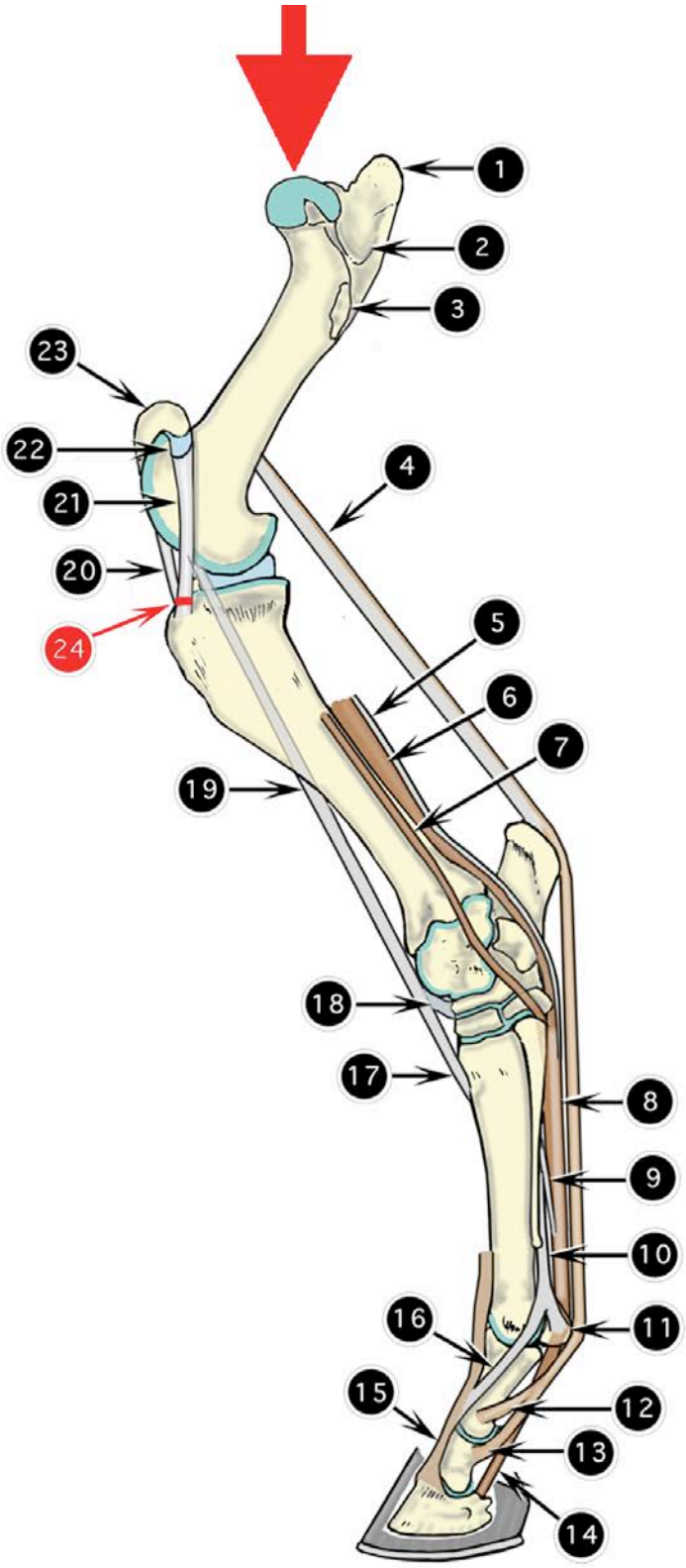


Figure 6-27. Major components of equine "stay apparatus" of pelvic limb, medial view: (1) greater trochanter of femur; (2) trochanteric fossa; (3) lesser trochanter of femur; (4) fibrous superficial digital flexor muscle (SDF); (5) tendon of caudal tibial head of deep digital flexor muscle (DDF); (6) lateral head of DDF; (7) medial head of DDF; (8) deep digital flexor tendon; (9) accessory ligament of DDF (check ligament); (10) interosseus 3 (suspensory ligament); (11) medial proximal sesamoid bone; (12) medial termination of SDF on proximal phalanx (Pp); (13) medial termination of SDF on middle phalanx (Pm); (14) termination of DDF on distal phalanx (Pd); (15) combined tendon of long, short, & lateral digital extensors; (16) medial extensor branch of 10; (17) termination of dorsal tendon of peroneus tertius on Mt 3; (18) lateral tendon of peroneus tertius; (19) fibrous peroneus tertius (originates from extensor fossa of femur in common with long digital extensor muscle); (20) intermediate patellar ligament; (21) medial patellar ligament; (22) parapatellar fibrocartilage; (23) patella, fully engaged in locked position over medial ridge of femoral trochlea; (24) site for medial patellar desmotomy. The large red arrow indicates the weight of the horse balanced over the mechanically supported limb.

But, aren't we forgetting the highly movable hip joint? No problem. It's not going anywhere, as long as the horse's weight is balanced over and pushing straight down on the limb. In order for the head of the femur to move downward, the medial trochlear ridge must be free to rotate upward. This is prevented by the patellar lock- -the femur is hooked under the patella like a crowbar under the edge of a building. Unless the horse falls over backward or forward, the hip joint doesn't need to be fixed in any way; it's a balancing act.

Proximal Fixation of Patella: As noted, the normal horse voluntarily engages the patella locking mechanism for rest and disengages it for motion. However, a **clinical problem** exists when the patella locking mechanism either partially or completely engages as the stifle is extended during locomotion. If only partially engaged, the patella may just catch momentarily and then slip off, causing an abrupt flexion of the stifle and tarsal joints. This may be accompanied by an audible "snap or pop." If the patella fully engages, the stifle and tarsal joints may become locked in extension, causing the horse to drag the toe of that hoof on the ground. "The pelvic limb may slip into park, while the rest of the horse is still in drive." In these cases, the patella may remain locked for a sustained period, with the horse unable to release it (Fig. 6-28).

The cause of this problem is not completely understood, but some clinicians feel it may be hereditarily predisposed in horses with an especially long, straight pelvic limb conformation. Once it occurs, recurrence is common. Some clinicians believe that frequent exercise in a young horse is important as a preventative measure.

As you should have observed, there are four structures involved in forming the loop that slips over the enlarged proximal end of the medial ridge of the femoral trochlea as the patella is locked. These are the medial patellar ligament, the parapatellar fibrocartilage, the patella, and the intermediate patellar ligament (Fig. 6-27). To prevent this undesirable (untimely) locking, surgical treatment is directed toward breaking this loop.

Specifically, the medial patellar ligament is cut near its attachment to the tibial tuberosity in an operation called a **medial patellar desmotomy**[22] (Fig. 6-27).

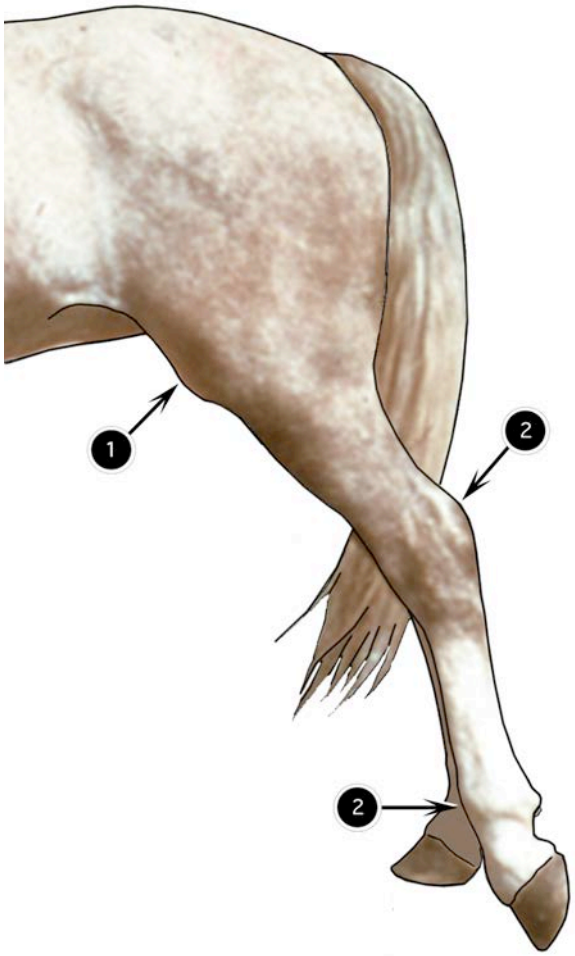


Figure 6-28. Horse with proximal fixation of patella: (1) patella is "locked" over medial ridge of femoral trochlea; (2) hock and digit are mechanically straightened due to traction of fibrous SDF.

This procedure is usually performed with the horse standing and using local anesthesia. After proper preparation, a small skin incision is made between the palpable distal parts of the medial and intermediate ligaments. A bistoury[23] (tenotomy) knife is inserted just lateral to the medial ligament. When properly positioned, the cutting edge

[22] desmo- (Greek, *desmos*)- band or ligament.

[23] bistoury (French, *bistouri*)- a long, narrow, surgical knife used for incising abscesses, fistulas, etc.

is turned toward the ligament, and it is transected near its attachment on the tibial tuberosity. If performed bilaterally, which is often the case, the horse will be unable to rest comfortably while standing. However, the ligament eventually heals, allowing the horse to use its normal locking mechanism again. The medial patellar desmotomy, if done correctly, does not invade the synovial capsule of the medial femorotibial joint.

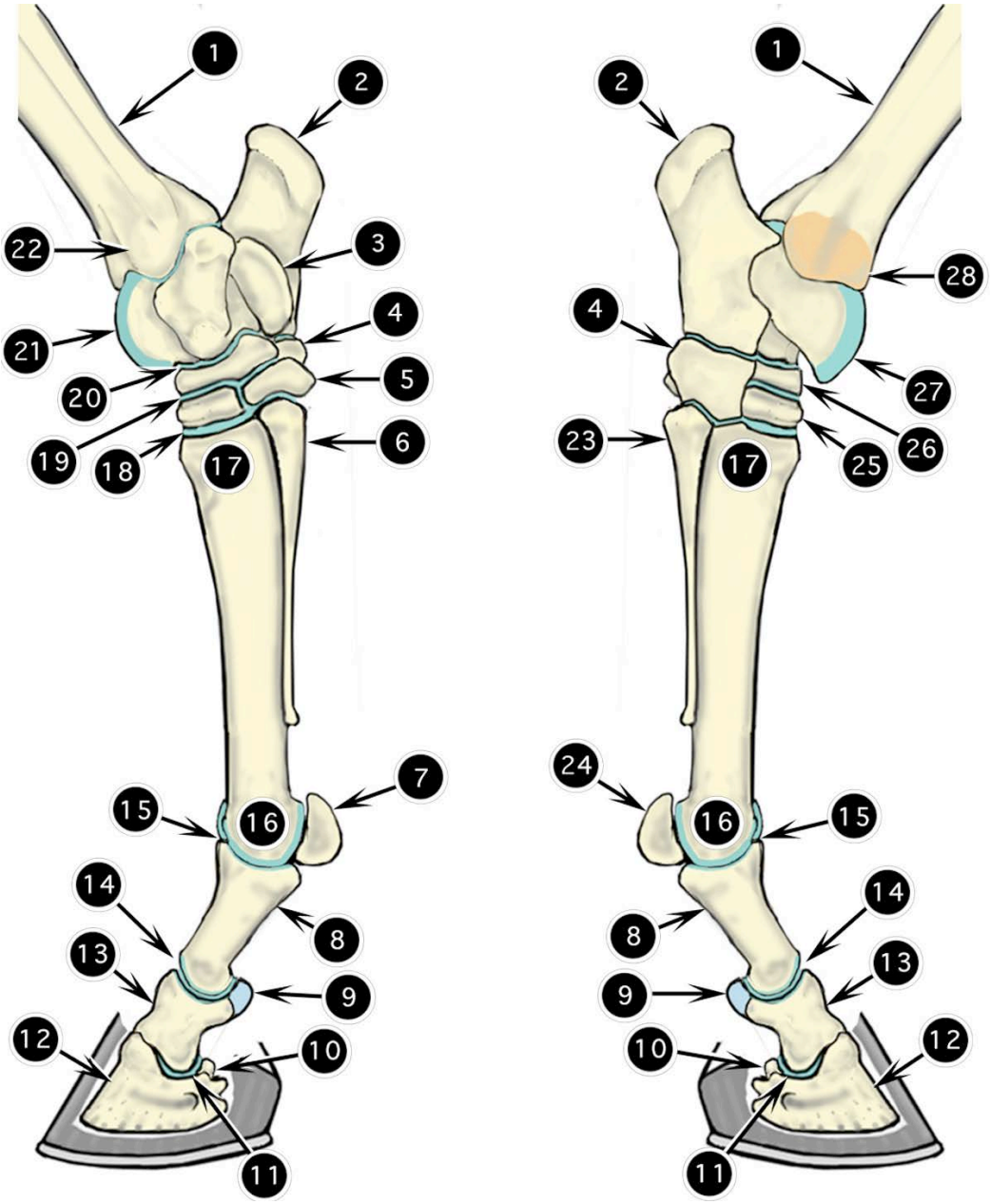


Figure 6-29. Equine pes, medial view (left), lateral view (right): (1) tibia; (2) tuber calcanei; (3) sustentaculum tali; (4) tarsal bone 4; (5) fused tarsal bones 1 & 2; (6) metatarsal bone 2; (7) medial proximal sesamoid bone; (8) proximal phalanx; (9) fibrocartilage of middle phalanx; (10) distal sesamoid bone; (11) distal interphalangeal joint; (12) distal phalanx; (13) middle phalanx; (14) proximal interphalangeal joint; (15) metatarsophalangeal joint; (16) head of metatarsal bone 3; (17) base of metatarsal bone 3; (18) tarsometatarsal joint; (19) distal intertarsal joint; (20) proximal intertarsal joint; (21) medial ridge of trochlea tali; (22) medial malleolus of tibia; (23) metatarsal bone 4; (24) lateral proximal sesamoid bone; (25) tarsal bone 3; (26) central tarsal bone; (27) lateral ridge of trochlea tali; (28) lateral malleolus of fibula.

Vessels and Nerves of Distal Limb: Because designation of the vessels and nerves of the distal limb is based on knowledge of skeletal anatomy, let's review the bones that form the distal part of the pelvic limb skeleton (Fig. 6-29). Refer to the skeletal models and note that the cannon bone of the horse is Mt3, whereas the smaller medial and lateral splint bones represent Mt2 and Mt4, respectively. Unlike that of other domestic mammals, the **axis** of the equine limb passes down the center of Mt3 and digit 3. In other species, the axis of the limb passes between metatarsals and digits three and four (Fig. 6-30).

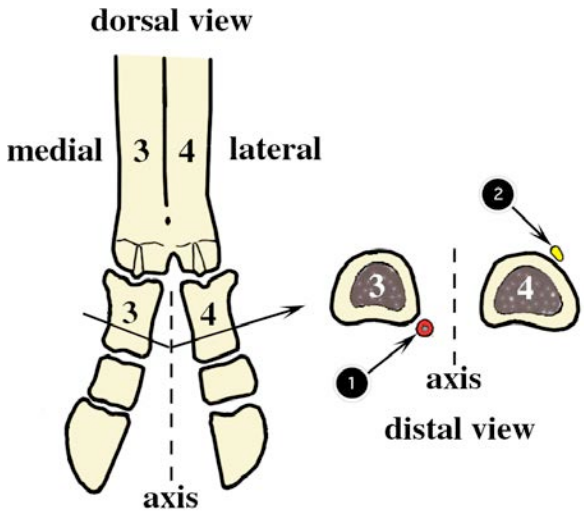


Figure 6-30. Schematic representation of skeletal anatomy of distal limb of ruminant: Those structures toward the axis are designated by the term axial; those away from the axis are termed abaxial. To name any proper digital vessel or nerve, one needs only to combine the terms that locate it: (1) axial plantar artery of digit 3; (2) abaxial dorsal nerve of digit 4.

The "cannon bone" of the ruminant is formed by the fused third and fourth metatarsal bones (Mt3+4). The small, discoid bone on the proximomedial plantar aspect of Mt3+4 is the **metatarsal sesamoid bone**, which is sometimes incorrectly referred to as a vestigial metatarsal bone. There are typically no remnants of the second and fifth metatarsal bones in the ruminant. Digits 2 and 5 are reduced to form the dewclaws, and all weight is supported by the principal digits (3 and 4).

The pig possesses Mt2 to Mt5 as separate bones, each associated with three phalanges. A small metatarsal sesamoid bone is associated with the proximoplantar aspect of Mt3 in the pig. Although skeletally complete, digits 2 and 5 are reduced to form the dewclaws, and all weight is supported by the principal digits (3 and 4).

Principal Arterial Channel: To this point, we have left the major artery of the limb at the femoral-popliteal junction, caudal to the stifle. We have noted that in the pig, a major continuation is the saphenous artery, but this is the exception and not the general rule for mammals. If you've done everything I've suggested on the detached limb, it's probably pretty well dissected by now. The attached limb should still be available, for dissection of the superficial vessels and nerves. The arteries that are to be followed and described are generally accompanied by a vein of the same name (Figs. 6-11 & 6-12).

Let's go back and pick up the principal arterial channel where we left it. After giving off the (distal) caudal femoral, the **popliteal artery** passes between the heads of the gastrocnemius, very close to the caudal aspect of the stifle joint (Fig. 6-13).

As it approaches the tibiofibular interspace, it gives rise to the smaller caudal tibial artery and continues between the tibia and fibula as the **cranial tibial artery** (Figs. 6-13 & 6-31). The latter emerges under protection of the craniolateral muscles of the leg and continues (out of harm's way) along the cranial aspect of the tibia, along with the deep peroneal nerve.

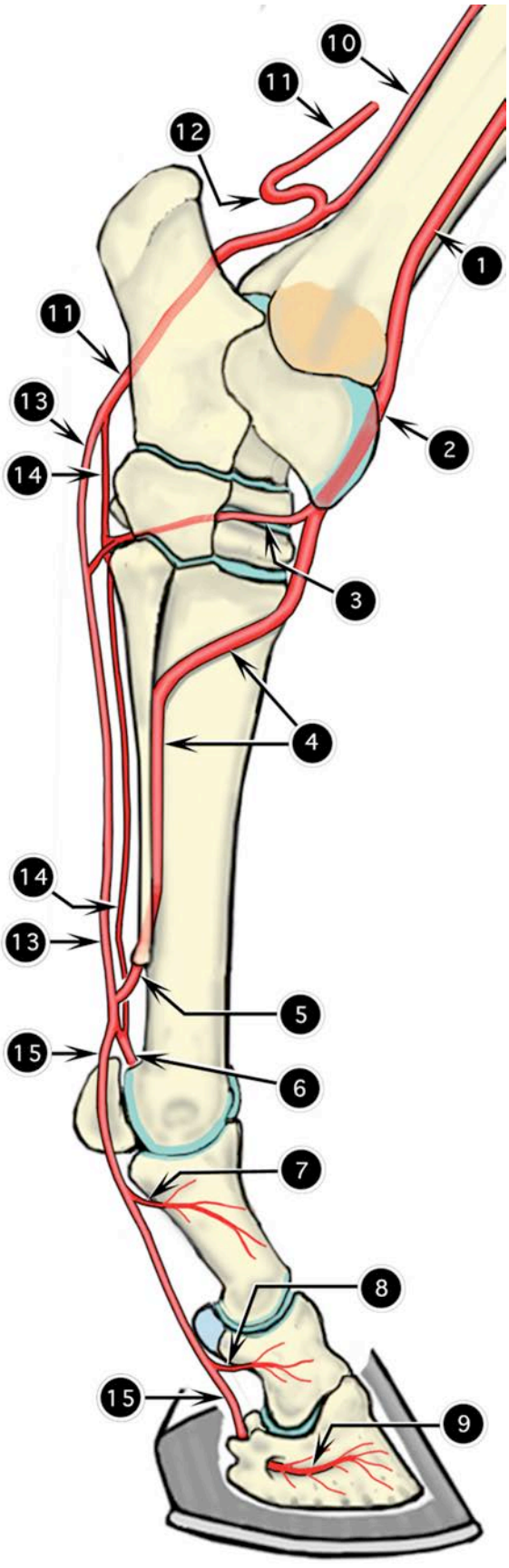


Figure 6-31. Arteries of distal limb of horse, lateral view: (1) cranial tibial artery; (2) dorsal pedal artery; (3) perforating tarsal artery; (4) dorsal metatarsal artery 3; (5) distal perforating branch of 4; (6) medial digital artery; (7) dorsal branch of proximal phalanx; (8) dorsal branch of middle phalanx; (9) dorsal branch of distal phalanx; (10) caudal tibial artery; (11) saphenous artery; (12) S-shaped anastomosis between 10 & 11; (13) lateral plantar artery; (14) medial plantar artery; (15) lateral digital artery.

As the artery crosses the tarsocrural joint, it is termed the **dorsal pedal artery**. As the dorsal pedal artery crosses the flexor surface of the tarsus, it gives rise to the **perforating tarsal artery**, which passes plantarly through the **tarsal canal**[24] accompanied by a vein and a branch of the deep peroneal nerve (Fig. 6-31).

The principal arterial channel continues distally as **dorsal metatarsal artery 3**. Although designation of the artery is the same in both the ruminants and horse, the course of the vessel varies with the relative development of the metatarsal bones. As would be expected, this vessel lies in the dorsal groove between Mt3 and Mt4. Because these fused bones are of about equal size in the ruminant, this groove is in a mid-dorsal position. However, in the horse, Mt3 is much larger than Mt4, so that the artery deviates plantarolaterally to reach this groove (Fig. 6-31).

Note that the dorsal metatarsal artery 3 of the horse passes obliquely across the proximolateral aspect of Mt3 in a relatively vulnerable location. Here it is largely unprotected and subject to traumatic injury. It would be more vulnerable except that it lies in an oblique groove that can be seen on

[24] It is really too bad that, somewhere along the line, this oblique passage between tarsal bones was designated the *tarsal canal*. Somebody used up a great term that could have been more effectively used to describe the *flexor canal* of the tarsus. Oh well, even anatomists goof occasionally.

the skeleton. *Using a common sense approach for your own safety, palpate the artery on the live horse, and feel the pulse at this location*.[25]

As Mt3 and Mt4 separate distally in the horse, dorsal metatarsal artery 3 passes between the bones as the **distal perforating branch**. It then receives the small plantar arteries and divides into the **medial and lateral digital arteries**, which are the principal arteries of the digit (Fig. 6-31).

In the ruminant, the distal perforating branch leaves dorsal metatarsal artery 3 and passes through a canal in the distal part of the metatarsus (see skeleton) to join the small plantar metatarsal arteries (Fig. 6-13). Dorsal metatarsal artery 3 passes between the digits as the **interdigital artery** to join the plantar common digital artery 3. From this union arise several branches, but the major vessels are the **axial plantar arteries of digits 3 and 4** (Figs. 6-13 & 6-30).

In the pig, dorsal metatarsal artery 3 is small, and the principal arterial channel is supplied by the continuation of the **saphenous artery**. The saphenous artery descends through the flexor canal of the tarsus, where it is primarily continued by the medial plantar artery. The medial plantar artery gives rise to the plantar common digital arteries, of which **plantar common digital artery 3** is the principal artery of the metatarsus. The latter divides into the **axial plantar arteries of digits 3 and 4**, which, as in the ruminant, are the major arteries of the digits.

Review of Nomenclature of Metapodial Vessels and Nerves: Memorization[26] of the names of the metapodial vessels and nerves is counterproductive. Knowledge of the nomenclature system is all that is necessary. This system is based on the following:

1. One must be able to differentiate between dorsal and plantar (palmar). Any problems here?

2. The deep vessels and nerves are designated as metatarsal or metacarpal; the superficial ones are called the common digitals. When determining whether a vessel or nerve is deep or superficial, consider the more proximal parent trunk, *i.e.*, did the parent trunk cross the tarsus [or carpus] in a superficial or deep position?

3. One must be able to differentiate among veins, arteries, and nerves (usually not a problem).

4. One must know which metatarsal (metacarpal) bones are present in the species and how the vessel (nerve) relates to these numbered bones. The human hand (which we usually have with us) can be used as a "handy" reference. As you should note, there are four interdigital spaces between the five digits. These are numbered 1 to 4, from medial to lateral. The vessel and nerve numbers correspond to these spaces.

Any vessel or nerve can be named simply by answering several questions about it and by arranging the answers to compose the name. It's just a matter of problem solving.

[25] Smallwood's First Law of Horses and Motorcycles: A horse is a lot like a motorcycle. When you first start out with one, you're pretty careful, but the more you're around them, the more comfortable and careless you become, and the more chances you take. No matter how confident you feel, *both can still kill you in the blink of an eye*.

[26] memorization- *to learn by heart*; even first-year veterinary students know that learning is not a reasonable function for the myocardium. Please feel free to use your cerebral cortex here.

Question 1: Is it dorsal or plantar (palmar)?
Answer 1: **dorsal**

Question 2: Is it deep or superficial?
Answer 2: deep = **metatarsal**.

Question 3: Is it an artery, vein, or nerve?
Answer 3: **artery**

Question 4: What is its relative location?
Answer 4: between Mt3 and Mt4 = **3**

Then it must be **dorsal metatarsal artery 3**.

Specific knowledge about the nerves of the distal limb is more clinically important in the horse, because specific branches are blocked in the diagnosis of lameness. Therefore, the nerves of the horse should be carefully followed and observed by all members of the group. Those of the other species should be followed only as time permits, after the equine pattern has been observed and understood.

Superficial Peroneal Nerve: This nerve has already been described in the horse, as it innervated the lateral digital extensor and descended caudal to the intermuscular septum between the long and lateral digital extensors. It continues as a sensory branch to the skin to about the level of the fetlock (Figs. 6-9 & 6-32).

In the ruminant, the large superficial peroneal nerve (Fig. 6-8) divides and continues distally on either side of the cranial branch of the lateral saphenous vein. The lateral branch becomes dorsal common digital nerve 4, and the medial branch supplies dorsal common digital nerves 2 and 3. In the pig, both the superficial peroneal and saphenous nerves supply the dorsal common digital nerves.

Deep Peroneal Nerve: The deep peroneal nerve crosses the dorsum of the tarsus with the dorsal pedal artery, and gives off a small branch that accompanies the perforating tarsal artery (Fig. 6-32). Distal to the tarsus, the deep peroneal nerve of the horse divides into the **medial** and **lateral dorsal metatarsal nerves** (Fig. 6-32)). The lateral nerve accompanies dorsal metatarsal artery 3, whereas dorsal metatarsal nerve 2 takes a more gradual, oblique course across the dorsomedial aspect of Mt3. These nerves are intimately associated with the periosteum of Mt3, but careful inspection should yield results.

In the ruminant, the deep peroneal nerve accompanies the cranial tibial artery, which continues across the tarsus as the dorsal pedal artery and becomes dorsal metatarsal artery 3 (Fig. 6-13). The deep peroneal nerve becomes dorsal metatarsal nerve 3 and lies just medial to the artery in the dorsal groove of Mt3+4 (Fig. 6-8). At the level of the fetlock, a communicating branch is present between dorsal common digital nerve 3 (from the superficial peroneal nerve) and dorsal metatarsal nerve 3. In the pig, the deep peroneal nerve also continues as dorsal metatarsal nerve 3.

Innervation of the equine pelvic digit differs substantially in one respect from that present in the thoracic limb. In the thoracic limb there are no dorsal digital nerves, but in the pelvic limb there are. The medial and lateral dorsal metatarsal nerves (branches of the deep peroneal nerve) continue as the respective dorsal digital nerves (Fig. 6-32). These nerves must be considered when selectively blocking the nerves of the digit, because they supply the dorsal parts of the coronary and laminar corium (sensitive tissue within the hoof).

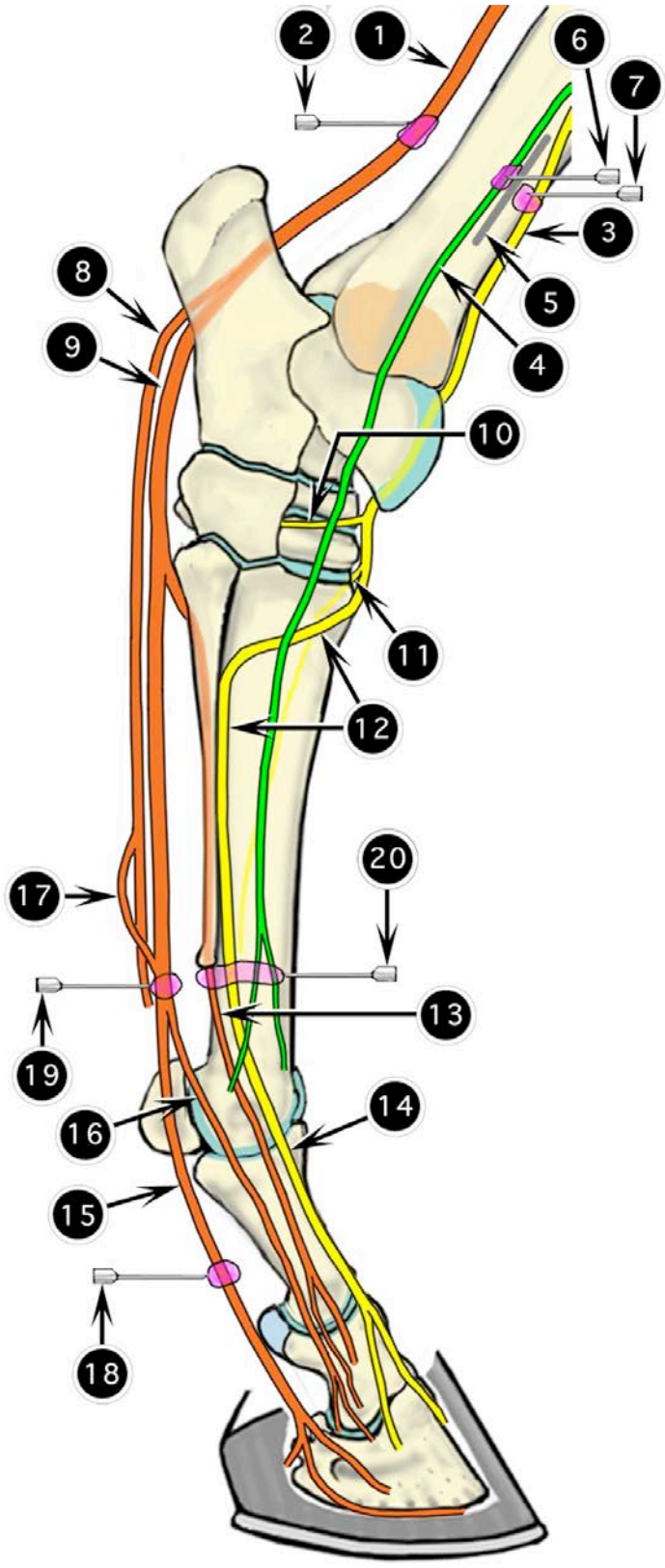


Figure 6-32. Nerves of distal limb of horse, lateral view: (1) tibial nerve; (2) injection site for blocking 1; (3) deep peroneal nerve; (4) superficial peroneal nerve; (5) intermuscular septum between long and lateral digital extensors; (6) injection site for blocking 4; (7) injection site for blocking 3; (8) medial plantar nerve; (9) lateral plantar nerve; (10) small branch of 3 that accompanies perforating tarsal artery; (11) medial dorsal metatarsal nerve; (12) lateral dorsal metatarsal nerve; (13) lateral plantar metatarsal nerve; (14) lateral dorsal digital nerve; (15) lateral plantar digital nerve; (16) dorsal branch of 15; (17) communicating branch between 8 & 9; (18) injection site for blocking 15; (19) injection site for blocking 9; (20) injection site for blocking 4, 13 &14; (21) deep branch of 9 that gives rise to plantar metatarsal nerves.

Medial and Lateral Plantar Nerves: The principal sensory branch of the tibial nerve was last noted as it "piggybacked" the deep digital flexor muscle toward the flexor canal of the tarsus (Fig. 6-32). It is accompanied here, in the distal crus, by the saphenous artery, and *the nerve can be easily palpated and blocked in the live horse*. The **tibial nerve** divides proximal to the flexor canal into the medial and lateral plantar nerves, which continue with the DDF tendons through the canal (Fig. 6-32). Just distal to the tarsus, the **lateral plantar nerve** gives off a **deep branch**. The latter provides innervation to the interosseus and is continued as the **medial and lateral plantar metatarsal nerves**, which course along the axial aspects of Mt2 and Mt4 until they emerge at the distal ends of these bones (Fig. 6-32).

Because they may supply sensitive tissue as far distally as the coronet of the hoof, these small nerves cannot be ignored when performing diagnostic blocks of the equine pelvic digit. Local anesthetic deposited in the fossae at the palpable distal ends of Mt2 and Mt4 should take care of them (Fig. 6-32). While you're in the neighborhood, inject additional anesthetic dorsally along the medial and lateral borders of Mt3, to block the dorsal digital nerves (Fig. 6-32).

The largest nerves in the equine metatarsus are the **medial and lateral plantar nerves**, which course distally alongside the deep digital flexor tendon and are continued as the **medial and lateral plantar digital nerves** (Fig. 6-32). The plantar digital nerves can also be blocked along side the DDF tendon, at the level of the palpable distal ends of Mt2 and Mt4, respectively. A block at this level should be proximal to the level at which they give off their dorsal branches. It should also be distal to the level of the **communicating branch** between the medial and lateral plantar nerves (Fig. 6-32). This communication, which courses obliquely in a distolateral direction across the SDF tendon, may be small (or occasionally absent). *Using a common sense approach, the communicating branch can typically be palpated in the live horse*. (In some horses, it is palpable in one limb but not the other.)

ANESTHESIA OF PELVIC LIMB

Diagnostic Nerve Blocks in Horse: Because a veterinarian's patients can't talk, we have to be a little smarter and a good deal more perceptive than our (nonpediatrician) physician counterparts. Our patients indicate to us that something's not quite right by limping, coughing, sneezing, having a drooping eyelid, and so forth. Our diagnostic challenge represents another of those problem-solving exercises. What we are trying to do with a diagnostic block is to localize the structure(s) that is hurting and causing the horse to be lame. The plan is to block out, selectively and sequentially, different parts of the limb in a lame horse until the horse no longer feels the pain and goes sound. It's kind of like looking for a marble concealed in a loaf of bread- we start at the distal end and try to turn the slices one by one until we find that marble.[27]

Following this protocol, we begin distally, blocking out areas of the limb supplied by specific nerves and testing the result after each block. We want to be as selective as possible so that, if and when the horse goes from lame to sound, we can have better (more specific) localization of the source of the pain. Consequently, we may begin by blocking only the plantar digital nerves, alongside the DDF tendon, in the pastern (Fig. 6-32). At this point, the horse should be insensitive to test pricking over the bulbs of the heel. If the horse goes sound, we have localized the problem to the sole area and/or plantar part of the foot.[28] If the horse is still lame, we could continue the search by blocking at the level of the distal ends of the splint bones, which include the dorsal branches of the plantar digital nerves, the plantar metatarsal nerves, and the dorsal digital nerves (Fig. 6-32)

[27] For purposes of this discussion, the distal end of a loaf of bread is the slice at the bottom of the bag *(i.e.,* the heel most distant from the tied end).

[28] We define the equine foot as the epidermal hoof and all structures contained therein. Except for the basal germinal layer of epidermis, the hoof is essentially a thick stratum corneum and is insensitive, because it has no nerve endings.

At this point, the horse should have no sensitivity anywhere around the coronet.[29] If the horse goes sound, we have then localized the pain source as the middle and more dorsal parts of the foot or pastern region. Less frequently, higher blocks proximal to the tarsus, such as the superficial and deep peroneal nerves and the tibial nerve can be used if the horse is still lame. Obviously, this can become a rather time-consuming (and expensive) procedure that should not be initiated until a thorough physical examination (and, in some cases, radiography) have failed to yield any positive findings that could account for the lameness.

The clinical importance of the **communicating branch** between plantar nerves is this. If the lateral plantar nerve were blocked proximal to the level at which the branch joined that nerve, and the medial nerve were blocked at the same level, but distal to the point at which the communicating branch left it, then we have an open pathway remaining. Afferent fibers originating from the lateral part of the digit could avoid both blocks and confuse interpretation of the results.

Although the nerves of the metatarsus can be selectively blocked in the non-equine species, this is usually done for surgical anesthesia rather than for lameness diagnosis. The object of surgical anesthesia is complete desensitization of the region, not a selective, sequential desensitization, which is the aim of diagnostic blocks.

Intravenous Limb Anesthesia in Cattle: Specific nerve blocks, or "ring blocks", have been largely replaced in cattle (ruminants) by this more recently developed technique. (This is one reason why students should not spend a great deal of time studying these nerves, but should concentrate on those of the horse.) Local, intravenous anesthesia of the distal limb can be accomplished by the following: (1) applying a rubber tubing tourniquet (over a protective pad) distal to the tarsus or carpus; (2) selecting a superficial vein, such as a dorsal common digital vein (Fig. 6-12); and (3) after proper preparation, intravenous injection of a local anesthetic. Anesthesia of the distal limb should be complete in about 5 minutes and persist for about an hour, if the tourniquet remains secure. After surgery, the tourniquet is slowly released over about a 10-second period (you don't want a "big bolus" of lidocaine arriving back at the heart).

Interdigital Sinus of Sheep: In the sheep, these sinuses are found in all four limbs. Each consists of a deep, curved recess that opens dorsally and receives the secretions of sebaceous and apocrine glands. The secretion is apparently released as the animal walks, and the scent is believed to mark the trail or territory of the individual. These sinuses are also present in the pelvic limbs of some deer and are also thought to function as part of the spoor[30] of the species.

Radiographic Anatomy of Hip and Stifle in Horse: Because most pelvic-limb lameness can be traced to other parts of the limb, radiography of the hip region is not commonly performed, even in the horse. When necessary, however, the horse must be anesthetized and typically placed in dorsal recumbency for ventrodorsal and oblique radiographs of the coxal joint and associated pelvic structures (Fig. 6-33). Radiography

[29] coronet- the junction of hair and hoof. Although sometimes called the *coronary band*, in reality there is no such anatomic structure as the coronary band (more on this with dissection of the foot of the forelimb).

[30] spoor- the track or trail of an animal, especially wild animals hunted as game.

of the equine stifle joint is performed more frequently, and satisfactory films can sometimes be obtained in a cooperative (sedated) patient without general anesthesia (Figs. 6-34, 6-35, & 6-37).

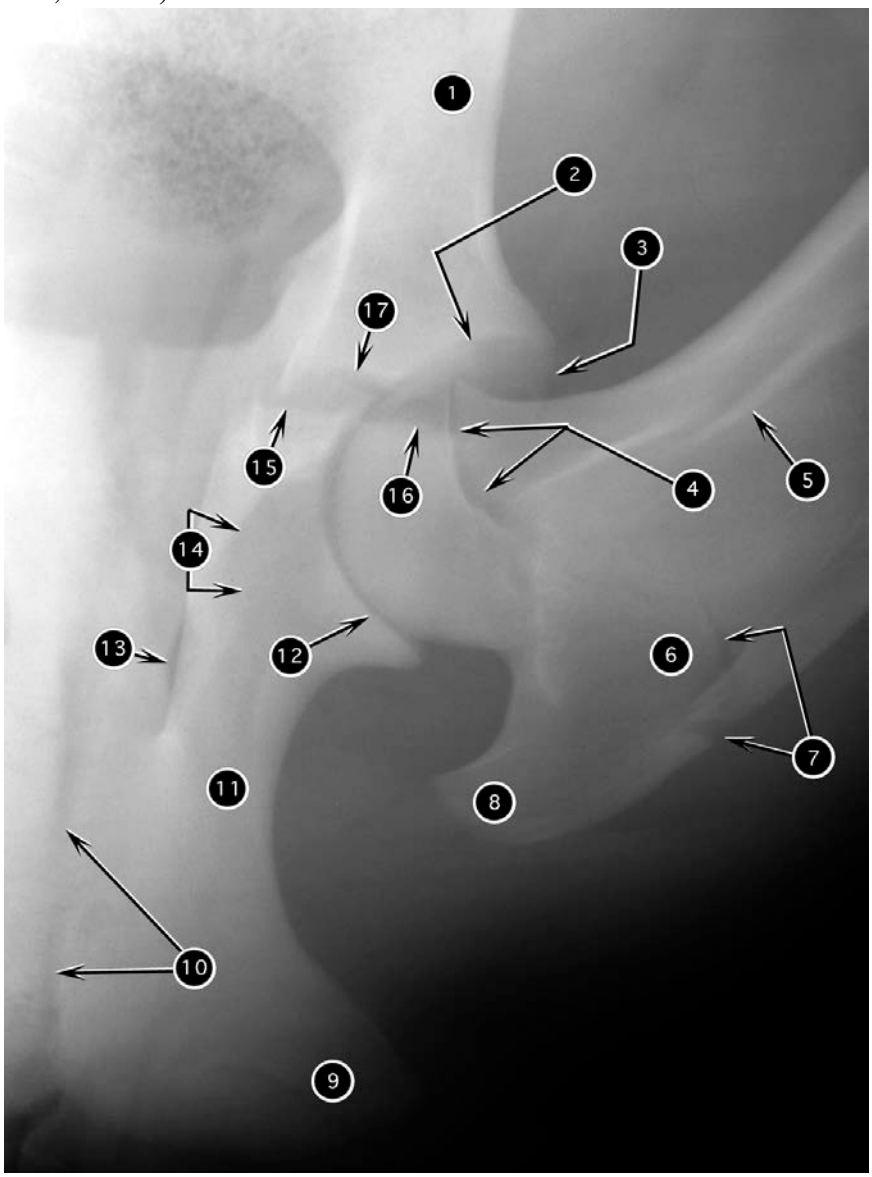


Figure 6-33. Ventromedial-dorsolateral Oblique (VM-DLO) radiograph of hip joint of 8-month-old horse: (1) body of ilium; (2) cranioventral border of acetabulum; (3) craniodorsal border of acetabulum; (4) proximal physis (epiphyseal cartilage) of femur; (5) shadow created by caudal edge of lesser trochanter; (6) radiolucent area created by trochanteric fossa of femur; (7) cartilaginous junction between greater trochanter and femoral body; (8) greater trochanter of femur, caudal part; (9) tuber ischiadicum; (10) cartilaginous pelvic symphysis; (11) body of ischium; (12) caudoventral border of acetabulum; (13) obturator foramen; (14) radiolucent area created by acetabular fossa; (15) radiolucent area created by groove on ventral surface of pubis for accessory ligament of femoral head; (16) radiolucent area created by fovea capitis of femoral head; (17) cranial edge of acetabular notch.

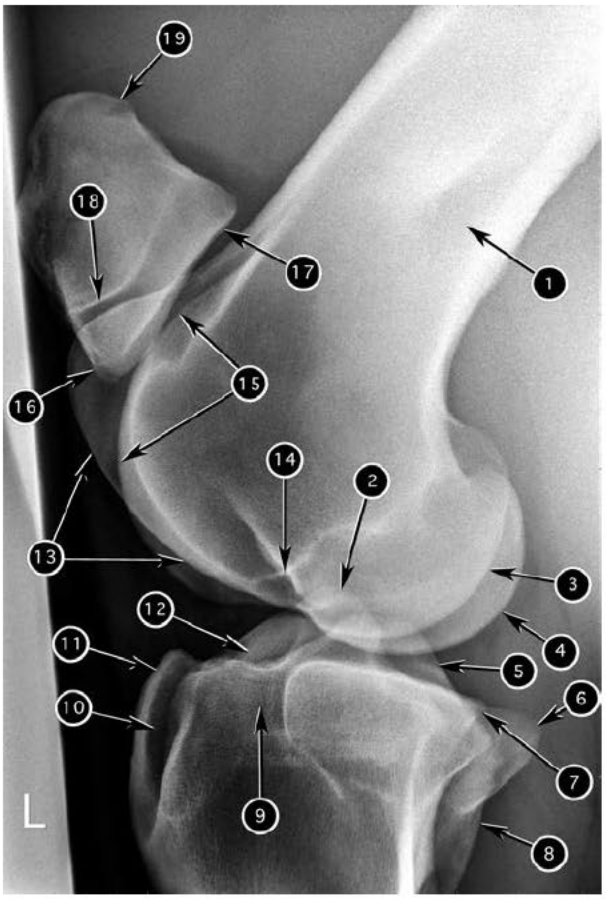


Figure 6-34. Mediolateral (ML) radiograph of equine stifle joint: (1) supracondylar fossa of femur for origin of SDF; (2) medial tubercle of intercondylar eminence; (3) lateral condyle of femur; (4) medial condyle of femur; (5) lateral tubercle of intercondylar eminence; (6) lateral condyle of tibia; (7) medial condyle of tibia; (8) fibula; (9) extensor groove of tibia; (10) groove for intermediate patellar ligament; (11) lateral part of tibial tuberosity; (12) cranial intercondylar area; (13) medial ridge of femoral trochlea; (14) extensor fossa of femur for origin of long digital extensor & peroneus tertius; (15) lateral ridge of femoral trochlea; (16) apex of patella; (17) articular surface of patella, gliding part; (18) articular surface of patella, resting part; (19) base of patella.

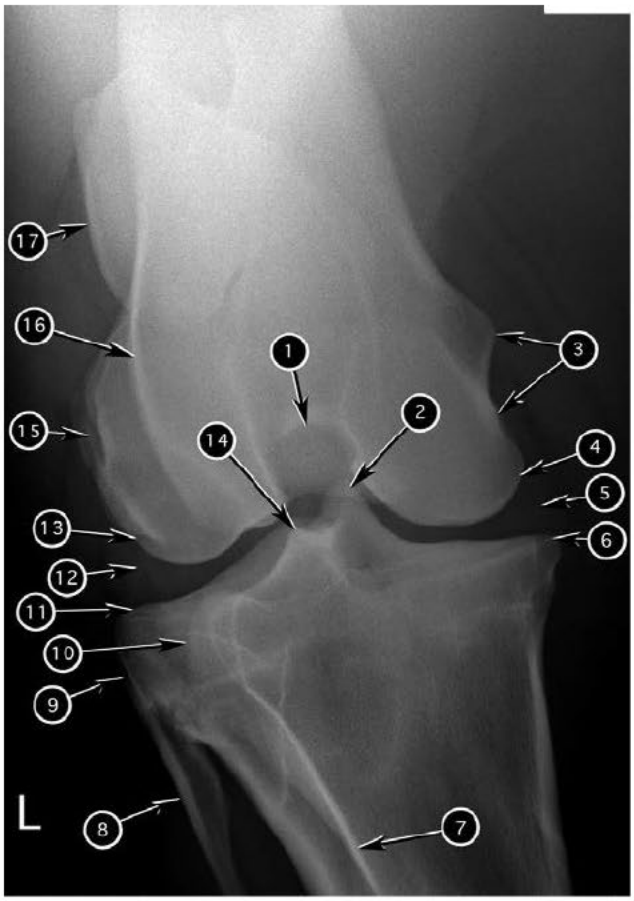


Figure 6-35. Caudocranial (CdCr) radiograph of equine stifle joint: (1) intercondylar fossa of femur; (2) medial tubercle of intercondylar eminence; (3) medial epicondyle of femur; (4) medial condyle of femur; (5) medial meniscus & femorotibial joint; (6) medial condyle of tibia; (7) cranial margin of tibia; (8) body of fibula; (9) head of fibula; (10) lateral part of tibial tuberosity; (11) lateral condyle of tibia; (12) lateral meniscus & femorotibial joint; (13) depression for origin of popliteus muscle; (14) lateral tubercle of intercondylar eminence; (15) lateral epicondyle of femur; (16) lateral ridge of femoral trochlea; (17) patella.

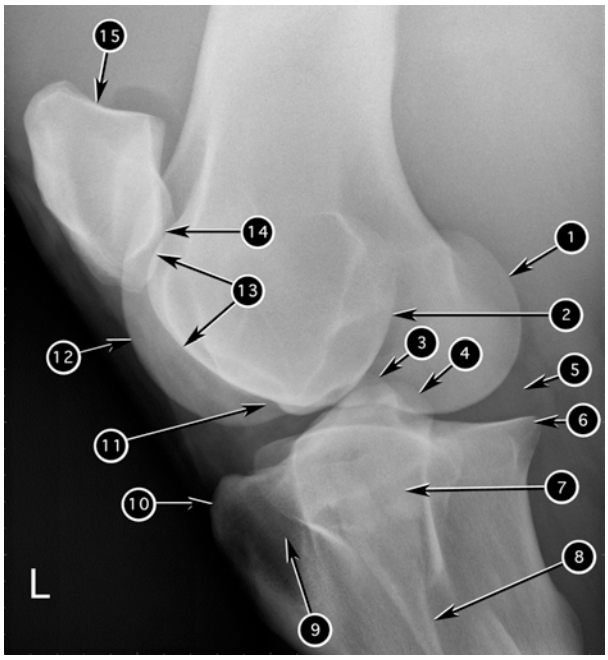


Figure 6-36. Caudolateral-Craniomedial Oblique (Cd-CrO) radiograph of equine stifle joint: (1) medial condyle of femur; (2) lateral condyle of femur; (3) medial tubercle of intercondylar eminence; (4) lateral tubercle of intercondylar eminence; (5) medial meniscus & femorotibial joint; (6) medial condyle of tibia; (7) head of fibula; (8) body of fibula; (9) extensor groove of tibia; (10) tibial tuberosity; (11) extensor fossa of femur; (12) lateral ridge of femoral trochlea; (13) groove of femoral trochlea; (14) femoropatellar joint; (15) patella.

Although radiographed infrequently, I have included a ventrodorsal (VD) radiograph of a bovine pelvis (Fig. 6-38) for reference only.

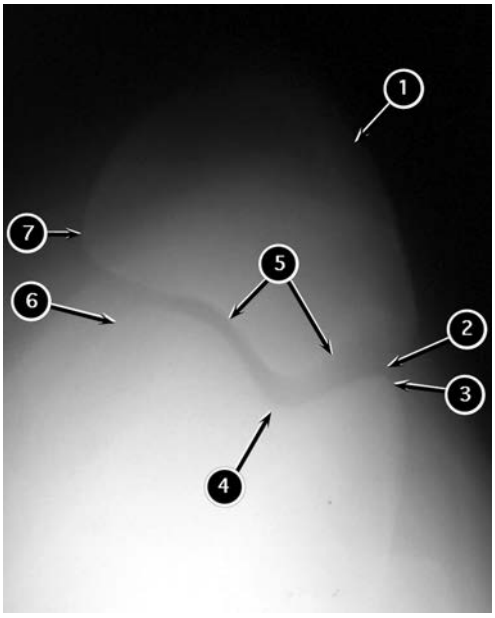


Figure 6-37. Cranioproximal-Craniodistal Oblique (CrPr-CrDiO) radiograph of equine stifle joint: (1) cranial surface of patella; (2) femoropatellar joint; (3) lateral ridge of femoral trochlea; (4) groove of femoral trochlea; (5) articular surface of patella; (6) medial ridge of femoral trochlea; (7) osseous part of cartilaginous process of patella, continued by parapatellar fibrocartilage.

Palpation Checklist for Pelvic Limb

Horse

1. Tuber sacrale
2. Tuber ischiadicum
3. Greater trochanter
4. Third trochanter
5. Tuber coxae
6. Tibial tuberosity
7. Patellar ligaments
8. Patella
9. Head of fibula
10. Common peroneal nerve as it crosses fibula
11. Dorsal pouch of the tarsocrural joint
12. Medial and lateral malleoli

13. Intermuscular septum between long and lateral digital extensors
14. Tendon of lateral digital extensor in crus and in metatarsus
15. Medial tendon of cranial tibial muscle (cunean tendon)
16. Tibial nerve in distal part of crus, with saphenous artery
17. Dorsal metatarsal artery 3 in proximal metatarsus
18. Distal ends of metatarsal bones 2 and 4
19. Communicating branch between medial and lateral plantar nerves (if possible)

Ox

1. Tuber sacrale
2. Tuber ischiadicum
3. Greater trochanter
4. Sacrotuberous ligament
5. Tuber coxae
6. Tibial tuberosity
7. Patella
8. Medial and lateral malleoli
9. Dorsal pouch of the tarsocrural joint

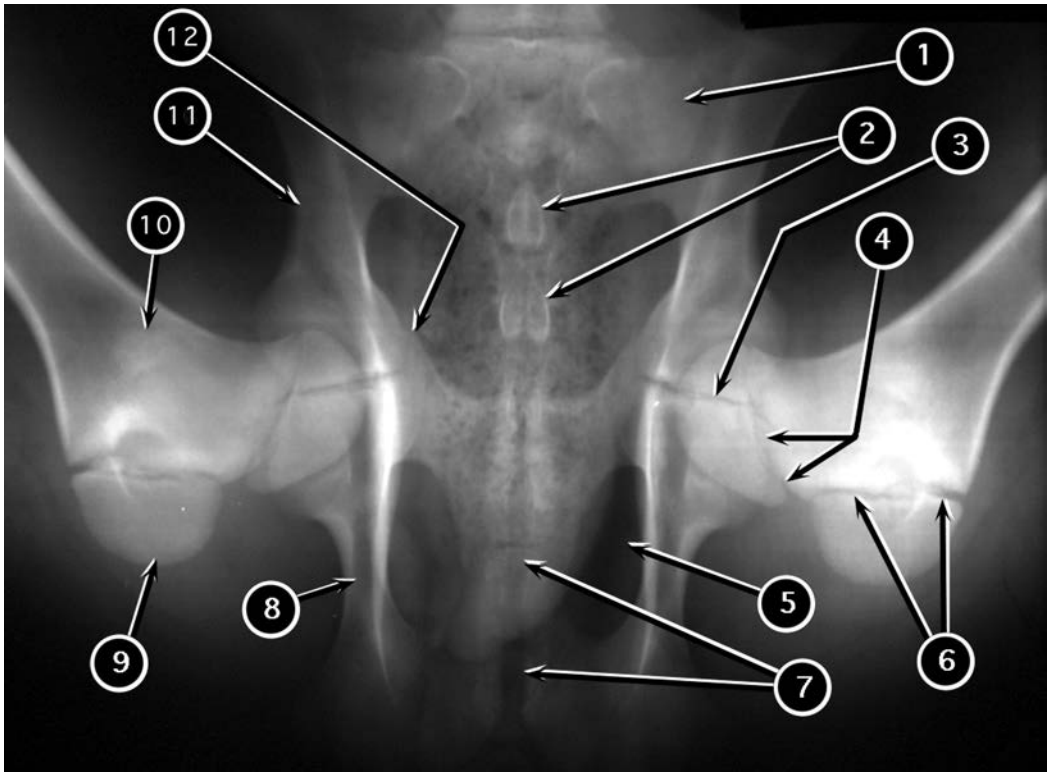


Figure 6-38. Ventrodorsal (VD) radiograph of pelvis of Holstein calf: (1) wing of sacrum; (2) spinous processes of sacral vertebrae; (3) cartilaginous junction between ilium & ischium; (4) proximal physis (epiphyseal cartilage) of femur; (5) obturator foramen; (6) cartilaginous junction between greater trochanter & body of femur; (7) cartilaginous pelvic symphysis; (8) body of ischium; (9) greater trochanter of femur; (10) lesser trochanter of femur; (11) body of ilium; (12) cranial ramus of pubis near iliopubic eminence.

Chapter 7 • The Tarsus

Because of the anatomic complexity and clinical importance of the tarsus, especially in the horse, we are discussing this region in its own chapter. One of the most important ways veterinarians look at the tarsus of the horse, and much less frequently that of the ruminant, is by radiographic examination. Therefore, much of the information contained in this chapter is presented in that form. Don't worry- you are not expected to learn all the details included in the figure legends. Much of this information is included here only for future reference, if needed. Those terms that are of special significance are indicated in **bold print**. Although the tarsus is certainly more than bones, the first step is to review the skeletal anatomy on the models and then to use these models as the radiographic anatomy is reviewed.

SKELETAL ANATOMY

Fusion of individual tarsal bones varies with the species. Review the skeletal models and note which bones are fused in each species (Table 7-1). Note that there is no fusion in the pig. Also, review the radiographic anatomy of the equine tarsus as presented in this chapter. The radiographs of the bovine tarsus are included for reference only.

Tarsal Joint Capsules: In the horse and ruminant, the **tarsocrural and proximal intertarsal joints** communicate. This information is important for two reasons. First, an infection (inflammation) of one joint automatically involves the other, because synovial fluid can flow back and forth between the two joints. Second, an injection in one joint would, infuse both, so that separate injections would not be necessary. There is apparently no such communication between these two joints in the pig.

Most veterinary anatomy textbooks either state or imply that there are no communications between the other tarsal joints of the horse. Oddly enough, this is how most veterinary anatomists have taught it for years. In 1979, a clinician reported that the two distal joints of the equine tarsus communicated in most, if not all, horses. This stimulated another investigation of these joints, the results of which were published in 1981.[1] The latter study indicated that these communications were most often created by the injection process, and that the two joints should be injected individually.

In the pig, the tarsometatarsal complex consists of two separate joint capsules, one proximal to Mt2 and Mt3 and another to Mt4 and Mt5. The distal intertarsal capsule communicates with the former, but not with the latter.

DISSECTION OF TARSUS

If appropriate demonstration specimens are available, dissection of these joints need not be destructive. *Open the dorsal pouch of the tarsocrural joint,* and observe the normal **synovial villi and/or folds**. Although these structures can enlarge to a pathologic state in arthritic animals, the presence of small villi and folds is normal.

[1] Sack, W. O. and Orsini, P. G. Distal intertarsal and tarsometatarsal joints in the horse: Communication and injection sites. JAVMA 179 (1981): 355-359.

Table 7-1. Comparative tarsal bone fusion in domestic ungulates

Horse	Ruminant	Pig
Talus	Talus*	Talus*
Calcaneus	Calcaneus	Calcaneus
Tc	Tc + T4†	Tc
T1+2	T1	T1
	T2 +3†	T2
T3		T3
T4		T4

* The talus of artiodactyls has both a proximal and distal trochlea tali.
† Fusion of these bones is characteristic of ruminants.

Tarsal hydrarthrosis (bog spavin)[2] is a distention of the tarsocrural joint capsule by excessive accumulation of synovium (Fig. 7-1). This swelling is usually most evident in the dorsal pouch, but enlargement of the plantarolateral and/or plantaromedial pouches may also be observed (Figs. 6-20, 7-2 & 7-3).

"Blood spavin" is a poorly defined term used to describe enlargement of the cranial branch of the medial saphenous vein in the vicinity of a distended dorsal pouch. The mysterious "occult, or blind, spavin" is used to describe a lameness, thought to originate in the tarsus, but without any definable physical or radiographic lesions. (This probably means that the lameness was produced by a problem in some other part of the limb, which had not been identified when this "pseudodiagnosis" was rendered).

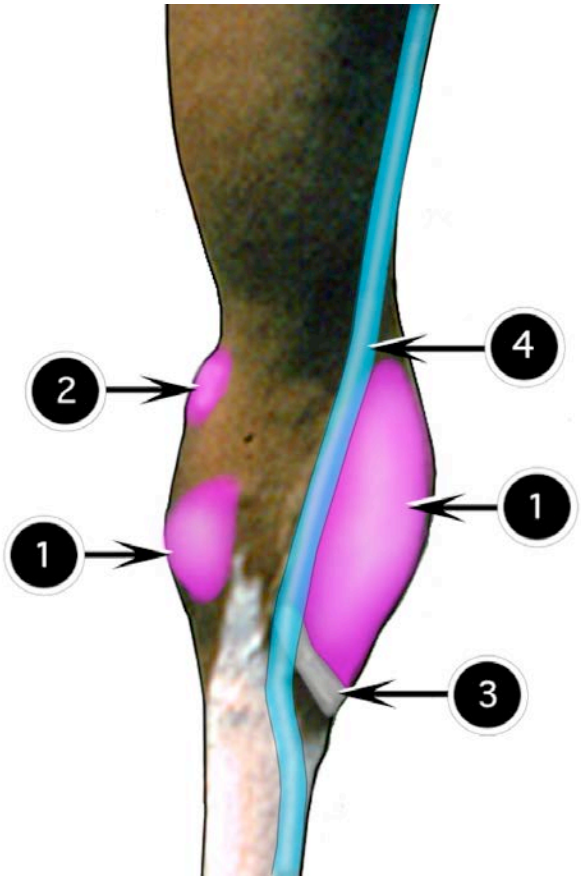


Figure 7-1. Right tarsus of horse with tarsal hydrarthrosis ("bog spavin"), dorsal view with selected structures indicated: (1) distended dorsal pouch of tarsocrural joint; (2) distended plantarolateral pouch of tarsocrural joint; (3) medial tendon of cranial tibial muscle ("cunean tendon"); (4) cranial branch of medial saphenous vein.

[2] The term *spavin* is a non-descriptive horseperson's name for almost any disorder of the equine hock. It may be modified by other, equally vague, adjectives (bone spavin, bog spavin, blood spavin, occult spavin, and jack spavin).

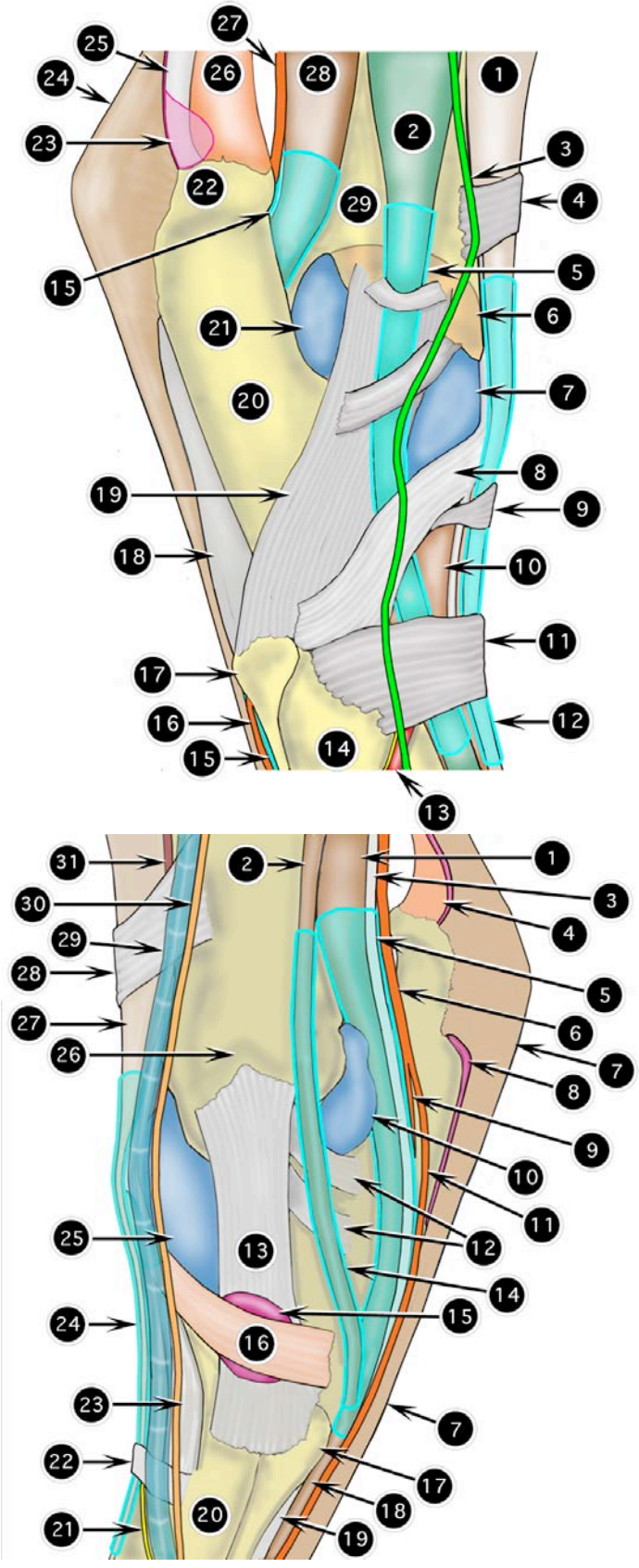


Figure 7-2. Tarsus of horse, lateral view: (1) long digital extensor muscle; (2) lateral digital extensor muscle; (3) superficial peroneal nerve; (4) proximal extensor retinaculum; (5) tendon sheath of 2; (6) lateral malleolus of fibula; (7) dorsal pouch of tarsocrural joint; (8) lateral tendon of peroneus tertius; (9) middle extensor retinaculum; (10) short digital extensor muscle; (11) distal extensor retinaculum; (12) tendon sheath of 1; (13) dorsal metatarsal artery & nerve 3; (14) metatarsal bone 3; (15) tarsal sheath; (16) lateral plantar nerve, from 27; (17) base of metatarsal bone 4; (18) long plantar ligament; (19) long part of lateral collateral ligament of tarsus; (20) body of calcaneus; (21) plantarolateral pouch of tarsocrural joint; (22) tuber calcanei; (23) subtendinous calcaneal bursa; (24) superficial digital flexor tendon; (25) tarsal tendons of biceps femoris & semitendinosus; (26) tendon of gastrocnemius; (27) tibial nerve; (28) lateral head of deep digital flexor muscle; (29) tibia.

Figure 7-3. Tarsus of horse, medial view: (1) lateral head of deep digital flexor muscle; (2) medial head of deep digital flexor muscle; (3) caudal tibial head of deep digital flexor muscle; (4) gastrocnemius tendon; (5) tarsal sheath surrounding 1 & 3 through flexor canal of tarsus; (6) tibial nerve; (7) superficial digital flexor tendon; (8) subtendinous calcaneal bursa; (9) lateral plantar nerve; (10) plantarolmedial pouch of tarsocrural joint; (11) medial plantar nerve; (12) short parts of medial collateral ligament of tarsus; (13) long part of medial collateral ligament of tarsus; (14) tendon sheath of 2; (15) bursa of medial tendon of cranial tibial; (16) medial tendon of cranial tibial muscle; (17) base of metatarsal bone 2; (18) deep digital flexor tendon; (19) interosseus 3; (20) metatarsal bone 3; (21) dorsal metatarsal nerve 2, from deep peroneal nerve; (22) distal extensor retinaculum of tarsus; (23) dorsal tendon of peroneus tertius; (24) tendon sheath of long digital extensor; (25) dorsal pouch of tarsocrural joint; (26) medial malleolus of tibia; (27) long digital extensor muscle; (28) proximal extensor retinaculum of tarsus; (29) cranial branch of medial saphenous vein; (30) saphenous nerve, from femoral nerve; (31) cranial tibial muscle.

When you have become familiar with the major bones and articulations of the tarsus, the major ligaments can be studied on demonstration specimens (Figs. 7-4 & 7-5). As you can see, there is a rather complex interconnection of the tarsal components. Both **medial and lateral collateral ligaments** have **long and short parts** that extend across one or more joints.

The complex arrangement and strength of the collateral and other intertarsal ligaments ensures that the tarsus is limited to flexion and extension, with minimal to no medial to lateral deviation during weight-bearing. In the horse, all of the flexion occurs at the tarsocrural joint, with only minimal displacement of the other joints. There is some "give" allowed by the intertarsal ligaments so that there is a little spreading of the more distal tarsal bones during loading of the tarsus. This slight displacement of perhaps a mm or less functions to absorb the extreme compressive forces the tarsus is subjected to, especially at faster gaits. More on this later.

Note the **long plantar ligament**, which extends along the plantarolateral aspect of the calcaneus and anchors it distally to Mt4 (Fig. 7-4). Horses derive much of their forward drive during locomotion from the powerful extension of their pelvic limbs. During propulsion of the body, there is obviously tremendous strain applied to the osseous lever formed by the calcaneus. If it were not firmly attached, it would be pulled loose by the powerful contraction of the gastrocnemius and other muscles that extend the tarsus.

Part of this traction is offset by the deep digital flexor tendons, which passes over the sustentaculum tali, but laterally the long plantar ligament helps anchor it distally. Sometimes horses tear their long plantar ligament, and the inflamed ligament thickens (desmitis), which produces a curve or convexity over the plantarolateral aspect of the tarsometatarsal region. This condition is commonly referred to as **curb** (Fig. 7-6).

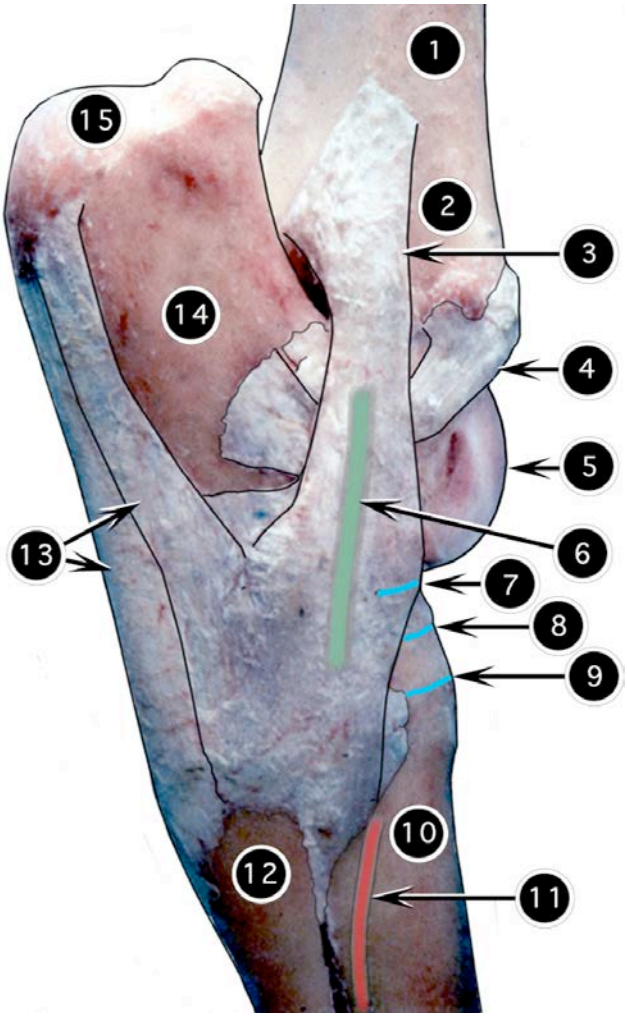


Figure 7-4. Ligaments of equine tarsus, lateral view: (1) tibia; (2) lateral malleolus of fibula; (3) long part of lateral collateral ligament; (4) short part of lateral collateral ligament; (5) lateral ridge of trochlea tali; (6) groove in 3 for lateral digital extensor tendon; (7) level of proximal intertarsal joint; (8) level of distal intertarsal joint; (9) level of tarsometatarsal joint; (10) metatarsal bone 3; (11) groove in 10 for dorsal metatarsal artery 3; (12) base of metatarsal bone 4; (13) long plantar ligament; (14) body of calcaneus; (15) tuber calcanei.

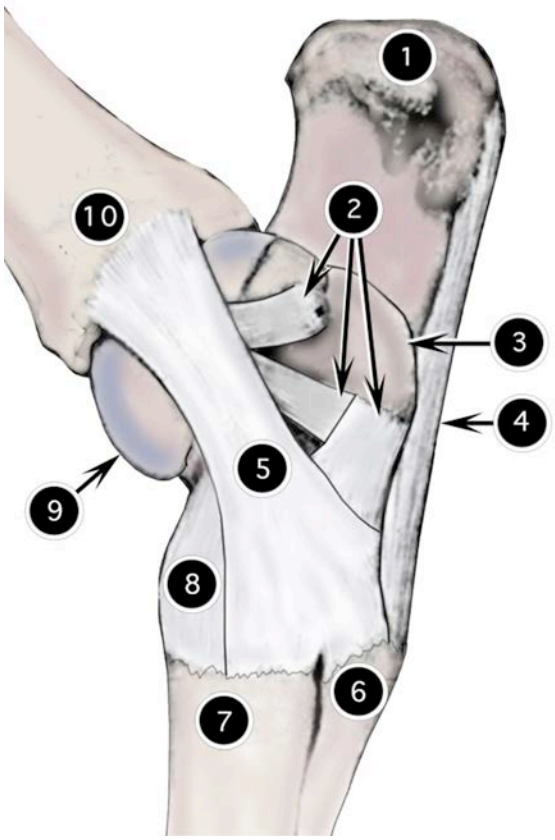


Figure 7-5. Ligaments of equine tarsus, medial view: (1) tuber calcanei; (2) short parts of medial collateral ligament; (3) sustentaculum tali; (4) long plantar ligament; (5) long part of medial collateral ligament; (6) base of metatarsal bone 2; (7) metatarsal bone 3; (8) fibrous capsule of intertarsal & tarsometatarsal joints (dorsal tarsal ligament); (9) medial ridge of trochlea tali; (10) medial malleolus of tibia. (Modified from *The Anatomy of Domestic Animals*, 4th Ed., Sisson and Grossman, W. B. Saunders Co., 1953, p. 242.)

Horses that are sickle-hocked or cow-hocked are thought to be predisposed to this condition, which is probably related to the increased and uneven pressures applied to the calcaneus with these types of conformation. It also makes sense that horses pulling against a load are more likely to tear this ligament. As the powerful extensor muscles strain against the calcaneus of a limb that is not free to move caudally because of the added resistance of the load, greater stress is placed on the calcaneus and its distal attachments- the long plantar ligament.

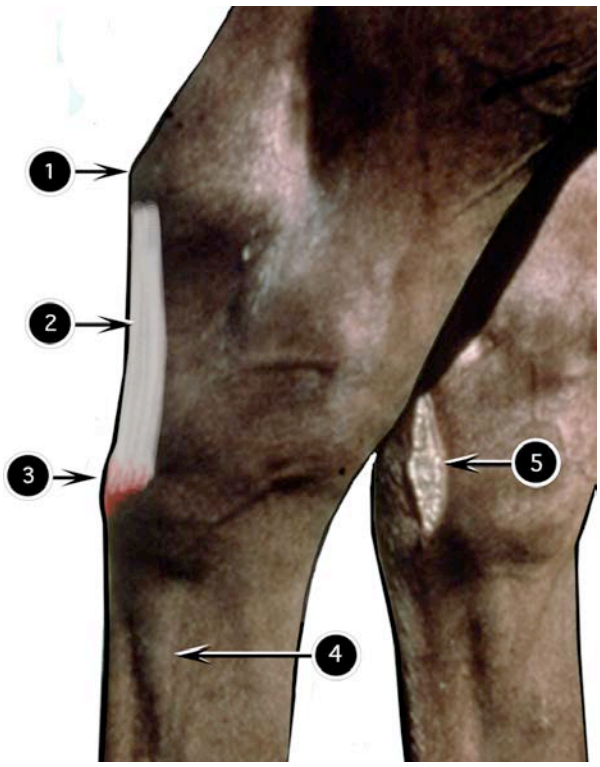


Figure 7-6. Horse with tearing of long plantar ligament at distal attachment to Mt 4, lateral view: (1) tuber calcanei; (2) long plantar ligament; (3) tearing & inflammation of 2 (clinical condition known as long plantar desmitis or "curb"); (4) metatarsal bone 4; (5) chestnut.

Complex Synovial Joints - Pouch Versus Sac: There is a difference between what is meant by a sac and a pouch of a synovial joint. Sac denotes the potential for separation (*i.e.*, the femoropatellar sac may not communicate with the lateral femorotibial sac in the horse). Pouch doesn't imply anything other than a part of the joint that is likely to enlarge when the joint becomes distended. Pouches represent areas of the synovial capsule that are not covered by such substantial structures as ligaments or tendons. In other words, a pouch is where the joint can "pooch out."

The **tarsocrural joint** represents the major area of flexion and extension in the

tarsus- less so in the artiodactyls, exclusively in the horse. When this important joint becomes inflamed, it swells- that is, the rate of synovial fluid production is greater than the rate of its resorption, which results in the accumulation of fluid. This distention is obvious to the observer in those areas of the joint that are not confined by strong ligamentous or tendinous structures. This translates to three areas.

The largest of these is the **dorsal pouch**, which is bounded distomedially by the medial cranial tibial (cunean) tendon and laterally by that of the long digital extensor (Figs. 6-20, 7-2 & 7-3). This explains why distention of the joint capsule in cases of tarsal hydrarthrosis (bog spavin) is most obvious dorsomedially (Fig. 7-1). Two other areas of this joint are also subject to distention, the **plantaromedial and plantarolateral pouches**, which represent those parts of the capsule immediately plantar to the collateral ligaments, medially and laterally, respectively (Figs. 7-2 & 7-3).

When digital pressure is applied to one of these distended areas, it is usually accompanied by increased distention of the other pouches. You are simply pushing excess fluid around in the joint. This is how distention of the tarsocrural joint (tarsal hydrarthrosis) can be distinguished clinically from distention of the tarsal sheath (tarsal tendosynovitis) in the live horse.

This represents differential diagnosis by a veterinarian, another example of problem solving, which is what diagnosis is all about. It then becomes necessary to determine why the joint (tendon sheath) is distended, which really needs to be established before effective therapy can be initiated. Perhaps radiography can better define the problem, and analysis of the synovial effusion could yield another clue. Results of these secondary tests may affect therapy and prognosis, but the first step is establishing a definitive, clinical diagnosis by a proper physical examination.

RADIOGRAPHIC ANATOMY

Equine Tarsus: The equine tarsus is a clinically important region that includes four major joints, six or seven tarsal bones, and five adjacent bones that articulate with one or more of the tarsal elements. This area is so complex anatomically that four standard radiographic views are generally considered necessary for an adequate examination: dorsoplantar (DPl), lateromedial (LM), dorsolateral-plantaromedial oblique (DL-PlMO), and dorsomedial-plantarolateral oblique (DM-PlLO). In addition, a lateromedial view of the flexed tarsus and a dorsoplantar view of the calcaneus and talus with the tarsus flexed may be required to demonstrate certain lesions. In order for you, as a veterinarian, to be proficient in the radiographic interpretation of the equine tarsus, a thorough understanding of the radiographic anatomy of this region is necessary.

The four standard radiographic views are indicated in figure 7-7. The oblique views were made at a 30° angle from the lateromedial line. The dorsoplantar view of the calcaneus and talus was obtained as indicated in figure 7-8.

Dorsoplantar View (Fig. 7-9): The **tibial cochlea** consists of medial and lateral grooves separated by an oblique ridge. This intermediate ridge is angled from the craniocaudal line so that its more pointed caudal end is imaged medial to its more rounded cranial end. The tibial cochlea is bounded medially by the prominent **medial malleolus** and laterally by the lateral malleolus. The **lateral malleolus**, although

fused to the tibia in the adult horse, represents the **distal epiphysis of the fibula**. The lateral malleolus is divided into caudal and cranial parts by a groove that accommodates the lateral digital extensor tendon (Fig. 7-3).

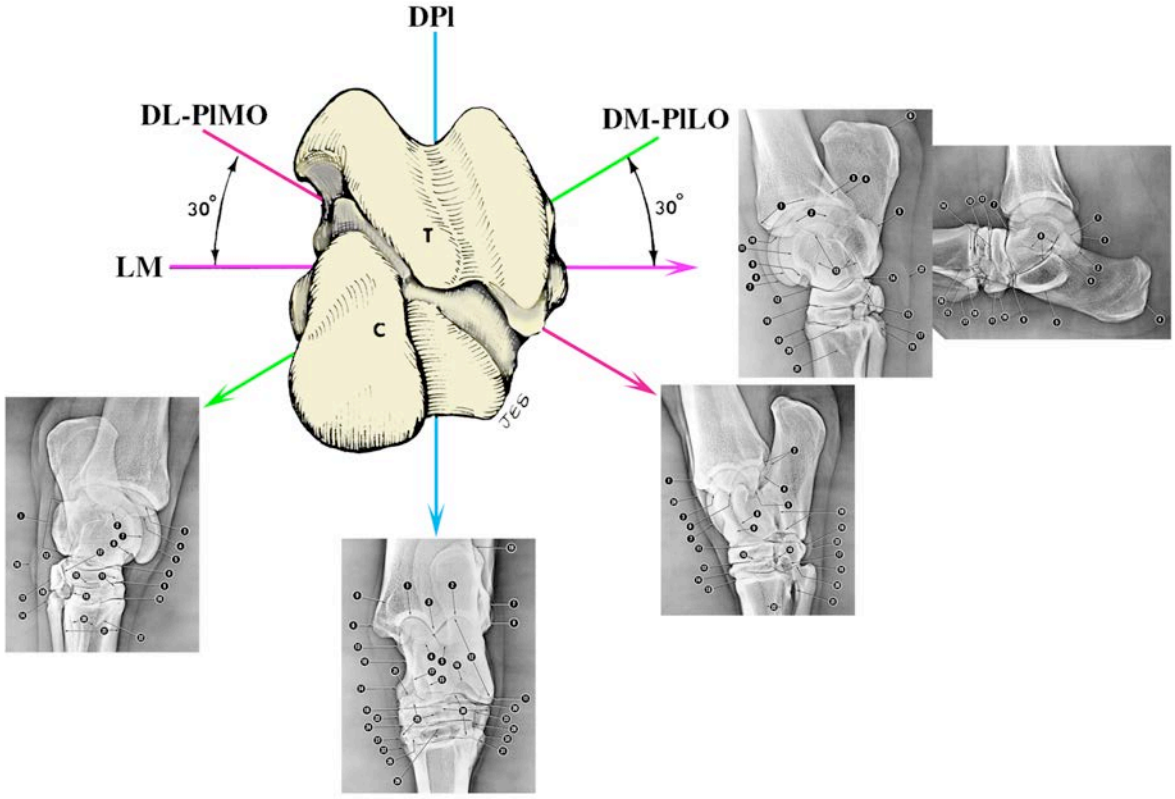


Figure 7-7. Proximal bones of equine tarsus (proximal view) illustrating orientation of central ray in four standard radiographic views: (DPl) dorsoplantar; (LM) lateromedial; (DL-PlMO) dorsolateral-plantaromedial oblique; (DM-PlLO) dorsomedial-plantarolateral oblique; (C) calcaneus; (T) talus.

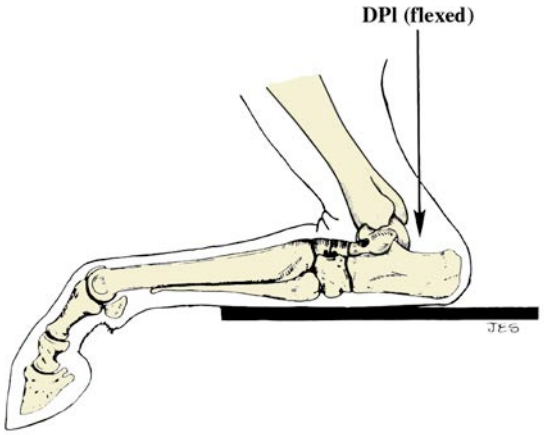


Figure 7-8. Limb, cassette, and central ray orientation for dorsoplantar view of equine calcaneus and talus with tarsus flexed.

There are typically six bones arranged in two rows in the equine tarsus. The two in the proximal row are largely superimposed in this view and include the **talus** dorsomedially and the **calcaneus** plantarolaterally (Fig. 7-9). The **trochlea tali** has two large ridges that articulate with the grooves of the **tibial cochlea** to form the **tarsocrural joint**.[3] Medially, the talus has proximal and distal tubercles for attachment of the short parts of the medial collateral ligaments (Fig. 7-5). The head of the talus articulates distally with the central tarsal bone to form part of the proximal intertarsal joint.

[3] Although this joint is frequently referred to as the *tibiotarsal joint*, this term ignores the fact that the fibula is also involved. If tarsocrural is good enough for other species, why should we use another term in the horse?

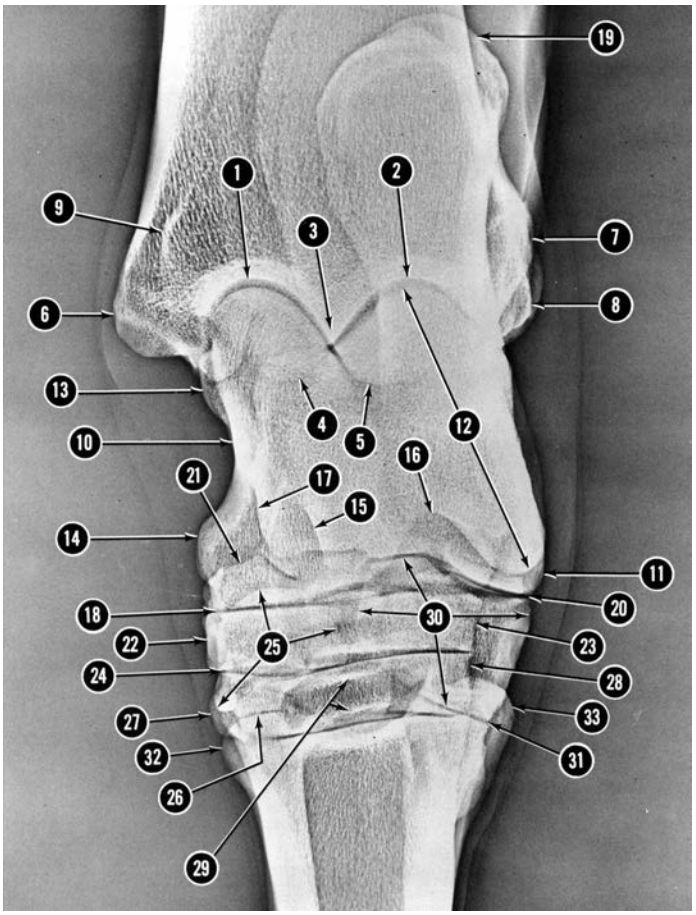


Figure 7-9. Dorsoplantar (DPl) xeroradiograph of left equine tarsus: (1) medial groove of tibial cochlea; (2) lateral groove of tibial cochlea; (3) oblique ridge separating 1 and 2; (4) pointed caudal end of 3; (5) rounded cranial end of 3; (6) medial malleolus; (7) caudal part of lateral malleolus; (8) cranial part of lateral malleolus; (9) radiopaque shadow (see text); (10) talus; (11) calcaneus; (12) lateral ridge of trochlea tali; (13) proximal tubercle of talus; (14) distal tubercle of talus; (15) medial ridge of trochlea tali; (16) groove between 12 and 15; (17) medial edge of sustentaculum tali; (18) proximal intertarsal (talocalcaneocentral) joint; (19) tuber calcanei; (20) calcaneoquartal joint; (21) proximoplantar aspect of Tc; (22) medial aspect of Tc; (23) lateral aspect of Tc; (24) distal intertarsal (centrodistal) joint; (25) fused first and second tarsal bones (T1+2); (26) articulation between 25 and Mt2; (27) medial aspect of third tarsal bone (T3); (28) lateral aspect of T3; (29) radiopaque lines (see text); (30) fourth tarsal bone; (31) tarsometatarsal joints (also, 26); (32) base of metatarsal bone 2 (Mt2); (33) base of metatarsal bone 4 (Mt4).

The largest bone of the tarsus is the **calcaneus**, which is largely superimposed on the **talus** in the dorsoplantar projection. The **tuber calcanei**, which serves as an attachment for the common calcanean tendon, is partially superimposed on the tibia. The calcaneus articulates distally with **T4** to form part of the **proximal intertarsal joint**. The proximal surface of the **central tarsal bone** (Tc) is concave, which causes the plantar aspect of its proximal surface to be superimposed on the talus. The medial and lateral aspects of Tc are both defined. Its distal surface, which is concave laterally and convex medially, articulates primarily with **T3** to form the **distal intertarsal joint**. The **first and second tarsal bones** are typically fused in the adult horse **(T1+2)** and are largely superimposed on Tc in the dorsoplantar view (Fig. 7-9).

The proximal surface of T3 conforms to the distal surface of Tc, and distally T3 articulates with Mt3. Radiopaque lines are produced by the walls of **nonarticular depressions** on the proximal and distal surfaces of T3. These depressions could be mistaken for pathologic erosions. Note that similar radiopaque lines represent the opposing walls of nonarticular areas on the distal surface of T3 and the base of Mt3. The articulations between the tarsal and metatarsal bones comprise the **tarsometatarsal joints**. The bases of Mt2 and Mt4 extend proximal to the base of Mt3 and are partially superimposed on the tarsal bones (Fig. 7-9).

Lateromedial View (Fig. 7-10): Much of the **calcaneus** is superimposed on the tibia and talus, but the **sustentaculum tali** and **tuber calcanei** are defined. As previously noted, muscles in the horse that attach to the tuber calcanei by the common calcanean tendon are the gastrocnemius, superficial digital flexor, biceps femoris, and semitendinosus.

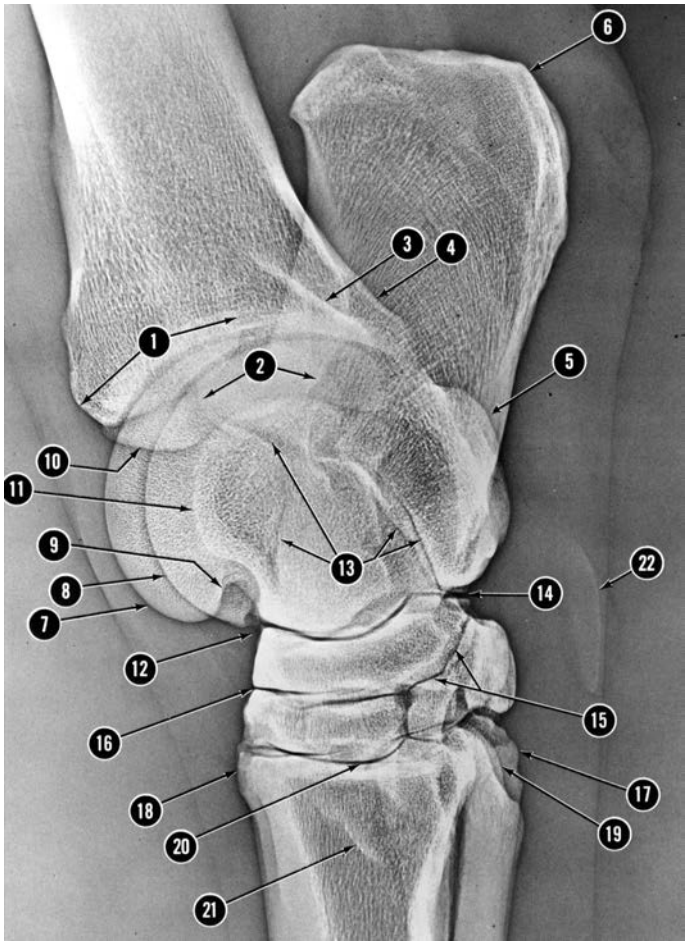


Figure 7-10. Lateromedial (LM) xeroradiograph of left equine tarsus: (1) lateral malleolus; (2) medial malleolus; (3) radiopaque line (see text); (4) medial part of caudal surface of tibia; (5) sustentaculum tali; (6) tuber calcanei; (7) lateral ridge of trochlea tali; (8) medial ridge of trochlea tali; (9) larger notch associated with 7; (10) intermediate part of tibial cochlea; (11) groove of trochlea tali- defined by radiopaque line; (12) proximal intertarsal joint; (13) articular surfaces between talus and calcaneus; (14) plantar aspect of 12; (15) articulation between Tc and T1+2; (16) distal intertarsal joint; (17) base of Mt2; (18) base of Mt3; (19) base of Mt4; (20) tarsometatarsal joint; (21) groove on proximolateral aspect of Mt3 for dorsal metatarsal artery 3; (22) chestnut (torus tarseus).

The **lateral and medial ridges of the trochlea tali** are clearly separated. Notches are present at the distal ends of both ridges, but note that the **larger notch is associated with the lateral ridge**, a feature that is helpful in differentiating the two ridges in the LM view. The intermediate part of the tibial cochlea is associated with the groove of the trochlea tali. The close proximity of the **tarsocrural joint** to the **proximal intertarsal joint** can be seen dorsally, where the synovial capsules of these joints communicate.

The articulations between Tc and T1+2 and between Tc and T3 form the **distal intertarsal joint**. The bases of the second, third, and fourth metatarsal bones articulate with the tarsal bones to form the **tarsometatarsal joints**. A radiopaque line is produced by the groove on the proximolateral aspect of Mt3 for dorsal metatarsal artery 3, which is the principal artery to the distal part of the limb. The chestnut (torus tarseus) produces a subtle image in this xeroradiograph.

Lateromedial View of Flexed Tarsus (Fig. 7-11): As is clearly demonstrated in this xeroradiograph, all appreciable flexion and extension of the equine tarsus occurs at the **tarsocrural joint**. This flexed positioning improves visualization of the coracoid process of the calcaneus and the proximal aspects of the medial and lateral ridges of the trochlea tali. The **tuber calcanei** and **sustentaculum tali** are well defined.

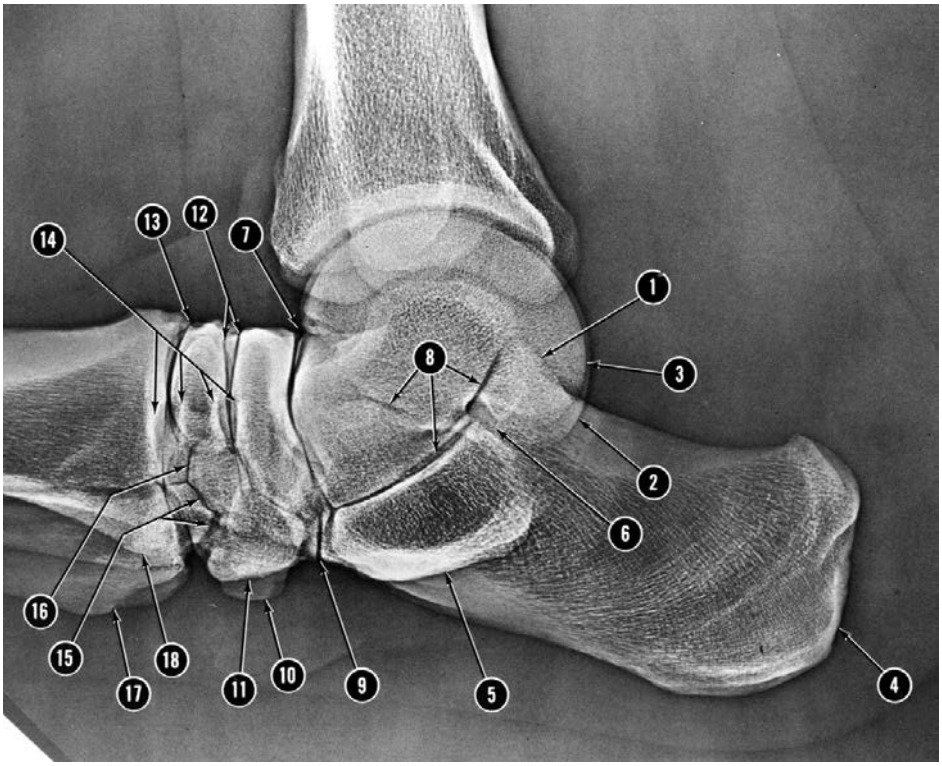


Figure 7-11. Lateromedial (LM) xeroradiograph of flexed left equine tarsus: (1) coracoid process of calcaneus; (2) medial ridge of trochlea tali; (3) lateral ridge of trochlea tali; (4) tuber calcanei; (5) sustentaculum tali; (6) radiolucent area (see text); (7) proximal intertarsal joint; (8) facets of talocalcaneal joint; (9) plantar aspect of 7; (10) plantar aspect of T4; (11) plantar aspect of T1+2: (12) dorsal aspect of distal intertarsal joint; (13) dorsal aspect of T3; (14) walls of nonarticular depressions between Tc and T3, and between T3 and Mt3; (15) tarsometatarsal joint between T1+2 and Mt2; (16) tarsometatarsal joint between T1+2 and Mt3; (17) base of Mt4; (18) base of Mt2.

The **proximal intertarsal joint** and several facets of the talocalcaneal joint are well defined in this view. The plantar aspects of T4 and T1+2 are separated. The dorsal aspects of the **distal intertarsal joint** and **third tarsometatarsal joint** are also defined. The walls of the **nonarticular depressions** between Tc and T3 and between T3 and Mt3 are demonstrated. The tarsometatarsal joints between T1+2 and Mt2 (15) and between T1+2 and Mt3 can be distinguished. The base of Mt4 is much larger than that of Mt2 (18) and projects further plantarly than Mt2 in this view.

Dorsolateral-Plantaromedial Oblique View (Fig. 7-12): The cranial aspect of the medial malleolus appears as a prominent projection in this view. The distal projections of the medial and lateral malleoli and the caudal and cranial aspects of the intermediate ridge of the tibial cochlea are defined. This view is helpful in demonstrating intracapsular fragments associated with **osteochondritis dissecans** lesions, which often involve the intermediate ridge.[4] The medial ridge of the trochlea tali is partially isolated in this projection, and the lateral ridge can be distinguished.

[4] Stromberg, B. and Rejno, S. Osteochondrosis in the horse. I. A clinical and radiologic investigation of osteochondritis dissecans in the knee and hock joint. *Acta Radiol*., Supplement 358 (1978): 139-152.

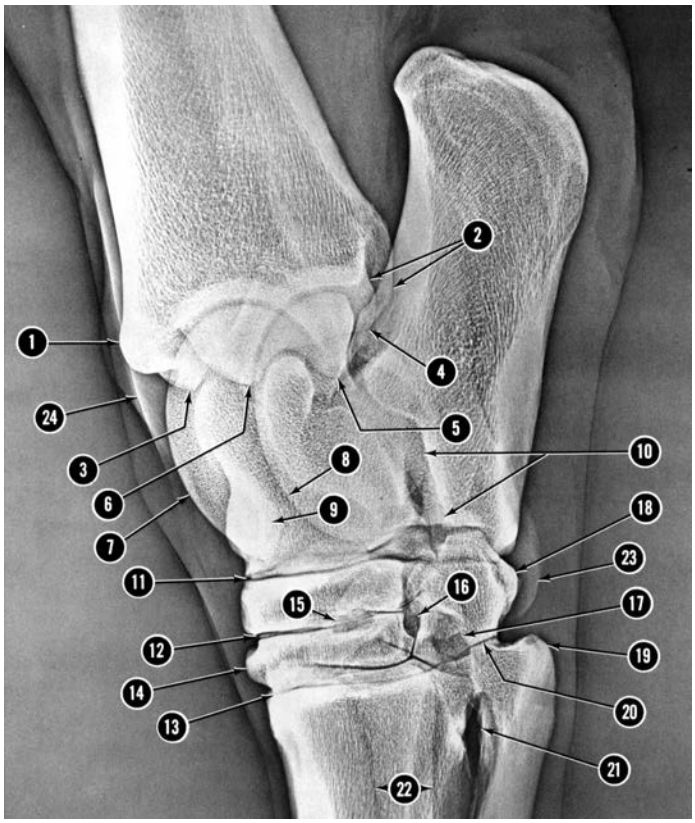


Figure 7-12. Dorsolateral-plantaromedial oblique (DL-PlMO) xeroradiograph of left equine tarsus: (1) cranial aspect of medial malleolus; (2) shadows produced by borders of groove in lateral malleolus; (3) distal projection of medial malleolus; (4) distal projection of lateral malleolus; (5) caudal aspect of intermediate ridge of tibial cochlea; (6) cranial aspect of intermediate ridge of tibial cochlea; (7) medial ridge of trochlea tali; (8) lateral ridge of trochlea tali; (9) radiopaque area (see text); (10) sinus tarsi; (11) dorsomedial aspect of proximal intertarsal joint; (12) dorsomedial aspect of distal intertarsal joint; (13) dorsomedial aspect of third tarsometatarsal joint; (14) ridge on dorsomedial aspect of T3; (15) nonarticular area between Tc and T3; (16) dorsal opening of tarsal canal; (17) plantar opening of tarsal canal; (18) plantar tuberosity on T4; (19) base of Mt4; (20) articulation between T4 and Mt4; (21) interosseous space between Mt3 and Mt4; (22) second metatarsal bone; (23) chestnut; (24) tendons crossing flexor surface of tarsus.

The dorsomedial aspects of the **proximal intertarsal joint**, the **distal intertarsal joint**, and the **third tarsometatarsal joint** are isolated in this view. The latter two joints are clinically important in cases of tarsal osteoarthrosis. The distinct ridge on the dorsomedial aspect of T3 is a normal anatomic feature, which provides attachment for one of the dorsal tarsal ligaments. The nonarticular area between Tc and T3 is clearly defined in this view. The dorsal opening of the "tarsal canal" produces a distinct radiolucent area bounded dorsomedially by the central and third tarsal bones and plantarolaterally by T4.

The "tarsal canal" transmits the perforating tarsal artery and vein and a branch of the deep peroneal nerve, which supplies the joints of the distal row of tarsal bones. The plantar opening of the tarsal canal is represented by a radiolucent area, which should not be mistaken for a lesion.

The plantarolateral aspect of a large plantar tuberosity on T4 and the prominent base of Mt4 serve as distal sites of attachment for the **long plantar ligament** of the tarsus. This ligament attaches along the plantar aspect of the calcaneus and, when inflamed, results in the clinical condition referred to as "curb" (Fig. 7-6). The articulation between T4 and Mt4 and the interosseous space between Mt3 and Mt4 are clearly defined in this view.

It is interesting to note that the chestnut, although located on the medial aspect of the limb, is positioned far enough plantarly to be visible in this xeroradiograph. The shadow of the chestnut should not be mistaken for a lesion. Because this view isolates the dorsomedial aspect of the tarsus, it is useful in evaluating distention of the dorsal pouch of the tarsocrural joint in cases of ***tarsal hydrarthrosis*** (bog spavin).

Dorsomedial-Plantarolateral Oblique View (Fig. 7-13): In this oblique view, the calcaneus is partly superimposed on the talus and the distal aspect of the tibia, but the **sustentaculum tali** is partially isolated. This view also isolates the **lateral ridge** of the **trochlea tali** and demonstrates the distinct notch distal to this ridge.

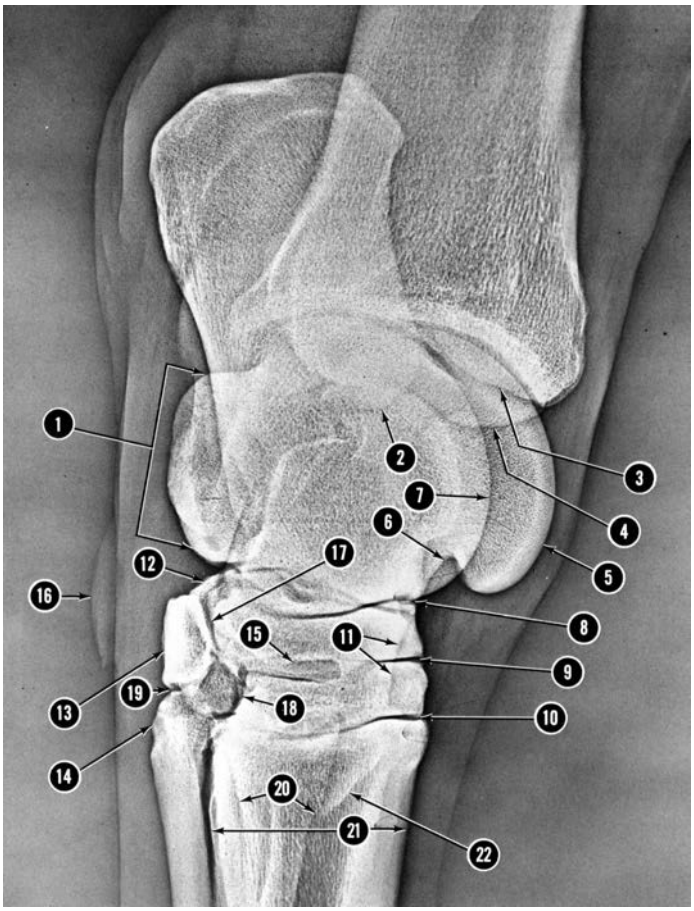


Figure 7-13. Dorsomedial-plantarolateral oblique (DM-PlLO) xeroradiograph of left equine tarsus: (1) sustentaculum tali; (2) distal extremity of medial malleolus; (3) distal extremity of lateral malleolus; (4) intermediate ridge of tibial cochlea; (5) lateral ridge of trochlea tali; (6) notch distal to 5; (7) medial ridge of trochlea tali; (8) dorsolateral aspect of proximal intertarsal joint; (9) dorsolateral aspect of distal intertarsal joint; (10) dorsolateral aspect of third tarsometatarsal joint; (11) dorsal aspect of T4; (12) plantaromedial aspect of Tc; (13) plantaromedial aspect of T1+2; (14) plantaromedial aspect of Mt2; (15) nonarticular depression between Tc and T3; (16) chestnut; (17) articulation between T1+2 and Tc; (18) articulation between T1+2 and T3; (19) articulation between T1+2 and Mt2; (20) fourth metatarsal bone; (21) third metatarsal bone; (22) radiopaque line produced by groove for dorsal metatarsal artery 3.

Although not isolated in this projection, the medial ridge is well defined. Both ridges of the trochlea tali are sites of osteochondritis dissecans, but the lateral ridge is more frequently involved. The dorsolateral aspects of the **proximal intertarsal joint**, the **distal intertarsal joint**, and the **third tarsometatarsal joints** are isolated in this view. The plantaromedial aspects of Tc, T1+2, and Mt2 are isolated in this projection. The nonarticular depressions between Tc and T3 and the chestnut are also demonstrated. The articulations between T1+2 and Tc, between T1+2 and T3, and between T1+2 and Mt2 are partially defined.

Dorsoplantar View of Calcaneus and Talus with Tarsus Flexed (Fig. 7-14): This special view of the tarsus isolates the slightly concave proximal aspect of the **sustentaculum tali**. Together with the smooth medial aspect of the calcaneus, the sustentaculum tali forms a groove for the tendons of the lateral and caudal tibial heads of the deep digital flexor muscle (Fig. 7-3). The tendons are surrounded at this level by the **tarsal sheath**, which is subject to inflammation, resulting in the condition commonly referred to as **tarsal tendosynovitis** or "thoroughpin." In chronic cases of this disease, exostoses (osseous changes) of the sustentaculum tali may be identified in this projection.[5]

[5] Edwards, G. B. Changes in the sustentaculum tali associated with distention of the tarsal sheath (thoroughpin). Eq. Vet. J. 10 (1978): 97-102.

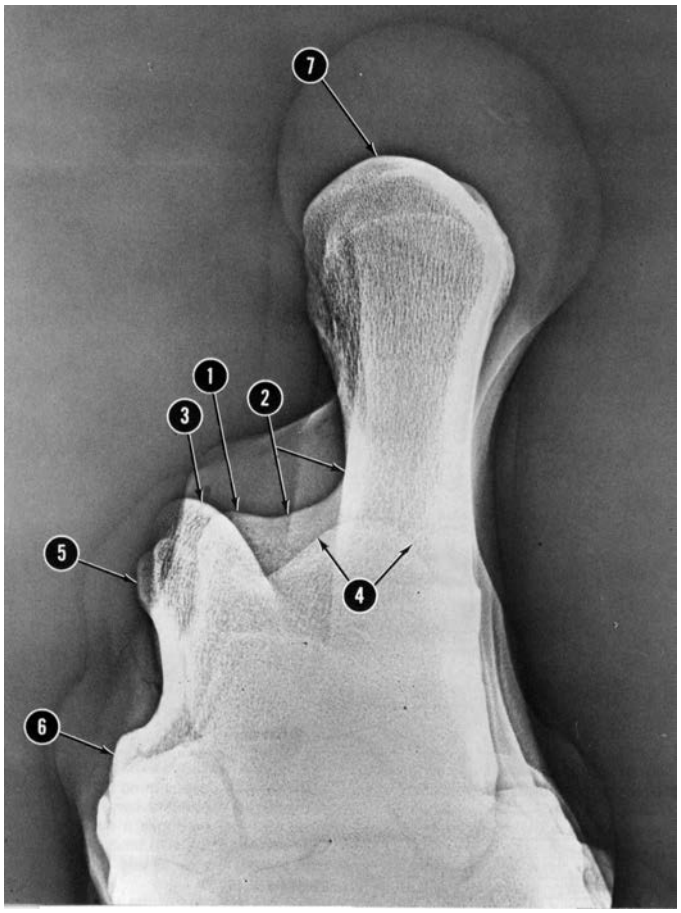


Figure 7-14. Dorsoplantar (DPl) xeroradiograph of left equine calcaneus and talus with tarsus flexed: (1) proximal aspect of sustentaculum tali; (2) groove for tendons of lateral and caudal tibial heads of deep digital flexor muscle; (3) medial ridge of trochlea tali; (4) lateral ridge of trochlea tali; (5) proximal tubercle of talus; (6) distal tubercle of talus; (7) tuber calcanei.

The more prominent medial ridge of the trochlea tali projects further proximally than the lateral ridge. The proximal and distal tubercles on the medial aspect of the talus are isolated in this projection. This view also offers excellent visualization of the **tuber calcanei**, over which the tendon of the **superficial digital flexor** passes. Although a large, consistently present, bursa is located between this tendon and the tuber calcanei (Figs. 7-2 & 7-3), cases of **calcanean bursitis** ("capped hock") are usually limited to an inconstant subcutaneous calcanean bursa.

Dorsoplantar View of 2-Week-Old Foal (Fig. 7-15): The tarsus of the foal lacks the sharp osseous margins that are present in the mature horse. The **distal epiphyseal cartilage (physis)** of the **tibia** is clearly evident and the **medial malleolus** is incompletely ossified. The distinctly separate **lateral malleolus** is the **distal epiphysis** of the **fibula** and has not yet fused to the tibia.

Radiographic fusion of the lateral malleolus to the tibia occurs at about 2 to 4 months of age.[6] The proximal aspect of the medial ridge of the trochlea tali is clearly defined, but that of the lateral ridge is less distinct because it is superimposed on the tibia and calcaneus. The sustentaculum tali is evident but is more rounded than in the adult because of incomplete ossification. Note also that the proximal and distal tubercles on the medial aspect of the talus (Fig. 7-9) have not yet ossified in this foal.

The tuber calcanei is superimposed on the tibia and the cartilage remaining between the calcaneus proper, and the secondary center of ossification for the tuber calcanei produces a subtle radiolucent line. The common calcanean tendon is superimposed on the tibia, and its medial and lateral borders can be identified.

The distal aspect of the lateral ridge of the trochlea tali is well

[6] Smallwood, J. E., Auer, J. A., Martens R. J., *et al*. The developing equine tarsus from birth to six months of age. Equine Pract. 6, #4 (1984): 7-48.

defined, but that of the medial ridge is less obvious.

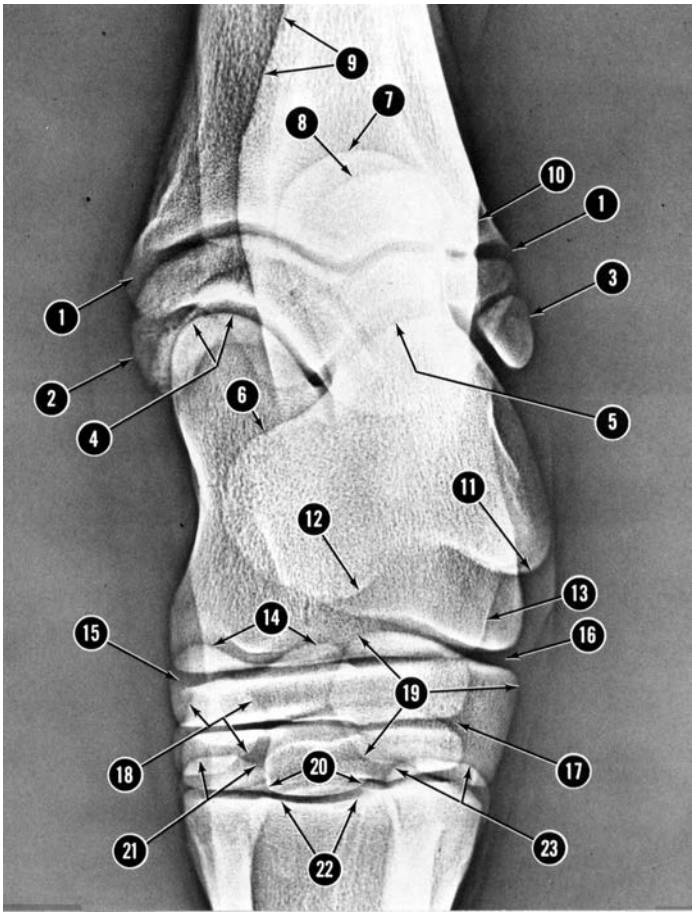


Figure 7-15. Dorsoplantar (DPl) xeroradiograph of left tarsus of a 2-week-old foal: (1) distal epiphyseal cartilage of tibia; (2) medial malleolus; (3) lateral malleolus; (4) proximal aspect of medial ridge of trochlea tali; (5) proximal aspect of lateral ridge of trochlea tali; (6) sustentaculum tali; (7) tuber calcanei; (8) radiolucent line (see text); (9) medial border of calcanean tendon; (10) lateral border of calcanean tendon; (11) distal aspect of lateral ridge of trochlea tali; (12) distal aspect of medial ridge of trochlea tali; (13) lateral aspect of head of talus; (14) prominences on plantar aspect of Tc; (15) proximal intertarsal joint; (16) calcaneoquartal joint; (17) distal intertarsal joint; (18) T1+2; (19) fourth tarsal bone (T4); (20) plantar projection of T3; (21) base of Mt2; (22) base of Mt3; (23) base of Mt4.

The **proximal and distal intertarsal joints** are clearly defined. These joints appear wider in the foal than in the adult as a result of incomplete ossification of the tarsal bones. There is incomplete definition of T1+2, but the outline of T4 is obvious. The plantar projection of T3 can be identified, as can the bases of Mt2, Mt3, and Mt4.

Lateromedial View of a 2-Week-Old Foal (Fig. 7-16): The secondary ossification center for the **tuber calcanei** is clearly defined but is only partially developed in this foal. With age, it will continue to ossify in a proximodorsal direction until it is fully formed.[7] Radiographic fusion of this center to the calcaneus proper occurs between 16 and 24 months of age.

The distal epiphyseal cartilage (physis) of the tibia is obvious, and the edges of the medial malleolus are defined. Although the ridges of the trochlea tali are almost exactly superimposed, a more pointed proximal end identifies the medial ridge. The distal notch of the lateral ridge can be identified. The sustentaculum tali of the calcaneus can be identified, and the talocalcaneal joint is well defined. Dorsally, the **proximal intertarsal joint**, the **distal intertarsal joint**, and the third **tarsometatarsal joint** appear wider, and the edges of the **central and third tarsal bones** are more rounded than in the adult.

The dorsal aspects of **T4** and **T1+2** can be differentiated. The larger **fourth tarsal bone** extends further plantarly than T1+2, and a dotted line marks the site of fusion between T1 and T2. In a maceration study of T1 and T2 in 23 foals from

[7] Smallwood, J. E., Auer, J. A., Martens R. J., *et al*. The developing equine tarsus from birth to six months of age. Equine Pract. 6,#4 (1984):7-48.

52 to 104 days of age, it was found that these bones were fused bilaterally in about 40% of the animals.[8] In the remaining foals, they were separate or were incompletely or unilaterally fused.

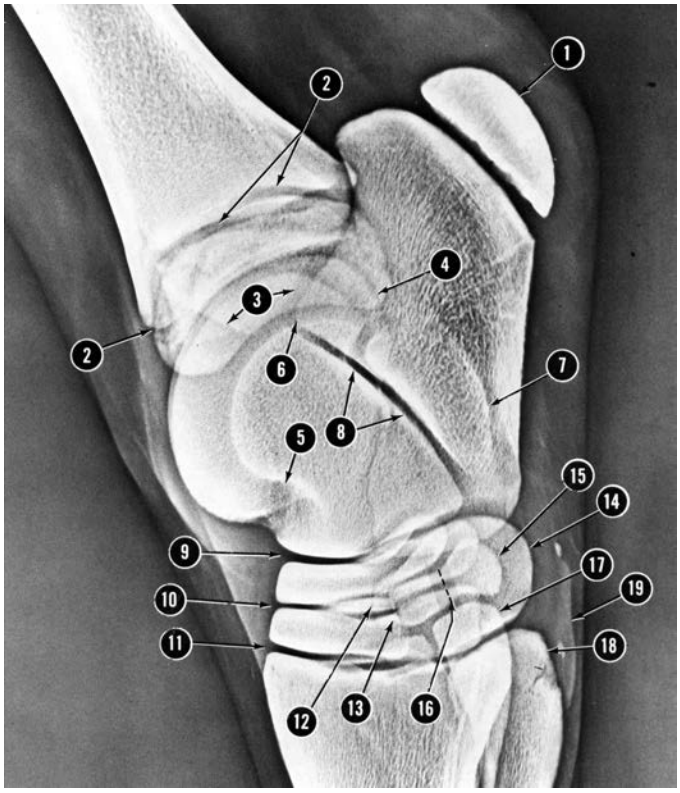


Figure 7-16. Lateromedial (LM) xeroradiograph of left tarsus of a 2-week-old foal: (1) secondary ossification center for tuber calcanei; (2) distal epiphyseal cartilage of tibia; (3) edges of medial malleolus; (4) medial ridge of trochlea tali; (5) notch distal to lateral ridge of trochlea tali; (6) coracoid process; (7) sustentaculum tali; (8) talocalcaneal joint; (9) proximal intertarsal joint; (10) distal intertarsal joint; (11) third tarsometatarsal joint; (12) dorsal aspect of T4; (13) dorsal aspect of T1+2; (14) plantar extension of T4; (15) plantar extension of T1+2; (16) line of fusion between T1 and T2; (17) base of Mt2; (18) base of Mt4; (19) chestnut.

In a radiographic study,[9] fusion of these two bones was noted to have occurred in 80% of the tarsi of nine foals by 6 months of age. The bases of Mt2 and Mt4, and the shadow of the chestnut, can be identified in this view.

Ostochondrosis (OC) – Osteochondritis dissecans (OCD) of Equine Tarsus: OCD is a potential sequela of an underlying condition known as osteochondrosis, a disturbance in bone-cartilage maturation. Although osteochondrosis is a complex disease that affects many areas of the body, basically there is disruption in the normal replacement of cartilage with bone during the ossification process. Thus, OC/OCD typically affects young, rapidly growing animals.

If this osteochondrosis occurs near an articular surface, the area of weakened bone/cartilage may "dissect" (thus, the name) its way to the surface, creating a fragmentation of the overlying bone and cartilage, and inflammation (OCD). As this continues, there is usually partial or complete detachment of the affected bone/cartilage at the surface, typically accompanied by more inflammatory disease (pain and swelling of joint). One site of OCD in the equine tarsus is the lateral ridge of the trochlea tali.

To illustrate this clinical problem, I have included radiographs of an 8-month-old quarter horse colt. This foal was presented with bilateral swelling of the tarsocrural joints ("bog spavin"). Distention of the right tarsocrural joint (Fig. 7-17) was first noted at 6 months of age, and more recently, the left tarsus has become swollen (Fig. 7-18).

[8] Brown, M. P. and MacCallum, F. J. A system of grading ossification in limbs of foals to assist in radiologic interpretation. Am. J. Vet. Res. 36 (1975): 655-661.

[9] Smallwood, J. E., Auer, J. A., Martens R. J., *et al*. The developing equine tarsus from birth to six months of age. Equine Pract. 6,#4 (1984):7-48.

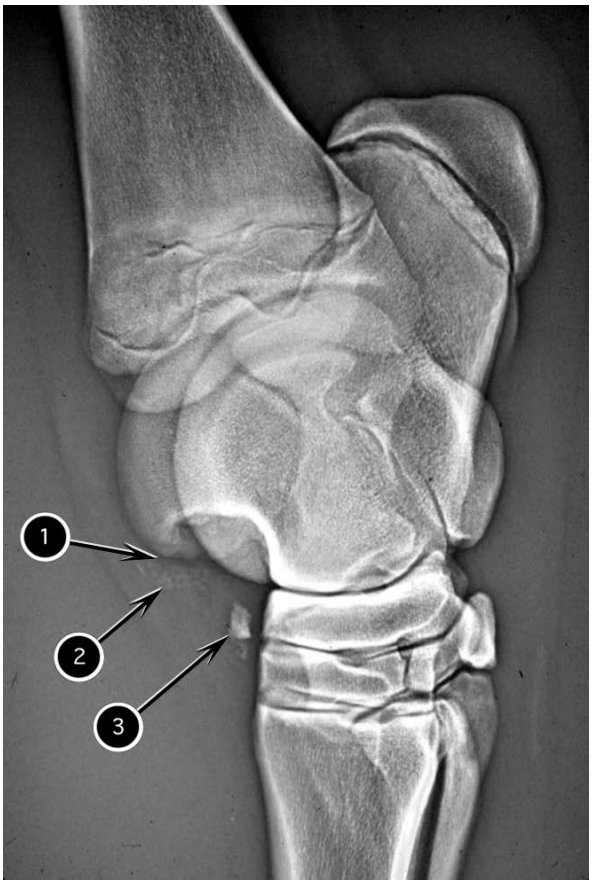


Figure 7-17. Dorsomedial-plantarolateral Oblique (DM-PlLO) xeroradiograph of right tarsus of 8-month-old quarter horse colt with OCD: (1) incomplete distal end of lateral ridge of trochlea tali; (2) small radiopaque fragments associated with 1; (3) large, detached osseous fragment free-floating in tarsocrural joint. Soft tissue swelling of the tarsocrural joint is also evident.

Figure 7-18 is basically a "flashback" to figure 7-17. Here we see the earlier break-up (dissection) of the distal end of the lateral ridge. There is less distension of the tarsocrural joint, and the large "joint mouse" has not yet completely detached. Small radiopaque fragments have already dislodged into the synovial fluid, and the left tarsus is progressing toward the same situation already present in the more swollen right tarsocrural joint.

Commentary: OC/OCD is commonly observed in most species of domestic mammals, including broilers. We have undoubtedly contributed to the high incidence of OC by line-breeding animals for rapid growth (genetic predisposition), and have enhanced its manifestation as OCD by pouring the feed to these animals (over-nutrition).

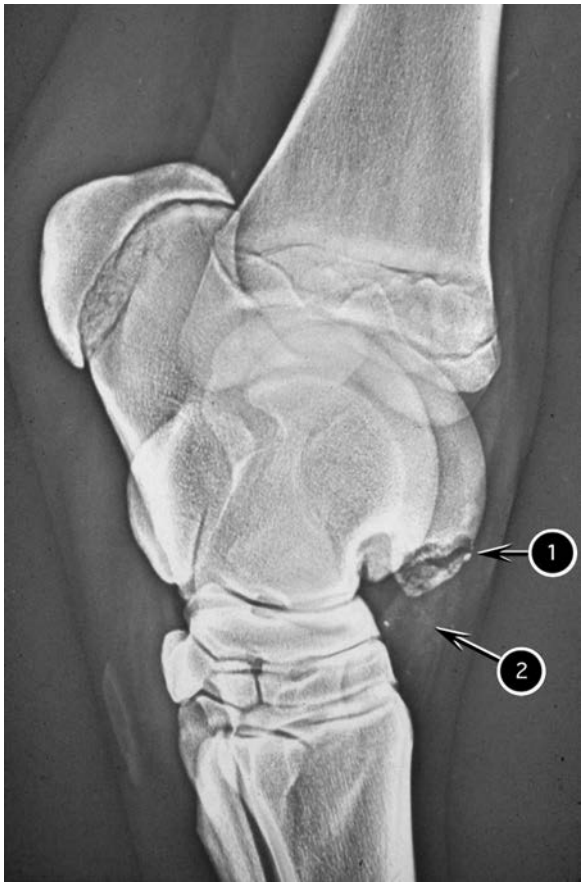


Figure 7-18. Dorsomedial-plantarolateral Oblique (DM-PlLO) xeroradiograph of left tarsus of 8-month-old quarter horse colt with OCD: (1) line of dissection of distal end of lateral ridge of trochlea tali; (2) small radiopaque fragments associated with 1.

As a follow-up, surgery was performed on both joints. The detached material was removed, the distal ends of both lateral ridges were curetted, and hyaluronic acid was injected into both tarsocrural joints. On examination one year later, the horse was not lame, the tarsocrural joints were not distended, and radiographs revealed no degenerative changes in either joint.

Another site within the equine tarsus where OC/OCD commonly occurs is in the cranial aspect of the intermediate ridge of the tibial cochlea. This lesion is best seen in the DM-PlLO view (Fig. 7-19).



Figure 7-19. DM-PlLO radiograph of left tarsus of 3-year-old Oldenburg[1] gelding with history of left tarsal effusion of 4 weeks duration: (1) OCD lesion off cranial aspect of intermediate ridge of tibial cochlea; (2) tarsocrural joint effusion; (3) sustentaculum tali; (4) fused T1+2; (5) Mt2.

[1] The Oldenburg is one of the oldest European Warm-Blood breeds, originating in the 1600s as a fine coach horse. Today's Oldenburg has been crossbred to produce a riding horse, frequently used in equestrian competition.

Bovine Tarsus: Although radiographed much less frequently than the equine tarsus, the bovine tarsus is a region of some clinical importance. In fact, the tarsal joint is second only to the stifle joint as the most common site of appendicular arthritis in cattle.[10]

The bovine tarsus includes four major joints, five tarsal bones, and three adjacent bones that articulate with one or more of the tarsal elements. This area is so complex anatomically that four standard radiographic views are generally considered necessary for an adequate examination: dorsoplantar (DPl), lateromedial (LM), dorsolateral-plantaromedial oblique (DL-PlMO), and dorsomedial-plantarolateral oblique (DM-PlLO) (Fig. 7-19).

Because the bovine tarsus is radiographed so infrequently relative to the horse, it is not practical for you to spend hours of time trying to store all this information for unassisted recall. In my opinion, **you should devote 97.5% of your time and attention to the equine tarsus, and when needed, use the following radiographs as reference material**.

Significant bovine tarsal features that should be noted (2.5% of your time) **include the following**:

1. The body of the fibula is absent, but the **lateral malleolus** remains as a distinctly separate bone that articulates with the tibia, talus, and calcaneus.

2. The lateral part of the tarsocrural joint is formed by the **articulation of the calcaneus with the lateral malleolus**. This is also true in the small domestic ruminants and pig, but not in the horse and carnivores.

3. The **talus** has a **distal trochlea** as well as a proximal one. This feature allows for significant movement at the proximal intertarsal joint and *is* characteristic of artiodactyls. In the horse, there is only one (proximal) trochlea tali.

4. The **central** and **fourth tarsal bones** are **fused**, as are the **second** and **third tarsal bones**. The first tarsal bone is separate.

5. A **metatarsal sesamoid** bone is present on the proximal plantaromedial aspect of the metatarsus. This bone has sometimes been incorrectly identified as a vestige of the second metatarsal bone, which it is not. It is a sesamoid associated with interosseus muscle 3.[11]

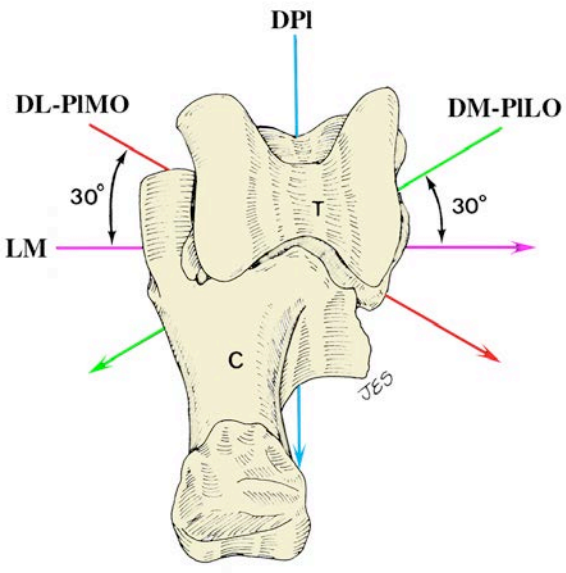


Figure 7-19. Proximal bones of bovine tarsus (proximal view) illustrating orientation of central ray in the four standard radiographic views: (DPl) dorsoplantar; (LM) lateromedial; (DL-PlMO) dorsolateral-plantaromedial oblique; (DM-PlLO) dorsomedial-plantarolateral oblique; (C) calcaneus; (T) talus.

[10] Greenough, P. R., MacCallum, F. J. and Weaver, D. A. *Lameness in Cattle*. J. B. Lippincott Co., Philadelphia, 1972.

[11] Its only significance is that it is of no clinical significance, which of course, is significant.

Dorsoplantar View (Fig. 7-20): The tibial cochlea consists of medial and lateral grooves separated by an intermediate ridge. Unlike the ridge of the horse, which is oblique, it is almost sagittal in the ox. The lateral groove of the tibial cochlea is incomplete laterally, where it is supplemented by the lateral malleolus of the fibula. In the horse, the **lateral malleolus** fuses to the tibia during the first few months of life, but it typically remains as a separate entity in the adult ox. The lateral malleolus articulates with the tibia at the distal tibiofibular joint.

Medial to the tibial cochlea is the medial malleolus, which possesses a distinct distal projection on its cranial aspect. The malleoli serve as sites of attachment for the collateral ligaments of the tarsus. The lateral collateral ligament helps stabilize the distal tibiofibular joint.

There are typically five bones arranged in two rows in the bovine tarsus. The two in the proximal row are largely superimposed in this view and include the talus and the calcaneus. Unlike that of the horse, the bovine **talus** has both a **proximal** and a **distal trochlea**, and the lateral ridge of the proximal trochlea of the talus extends further proximally than the medial ridge, a feature that can be used to differentiate them in LM views. The proximal trochlea tali articulates with the tibial cochlea and lateral malleolus to form much of the tarsocrural joint.

The lateral part of this joint is formed by the articulation of the lateral malleolus with the calcaneus, an articulation that is not present in the horse or carnivores. The distal trochlea tali consists of two ridges separated by a sagittal groove. The distal trochlea articulates with the fused central and fourth tarsal bones (Tc+4) to form part of the proximal intertarsal joint. The synovial cavity of the proximal intertarsal joint communicates with that of the tarsocrural joint.

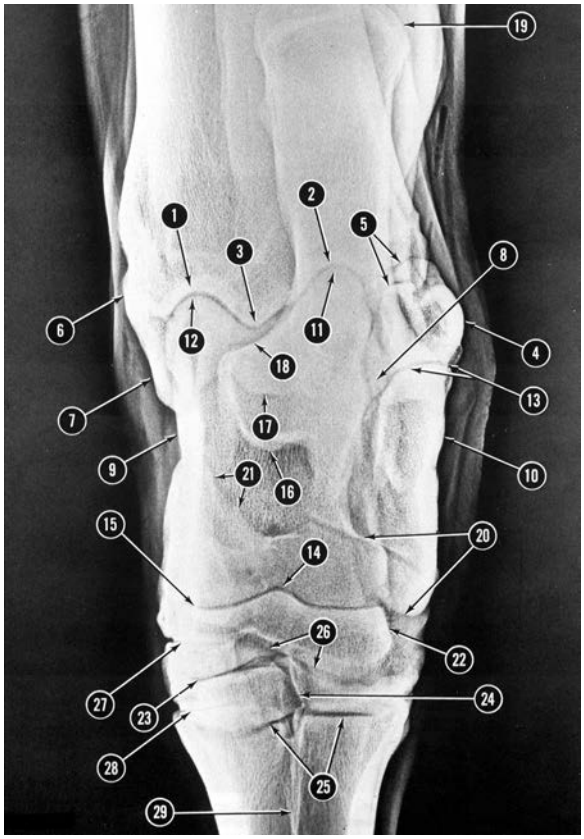


Figure 7-20. Dorsoplantar (DPl) xeroradiograph of left bovine tarsus: (1) medial groove of tibial cochlea; (2) lateral groove of tibial cochlea; (3) intermediate ridge separating 1 and 2; (4) lateral malleolus of fibula; (5) distal tibiofibular joint; (6) medial malleolus; (7) distal projection on cranial aspect of 6; (8) distal extension of lateral malleolus; (9) talus; (10) calcaneus; (11) lateral ridge of proximal trochlea of 9; (12) medial ridge of proximal trochlea of 9; (13) articulation of lateral malleolus with 10; (14) sagittal groove separating ridges of distal trochlea tali; (15) proximal intertarsal joint; (16) distal edge of sustentaculum tali; (17) craniodistal aspect of 3; (18) proximal border of sustentaculum tali; (19) tuber calcanei; (20) calcaneoquartal joint; (21) plantar aspect of proximal surface of Tc+4; (22) shadow produced by lateral edge of Tc+4; (23) distal intertarsal joint; (24) intertarsal joint; (25) tarsometatarsal joint; (26) oblique shadow- produced by plantar part of 23; (27) proximal articulation of T1 with Tc+4; (28) distal articulation of T1 with Mt3+4; (29) line of fusion between Mt3 and Mt4.

The largest bone of the tarsus is the **calcaneus**, which is partially superimposed on the talus in the DPl projection. The proximal border of the sustentaculum tali is defined. The tuber calcanei is partially superimposed on the tibia. The calcaneus articulates distally with Tc+4 to form part of the **proximal intertarsal joint**. The proximal surface of Tc+4 is concave, which causes the plantar aspect of its proximal surface (21) to be superimposed on the talus. Medially, Tc+4 articulates with the fused second and third tarsal bones (T2+3) to form the **distal intertarsal** joint.

The small first tarsal bone (T1) articulates proximally with Tc+4, forming part of the distal intertarsal joint, and distally with Mt3+4. It is superimposed on Tc+4 and T2+3 in this projection. A radiopaque shadow represents the line of fusion between Mt3 and Mt4.

Lateromedial View (Fig. 7-21): The cranial and caudal aspects of the articulation between the intermediate ridge of the tibial cochlea and the groove of the proximal trochlea tali are indicated.

The most distal part of the tarsocrural joint that is defined in this view is the articulation of the lateral malleolus with the coracoid process of the calcaneus. This articulation is not present in the horse or carnivores. The dorsal aspects of the medial and lateral ridges of the distal trochlea tali can be differentiated in this projection. A radiolucent area is produced by the deep fossa on the dorsal surface of the talus.

The calcaneus of the ox is more slender than that of the horse. The dorsal aspect of the proximal part of the bovine calcaneus is slightly concave. The tuber calcanei serves as an attachment site for the common calcanean tendon. Muscles in the ox that attach to the tuber calcanei by this tendon are the gastrocnemius, superficial digital flexor, biceps femoris, and semitendinosus.

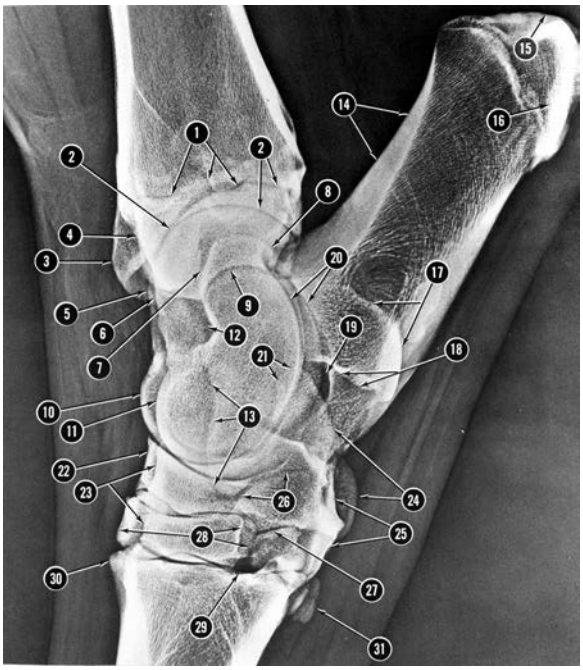


Figure 7-21. Lateromedial (LM) xeroradiograph of left bovine tarsus: (1) distal tibiofibular joint; (2) tarsocrural joint; (3) medial malleolus of tibia; (4) lateral malleolus of fibula; (5) medial ridge of proximal trochlea tali; (6) lateral ridge of proximal trochlea tali; (7) cranial aspect of articulation between intermediate ridge of tibial cochlea and groove of proximal trochlea tali; (8) caudal aspect of articulation between intermediate ridge of tibial cochlea and groove of proximal trochlea tali; (9) articulation of lateral malleolus with coracoid process of calcaneus; (10) medial ridge of distal trochlea tali; (11) lateral ridge of distal trochlea tali; (12) fossa on dorsal surface of talus; (13) dorsal aspect of calcaneus; (14) dorsal aspect of proximal part of calcaneus; (15) tuber calcanei; (16) walls of groove for superficial digital flexor tendon; (17) sustentaculum tali; (18) distal free edge of 17; (19) plantar aspect of sinus tarsi; (20) talocalcaneal joint; (21) plantaromedial aspect of Tc+4; (22) dorsal surface of Tc; (23) dorsal surface of T4; (24) plantar aspect of Tc; (25) plantar aspect of T4; (26) calcaneoquartal joint; (27) articulation of T1 with Tc+4; (28) T2+3; (29) nonarticular area between distal tarsal bones and Mt3+4; (30) proximodorsal aspect of Mt3+4; (31) metatarsal sesamoid bone.

In the horse, the sustentaculum tali tapers uniformly to the level of the proximal intertarsal joint, but in the ox, the sustentaculum tali terminates abruptly to form a distinct free edge distally.

The plantaromedial aspect of Tc+4 extends proximally as a prominent process, which is superimposed on the talus and calcaneus. Although the central and fourth tarsal bones are fused in the ox, the dorsal surfaces of Tc and T4 are separated in this projection. A distinct radiolucent line is produced by the calcaneoquartal joint. The first tarsal bone is located in the plantaromedial aspect of the distal row, and its articulation with Tc+4 forms part of the distal intertarsal joint. Dorsally, T1 articulates with T2+3. A distinct radiolucent area is produced by a large nonarticular area between the distal tarsal bones and Mt3+4.

The proximodorsal aspect of Mt3+4 is normally characterized by a slightly roughened area, which provides attachment for the tendon of the peroneus tertius muscle. On the plantaromedial aspect of Mt3+4 is a small discoid bone, which has been incorrectly identified in some anatomy and radiology texts as a vestigial Mt2. However, a developmental study[12] has shown that it is actually a sesamoid bone that develops in the third interosseus muscle. The official name for this structure is the **metatarsal sesamoid bone**. It is not ossified in the newborn calf.

Lateromedial View of Flexed Tarsus (Fig. 7-22): In contrast to the horse and carnivores, in which all appreciable flexion occurs at the tarsocrural joint, figure 7-22 demonstrates that in the ox, considerable flexion also occurs at the proximal intertarsal joint. This fact can be verified by the separation of the dorsal aspect of the calcaneus and the ridges of the proximal trochlea tali in this flexed position, as compared with their superimposed relationship in the extended position. This flexed positioning improves visualization of the proximal aspects of the medial and lateral ridges of the proximal trochlea tali. The medial ridge can be differentiated from the lateral ridge because the latter extends further proximally.

During flexion of the tarsocrural joint, the cranial aspect of the intermediate ridge of the tibial cochlea projects into the deep fossa on the dorsal surface of the talus. A distinct radiolucent area is produced by a large, transverse **synovial fossa** that interrupts the articular surface of the tibial cochlea. This shadow should not be mistaken for an erosion of the articular surface. The articulation between the lateral malleolus and the coracoid process of the calcaneus is well defined, as is part of the talocalcaneal joint. The undulating proximal intertarsal joint is imaged as three radiolucent lines that represent different levels of this articulation.

In this projection, the dorsal surface of Tc+4 is isolated proximally, but distal to the distal intertarsal joint, the dorsal surface of T2+3 extends further dorsally. The smooth projection on the proximodorsal aspect of Mt3+4 serves as a distal attachment site for the peroneus tertius muscle and should not be mistaken for a proliferative lesion. The irregular tarsometatarsal joints are interrupted by a nonarticular area that produces a prominent radiolucent image.

[12] Smith, R. N. The proximal metatarsal sesamoid of the domestic ruminants. Is it the vestige of second metatarsal? Anat. Anz. Bd. 103 (1956): 241-245.

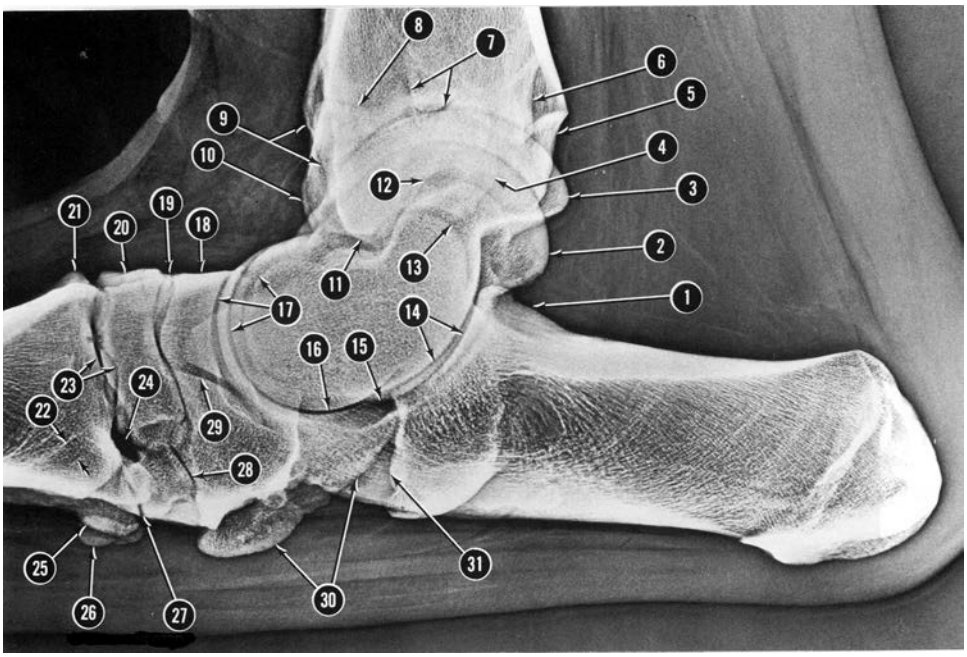


Figure 7-22. Lateromedial (LM) xeroradiograph of left bovine tarsus in flexed position: (1. Dorsal aspect of calcaneus; (2) medial ridge of proximal trochlea tali; (3) lateral ridge of proximal trochlea tali; (4) caudal edge of lateral malleolus; (5) medial aspect of tibia; (6) lateral aspect of tibia; (7) distal tibiofibular joint; (8) cranial part of 7; (9) cranial edge of lateral malleolus; (10) cranial edge of medial malleolus; (11) cranial aspect of intermediate ridge of tibial cochlea; (12) transverse synovial fossa in tarsocrural joint; (13) articulation between lateral malleolus and coracoid process of calcaneus; (14) talocalcaneal joint; (15) sinus tarsi; (16) articulation between talus and proximal process on plantaromedial aspect of Tc+4; (17) proximal intertarsal joint; (18) dorsal surface of Tc+4; (19) distal intertarsal joint; (20) dorsal surface of T2+3; (21) projection on proximodorsal aspect of Mt3+4; (22) plantar part of tarsal canal; (23) tarsometatarsal joints; (24) nonarticular area that interrupts 23; (25) medial part of proximoplantar aspect of Mt3+4; (26) metatarsal sesamoid bone; (27) articulation between T1 and Mt3+4; (28) articulation between T1 and Tc+4; (29) articulation between distal projection of calcaneus and Tc+4; (30) medial aspect of plantar surface of Tc+4; (31) distal edge of sustentaculum tali.

Partly superimposed on the medial part of the proximoplantar aspect of Mt3+4 is the **metatarsal sesamoid bone**, embedded in the third interosseus muscle. The articulations between T1 and Mt3+4 and between T1 and Tc+4 are defined. A wider radiolucent line demarcates the articulation between the distal projection of the calcaneus and Tc+4. This view also isolates the medial aspect of the plantar surface of Tc+4, which extends proximally to the level of the distal edge of the sustentaculum tali.

Dorsolateral-Plantaromedial Oblique View (Fig. 7-23): This oblique view isolates the craniomedial aspect of the medial malleolus, which is indented by an oblique groove that accommodates parts of the complex medial collateral ligament. The articulation of the medial ridge of the proximal trochlea tali is well defined and is imaged proximal to a prominent radiolucent line produced by the medial aspect of the tarsocrural joint. The cranial aspect of the intermediate ridge of the tibial cochlea, which is well defined in this view, has been reported as a site for **osteochondritis dissecans** lesions in rapidly growing bulls.[13]

[13] Reiland, S., Stromberg, B., Olsson, S. E., *et al*. Osteochondrosis in growing bulls. *Acta Radiol*., Supplment 358 (1978): 179-196.

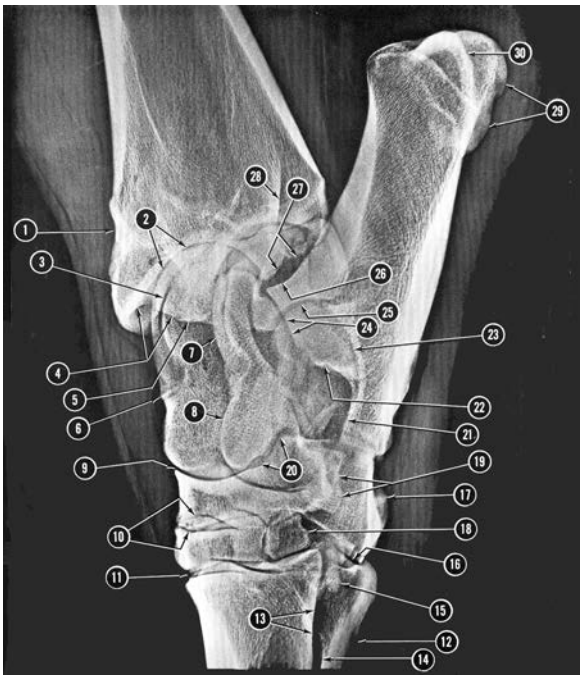


Figure 7-23. Dorsolateral-plantaromedial oblique (DL-PlMO) xeroradiograph of left bovine tarsus: (1) oblique groove on craniomedial aspect of medial malleolus; (2) articulation of medial ridge of proximal trochlea tali, part of tarsocrural joint; (3) medial aspect of tarsocrural joint; (4) cranial edge of tibial cochlea; (5) cranial aspect of intermediate ridge of tibial cochlea; (6) distal edge of medial ridge of proximal trochlea tali; (7) lateral ridge of proximal trochlea tali; (8) lateral ridge of distal trochlea tali; (9) dorsomedial aspect of proximal intertarsal joint; (10) dorsomedial aspect of distal intertarsal joint; (11) dorsomedial aspect of third tarsometatarsal joint; (12) plantarolateral aspect of Mt3+4; (13) medial part of plantar surface of Mt3+4; (14) plantarolateral cortex of Mt3+4; (15) metatarsal sesamoid bone; (16) articulation between Tc+4 and Mt3+4; (17) tuberosity on plantar aspect of Tc+4; (18) first tarsal bone; (19) plantaromedial aspect of Tc+4; (20) nonarticular area between Tc+4 and talus; (21) medial edge of plantar aspect of calcaneus; (22) sustentaculum tali; (23) lateral aspect of talocalcaneal joint; (24) medial aspect of talocalcaneal joint; (25) articulation between lateral malleolus and coracoid process of calcaneus; (26) dorsal edge of calcaneus; (27) caudal surface of tibia; (28) medial part of caudal tibial surface; (29) plantarolateral aspect of tuber calcanei; (30) plantaromedial part of tuber calcanei.

A small projection marks the distal edge of the medial ridge of the proximal trochlea tali. Although not isolated in this projection, both the lateral ridge of the proximal trochlea tali and the lateral ridge of the distal trochlea are well defined.

The dorsomedial aspects of the proximal intertarsal joint, the distal intertarsal joint, and the third tarsometatarsal joint are isolated in this view. The mottled pattern associated with the dorsomedial part of the distal intertarsal joint is produced by the convergence of the dorsal and medial parts of the joint as well as by numerous vascular foramina associated with the joint capsule.

In this oblique projection, the plantarolateral aspect of Mt3+4 is isolated and has the illusion of being separated from the remainder of the bone. The metatarsal sesamoid bone is superimposed on Mt3+4.

A large tuberosity on the plantar aspect of Tc+4 is partially isolated in this view, and T1 is well defined. The plantaromedial aspect of Tc+4 can be identified, and a radiolucent shadow is produced by a nonarticular area between Tc+4 and the talus. A sharply defined radiographic shadow represents the medial edge of the plantar aspect of the calcaneus, which is continuous proximally with the sustentaculum tali. Both the lateral and the medial aspects of the talocalcaneal joint are defined, as is the articulation between the lateral malleolus and the coracoid process of the calcaneus.

A prominent radiolucent area is produced between the dorsal edge of the calcaneus and the distal edge of the caudal surface of the tibia. Although the plantarolateral aspect of the tuber calcanei is isolated in this view, a prominent radiopaque outline of the plantaromedial part of this tuberosity is produced.

Dorsomedial-Plantarolateral Oblique View (Fig. 7-24): The plantaromedial aspect of the tuber calcanei is isolated, and the dorsal part of the calcaneus is superimposed across the caudomedial part of the tibia. Medial and lateral ridges of the proximal trochlea tali are separated, and their individual articulations with the tibia are defined. Additional articulations of the tarsocrural joint that can be identified are those between the intermediate ridge of the tibial cochlea and the groove of the proximal trochlea tali, and between the lateral malleolus and coracoid process of the calcaneus.

The plantaromedial aspect of the sustentaculum tali is isolated in this view, and part of the talocalcaneal joint is defined. Partially isolated in this view is the prominent proximal process on the plantaromedial part of Tc+4, and its extensive articulation with the medial part of the distal trochlea tali is defined.

The plantaromedial aspect of the distal intertarsal joint between Tc+4 and T1 is isolated, but the metatarsal sesamoid bone is superimposed on the plantaromedial aspect of Mt3+4 in this oblique projection. Medial and lateral edges of the plantar surface of Mt3+4 are separated, and a distinct radiolucent area is produced by the large nonarticular area between Tc+4 and Mt3+4.

The most distal part of this nonarticular area is represented by a subtle excavation in the base of Mt3+4, which should not be mistaken for an erosion of the articular surface. Lateral and medial ridges of the distal trochlea tali are separated, as are the cranial edges of the lateral malleolus and the lateral aspect of the tibia.

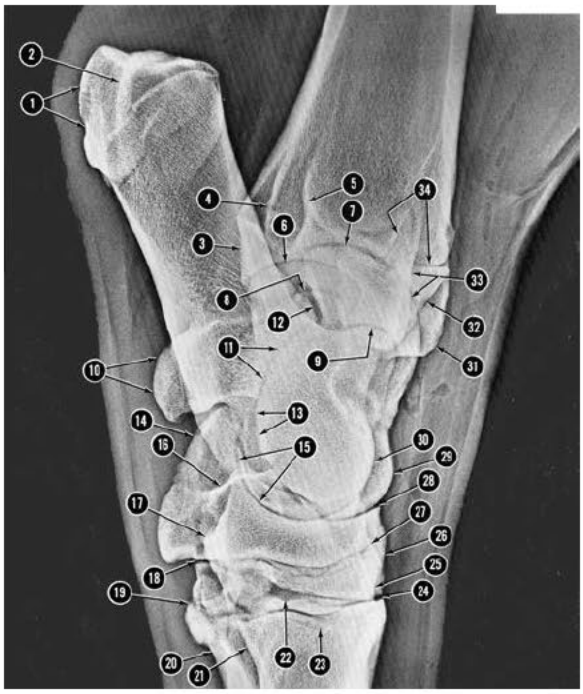


Figure 7-24. Dorsomedial-plantarolateral oblique (DM-PlLO) xeroradiograph of left bovine tarsus: (1) plantaromedial aspect of tuber calcanei; (2) radiopaque shadow (see text); (3) caudomedial part of tibia; (4) caudal edge of medial malleolus; (5) caudal edge of lateral part of tibia; (6) medial ridge of proximal trochlea tali; (7) lateral ridge of proximal trochlea tali; (8) articulation between intermediate ridge of tibial cochlea and groove of proximal trochlea tali; (9) articulation between lateral malleolus and coracoid process of calcaneus; (10) plantaromedial aspect of sustentaculum tali; (11) talocalcaneal joint; (12) nonarticular area between calcaneus and lateral part of proximal trochlea tali; (13) articular surface of talus (see text); (14) proximal process on plantaromedial part of Tc+4; (15) articulation of 14 with medial part of distal trochlea tali; (16) proximal nonarticular surface of Tc+4; (17) tuberosity on plantar surface of Tc+4; (18) plantaromedial aspect of distal intertarsal joint; (19) metatarsal sesamoid bone; (20) medial edge of plantar surface of Mt3+4; (21) lateral edge of plantar surface of Mt3+4; (22) nonarticular area between Tc+4 and Mt3+4; (23) excavation in base of Mt3+4; (24) fourth tarsometatarsal joint; (25) dorsolateral surface of T2+3; (26) dorsolateral surface of Tc+4; (27) dorsolateral aspect of distal intertarsal joint; (28) proximal intertarsal joint; (29) lateral ridge of distal trochlea tali; (30) medial ridge of distal trochlea tali; (31) cranial edge of lateral malleolus; (32) lateral aspect of tibia; (33) cranial edge of medial malleolus; (34) distal tibiofibular joint.

Dorsoplantar View of a 1-Day-Old Calf (Fig. 7-25): The tarsus of this calf lacks the sharp osseous margins that are present in the mature ox.

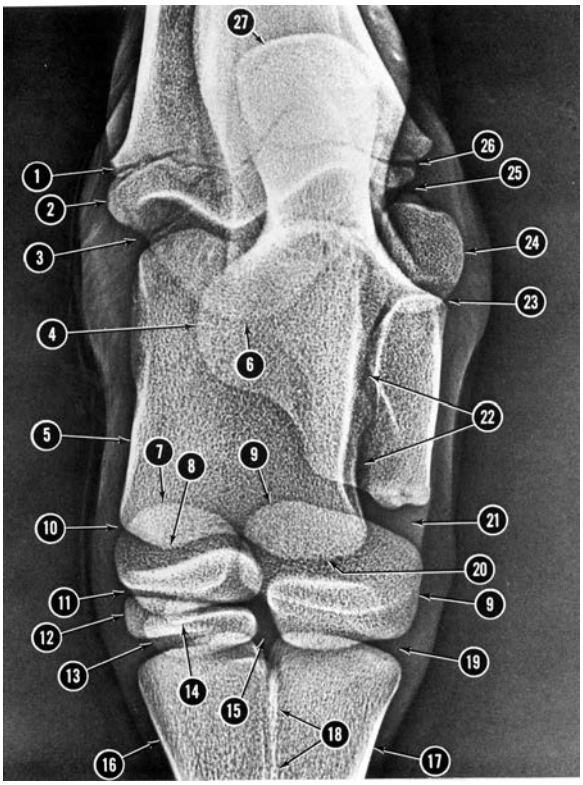


Figure 7-25. Dorsoplantar (DPl) xeroradiograph of left tarsus of a 1-day-old calf: (1) medial aspect of distal epiphyseal cartilage of tibia; (2) medial malleolus; (3) tarsocrural joint space; (4) sustentaculum tali; (5) talus; (6) cranial aspect of intermediate ridge of tibial cochlea; (7) plantar aspect of Tc; (8) medial ridge of distal trochlea tali; (9) ossification center for T4; (10) proximal intertarsal joint; (11) distal intertarsal joint; (12) plantar part of T2+3; (13) dorsal part of T2+3; (14) radiopaque area-from superimposition of ossification center of T1; (15) tarsal canal; (16) third metatarsal bone; (17) fourth metatarsal bone; (18) line of fusion between 16 and 17; (19) fourth tarsometatarsal joint; (20) lateral ridge of distal trochlea tali; (21) calcaneoquartal joint; (22) sinus tarsi; (23) lateral part of tarsocrural joint; (24) lateral malleolus of fibula; (25) distal tibiofibular joint; (26) lateral part of distal epiphyseal cartilage of tibia; (27) tuber calcanei.

Because of the large amount of cartilage present in this newborn calf, all joint spaces appear wide radiographically. It should also be noted that the ossification centers for Tc and T4 are separate in this newborn calf.

Lateromedial View of a 1-Day-Old Calf (Fig. 7-26): The center of ossification for the tuber calcanei is only partially developed in this neonatal calf. Radiographic fusion of this center to the calcaneus proper occurs at about 3 years of age. Radiographic fusion of the distal epiphysis of the tibia occurs at about 30 months of age. Note also that the ossification center for the metatarsal sesamoid bone is not present in this neonatal calf.

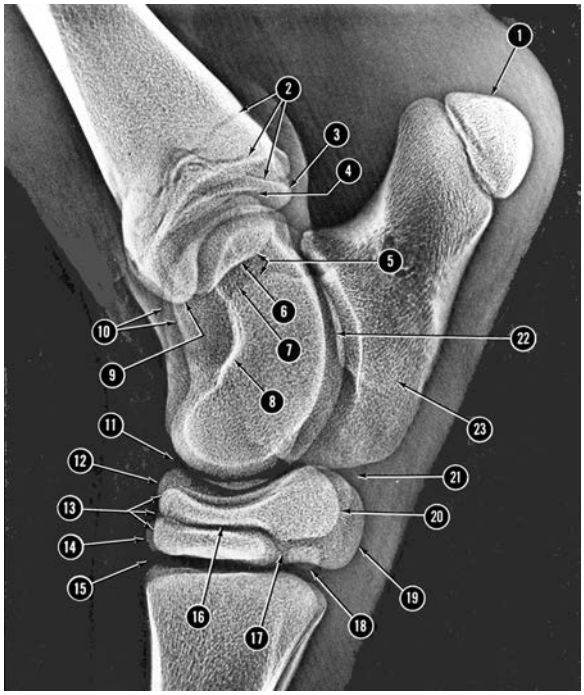


Figure 7-26. Lateromedial (LM) xeroradiograph of left tarsus of a 1-day-old calf: (1) ossification center for tuber calcanei; (2) distal epiphyseal cartilage of tibia; (3) distal epiphysis of tibia; (4) distal tibiofibular joint; (5) articulation between lateral malleolus and coracoid process of calcaneus; (6) lateral malleolus; (7) coracoid process of calcaneus; (8) fossa on dorsal surface of talus; (9) cranial aspect of intermediate ridge of tibial cochlea; (10) ridges of proximal trochlea tali; (11) proximal intertarsal joint; (12) dorsal surface of Tc; (13) dorsal surface of T4; (14) dorsal surface of T2+3; (15) tarsometatarsal joints; (16) distal intertarsal joint; (17) articulation between T2+3 and T1; (18) first tarsal bone; (19) plantar aspect of T4; (20) plantar aspect of Tc; (21) plantar aspect of calcaneoquartal joint; (22) talocalcaneal joint; (23) sustentaculum tali.

Chapter 8 • The Forelimb

It is now time to retrieve those thoracic limbs left over from Chapter 3 and to begin our study of this important supporting structure. As you have already observed, the thoracic limb (forelimb) was attached to the trunk by a group of muscles known as the extrinsic muscles of the limb. This type of muscular attachment is known as a synsarcosis.[1]

The limb was attached to the trunk by the trapezius, rhomboideus, omotransversarius, brachiocephalicus, superficial and deep pectoral, latissimus dorsi, and serratus ventralis muscles (Fig. 8-1). Assuming that none have been misplaced, you should have access to two thoracic limbs per cadaver. Thus, you should have one that can be dissected primarily for the muscles and deeper structures, and another that can be dissected to preserve the more superficial structures. As with the pelvic limb, frequent reference to the skeleton is important to understand where you are relative to the limb.

Review the stumps of the extrinsic muscles on the detached limb. Note the well-developed pectoral muscles of the horse and pig, including the **subclavius**, which attaches cranially over the supraspinatus muscle (Fig. 8-1). *The subclavius muscle can be easily palpated in the live horse*. The stumps of the **superficial pectoral muscle** overlap one another but can be separated into the **descending pectoral** and **transverse pectoral muscles**. The right and left descending pectoral muscles form the distinct "breast muscles" that are evident in the live horse (Fig. 8-1).

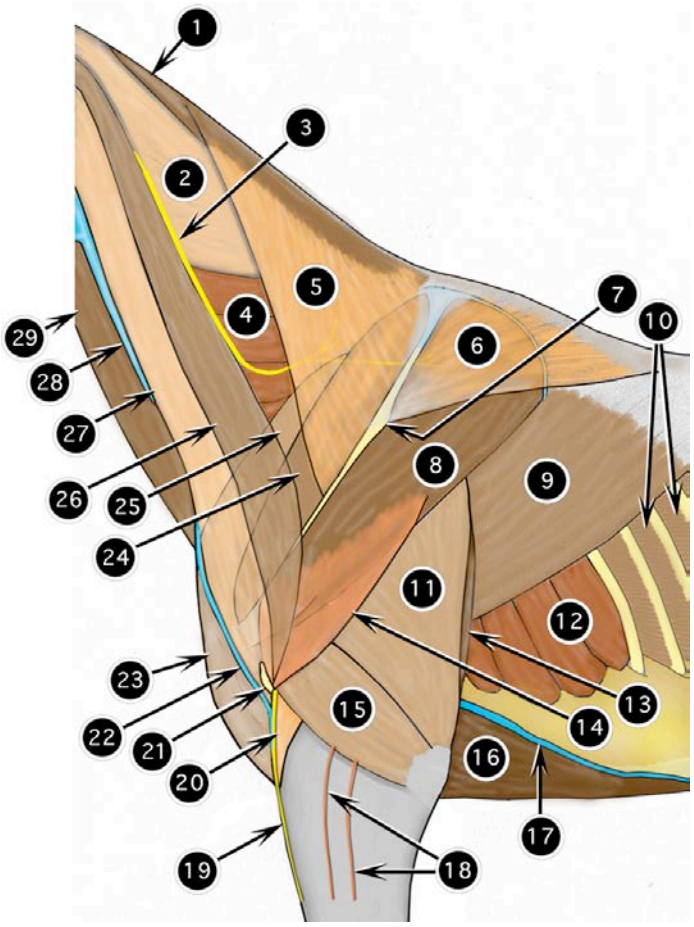


Figure 8-1. Shoulder & arm region of horse, lateral view: (1) rhomboideus cervicis muscle; (2) splenius muscle; (3) dorsal branch of CN XI; (4) serratus ventralis cervicis; (5) trapezius cervicis; (6) trapezius thoracis; (7) spinous tuberosity; (8) infraspinatus muscle; (9) latissimus dorsi muscle; (10) external intercostal muscles; (11) long head of triceps brachii muscle; (12) serratus ventralis thoracis; (13) tensor fasciae antebrachii muscle; (14) deltoideus muscle; (15) lateral head of triceps brachii muscle; (16) deep (ascending) pectoral muscle; (17) superficial thoracic vein; (18) lateral cutaneous antebrachial nerve (from radial); (19) cranial cutaneous antebrachial nerve (from axillary); (20) brachialis muscle; (21) deltoid tuberosity; (22) cephalic vein; (23) descending pectoral muscle; (24) supraspinatus muscle; (25) subclavius muscle; (26) omotransversarius muscle; (27) cleidomastoideus muscle; (28) external jugular vein; (29) sternocephalicus muscle.

[1] synsarcosis- together by muscle.

SKELETAL ANATOMY

Next, look over the skeletal anatomy of the limb, and note those prominences that are likely to be palpable landmarks on the live animal. On the **scapula**, you should note that the horse and pig do not have an acromion, but both have a prominence on the scapular spine, the **spinous tuberosity** (Figs. 8-1 & 8-2). Although better developed in the pig, the spinous tuberosity is a *palpable landmark in the horse*. The **acromion** is a distinct, pointed structure in the ruminant (Fig. 8-3). The spine divides the lateral surface of the scapula into two areas, the **supraspinous and infraspinous fossae**. The **supraglenoid tubercle** serves as the origin of the biceps brachii muscle, and the **coracoid process**, which forms a medial lip off the supraglenoid tubercle, serves as origin for the coracobrachialis muscle. With the exception of the **serrated face**, which serves as the area of termination of the serratus ventralis muscle, the medial surface of the scapula forms the large, shallow **subscapular fossa**.

Scapular Cartilage: In domestic carnivores, the dorsal border of the scapula is capped by a small rim of cartilage. You might observe that the dorsal end of the scapula is more squared off in the horse and ruminants. This is because the dorsal aspect of the bone is formed by the **scapular cartilage**, which is more extensive than in carnivores and provides a large area for attachment of the rhomboideus muscle (Figs. 8-2 & 8-3).

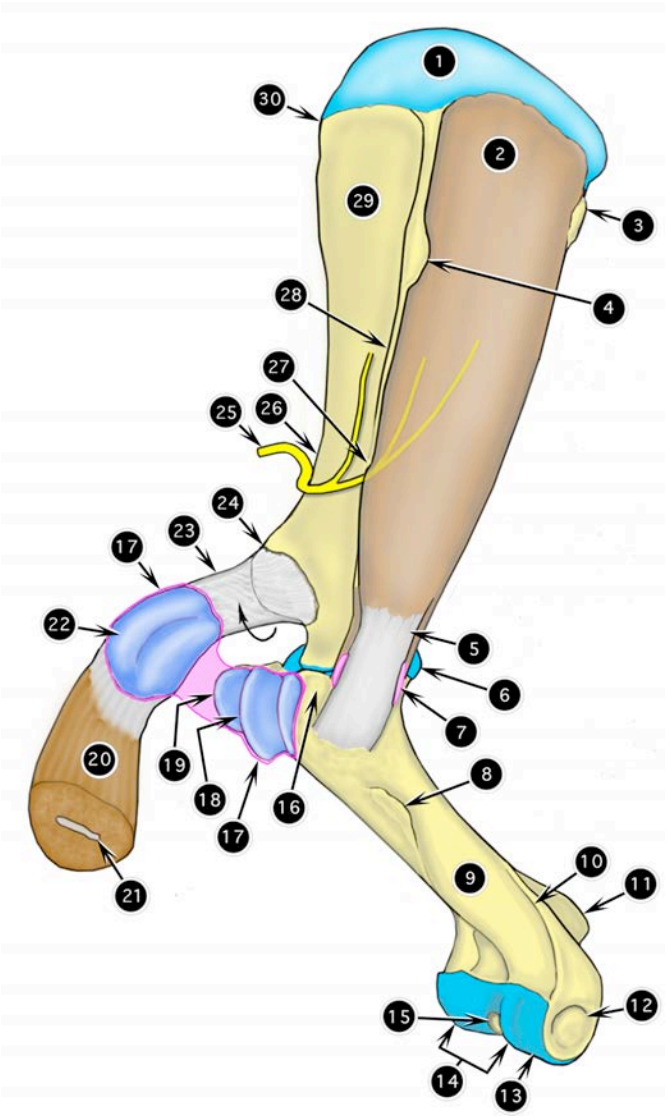


Figure 8-2. Selected structures of equine shoulder & arm, craniolateral view: (1) scapular cartilage; (2) infraspinatus muscle; (3) caudal angle of scapula; (4) spinous tuberosity; (5) tendon of 2 passing over caudal part of greater tubercle; (6) head of humerus; (7) infraspinatus bursa; (8) deltoid tuberosity; (9) brachial groove of humerus; (10) lateral supracondylar crest; (11) medial epicondyle; (12) lateral epicondyle; (13) capitulum of humeral condyle; (14) trochlea of humeral condyle; (15) nonarticular area (synovial fossa); (16) cranial part of greater tubercle; (17) synovial membrane of intertubercular bursa; (18) intermediate tubercle; (19) cranial part of lesser tubercle; (20) biceps brachii muscle; (21) tendon passing through to form lacertus fibrosus; (22) fibrocartilage pad molded to conform with intertubercular groove; (23) tendon of origin of 20; (24) supraglenoid tubercle; (25) suprascapular nerve; (26) neck of scapula; (27) absence of acromion; (28) spine of scapula; (29) supraspinous fossa; (30) cranial angle of scapula.

The scapula cartilage can be palpated in the live horse and ox. In older animals, the scapular cartilage may be partially replaced by bone (progressive ossification).

Humerus: The **intermediate tubercle** divides the **intertubercular groove** of the equine humerus (Fig. 8-2). In contrast to that of the horse, the **greater tubercle** of artiodactyls is much larger than the **lesser tubercle** (Fig. 8-3). The greater (major) tubercle forms the point of the shoulder. In the pig, the greater and lesser tubercles may actually meet to form an osseous foramen at the intertubercular groove.

Note that the greater tubercle is divided into **cranial and caudal parts** in the horse (Fig. 8-2). Also, note the roughened area distolateral to the greater tubercle that serves as the attachment site for the tendon of the infraspinatus muscle. The division of the humeral condyle[2] into a medial **trochlea** and a small, lateral **capitulum** is more obvious than in carnivores.

The **deltoid tuberosity** and **lateral epicondyle** are also *palpable landmarks in the horse*. Of academic interest, a supratrochlear foramen may occasionally be present in the pig.

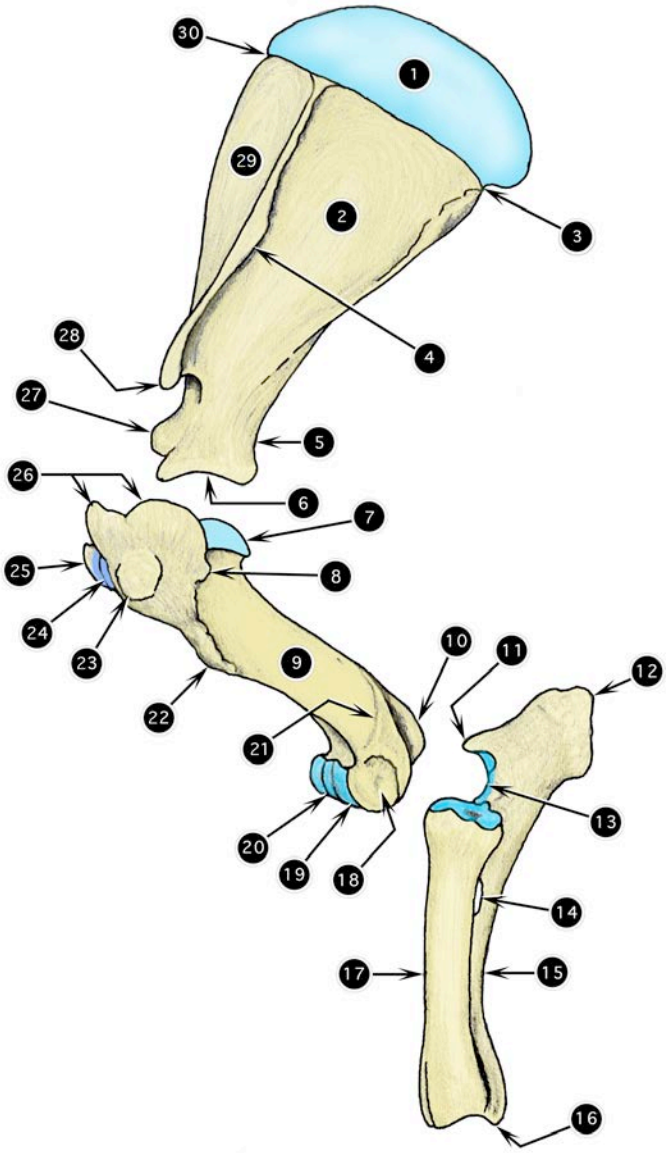


Figure 8-3. Skeleton of left shoulder, arm, and forearm of ox, lateral view: (1) scapular cartilage; (2) infraspinous fossa; (3) caudal angle of scapula; (4) spine of scapula; (5) neck of scapula; (6) glenoid cavity of scapula; (7) head of humerus; (8) tuberosity for teres minor; (9) brachial groove; (10) medial epicondyle of humerus; (11) anconeal process of ulna; (12) tuber olecrani; (13) trochlear notch of ulna; (14) proximal interosseous space; (15) body of ulna; (16) lateral styloid process of ulna; (17) body of radius; (18) lateral epicondyle of humerus; (19) capitulum of humeral condyle; (20) trochlea of humeral condyle; (21) lateral supracondylar crest of humerus; (22) deltoid tuberosity; (23) roughened area for termination of infraspinatus tendon; (24) intertubercular groove; (25) lesser tubercle of humerus; (26) greater tubercle of humerus; (27) supraglenoid tubercle; (28) acromion; (29) supraspinous fossa of scapula; (30) cranial angle of scapula.

[2] Note: There is only one condyle per humerus. Unfortunately, some texts (and uninformed people) make incorrect reference to the medial condyle or lateral condyle of the humerus. Please have patience with these mistaken individuals.

The **brachial groove**, which accommodates the brachialis muscle, spirals around the body of the humerus; it is bounded caudally in the distal part of the humerus by the **lateral supracondylar crest**, from which the extensor muscles of the carpal and digital joints partly originate.

Radius and Ulna: As in the carnivores, the ulna is a complete and separate bone in the pig. In the ruminants, the ulna is fused to the radius (Fig. 8-3). Because of this fusion, there is no supination or pronation movement of the antebrachium. In the horse, not only is the ulna fused, but the bone is incomplete. The body of the equine ulna variably ossifies, and the distal epiphysis fuses to the radius to form the **lateral styloid process**. A proximal interosseous space is present in both the horse and ruminant, but only the latter has a distal interosseous space. The thin body of the ulna ossifies to a varying degree in the horse and, when present, may cause confusion in radiographic examination. The skeletal anatomy of the carpus and distal part of the limb will be considered later.

EXTERNAL FEATURES

The **chestnut** of the equine forelimb represents the vestige of the carpal pad, and the **ergot** is a remnant of the metacarpal pad. Although sometimes stated as such, neither of these structures represents any long-lost digits of the horse.[3] The **dewclaws** of the artiodactyls are similar to those of the pelvic limb and do represent digits 2 and 5. In the pig, these small digits have complete skeletal components, but in the ruminants they are much more vestigial. The **interdigital sinus** of the sheep is also present in the forelimb.

Carpal Organ of Pig: As you should recall, this structure was observed in the cat, in which it is represented by a tactile elevation (haarscheiben) and tactile hairs (vibrissae) associated with tubular glands. In the cat, it functions primarily as a tactile organ. In the pig, the carpal organ is located on the caudomedial surface of the antebrachium, where a row of four to ten duct openings should be found. Apocrine tubular glands associated with these openings produce a secretion that is believed to function as a marker and sexual stimulant. It is thought that the boar marks his mate by applying this secretion while gripping her during copulation.

Lateral Structures of Shoulder: The lateral muscles of the shoulder consist of the deltoideus, supraspinatus, infraspinatus, and teres minor. The absence of an acromion in the horse and pig makes division of the **deltoideus muscle** into acromial and scapular parts less obvious (Fig. 8-1). This division is more distinct in the ruminant (Fig. 2-6). The acromial (cranial) part arises from the acromion, whereas the scapular part (caudal) arises primarily from the epimysium of the infraspinatus, which can be traced to the spine of the scapula. Both parts of the deltoideus converge and terminate on the deltoid tuberosity of the humerus (Fig. 8-4).

The deltoideus muscle is primarily a flexor and abductor of the shoulder joint and is innervated by the **axillary nerve**. A sensory branch of the axillary, the **cranial cutaneous antebrachial nerve**, emerges just caudal to the termination of the muscle on the deltoid tuberosity (Fig 8-1).

[3] Another incorrect assumption on the part of some veterinary students is that when I first started teaching anatomy, horses had three toes and were the size of a large dog. Utter nonsense, but I do admit their splint bones were slightly larger.

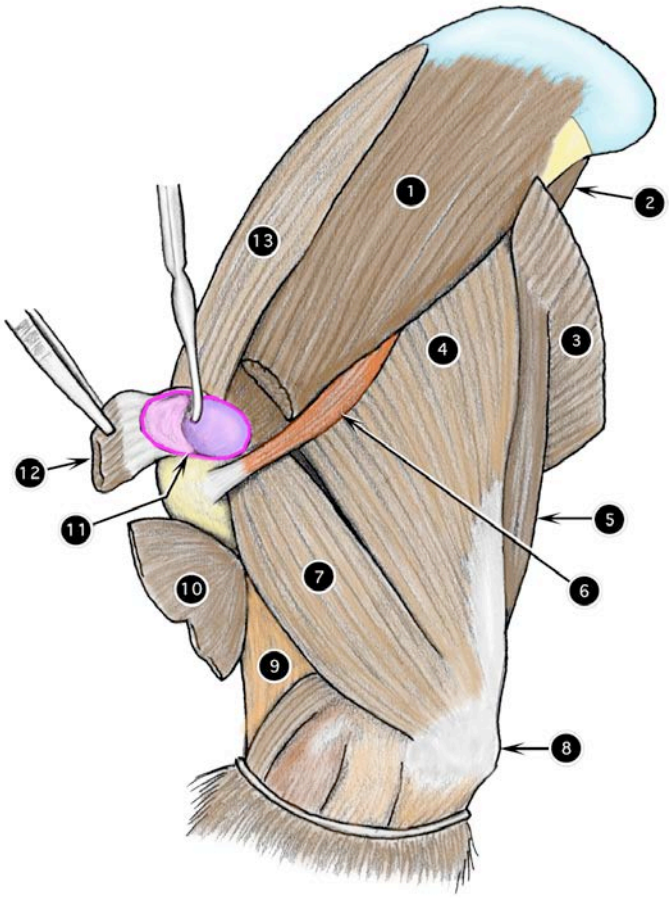


Figure 8-4. Lateral muscles of shoulder & arm of newborn calf: (1) infraspinatus muscle; (2) teres major muscle; (3) latissimus dorsi muscle; (4) long head of triceps brachii muscle; (5) tensor fasciae antebrachii muscle; (6) teres minor muscle; (7) lateral head of triceps brachii muscle; (8) tuber olecrani; (9) brachialis muscle; (10) reflected deltoideus muscle; (11) infraspinatus bursa; (12) reflected tendon of infraspinatus muscle; (13) supraspinatus muscle.

The **supraspinatus muscle** occupies and originates from the supraspinous fossa of the scapula (Figs. 8-4 & 8-5)). It terminates on the greater and lesser tubercles of the humerus, thus bridging the intertubercular groove and bicipital tendon of origin. Although its action is usually given as extension of the shoulder joint, its most important function is that of a stabilizer and antiflexor of the shoulder joint in resistance to weight being transferred to the limb at the attachment of the serratus ventralis. The supraspinatus muscle is innervated by the **suprascapular nerve** (Fig. 8-2).

Transect the deltoid muscle just proximal to the level of the shoulder joint, and reflect both parts to their termination. Once the deltoid muscle has been reflected, the large **infraspinatus muscle** can be observed (Figs. 8-2 & 8-4). This muscle occupies and originates from the infraspinous fossa of the scapula and terminates on and over the greater tubercle of the humerus.

The infraspinatus muscle is innervated by the **suprascapular nerve**. The more superficial part of the muscle converges to form a large *palpable* tendon that crosses the greater tubercle to attach to a roughened area on the humerus, distal to the tubercle (Figs. 8-2 & 8-4). Although its action is usually given as flexion and abduction of the shoulder joint, the infraspinatus also serves as an important stabilizer of the joint.

Undermine its tendon proximal to the greater tubercle, and transect the more superficial part of the muscle several centimeters proximal to the tubercle. Carefully reflect the tendon to its termination. In doing so, you will open the **infraspinatus bursa**, which is located between the tendon and greater tubercle (Figs. 8-2 & 8-4). The bursa is located over the caudal part of the tubercle in the horse, which *can be distinguished by palpation* in the live animal. Like other bursae, the infraspinatus bursa is subject to inflammation (bursitis) and may occasionally account for shoulder lameness in the horse.

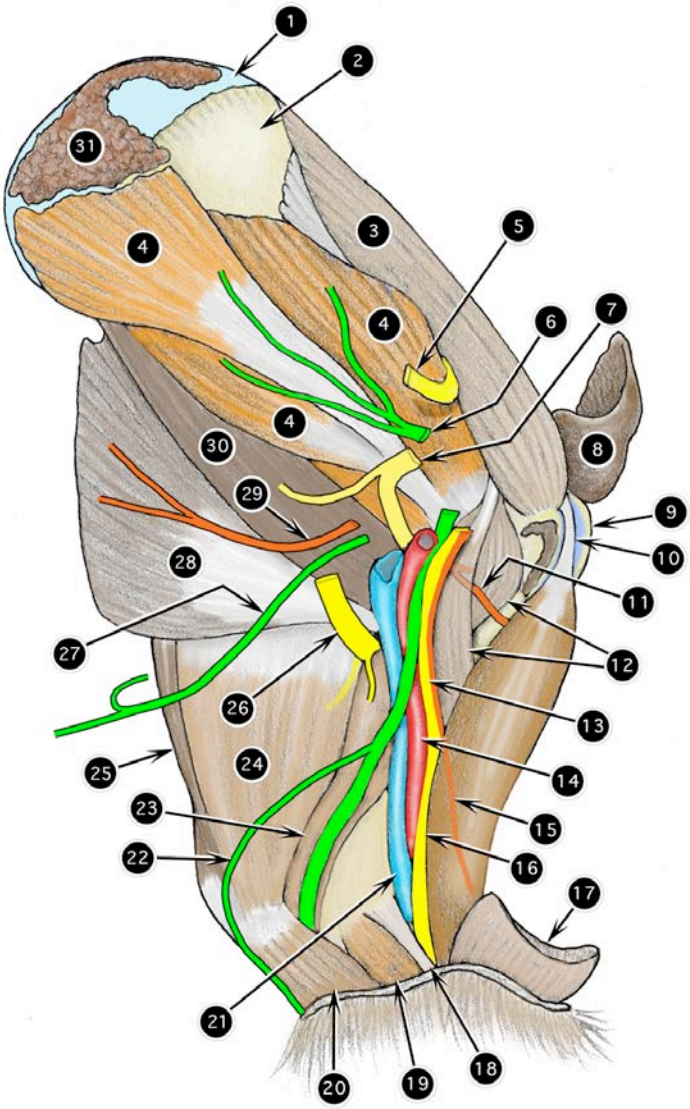


Figure 8-5. Medial structures of shoulder & arm of newborn calf: (1) scapular cartilage; (2) serrated face of scapula; (3) supraspinatus muscle; (4) subscapularis muscle; (5) suprascapular nerve; (6) subscapular nerve; (7) axillary nerve; (8) reflected stump of deep pectoral muscle; (9) greater tubercle of humerus; (10) tendon of origin of biceps brachii muscle within intertubercular groove; (11) proximal branch of musculocutaneous nerve to biceps brachii; (12) coracobrachialis muscle; (13) combined median & musculocutaneous nerves; (14) brachial artery; (15) distal branch of musculocutaneous nerve to brachialis muscle, continued as medial cutaneous antebrachial nerve; (16) median nerve; (17) stump of superficial pectoral muscle; (18) pronator teres; (19) flexor carpi radialis muscle; (20) flexor carpi ulnaris muscle; (21) brachial vein; (22) caudal cutaneous antebrachial nerve; (23) medial head of triceps brachii muscle; (24) long head of triceps brachii muscle; (25) tensor fasciae antebrachii muscle; (26) radial nerve; (27) lateral thoracic nerve; (28) latissimus dorsi muscle; (29) thoracodorsal nerve; (30) teres major muscle; (31) stump of rhomboideus thoracis muscle.

The infraspinatus bursa can be injected with local anesthetic or anti-inflammatory medication as a diagnostic and therapeutic procedure, respectively. *Palpation of the caudal part of the greater tubercle and tendon of the infraspinatus provides important landmarks for arthrocentesis of the shoulder joint*. Be sure you can locate these on the live horse.

After the infraspinatus tendon has been defined and reflected, the small **teres minor muscle** should be discovered caudal to the infraspinatus (Fig. 8-4). It is considered to be a flexor of the shoulder joint and is innervated by the **axillary nerve**.

Medial Structures of Shoulder and Arm: Now, turn the limb over and examine its medial surface. *You will need to remove some of the fat and fascia that cover the muscles on the medial surface of the scapula; do this carefully to preserve the nerves and vessels of the area*.

Once the fat and fascia have been removed, review the attachments of some of the muscles already studied. The **transverse pectoral muscle** can be observed inserting on the medial fascia of the arm and forearm. Proximal to this muscle is the stump of the **deep (ascending) pectoral muscle**, which terminates on the

greater and lesser tubercles of the humerus (Fig. 8-5).

Brachial Plexus (Numbers In, Names Out): As the ventral branches of C6 to T2 emerge from their intervertebral foramina, the nerve fibers get mixed up (Fig. 8-6). This "tangle" is created because of the rather complex embryologic development of the limb, as compared with the relatively simple body wall. Packaging of individual nerve fibers needs to be rearranged to group them into appropriate bundles destined for the corresponding areas of the embryo from which they developed.

If we were to consider the thoracic wall as wearing a striped shirt, with the stripes running around it, then, when we come to the sleeves of the shirt, it's not so easy to keep all the stripes lined up exactly. As long as we have a relatively simple, flat surface (body wall), everything is nice and neat, but when we attach a sleeve (appendage), things get a little tricky. First of all, it takes more fabric (so the nerves are bigger). Then, the fabric (nerve) fibers that go to specific stripes on the shirt get a little mixed up. We have to make some adjustments here to keep things lined up.

Thus, there is a concentrated area of fiber exchange where the neatly numbered ventral branches are rearranged into named nerves that emerge from the plexus in packaging more appropriate for distribution to the limb. This area of fiber exchange is the **brachial plexus** (Figs. 8-6 & 8-7). Although not mentioned at the time, this is obviously the same thing that occurs in the lumbosacral plexus.

Nerves and Nerve Injuries: Some nerves from the brachial plexus innervate extrinsic muscles of the limb (*i.e.*, those muscles that attach the limb to the trunk). The **long thoracic nerve** is distributed to the **serratus ventralis muscle**, and the **lateral thoracic nerve** innervates the **cutaneus trunci muscle**. The pectoral muscles also receive nerves from the brachial plexus; those that innervate the **superficial pectoral muscle** (and subclavius muscle) are the **cranial pectoral nerves**, and those distributed to the **deep pectoral muscle** are the **caudal pectoral nerves**. The **latissimus dorsi** is innervated by the **thoracodorsal nerve** (Fig. 8-5). Between the supraspinatus and subscapularis muscles, identify the stump of the **suprascapular nerve** (Fig. 8-5). The suprascapular nerve originates from the cranial part of the brachial plexus (primarily from ventral branch of C6) and provides motor innervation to the **supraspinatus** and **infraspinatus muscles** (Fig. 8-2).

For reasons not completely understood, the suprascapular nerve is subject to injury, especially in the horse. When it is damaged, there is, in effect, an "unplugging" of these muscles, which means that they will atrophy rapidly, having lost their lower motor neuron connection to the central nervous system.[4] When this occurs, it is rather obvious in the live horse because the spine of the scapula, normally represented by a groove due to the fullness of these muscles, becomes a prominent ridge because of their atrophy. The condition is referred to as "shoulder sweeny" (Fig. 8-8).

Because the horse lacks an acromion, some have proposed that this makes the nerve more vulnerable to direct trauma as it crosses the neck of the scapula on its way to the supraspinatus and infraspinatus muscles.

[4] Degeneration of a muscle that has been detached from its motor innervation (neurogenic atrophy) is a rapid process, occurring within a few weeks' time. This difference helps distinguish it from disuse atrophy, which is more gradual in development.

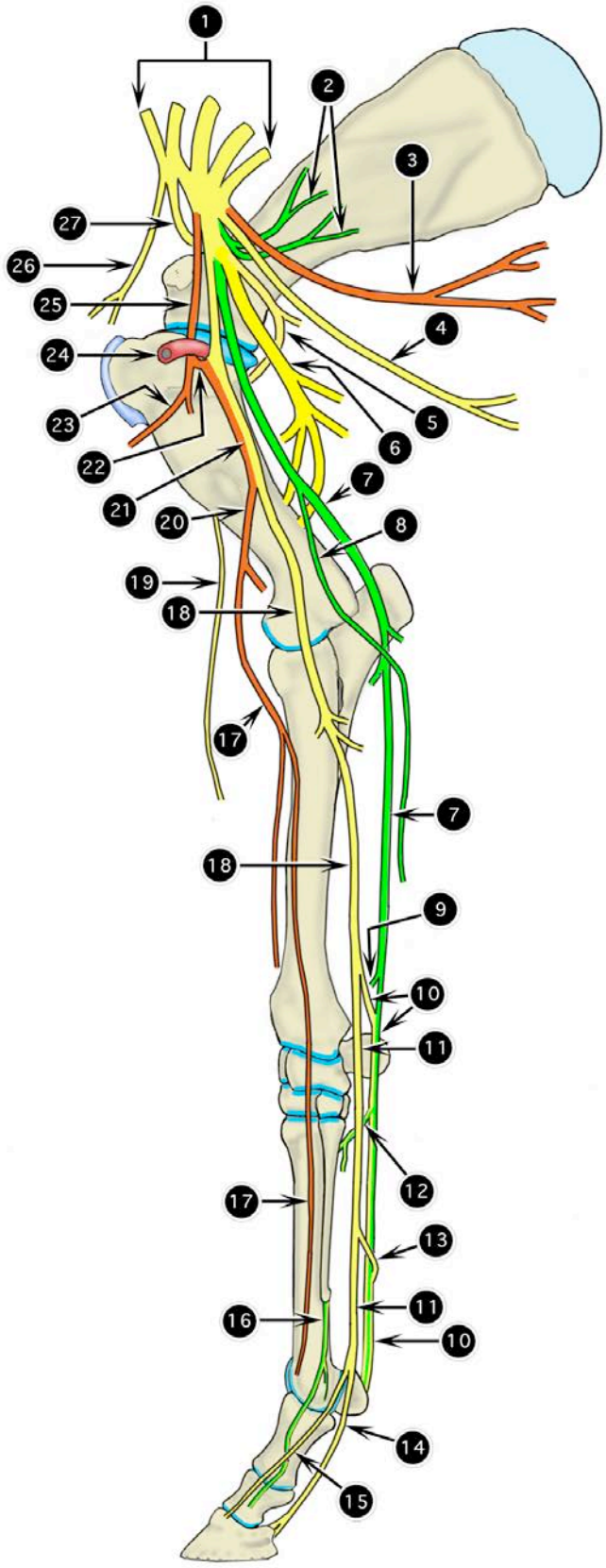


Figure 8-6. Nerves of equine thoracic limb, medial view: (1) roots of brachial plexus from ventral branches of C6 – T2; (2) subscapular nerve to subscapular muscle; (3) thoracodorsal nerve to latissimus dorsi muscle; (4) lateral thoracic nerve to cutaneus trunci muscle; (5) axillary nerve to teres major, teres minor, & deltoideus muscles; (6) radial nerve to extensors of elbow, carpal, & digital joints; (7) ulnar nerve; (8) caudal cutaneous antebrachial nerve; (9) dorsal branch of 7: (10) lateral palmar nerve; (11) medial palmar nerve; (12) deep branch of 10; (13) communicating branch between 11 & 10; (14) medial palmar digital nerve; (15) dorsal branch of 14; (16) medial palmar metacarpal nerve from 12; (17) medial cutaneous antebrachial nerve; (18) median nerve; (19) cranial cutaneous antebrachial nerve; (20) distal branch of musculocutaneous nerve to brachialis muscle, continued as 17; (21) combined musculocutaneous & median nerves; (22) ansa axillaris; (23) proximal branch of musculocutaneous nerve to coracobrachialis & biceps brachii muscles; (24) axillary artery; (25) musculocutaneous nerve; (26) cranial pectoral nerve to superficial pectoral & subclavius muscles; (27) suprascapular nerve to supraspinatus & infraspinatus muscles.

If a horse bangs its shoulder on a gatepost or some other immovable object, the nerve is damaged. This sounds reasonable at first, but note how deeply the nerve is located at this level (Fig. 8-2). It has a very thick muscle pad over it, including the brachiocephalicus and supraspinatus muscles. Although this etiology can't be ruled out, I would say that if a horse sustained a direct blow, sufficient to damage the nerve, it would be intuitively obvious, even to the more casual observer, that the horse had experienced some heavy-duty trauma. I think there is a more logical theory of injury.

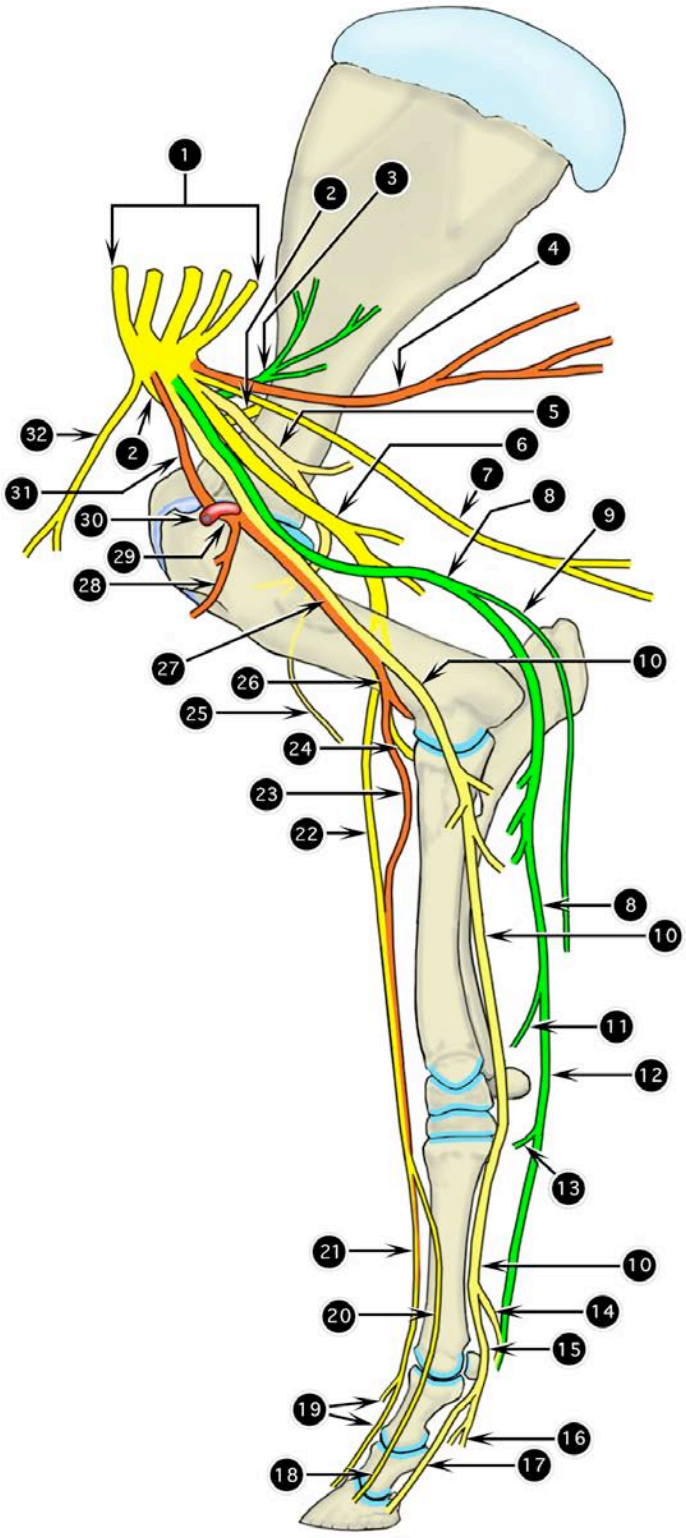


Figure 8-7. Nerves of bovine thoracic limb, medial view: (1) roots of brachial plexus from ventral branches of C6 – T2; (2) suprascapular nerve to supraspinatus & infraspinatus muscles; (3) subscapular nerve to subscapular muscle; (4) thoracodorsal nerve to latissimus dorsi muscle; (5) axillary nerve to teres major, teres minor and deltoideus muscles; (6) radial nerve to extensors of elbow, carpal & digital joints; (7) lateral thoracic nerve to cutaneus trunci muscle; (8) ulnar nerve; (9) caudal cutaneous antebrachial nerve; (10) median nerve; (11) dorsal branch of 8; (12) palmar branch of 8; (13) deep branch of 8; (14) communicating branch of 10 to 12; (15) palmar common digital nerve 3; (16) axial palmar nerves of digits 3 & 4; (17) abaxial palmar digital nerve 3; (18) abaxial dorsal digital nerve 3; (19) axial dorsal nerves of digits 3 & 4; (20) dorsal common digital nerve 2; (21) dorsal common digital nerve 3; (22) superficial (sensory) branch of 6; (23) medial cutaneous antebrachial nerve; (24) deep (motor) branch of 6; (25) cranial cutaneous antebrachial nerve; (26) distal branch of musculocutaneous nerve to brachialis muscle, continued as 23; (27) combined median & musculocutaneous nerves; (28) proximal branch of musculocutaneous nerve to coracobrachialis & biceps brachii muscles; (29) ansa axillaris; (30) axillary artery; (31) musculocutaneous nerve; (32) cranial pectoral nerve to superficial pectoral muscle.

Nerve Injuries and the Vacuum Cleaner: Let's talk about nerve injuries for a moment. One thing you might have already noticed about nerves located in movable parts of the body is that they are rather "wavy," or at least they were before you started dissecting and stretching them beyond recognition. Why are they so wavy? Very simply, they have enough slack in them to allow for the normal range of motion of the body parts.

When things happen so that a body part moves beyond that normal range of motion, nerves get stretched. Like the electrical cord on your vacuum cleaner, nerves can take a little stretch, but when the slack runs out, and you keep on going, you pull the plug out of the socket and the vacuum cleaner stops.

Unlike the vacuum cleaner cord, however, nerves are not so easy to plug back in. Nerve injuries may result in the nerve rootlets being pulled loose from the spinal cord; such injuries are referred to as *avulsion injuries*. This is how many nerve injuries may occur, including that of the suprascapular nerve.

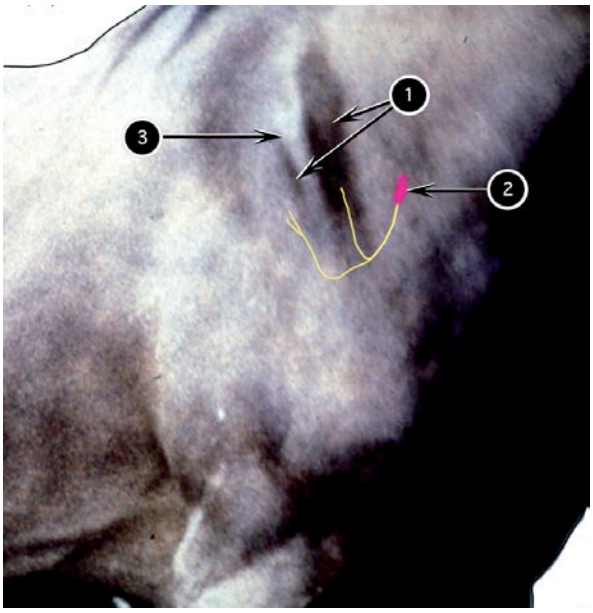


Figure 8-8. Horse with "shoulder sweeny:" (1) marked atrophy of supraspinatus & infraspinatus nerve; (2) probable site of avulsion injury of suprascapular nerve; (3) prominence of spinous tuberosity & scapular spine.

As mentioned previously, the suprascapular nerve is the most cranial nerve of the brachial plexus, arising primarily from C6. When a horse has poor footing and slips, so that the forelimb is thrust violently backward, it naturally attempts to keep its balance by shifting its head and neck toward the other limb, thus increasing the distance between neck and shoulder. If this distance becomes greater than the stretchable limit of the suprascapular nerve, something has to give, and an avulsion injury is likely to occur.

The **subscapular nerve** is typically represented by several nerves that emerge from the brachial plexus and are distributed to the **subscapularis muscle** (Figs. 8-6 & 8-7). Identify the stumps of the subscapular nerve as they enter the muscle.

The **musculocutaneous nerve** leaves the brachial plexus and forms a loop (ansa axillaris) under the axillary artery as the nerve turns caudally to join the median nerve (Figs. 8-6 & 8-7). The **proximal branch** of the musculocutaneous, which is given off to the coracobrachialis and biceps brachii muscles, passes along with the cranial circumflex humeral artery between the two bellies of the coracobrachialis muscle. The remainder of the nerve continues distally in a common fascial sheath with the median nerve.

The **median nerve** leaves the brachial plexus and passes caudal to the axillary artery (Figs. 8-6 & 8-7). Here it receives a communicating branch, the ansa axillaris, from the musculocutaneous nerve and continues distally caudal to the brachial artery. In the horse, it is closely associated with the radial nerve as it leaves the plexus , whereas in the ruminants, it is more closely associated with the ulnar nerve (Fig. 8-7).

The **axillary nerve** provides motor innervation to the flexors of the shoulder joint- the teres major, teres minor, and deltoideus muscles. It leaves the plexus, innervates the teres major, and then passes caudal to the shoulder joint, along with the caudal circumflex humeral vessels, to the lateral side of the limb (Figs. 8-6 & 8-7). Note that it passes proximal to the teres major muscle to reach the teres minor and deltoideus. Its sensory branch, the **cranial cutaneous antebrachial nerve**, emerges

just caudal to the deltoid tuberosity and provides sensory innervation to the skin over the craniolateral aspect of the forearm.

The **radial nerve** is usually the largest nerve of the brachial plexus, and it is also destined for the lateral side of the limb. The radial nerve passes distal[5] to the teres major muscle to reach the triceps brachii and other extensors of the elbow, carpal, and digital joints (Fig. 8-6 & 8-7). In the horse, its sensory component is limited to the **lateral cutaneous antebrachial nerve**, which emerges through the distal part of the lateral head of the triceps brachii muscle (Fig. 8-1). It is usually represented by two branches that are distributed to the skin over the lateral surface of the forearm. In the artiodactyls, the sensory branch of the radial nerve is represented by a large **superficial branch**, which includes the lateral cutaneous antebrachial nerve, but also accompanies the cephalic and accessory cephalic veins into the distal part of the limb (Fig. 8-7).

The **ulnar nerve** leaves the brachial plexus and courses distally in association with the brachial vessels. In the horse (Fig. 8-6), it lies caudal to the vessels, whereas in the ruminants (Fig. 8-7), it emerges from the plexus with the median nerve, then separates and crosses the vessels obliquely from cranial to caudal. At about the middle of the arm, it detaches the **caudal cutaneous antebrachial nerve**, which, as the name implies, provides sensory innervation to the skin on the caudal aspect of the forearm.

The **supraspinatus muscle** should be identified, and in the horse and pig, the subclavius muscle should be noted. Caudal to the supraspinatus is the **subscapularis muscle**, which has several parts that converge near the shoulder joint to form a strong tendon (Fig. 8-5). This tendon passes over the medial aspect of the joint to terminate on the lesser tubercle of the humerus. In addition to adduction of the shoulder joint, it also functions as an important stabilizer. The subscapularis is innervated by the **subscapular nerve**, which, because it was transected so close to the brachial plexus, may be represented by several branches.[6]

Caudal to the subscapularis is the **teres major muscle** (Fig. 8-5), which originates from the caudal border of the scapula and terminates in common with the latissimus dorsi on the tuberosity for the teres major on the humerus. It is considered a flexor of the shoulder joint and is innervated by the axillary nerve.

Now, reflect the stump of the deep pectoral muscle cranially to its humeral attachment; you may remove and discard part of this stump if it is excessive. This should reveal the tendon of the **coracobrachialis muscle** passing obliquely across the shoulder joint and over the tendon of the subscapularis (Fig. 8-5). The two-part belly of this muscle can be observed extending distally over the medial surface of the arm to terminate on the humerus. This muscle is considered a flexor of the shoulder joint, but again also functions as a stabilizer and adductor of the joint. In the horse, there is a **coracobrachialis bursa** located between the tendons of the coracobrachialis

[5] The radial and axillary nerves can be differentiated by their relationships to the teres major muscle. Both pass laterally, but the axillary courses proximal to the muscle, whereas the radial courses distal to the teres major.

[6] Some people like to say that the subscapularis muscle is innervated by both the subscapular nerve and a branch of the axillary nerve. Unless there is some embryologic justification (unknown to me) for this dual innervation idea, it seems to be an unnecessary complication.

and subscapularis muscles; like any bursa, it is subject to inflammation.

Axillary Lymph Nodes: Most of the superficial lymph drainage of the thoracic limb passes to the superficial cervical lymphocenter. The axillary lymphocenter receives the deep lymph vessels of the limb. Proper axillary lymph nodes are not present in the pig, but are found near the division of the axillary into brachial and subscapular arteries in the other species. The axillary lymph node of the first rib is present in the ruminants, pig, and cat. Accessory axillary lymph nodes may be present lateral to the third or fourth rib in carnivores and some ruminants. These differences are mentioned here, but primarily of academic interest as variations in the axillary lymphocenter.

In the distal part of the arm, the remaining fibers of the **musculocutaneous nerve** leave the median nerve as the **distal branch** to innervate the brachialis muscle and continue as the **medial cutaneous antebrachial nerve** (Figs. 8-6 & 8-7). As the name implies, the medial cutaneous antebrachial nerve provides sensory innervation to the skin on the medial aspect of the antebrachium; however, in the horse, it continues distally in company with the cephalic and accessory cephalic veins to innervate the skin over the medial part of the limb to the level of the fetlock joint. *This nerve is palpable in the live horse as it crosses the medial surface of the lacertus fibrosus*. It can be blocked at this location.

The **lacertus fibrosus** is a tendon of termination of the **biceps brachii muscle** that leaves the muscle belly and joins the tendon of the extensor carpi radialis muscle. Because it forms part of the stay apparatus of the thoracic limb, the lacertus fibrosus is very tense and firm when the limb is bearing weight.

Axillary Vessels: The following arteries are typically accompanied by veins of the same name that will not be described separately; in some cases, the veins are double. The subclavian artery is continued as the **axillary artery** as it rounds the first rib to exit the thoracic cavity and enter the axilla (Figs. 8-9 & 8-10). Although the branching pattern varies somewhat with the species and individual animal, the first branch is typically the **external thoracic artery**, which is distributed primarily to the superficial pectoral muscles. The **suprascapular artery** passes dorsally to join the suprascapular nerve and supply the supraspinatus and infraspinatus muscles.

The axillary artery terminates by giving off the large **subscapular artery**, which courses proximally along the caudal border of the scapula, and continues distally as the **brachial artery**.[7] The **thoracodorsal artery** is given off the subscapular artery to join the nerve of the same name and supply the latissimus dorsi muscle. The **caudal circumflex humeral artery** passes laterally, caudal to the shoulder joint with the axillary nerve. Regardless of origin, the collateral radial artery accompanies the radial nerve, the collateral ulnar artery accompanies the ulnar nerve, and so forth.[8]

---

[7] According to *NAV* the axillary artery is continued by the brachial artery at the origin of the cranial circumflex humeral artery; however, because of the variability in the origin of the latter, it is easier and more consistent to consider the origin of the subscapular to mark the beginning of the brachial artery. (Hey, I'm only a 98% pure anatomist; I reserve the right to retain 2% common sense.)

[8] The adjective collateral, with respect to these vessels, denotes that the vessel accompanies the nerve of the same name.

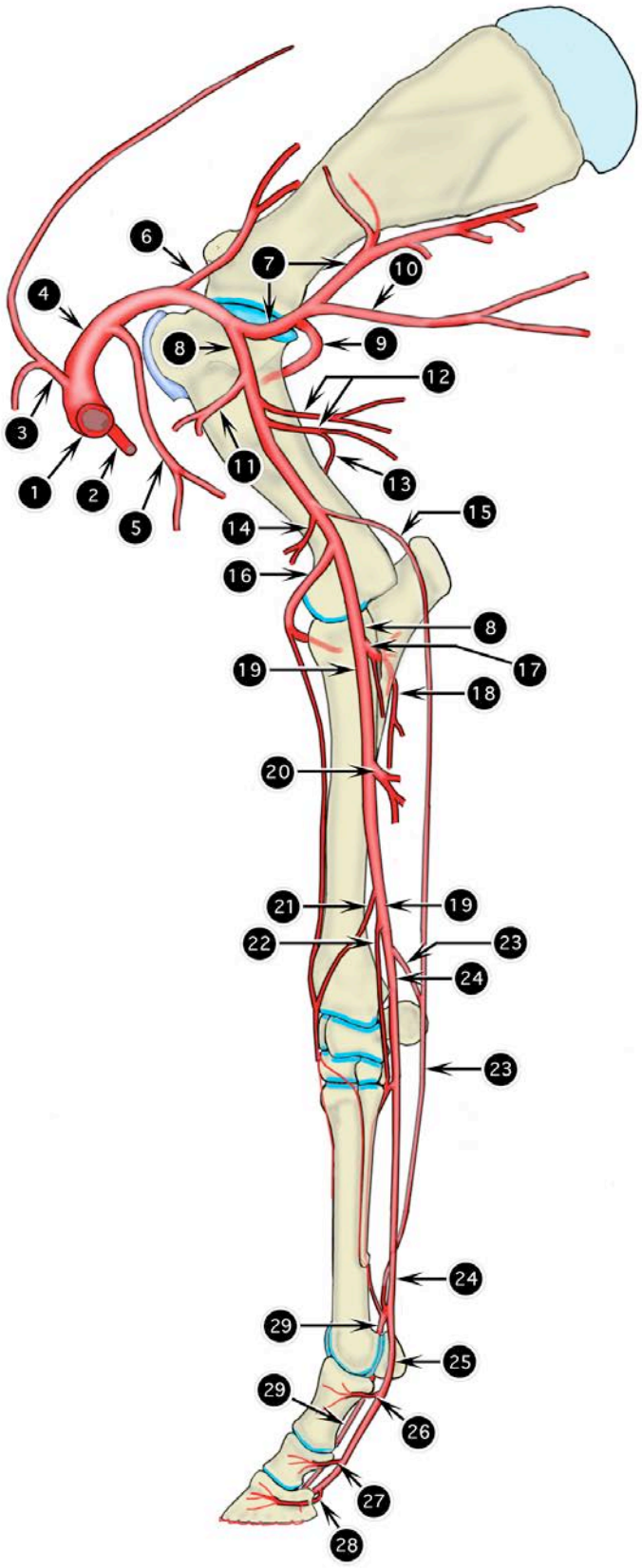


Figure 8-9. Branches of axillary artery of horse, medial view: (1) subclavian artery, proximal to rib 1; (2) internal thoracic artery; (3) superficial cervical artery; (4) axillary artery, distal to rib 1; (5) external thoracic artery to pectoral muscles; (6) suprascapular artery; (7) subscapular artery; (8) brachial artery; (9) caudal circumflex humeral artery; (10) thoracodorsal artery to latissimus dorsi muscle; (11) cranial circumflex humeral artery; (12) deep brachial artery (double); (13) collateral radial artery, accompanies radial nerve; (14) bicipital artery; (15) collateral ulnar artery, accompanies ulnar nerve; (16) transverse cubital artery to craniolateral muscle group; (17) common interosseous artery; (18) cranial interosseous artery to craniolateral muscle group; (19) median artery; (20) deep antebrachial artery to caudomedial muscle group; (21) dorsal carpal branch of 19: (22) radial artery, crosses flexor retinaculum of carpus; (23) lateral palmar artery;* (24) medial palmar artery;* (25) medial digital artery; (26) dorsal branch of proximal phalanx; (27) dorsal branch of middle phalanx; (28) dorsal branch of distal phalanx; (29) lateral digital artery.

_____

* intentional deviations from NAV

In addition to the veins that accompany arteries of the same name, there is a more superficial set of veins that deserves some attention. This group includes the cephalic, accessory cephalic, and median cubital veins (Figs. 8-11 & 8-12). In the horse, the **cephalic vein** is obvious in the live animal along the medial surface of the forearm. The **accessory cephalic vein** does not join the cephalic vein in the distal half of the antebrachium in the horse as it does in the pig, carnivores, and ruminants; instead, this union is in the proximal antebrachium, near the elbow (Fig. 8-11).

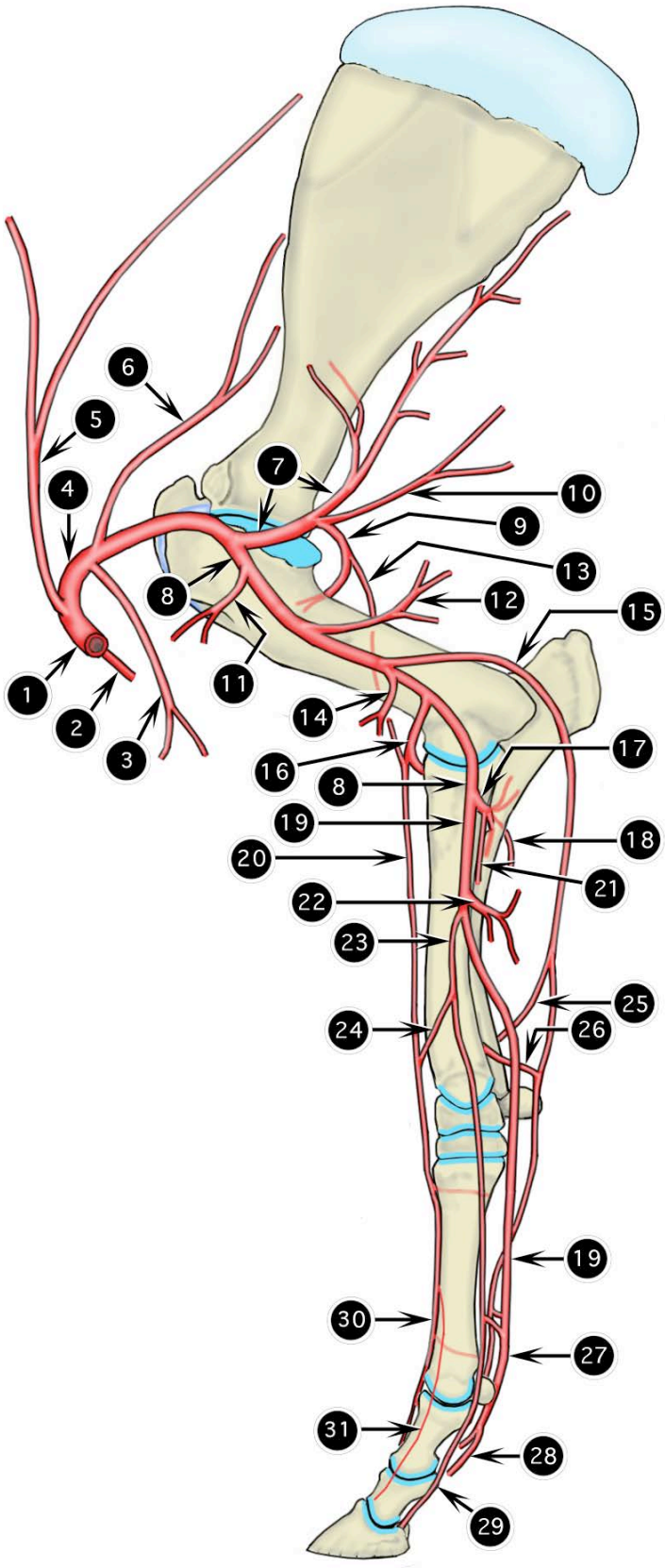


Figure 8-10. Branches of axillary artery of ox, medial view: (1) subclavian artery, proximal to rib 1; (2) internal thoracic artery; (3) external thoracic artery to pectoral muscles; (4) axillary artery, distal to rib 1; (5) superficial cervical artery; (6) suprascapular artery; (7) subscapular artery; (8) brachial artery; (9) caudal circumflex humeral artery; (10) thoracodorsal artery to latissimus dorsi muscle; (11) cranial circumflex humeral artery; (12) deep brachial artery; (13) collateral radial artery, accompanies radial nerve; (14) bicipital artery; (15) collateral ulnar artery, accompanies ulnar nerve; (16) transverse cubital artery to craniolateral muscle group; (17) common interosseous artery; (18) cranial interosseous artery to craniolateral muscle group; (19) median artery; (20) superficial antebrachial artery; (21) caudal interosseous artery; (22) deep antebrachial artery to caudomedial muscle group; (23) radial artery; (24) dorsal carpal branch of 23; (25) dorsal branch of 15; (26) anastomotic branch from 18; (27) palmar common digital artery 3: (28) axial palmar artery of digit 3; (29) abaxial palmar artery of digit 3; (30) dorsal common digital artery 3; (31) abaxial dorsal artery of digit 3.

The **median cubital vein** of the horse is similar to that of the dog in that it courses caudoproximally from the cephalic to the brachial vein. The cephalic vein continues proximally from this union and lies in the groove formed between the brachiocephalicus and descending pectoral muscles (Fig. 8-1).

The cephalic vein is palpable in this groove in the live horse as it continues proximally to join the external jugular vein. The cephalic vein is accompanied here by a descending (deltoid) branch of the superficial cervical artery.

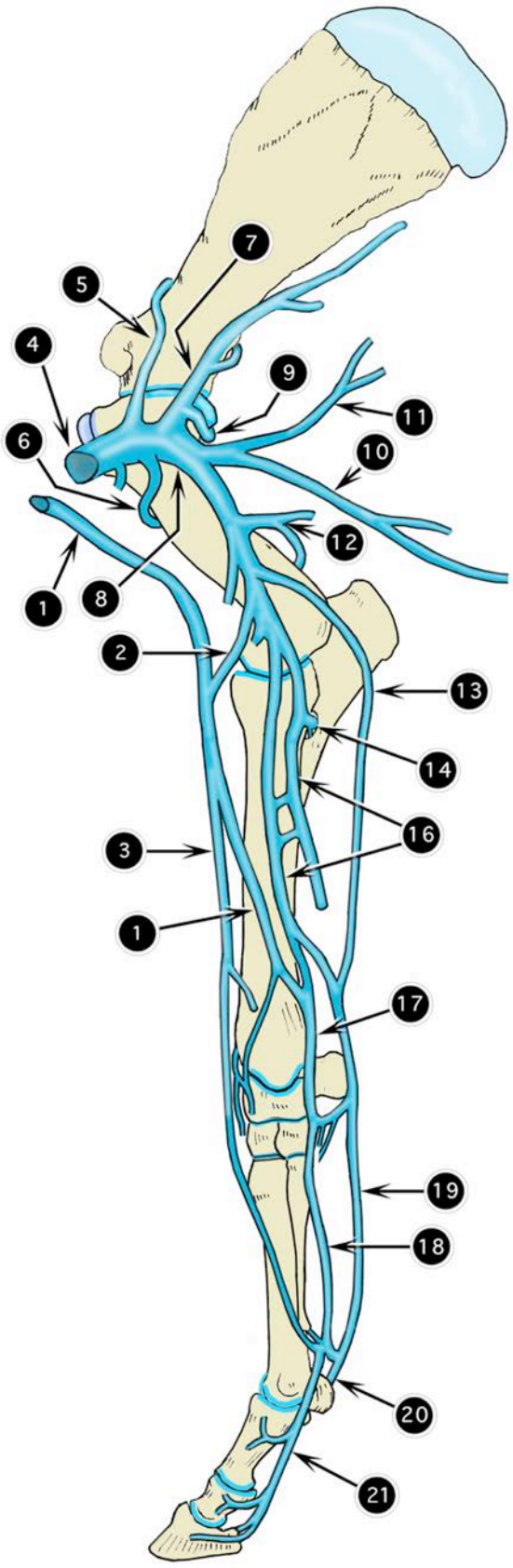


Figure 8-11. Branches of cephalic & axillary veins of horse, medial view: (1) cephalic vein; (2) median cubital vein; (3) accessory cephalic vein; (4) axillary vein; (5) suprascapular vein; (6) cranial circumflex humeral vein; (7) subscapular vein; (8) brachial vein; (9) caudal circumflex humeral vein; (10) superficial thoracic vein; (11) thoracodorsal vein; (12) deep brachial vein; (13) collateral ulnar vein; (14) common interosseous vein; (15) cranial interosseous vein; (16) median vein (double); (17) radial vein; (18) medial palmar vein; (19) lateral palmar vein; (20) lateral digital vein; (21) medial digital vein.

The **cephalic vein** of the ox receives the accessory cephalic in the distal part of the forearm and continues proximally, but the **median cubital vein** is different from that of the horse.[9] Rather than being a short connector vein at the elbow, it courses cranioproximally in the groove between the brachiocephalicus and descending pectoral muscles (Fig. 8-12). The cephalic vein ascends across the surface of the brachiocephalicus, lateral to the groove, and receives the median cubital vein. The cephalic vein then continues in the groove to the external jugular vein.

Cubital Lymph Nodes: In the horse, and sometimes in the sheep, there is an additional collection of lymph nodes medial to the brachial vessels in the distal part of the arm. These cubital nodes are typically not present in the other species.

As you recall from your study of the carnivores, the **tensor fasciae antebrachii** is a small muscle with a long name. It is also small in the ruminants (Fig. 8-4 & 8-5), but is better developed in the horse and pig (Fig. 8-13).

---

[9] The difference in the median cubital vein is mentioned almost out of necessity in that it inevitably causes confusion. I know of no clinical importance of this difference. It's just one of those things that you need to point out so that students don't waste time trying to figure it out.

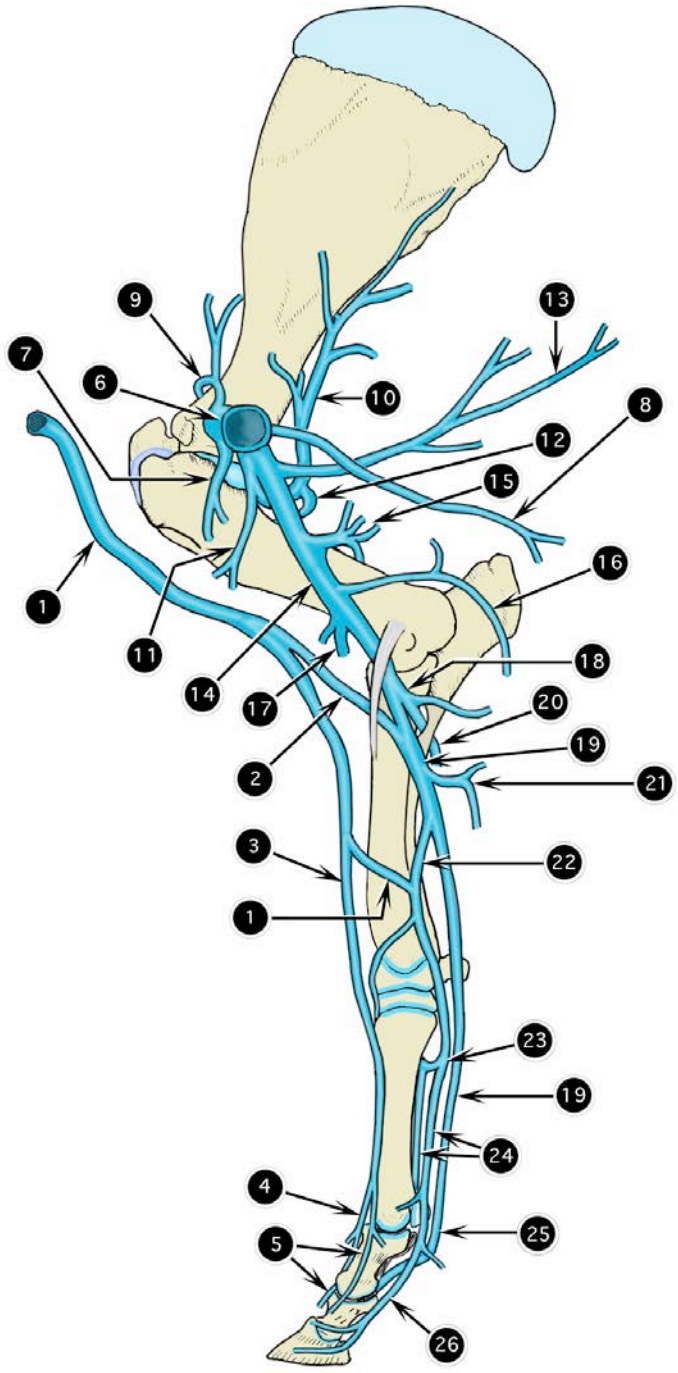


Figure 8-12. Branches of cephalic & axillary veins of ox, medial view: (1) cephalic vein; (2) median cubital vein; (3) accessory cephalic vein; (4) dorsal common digital vein 3; (5) dorsal proper digital veins; (6) axillary vein; (7) external thoracic vein; (8) superficial thoracic vein; (9) suprascapular vein; (10) subscapular vein; (11) cranial circumflex humeral vein; (12) caudal circumflex humeral vein; (13) thoracodorsal vein; (14) brachial vein; (15) deep brachial vein; (16) collateral ulnar vein; (17) transverse cubital vein; (18) common interosseous vein; (19) median vein; (20) cranial interosseous vein; (21) deep antebrachial vein; (22) radial vein; (23) deep palmar arch; (24) palmar metacarpal veins; (25) palmar common digital vein 3; (26) abaxial palmar vein of digit 3.

In the horse and pig, the tensor fasciae antebrachii is divided into cranial and caudal parts, which largely cover the medial surface of the triceps brachii muscle. *The cranial part of the muscle needs to be reflected in the horse and pig so you can continue following the vessels and nerves of the brachium.*

As the name implies, the **cranial circumflex humeral artery** courses cranially, along with the proximal branch of the musculocutaneous nerve. It forms small anastomoses with branches of the caudal circumflex humeral on the lateral side of the humerus. The **deep brachial artery** is a muscular branch that helps supply the triceps brachii muscle. It may be small in the ox and may be double in the horse (Fig. 8-9). The **collateral ulnar artery** accompanies the ulnar nerve.

As the name implies, the **bicipital artery** is a muscular branch distributed to the biceps brachii muscle. The **transverse cubital artery** is a large, muscular branch that leaves the brachial artery and passes laterally, across the flexor surface of the elbow joint, to supply the large extensor muscles of the carpal and digital joints (Figs. 8-9 & 8-10). It can be better observed when the muscles of the arm and forearm are dissected.

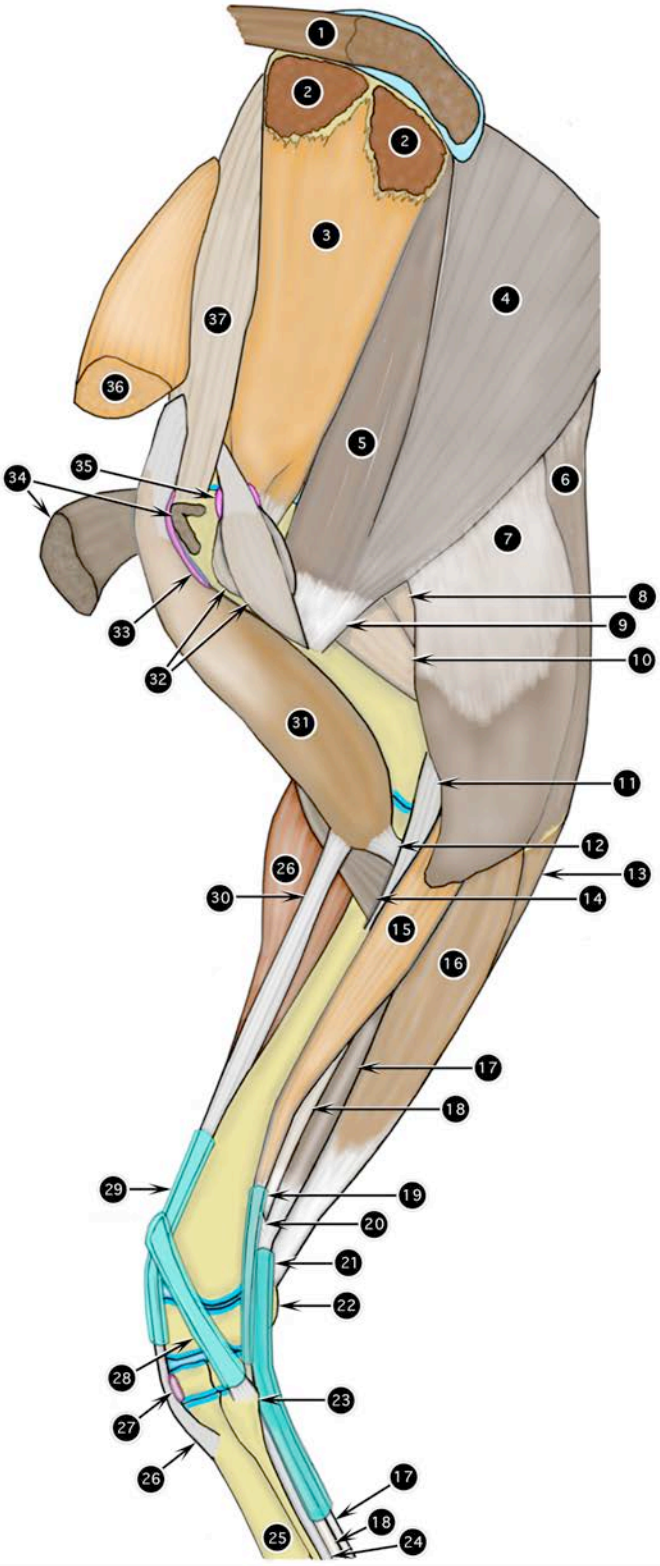


Figure 8-13. Muscles of shoulder, arm, & forearm of horse, medial view: (1) rhomboideus; (2) serratus ventralis; (3) subscapularis; (4) latissimus dorsi; (5) teres major; (6) caudal part of tensor fasciae antebrachii; (7) cranial part of tensor fasciae antebrachii; (8) long head of triceps brachii; (9) common tendon of termination of 4 & 5; (10) medial head of triceps brachii; (11) medial collateral ligament of elbow; (12) short tendon of termination of biceps brachii on radial tuberosity; (13) ulnar head of flexor carpi ulnaris; (14) termination of brachialis; (15) flexor carpi radialis; (16) humeral head of flexor carpi ulnaris; (17) superficial digital flexor; (18) deep digital flexor; (19) tendon sheath for 15; (20) accessory ligament of 17 (proximal check ligament); (21) carpal sheath for 17 & 18; (22) accessory carpal bone; (23) base of metacarpal 2; (24) interosseus 3 (suspensory ligament); (25) metacarpal bone 3; (26) extensor carpi radialis; (27) bursa for 26; (28) tendon sheath for abductor pollicis longus (extensor carpi obliquus); (29) tendon sheath of 26; (30) lacertus fibrosus (long tendon of termination of biceps brachii, joining tendon of 26; (31) biceps brachii; (32) coracobrachialis; (33) intertubercular (bicipital) bursa; (34) ascending (deep) pectoral; (35) bursa for 32; (36) subclavius; (37) supraspinatus.

Incise the skin along the caudal aspect of the antebrachium and carpus, and carefully reflect it to the level of the metacarpus. The **biceps brachii muscle** (Figs. 8-2 & 8-13) originates from the supraglenoid tubercle of the scapula and terminates by two tendons. In the horse and ruminant, the short tendon attaches to the radial tuberosity, and the long tendon, the **lacertus fibrosus**, blends with the tendon of the extensor carpi radialis and continues functionally to the metacarpal tuberosity (Fig. 8-13). The lacertus fibrosus is less developed in the ruminants and is not present in the pig.

To observe the tendon of origin of the biceps brachii, *detach the stump of the deep pectoral from the lesser tubercle, and reflect it to its attachment on the greater tubercle*. This should expose the tendon as it passes through the intertubercular groove of the humerus. Here it is lubricated by a large bursa, the intertubercular (bicipital) bursa (Figs. 8-2 & 8-13).

On one limb only, transect the supraspinatus muscle just proximal to the level of the suprascapular nerve. Preserving the nerve in the process, remove the distal part of the muscle to expose the origin of the biceps brachii from the supraglenoid tubercle. Trace the suprascapular nerve as it passes distal to the scapular spine to enter the infraspinatus (Fig. 8-2). In the horse, note the thickness of the supraspinatus muscle that was removed to expose the nerve. As you can see, the muscle provides a lot of protection to the nerve in this area of vulnerability.

Intertubercular Bursa: On the same limb, transect the biceps brachii through the middle of its belly. Gently reflect the proximal stump to open the large intertubercular bursa (Fig. 8-2). Unlike the situation in the dog and pig, where the shoulder joint capsule extends distally to lubricate the biceps tendon, the intertubercular (bicipital) bursa of the horse and ruminants does not typically communicate with the shoulder joint capsule. This is an important difference in that inflammation of the bursa in the horse (bicipital bursitis) must be treated separately. Injection of medication into the shoulder joint would typically not alleviate pain originating in the bursa, and *vice versa*.

The intertubercular bursa can be injected by palpating the deltoid tuberosity and inserting a needle proximally along the cranial aspect of the humerus to enter the bursa (Fig. 8-14).

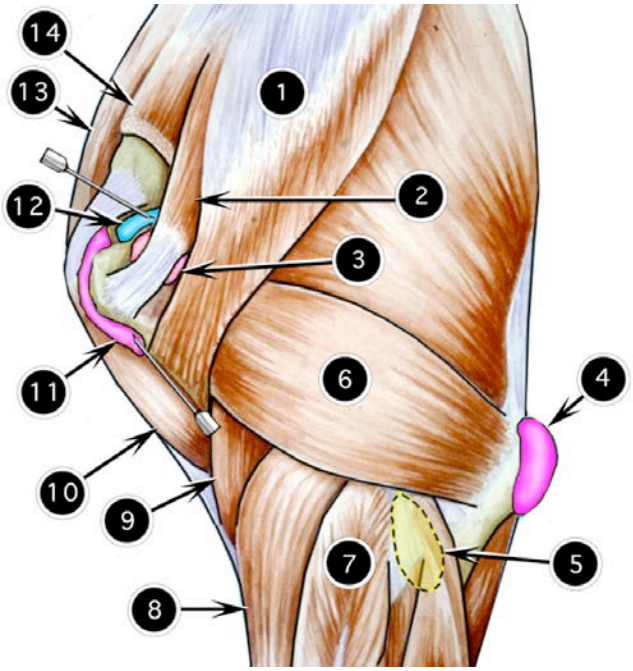


Figure 8-14. Equine shoulder, arm, & elbow regions showing needle placement for arthrocentesis of shoulder joint & tapping of intertubercular bursa, lateral view: (1) deltoideus muscle; (2) infraspinatus muscle; (3) infraspinatus bursa; (4) inconstant subcutaneous bursa formed in cases of olecranon bursitis; (5) approximate location of subtendinous bursa of ulnaris lateralis muscle; (6) lateral head of triceps brachii muscle; (7) common digital extensor muscle; (8) extensor carpi radialis muscle; (9) brachialis muscle; (10) biceps brachii muscle; (11) intertubercular bursa; (12) shoulder joint capsule; (13) subclavius muscle; (14) supraspinatus muscle.

Compare the biceps tendon of origin in the horse with that of the other species. Note that, in the horse, the tendon *is* partly cartilaginous and is molded to fit over the intermediate tubercle. This is an example of how the body uses a fibrocartilaginous pad to absorb pressure where a sesamoid bone is not needed. Partial ossification of this tendon has, however, been reported as a cause of lameness in the horse.[10]

[10] Meagher, D. M., Pool, R. R., and Brown, M. P. Bilateral ossification of the tendon of the biceps

Also, examine the cut surface of the biceps brachii muscle in the horse. You should see a definite tendon within the muscle (Fig. 8-2). This is a fibrous band that passes completely through the muscle from supraglenoid tubercle to exit distally as the lacertus fibrosus.

Shoulder Joint of Horse: Now that you've cut and reflected the tendon of the infraspinatus and removed part of the supraspinatus, go ahead and *cut away the short attachment of the infraspinatus to the greater tubercle and expose the lateral surface of the shoulder joint capsule* (Fig. 8-14). Before I go any further, let me say that shoulder joint lameness is not as much a real problem in the horse as a perceived problem. When horses are lame in a forelimb, they generally shorten their step in that limb and advance the shoulder in a peculiar way. Thus, the horseperson perceives that the horse is lame in the shoulder. After clinical examination, however, most cases of shoulder lameness are traced to a problem in the more distal part of the limb.

Palpation of the infraspinatus tendon and the caudal part of the greater tubercle are the keys to locating the shoulder joint in the live horse. Arthrocentesis of the joint can be performed by inserting a needle immediately cranial to the tendon and just proximal to the greater tubercle (Fig. 8-14). If the needle is directed slightly caudodistally from the junction of tendon and tubercle, you should puncture the shoulder joint capsule (see skeleton, *and palpate these landmarks on a live horse*). It is easier to drain and inject a distended joint than a normal one.

The reason for directing the needle slightly caudally is to avoid the possibility of entering the intertubercular bursa, which, as previously noted, does not communicate with the shoulder joint capsule. Go ahead and *incise the joint capsule* and examine the articular cartilage of the humeral head. The head of the humerus is much larger than the glenoid cavity of the scapula, so the cavity can slip around on the head in a big ball-shallow socket joint.

It should be understood that whenever a veterinarian is going to place a needle into any joint, aseptic technique is used- clip, scrub, and use a sterile needle. The first law of medicine is *primum non nocere*.[11] Never insert a needle into any joint (or any other synovial structure) without proper site preparation and use of aseptic technique. Synovial fluid is a nice fluid, rich in nutrients for bacterial happiness, but iatrogenic[12] infections are definitely unpleasant- not only for the patient, but subsequently for the doctor.

As you recall, the **triceps brachii muscle** consists of four heads in carnivores. The accessory head is not present in the horse and pig and is difficult to demonstrate by dissection in the ox and sheep. In the goat it can be partially separated from the medial head. The largest head of the muscle is the **long head**, which originates from the caudal border of the scapula and, with the other heads, terminates on the tuber olecrani. It can be seen from both the lateral and the medial sides of the limb (Figs. 8-4 & 8-5).

Like the quadriceps femoris muscle of the pelvic limb, the triceps brachii is the key functional muscle of the forelimb in terms of weight-bearing. Without the triceps brachii, the animal cannot fix the elbow joint in an extended position to bear weight. Therefore, the innervation to this important muscle is

brachii muscle in the horse. JAVMA 174 (1979): 282-285.

[11] *Primum non nocere*- first, do no harm.

[12] iatrogenic- resulting from the actions of a physician (veterinarian).

critical to weight-bearing. Damage to the radial nerve, proximal to its branches to the triceps brachii muscle, results in a limb incapable of supporting weight (Fig. 8-15).

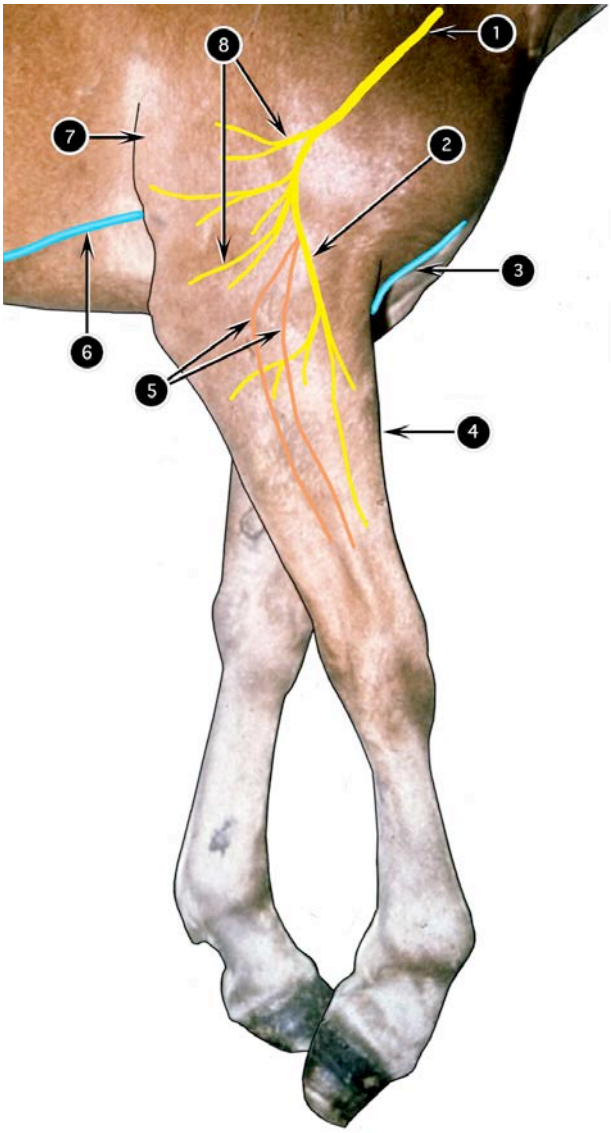


Figure 8-15. Horse with "radial paralysis:" (1) radial nerve, near brachial plexus; (2) deep (motor) branch of 1 to extensors of carpal & digital joints; (3) cephalic vein; (4) atrophy of extensors of carpal & digital joints; (5) superficial branch of 1, represented in horse by lateral cutaneous antebrachial nerve; (6) superficial thoracic vein; (7) atrophy of triceps brachii; (8) motor branches of 1 to triceps brachii, tensor fasciae antebrachii, and anconeus muscles.

Like the rectus femoris of the pelvic limb, the long head of the triceps brachii muscle crosses two joints, the shoulder and elbow joints. Thus, it not only functions in extension of the elbow, but also assists in flexion of the shoulder joint.

The division between the long head and the lateral head should be defined (Figs. 8-4 & 8-14)). *This division can be palpated in the live horse. When you palpate the triceps brachii of a standing horse, you should note that the muscle is rather flabby, and doesn't appear to be overworking itself.* This is because the horse has engaged its "stay apparatus," which takes most of the work out of weight support, even though the triceps brachii muscle is necessary to engage the stay apparatus.

The tensor fasciae antebrachii muscle, which is innervated by the radial nerve, has already been described- enough said. The **brachialis muscle** Figs. 8-4 & 8-14) occupies the brachial groove of the humerus and assists the biceps brachii in flexion of the elbow joint. Like the biceps brachii, it is innervated by the musculocutaneous nerve.

The **radial nerve** piggybacks the brachialis muscle as it spirals around the humerus. *On one limb, transect the lateral head of the triceps brachii near its origin, and reflect it to the tuber olecrani.* This should expose the brachialis muscle and radial nerve more completely (Fig. 8-16).

The radial nerve should be observed to divide into a deep branch, which innervates the extensor muscles of the carpal and digital joints and, except in the horse, a large superficial branch, which continues to ramify with the branches of the accessory cephalic vein on the dorsal aspect of the distal limb all the way to the digits (Fig. 8-7). The superficial branch should be preserved and eventually followed.

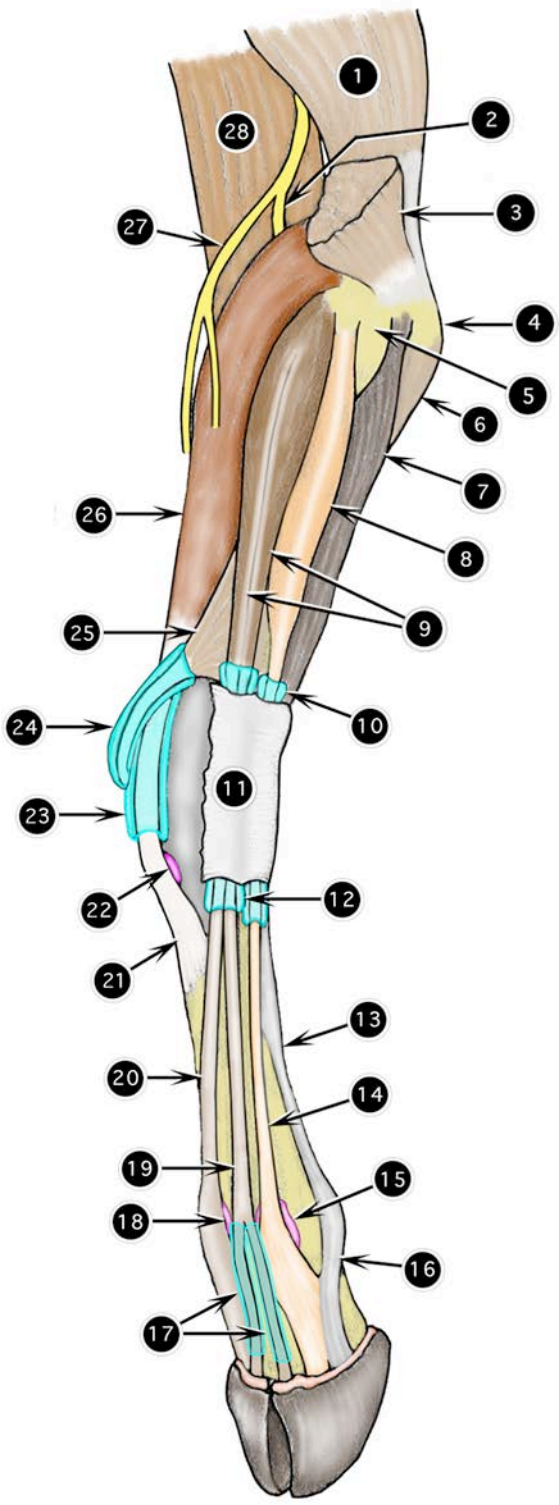


Figure 8-16. Craniolateral muscles of forearm of newborn calf: (1) long head of triceps brachii; (2) deep branch of radial nerve; (3) transected lateral head of triceps brachii; (4) tuber olecrani; (5) lateral epicondyle of humerus; (6) ulnar head of deep digital flexor; (7) ulnaris lateralis; (8) lateral digital extensor; (9) common digital extensor; (10) tendon sheath of 8; (11) extensor retinaculum of carpus, partially removed; (12) tendon sheath of 9 at carpus; (13) interosseus 4; (14) lateral digital extensor tendon to digit 4; (15) bursa of 14 at fetlock; (16) abaxial extensor branch of interosseus 4; (17) tendon sheaths of 19 at digit; (18) bursa of 20 at fetlock; (19) common tendon of common digital extensor to digits 3 and 4; (20) medial tendon of common digital extensor (medial digital extensor) to digit 3; (21) termination of tendon of extensor carpi radialis on metacarpal tuberosity; (22) bursa of 21; (23) tendon sheath of 26; (24) tendon sheath of 25; (25 abductor pollicis longus (extensor carpi obliquus); (26) extensor carpi radialis; (27) superficial branch of radial nerve; (28) brachialis.

With the lateral head of the triceps brachii reflected, examine the area between the tendon of the long head and the tuber olecrani. A deeper, shorter muscle, the **anconeus**, originates from the caudal aspect of the humerus and terminates on the olecranon. It is innervated by the radial nerve and covers the olecranon fossa of the humerus. The deep surface of the anconeus muscle is closely associated with the joint capsule of the elbow.

A constant, **subtendinous bursa** is located between the tendon of the long head of the triceps brachii muscle and the tuber olecrani. Similar to the situation over the tuber calcanei, there is sometimes increased pressure (trauma) over the tuber olecrani (point of elbow). When this occurs, a **subcutaneous bursa** develops in response to the trauma. This clinical condition is known as "capped elbow" or **olecranon bursitis** (Fig. 8-17). Because it is sometimes related to pressure (when lying down) or striking (when moving) of the elbow with the horseshoe, it is also referred to as a "shoe boil." The medial head of the triceps brachii muscle is small, but not forgotten (Figs. 8-5 & 8-13). It helps out when needed.

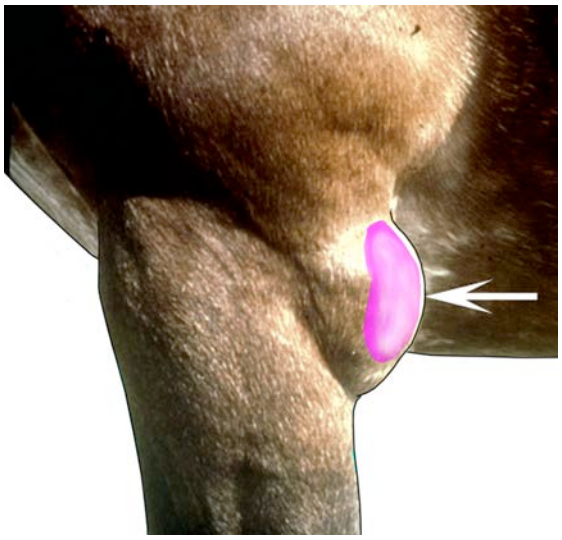


Figure 8-17. Horse with olecranon bursitis. A subcutaneous bursa (arrow) has formed over the tuber olecrani in response to trauma.

On one limb, detach the anconeus muscle, and reflect it to the olecranon. This should expose and open the elbow joint capsule. Examine the articular surfaces of the joint, including the anconeal process of the ulna and the humeral condyle. The latter is a common site for **osteochondrosis** in the pig. By the way, the correct anatomic name for the elbow joint is the **cubital joint**.[13]

The **medial cutaneous antebrachial nerve**, which is a sensory branch of the musculocutaneous nerve, has a more extensive distribution in the horse than in other domestic mammals (Fig. 8-6). As noted above, the radial nerve does not have a large superficial branch in the horse, and it is the medial cutaneous antebrachial nerve that accompanies the cephalic and accessory cephalic veins to the area of the fetlock.

The medial cutaneous antebrachial nerve of the ox provides sensory innervation to the skin on the medial aspect of the forearm and joins the superficial branch of the radial nerve (Fig. 8-7). In the small ruminants and pig, this nerve provides sensory innervation to the skin of the medial antebrachium, as in the carnivores.

In review, the four cutaneous nerves of the antebrachium are derived as follows:

1. Cranial: axillary nerve
2. Lateral: radial nerve
3. Caudal: ulnar nerve
4. Medial: musculocutaneous nerve

Craniolateral Muscles of Forearm: *Continue reflection of the skin to the level of the hoof (hooves)*. The muscles of the forearm can be conveniently divided into two groups. The craniolateral group consists of the extensors of the carpal and digital joints**,** which receive their motor innervation through the radial nerve. Like the muscles of the crus, these muscles are enveloped by a tough layer of deep fascia, which surrounds the muscle group and extends between individual muscles as intermuscular septa. This heavy fascia not only provides considerable protection against penetrating skin wounds, but also functions in support, like an internal stockinet of support hose.

It is necessary to remove the deep fascia on one limb to expose the individual muscles. The largest and most cranial muscle of this group is the **extensor carpi radialis**, which arises from the lateral supracondylar crest of the humerus and terminates on the metacarpal tuberosity (Figs. 8-13 & 8-16). In the horse and ruminants, the tendon of this muscle receives the lacertus fibrosus from the biceps brachii muscle (Fig. 8-13).

Proximal to the carpus, the extensor carpi radialis tendon is crossed laterally to

[13] cubital- pertaining to the elbow; cubit (Latin, *cubitus*): the distance from the human tuber olecrani to the tip of the third digit (≈ 50±3 cm).

medially by the oblique tendon of the **abductor pollicis longus** (extensor carpi obliquus).[14] Trace this latter tendon proximally to expose the triangular muscle that arises from the lateral aspect of the radius, deep to the common digital extensor muscle (Fig. 8-16). As the tendons of these muscles pass over the carpus, they are held in position by the **extensor retinaculum** of the carpus and are lubricated by synovial sheaths and bursae (Fig. 8-16).

Sometimes epidermal thickenings (callouses) form over the dorsum of the carpus in response to pressure. These are most obvious (normal) in the goat, but may also become prominent in cattle that lie down a lot on hard surfaces. These thickenings are sometimes accompanied by the development of a subcutaneous bursa, which can become clinically significant. Such an abnormal, thick-walled bursa is called a **hygroma** (Fig. 8-18).

The **common digital extensor** is a large muscle that, in the artiodactyls, is divided into two parts (Fig. 8-16). In the horse, locate the single tendon as it continues across the dorsolateral aspect of the metacarpus (Fig. 8-19). *Undermine the tendon, and trace it proximally, incising the extensor retinaculum as needed to isolate the muscle*. In the ruminants, there are two tendons to trace proximally, and in the polydactyl pig, three tendons can be identified. *Trace these proximally to define the individual muscle bellies*.

Like the long digital extensor of the pelvic limb, the more medial component to digit 3 (2 and 3 in the pig) is often described as the **medial digital extensor**. Again, it represents part of the common digital extensor muscle. The medial tendon(s) is distributed to the medial digit(s), whereas the more lateral (common) tendon divides and attaches to the distal phalanges of the major, weight-bearing digits (Fig. 8-16). As these tendons are undermined and lifted away from their carpal beds, you should note that they occupy individual grooves in the craniodistal part of the radius (see skeletons). The extensor retinaculum merely retains them in their appropriate groove.

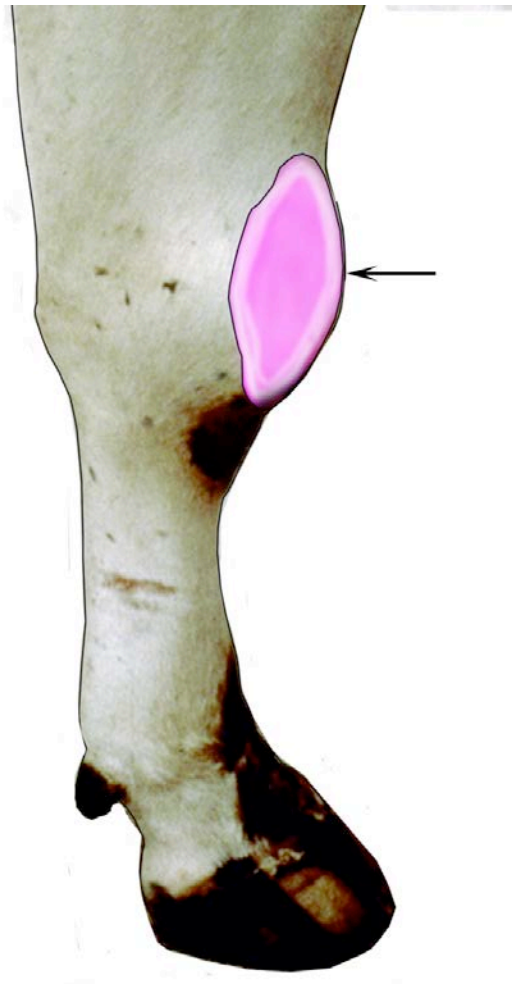


Figure 8-18. Dairy cow with carpal hygroma: A large, thick-walled, bursa (arrow) has formed subcutaneously over the dorsum of the carpus in response to pressure/trauma from resting on a hard surface with insufficient bedding.

[14] Although the term "extensor carpi obliquus" is used frequently in large-animal anatomy texts, I prefer to use the same name for the same muscle in all domestic mammals, regardless of whether they have a pollex (first digit) that needs abducting.

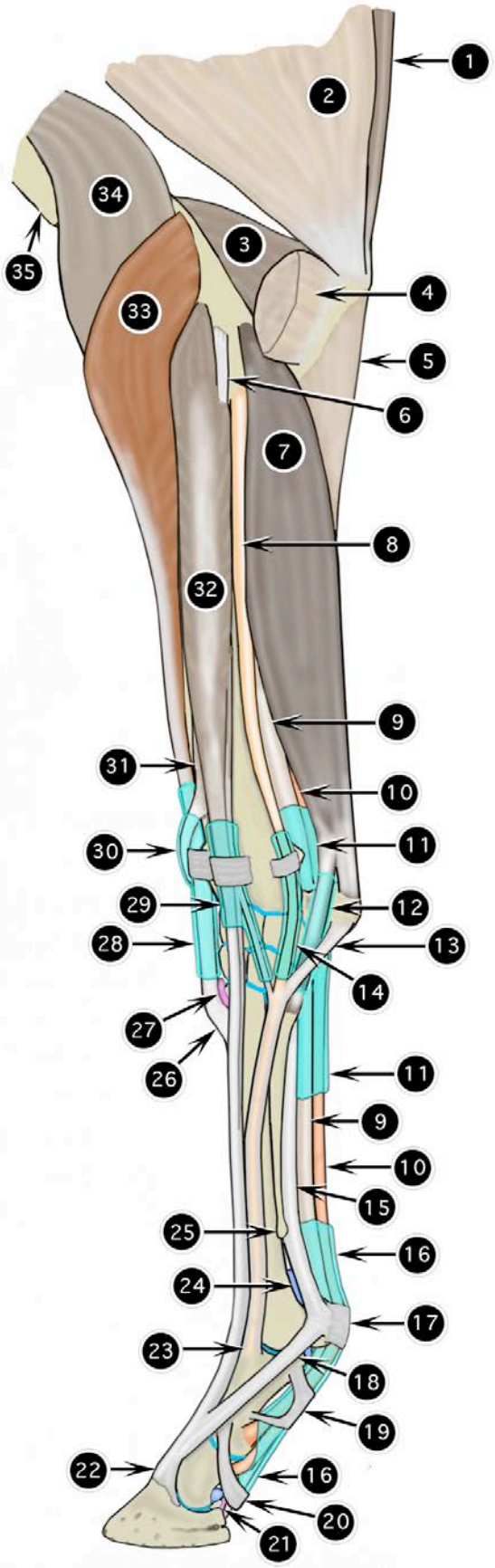


Figure 8-19. Muscles of equine antebrachium & manus, lateral view: (1) tensor fasciae antebrachii; (2) long head of triceps brachii; (3) anconeus; (4) lateral head of triceps brachii; (5) ulnar head of deep digital flexor; (6) lateral collateral ligament of elbow; (7) ulnaris lateralis; (8) lateral digital extensor; (9) deep digital flexor; (10) superficial digital flexor; (11) carpal sheath; (12) tendon sheath of long tendon of 7 to base of metacarpal bone 4; (13) band of fibers from accessory carpal bone to tendon of 8; (14) tendon sheath of 8; (15) interosseus 3 (suspensory ligament); (16) digital sheath; (17) palmar annular ligament of fetlock; (18) lateral extensor branch of 15; (19) proximal digital annular ligament; (20) distal digital annular ligament; (21) podotrochlear (navicular) bursa; (22) termination of common digital extensor on extensor process of Pd; (23) termination of lateral digital extensor on dorsoproximal prominence of Pp; (24) proximal part of palmar pouch of fetlock joint; (25) head of metacarpal bone 4; (26) termination of extensor carpi radialis on metacarpal tuberosity; (27) bursa under tendon of extensor carpi radialis; (28) tendon sheath of extensor carpi radialis; (29) tendon sheath of common digital extensor; (30) tendon sheath of abductor pollicis longus; (31) abductor pollicis longus (extensor carpi obliquus); (32) common digital extensor; (33) extensor carpi radialis; (34) brachialis; (35) deltoid tuberosity of humerus.

The **lateral digital extensor** is a rather large muscle in those species with a lateral digit that needs extending (Fig. 8-16). Of course, the horse does not have a lateral digit, and thus the muscle is greatly reduced in size (Fig. 8-19). Identify the tendon of this muscle in the metacarpus. Follow it proximally to identify and isolate the muscle belly. In the horse, the tendon is much larger (wider) in the metacarpus than it is proximal to the carpus.

This is because it is joined by tendon fibers from the common digital extensor and by a substantial band of fibers that originates from the accessory carpal bone (Fig. 8-19). In the horse, the lateral digital extensor tendon occupies a small groove in the caudolateral aspect of the radius (see skeleton). As it crosses the carpus, it is lubricated by a synovial sheath and passes deep to the lateral collateral ligament of the carpus (Fig. 8-19). Even though it is a digital extensor, it actually passes the carpal joints palmar to the center of rotation for flexion of these joints. It would appear that this muscle might serve more as an "antihyperextensor" of the carpus in the horse, because its simultaneous contraction helps dampen the strong carpal extension produced by the extensor carpi radialis and common digital extensor muscles.[15]

Unlike the arrangement in the pelvic limb, the tendon of the lateral extensor of the horse does not join that of the common digital extensor; rather, it terminates separately on the dorsoproximal aspect of the proximal phalanx (see prominence on skeleton). *Palpate the tendon of the lateral digital extensor, just proximal to the carpus, in the live horse.*

The last muscle of the group is the **ulnaris lateralis** (Figs. 8-16 & 8-19). Although innervated by the radial nerve, this muscle is definitely located too far caudally (palmarly) to serve as an extensor of the carpus. Like the lateral digital extensor, it serves as an "antihyperextensor." It arises from the lateral epicondyle of the humerus and terminates by way of two tendons, one on the accessory carpal bone (Ca) and a long one that continues to the base of the fourth metacarpal bone (Fig. 8-19). The latter tendon passes through a groove in the accessory carpal bone (see skeleton).

On one limb of the horse, transect the ulnaris lateralis muscle through the middle of its belly and reflect the proximal stump toward the elbow joint. Lying deep to the tendon of origin of this muscle is the bursa of the ulnaris lateralis, which may communicate with the elbow joint (Fig. 8-14). This bursa has been described as the site of an infectious bursitis following a laceration, which spread to the joint, resulting in a septic arthritis.[16]

Caudomedial Muscles of Forearm: Now, turn the limb over, and examine the medial surface. *It is necessary to remove some of the loose connective tissue and reflect the stump of the transverse pectoral muscle to expose the origins of these muscles from the medial epicondyle of the humerus and olecranon.* Note that a triangular area of the distal radius is subcutaneous; no muscles or tendons cross this area, and the deep fascia of the forearm blends with the periosteum of the radius (Figs. 8-13 & 8-20). *This heavy protective and supportive fascia must also be removed to observe the caudomedial muscles.*

The caudomedial muscles of the forearm consist of the flexors of the carpal and digital joints and receive their motor innervation through branches of the median and ulnar nerves (Figs. 8-6 & 8-7).

[15] "Antihyperextensor" is a made-up term. Hyperextension of the carpus in the horse is bad for carpal bones. When a horse is moving forward at a rapid gait (gallop), the forward swing of the limb automatically snaps the carpus into extension. What is really needed is an antagonistic action to keep the carpus from popping into hyperextension, sort of like the spring on a screen door to keep it from slamming open.

[16] Dunkerley, S. C., Schumacher, J., Marshall, A. E. Sepsis of the ulnaris lateralis bursa and elbow joint in a horse. JAVMA 208 (1996): 1238-1239.

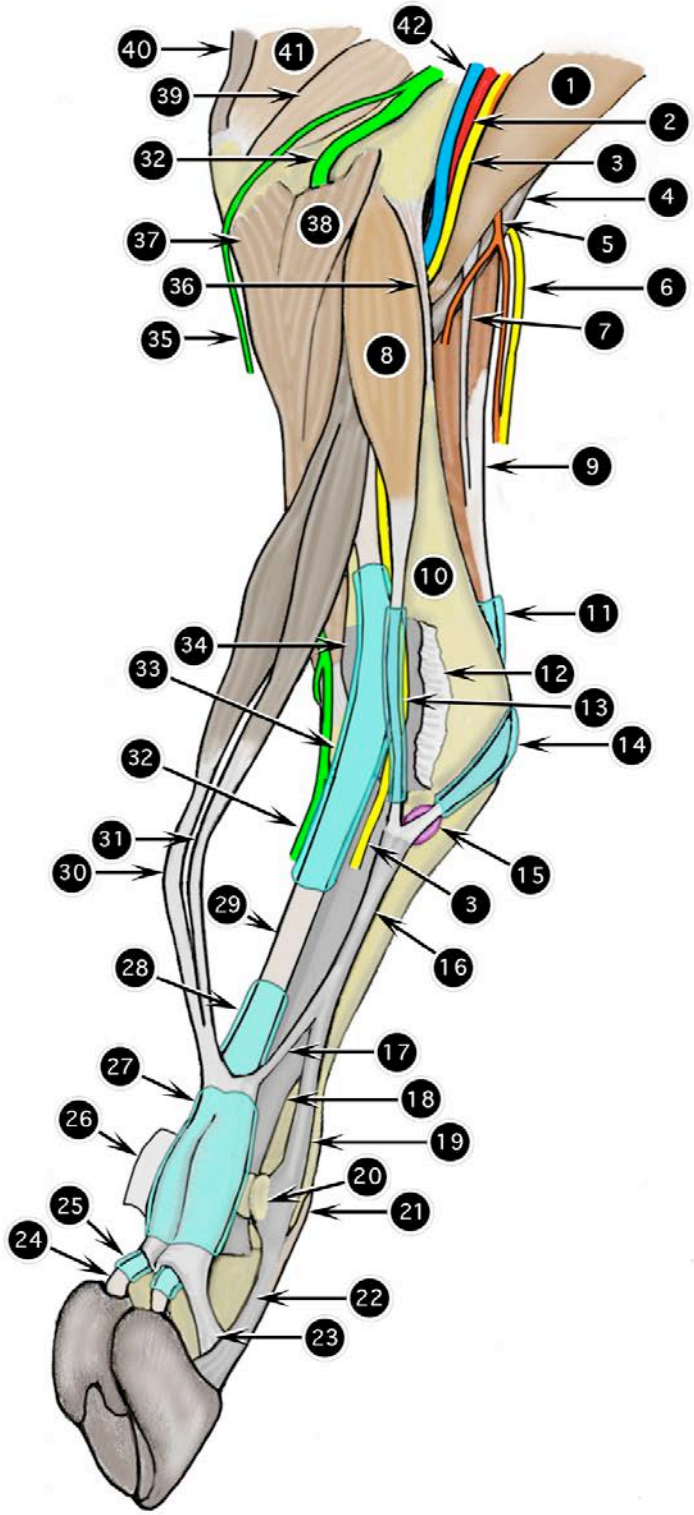


Figure 8-20. Muscles of bovine antebrachium & manus, medial view: (1) biceps brachii; (2) brachial artery; (3) median nerve; (4) brachialis; (5) medial cutaneous antebrachial nerve, from musculocutaneous; (6) superficial branch of radial nerve; (7) lacertus fibrosus; (8) flexor carpi radialis; (9) extensor carpi radialis; (10) radius; (11) tendon sheath of 9; (12) flexor retinaculum of carpus, partially removed; (13) tendon sheath of 8; (14) tendon sheath of abductor pollicis longus (extensor carpi obliquus); (15) bursa of abductor pollicis longus; (16) interosseus 3; (17) branch of interosseus 3 to superficial digital flexor tendon; (18) axial tendon of interosseus 3; (19) abaxial tendon of interosseus 3; (20) abaxial proximal sesamoid bone of digit 3; (21) tendon of medial digital extensor; (22) abaxial extensor branch of 16; (23) abaxial termination of medial branch of superficial digital flexor tendon to middle phalanx of digit 3; (24) lateral branch of deep digital flexor tendon to distal phalanx of digit 4; (25) distal part of digital sheath; (26) palmar annular ligament of fetlock joint, partially removed & reflected; (27) part of digital sheath surrounding double sleeve (manica) formed by superficial digital flexor tendon; (28) proximal part of digital sheath; (29) deep digital flexor tendon; (30) superficial part of superficial digital flexor; (31) deep part of superficial digital flexor; (32) ulnar nerve; (33) carpal sheath; (34) palmar carpal ligament forming dorsal wall of carpal canal; (35) caudal cutaneous antebrachial nerve; (36) pronator teres (mostly fibrous); (37) ulnar head of flexor carpi ulnaris; (38) humeral head of flexor carpi ulnaris; (39) medial head of triceps brachii; (40) tensor fasciae antebrachii; (41) long head of triceps brachii; (42) brachial vein.

As the median nerve and brachial vessels are traced across the medial surface of the elbow joint, except in the horse, they pass deep to the **pronator teres** (Fig. 8-20). Although a fleshy muscle in the pig, it is logically reduced in those species that are incapable of pronation and supination movements (*i.e.*, the radius and ulna are fused). In the ruminants, the pronator teres is essentially reduced to a fibrous band (Fig. 8-20), and the horse has done away with it altogether (Fig. 8-13).

Unlike the arrangement in carnivores, the superficial digital flexor muscle is not the most superficial muscle in the proximal part of the medial antebrachium of the ungulates. Disregarding the small (or absent) pronator teres, the most cranial muscle of the group is the **flexor carpi radialis** (Figs. 8-13 & 8-20). *Isolate this muscle and trace its tendon to the carpus*.

Caudal to the proximal part of the flexor carpi radialis, locate the **flexor carpi ulnaris muscle** (Figs. 8-13 & 8-20). This muscle originates by two heads, one from the humerus, the other from the ulna. *Separate the flexor carpi ulnaris from the other muscles, and trace its tendon to the carpus, where it terminates with the ulnaris lateralis on the accessory carpal bone*.

The remaining muscles of the caudomedial group are the digital flexor muscles, which can be identified by tracing their tendons proximally from the metacarpal region. *Carefully remove some of the fascia from the palmar aspect of the metacarpus, and isolate the most superficial tendon*. Trace it proximally to the carpus. *In the horse, it will be necessary to incise the flexor retinaculum of the carpus* to follow the tendon of the **superficial digital flexor** to its muscle belly.

Just proximal to the carpus of the horse, note that the tendon is attached to the distomedial aspect of the radius by a short fibrous band, the **accessory ligament of the superficial digital flexor** (Fig. 8-21). This "ligament" represents the completely fibrous radial head of the muscle and forms a direct attachment of the tendon to the caudodistomedial aspect of the radius. Thus, it forms what is frequently referred to as the **proximal (radial) check ligament** of the horse. Transection (desmotomy) of this accessory ligament has been used with some success in the treatment of superficial digital flexor tendinitis in racing Thoroughbred and Standardbred horses.[17]

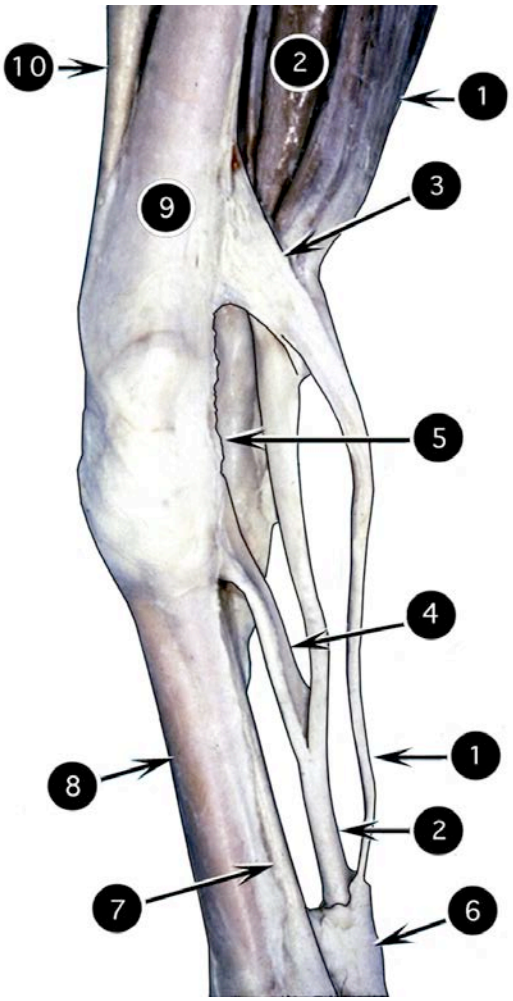


Figure 8-21. Accessory (check) ligaments of digital flexor muscles of horse, medial view: (1) superficial digital flexor; (2) deep digital flexor; (3) accessory ligament of superficial digital flexor (proximal check ligament); (4) accessory ligament of deep digital flexor (distal check ligament); (5) palmar carpal ligament forming dorsal boundary of carpal canal; (6) sleeve for deep digital flexor formed by superficial digital flexor; (7) interosseus 3 (suspensory ligament); (8) metacarpal bone 3; (9) radius; (10) extensor carpi radialis muscle.

[17] Hawkins, J. F., Ross, M. W. Transection of the accessory ligament of the superficial digital flexor muscle for the treatment of superficial digital tendinitis in Standardbreds: 40 cases (1988-1992). JAVMA 206 (1995): 674-678.

Unlike that of the horse, the superficial digital flexor of artiodactyls is composed of superficial and deep parts (Fig. 8-20). The tendon of the superficial part passes between two layers of the carpal flexor retinaculum, whereas that of the deep part passes through the **carpal canal** with the deep digital flexor tendon. By pulling the superficial tendon of the superficial digital flexor palmarly in the metacarpus, a smaller tendon should be found to join it just above the fetlock. This is the tendon of the deep part of the superficial digital flexor.

Incise the flexor retinaculum of the carpus as necessary to follow the smaller tendon proximally through the carpal canal to identify another head of the superficial digital flexor (Fig. 8-20). Also in artiodactyls, this deep part is intimately attached to the deep digital flexor tendon by one or more adhesions, which represent the interflexorii muscles. There is no accessory ligament of the superficial digital flexor in the artiodactyls.

Now locate the tendon of the **deep digital flexor** in the metacarpus. Follow this heavy tendon proximally through the carpal canal to observe that it is formed by three heads. Again, in the horse, there is a direct fibrous attachment that originates from the junction of carpus and metacarpus, the **accessory ligament of the deep digital flexor**, which is frequently referred to as the **distal (carpal) check ligament**. (Fig. 8-21).[18] You're right again, this is just another component of the stay apparatus.

[18] The term "check ligament" is commonly used to describe these fibrous structures because they tend to check or limit the tendon from being pulled around the corner of the fetlock joint in response to weight being applied to this seemingly awkward angle. The downward push produced by gravity and acceleration forces are trying to drive the ergot (fetlock joint) into the ground.

The accessory ligament of the deep digital flexor is sometimes cut in foals with **flexor deformity** of the distal interphalangeal joint or so-called "contracted tendons." This operation is referred to clinically as a **distal check ligament desmotomy**. As you can see, this ligament can be approached through a medial or lateral incision. The lateral incision is preferred by some because it avoids the medial palmar artery, which is the principal arterial channel in the equine metacarpus.

Nerves and Vessels: Now that you've gotten this limb fairly well dissected, let's turn our attention to the other limb for consideration of the nerves and vessels of the antebrachium. We'll come back to this "more dissected" limb later to consider the digital region. As you recall, we left the vessels and nerves of the limb at about the level of the elbow joint. Four cutaneous nerves of the antebrachium have already been mentioned. The major nerves that are to be followed distally include the median, ulnar, and, in the artiodactyls, the radial nerve.

As noted, the sensory component of the **radial nerve** of the horse is greatly reduced, consisting primarily of the lateral cutaneous antebrachial nerve. The musculocutaneous (medial cutaneous antebrachial) nerve accompanies the cephalic and accessory cephalic veins and provides sensory innervation to the skin to the level of the fetlock joint in the horse. For all practical purposes, however, the two major nerves that innervate the deeper (lameness-producing) structures of the limb are the median and ulnar nerves in the horse. The median nerve, being a little insecure, stays right with the protected median artery through the forearm, so it never becomes very superficial (vulnerable).

Median Artery: The brachial artery gives off the **transverse cubital artery**, and continues into the forearm (Figs. 8-9 & 8-10). *Transect the flexor carpi radialis muscle through the middle of its belly, and reflect its origin to follow the brachial vessels and median nerve*. After giving off the **common interosseous artery**, the brachial artery is continued as the **median artery**. The common interosseous gives off the caudal interosseous artery (essentially absent in horse), and then continues through the proximal interosseous space (between the radius and ulna) as the **cranial interosseous artery** (Figs. 8-9 & 8-10).

Reaching the craniolateral aspect of the forearm, the cranial interosseous artery helps supply the extensors of the carpal and digital joints. The median artery continues, under cover of the flexor carpi radialis muscle, where it gives rise to the **deep antebrachial artery** (Figs. 8-9 & 8-10). Like the deep brachial artery, this is the primary muscular branch to the caudomedial muscles of the antebrachium. By the time they reach this level, the median vessels and nerve are closely associated with the major tendons (*i.e.,* superficial and deep digital flexors) that they are going to accompany through the carpal canal.

In the middle to distal part of the forearm, the median artery gives rise to the **radial artery** (Figs. 8-9 & 8-10), which becomes superficial and passes across the carpal flexor retinaculum just palmar to the radial vein. The radial vein forms an anastomosis with the cephalic vein (Figs. 8-11 & 8-12). Although it is possible to take the pulse of the horse from the radial artery as it crosses the flexor retinaculum of the carpus, there are better places to do this in the standing horse.

The horse has a small proximal radial artery, which should not be mistaken for the larger radial artery. Before entering the carpal canal, the median artery of the horse gives off a **lateral palmar artery**, which moves over to anastomose with the collateral ulnar artery and accompany the lateral palmar nerve through the flexor retinaculum of the carpus (Fig. 8-9). The principal arterial channel continues with the median nerve and digital flexor tendons as the **medial palmar artery** (Fig. 8-9).

Median and Ulnar Nerves: Now, let's follow the median and ulnar nerves through the forearm of the **horse**. The flexors of the carpal and digital joints are innervated by branches of these two nerves. Similar to the crus of the pelvic limb, most of the muscular branches arise in the proximal part of the antebrachium. The median nerve accompanies the median artery, whereas the ulnar nerve traverses the forearm in a more caudal location (Fig. 8-6).

After passing between the medial epicondyle of the humerus and olecranon, the ulnar nerve descends between the ulnaris lateralis and flexor carpi ulnaris muscles, where it is located just deep to the heavy antebrachial fascia surrounding these muscles. The narrow tendon of the ulnar head of the deep digital flexor is closely associated with the nerve, and although the tendon is larger, these two structures can be confused. (Of course, you wouldn't do that.)

In the distal half of the forearm, the median nerve divides into medial and lateral palmar nerves (Fig. 8-6), and an important redistribution of nerve fibers occurs. The **medial palmar nerve** continues through the carpal canal with the medial palmar artery. A few centimeters proximal to the accessory carpal bone, the **ulnar nerve** divides into **dorsal and palmar branches**. The dorsal

branch immediately penetrates the tendon of the ulnaris lateralis and is distributed to the dorsolateral aspect of the carpus and metacarpus (Fig. 8-22). The palmar branch joins the **lateral palmar nerve** from the median nerve, and the combined unit accompanies the lateral palmar artery through the flexor retinaculum of the carpus (Fig. 8-6).

Thus, the medial palmar nerve is derived entirely from the median nerve, whereas the lateral palmar nerve represents a mixture of median and ulnar fibers (Fig. 8-22). Similar to the situation in the pelvic limb, the lateral palmar nerve gives off to a **deep branch**, which innervates the interosseus and gives origin to the **medial and lateral palmar metacarpal nerves** (Fig. 8-22). These deep nerves descend along the axial borders of the small metacarpal bones to emerge distal to them.

Ulnar Nerve Block: The ulnar nerve of the horse can be blocked rather easily approximately 10 cm proximal to the palmar border of the accessory carpal bone.[19] By palpating proximally from the accessory carpal bone along the caudal aspect of the forearm, a shallow groove can be defined between the converging flexor carpi ulnaris and ulnaris lateralis muscles. As noted, the ulnar nerve descends between these muscles. It lies just a few millimeters deep to the heavy antebrachial fascia at the level where the block is performed. The needle must penetrate this heavy fascia for the block to be effective. If a subcutaneous bleb forms as the anesthetic is injected, the deep fascia has not been penetrated, and the needle must be advanced to pop through the fascia. This means you have probably passed beyond the nerve. Once injection of the local anesthetic solution begins, the needle can be slowly withdrawn to bathe the nerve as the needle tip passes by on its way out.

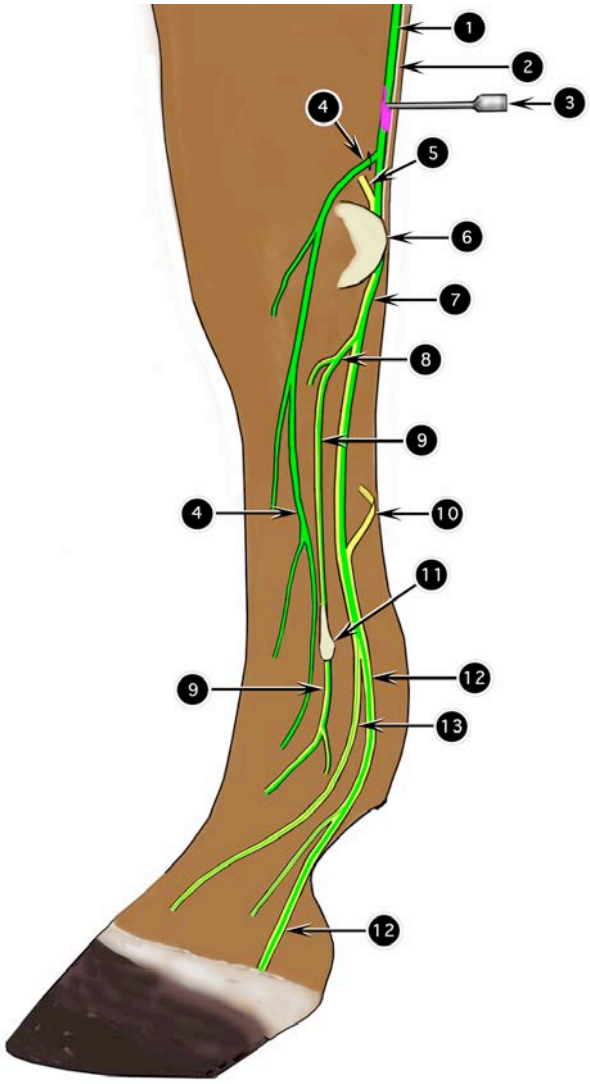


Figure 8-22. Distal forelimb of horse showing some nerves & landmarks, lateral view: (1) ulnar nerve; (2) deep fascia of forearm; (3) needle indicating site of injection for ulnar nerve block; (4) dorsal branch of ulnar nerve as it penetrates and crosses tendon of ulnaris lateralis; (5) lateral palmar nerve from median nerve; (6) accessory carpal bone; (7) lateral palmar nerve containing both median & ulnar fibers; (8) deep branch of 7; (9) lateral palmar metacarpal nerve; (10) communicating branch between medial and lateral palmar nerves; (11) distal end of metacarpal bone 4; (12) lateral palmar digital nerve; (13) dorsal branch of 12.

[19] Place your pinkie on the accessory carpal bone and, with digits 3 and 4 neatly flexed and held down with your pollex, allow your extended index finger to touch the horse and find the shallow groove ≈ 10 cm (4 inches) proximal to the accessory carpal bone.

Note that the site of the ulnar nerve block is proximal to the origin of its dorsal branch (Fig. 8-22). *The dorsal branch can be palpated as it crosses the lateral surface of ulnaris lateralis tendon, just proximal to the accessory carpal bone*. If effective, the horse should be insensitive to the "ballpoint pen test"[20] over the dorsolateral aspect of the metacarpus because the dorsal branch of the ulnar nerve has been included in the block.

Median Nerve Block: Although the median nerve can be blocked near the elbow by passing a needle through the transverse pectoral muscle, this site is proximal to its muscular branches. Thus, blocking the nerve here would result in paralysis of some of the caudal antebrachial muscles. An alternative site is in the middle of the antebrachium, about 10 cm proximal to the chestnut. The needle is inserted at the caudal border of the flexor carpi radialis muscle and directed toward the caudal surface of the radius. The nerve is relatively deep at this level, and blocking the median nerve is more difficult than blocking the medial cutaneus antebrachial nerve (palpable as it crosses the lacertus fibrosus) and the more superficially located ulnar nerve. Fortunately, blocking the median, ulnar, and medial cutaneous antebrachial nerves is not routinely necessary to confirm a lameness diagnosis.

Comparative Notes on Artiodactyls: The **radial artery** of the ruminants (Fig. 8-10) and pig arises further proximally than that of the horse. The **median nerve** of ruminants and the pig does not divide into medial and lateral palmar nerves in the distal part of the antebrachium, as it does in the horse (Fig. 8--7). It continues through the carpal canal with the median artery, and in the distal metacarpus, a communicating branch to the palmar branch of the ulnar nerve is present.

In the distal antebrachium, the **ulnar nerve** divides into dorsal and palmar branches in all species (Figs. 8-6 & 8-7). The dorsal branch provides sensory innervation to the dorsolateral aspect of the carpus and metacarpus. It continues to form the dorsal common digital nerve 4 in the ruminants and pig. The palmar branch continues through the flexor retinaculum of the carpus. The **median artery** continues the principal arterial channel and passes through the carpal canal. Only in the horse does the lateral palmar artery arise proximal to the carpus.

Cubital (Elbow) Joint of Pig: Because joint disease is common in the pig, *the medial collateral ligament should be cut and the cubital joint opened and disarticulated on one limb*. The humeral condyle is a common site for lesions of **osteochondritis dissecans.** Note the presence of the normal **synovial fossae**, which should not be confused with pathologic erosions.

Venipuncture in Pot-Bellied Pigs: A blood sample can be obtained from Vietnamese Pot-Bellied Pigs from the radial vein. Restraint is accomplished by grasping the pig from above just behind the forelimbs and pulling up and back as the restrainer sits back; the pig is then held between the legs in a “cradle-like” fashion (Fig. 8-23). Holding the pig in this position can also be used for trimming their feet or other husbandry procedures. The veins are compressed just above the elbow, and the needle is inserted proximally into the radial vein as it crosses the flexor retinaculum of the carpus (Fig. 8-24). The superficial veins of the region and needle-placement are shown in a dissection specimen (Fig. 8-25).

[20] The extended tip of a ballpoint pen is just sharp enough to stimulate a reaction in unanesthetized skin, but just dull enough to prevent skin injury. The fine or medium point works best.



Figure 8-23. Method of restraint and calming of pot-bellied pig for foot trimming, radial vein venipuncture or other procedures.



Figure 8-24. Obtaining blood sample from radial vein of pot-bellied pig.

Radiographic Anatomy of Shoulder and Elbow of Horse: Because most forelimb lameness can be traced to other parts of the limb, radiography of the shoulder is not commonly performed. Although a mediolateral radiograph of the shoulder can be made with the horse awake and standing, better quality, diagnostic radiographs can be obtained under anesthesia with the horse in lateral recumbency (Fig. 8-26). Radiography of the equine elbow joint is performed more frequently, and satisfactory films can sometimes be obtained in a cooperative patient without the use of general anesthesia. Again, better quality radiographs can be made with the horse anesthetized (Figs. 8-27 & 8-28).

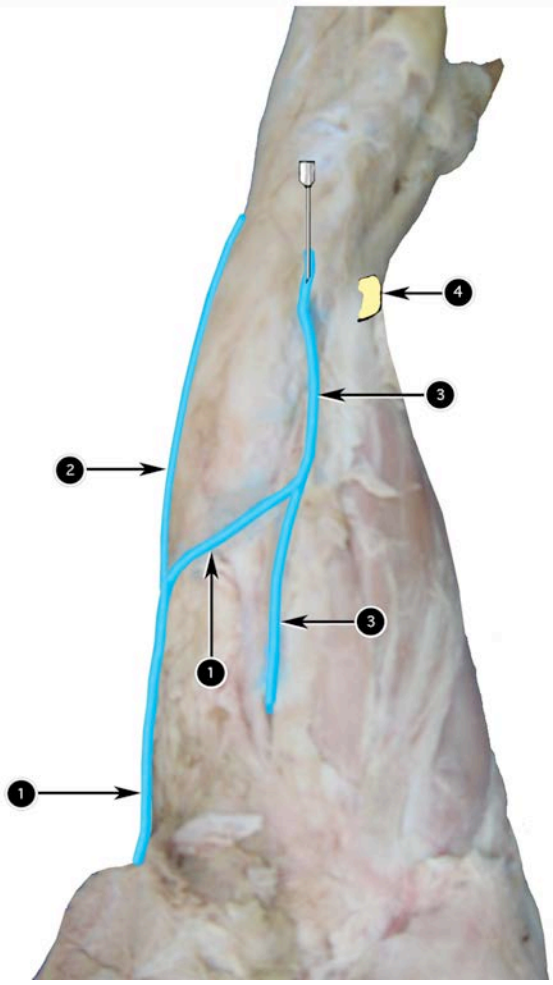


Figure 8-25. Dissection of forearm of domestic pig showing superficial veins and landmarks: (1) cephalic vein; (2) accessory cephalic vein; (3) radial vein; (4) location of accessory carpal bone (palpable). The needle indicates the site for venipuncture as the radial vein crosses the flexor retinaculum of carpus.

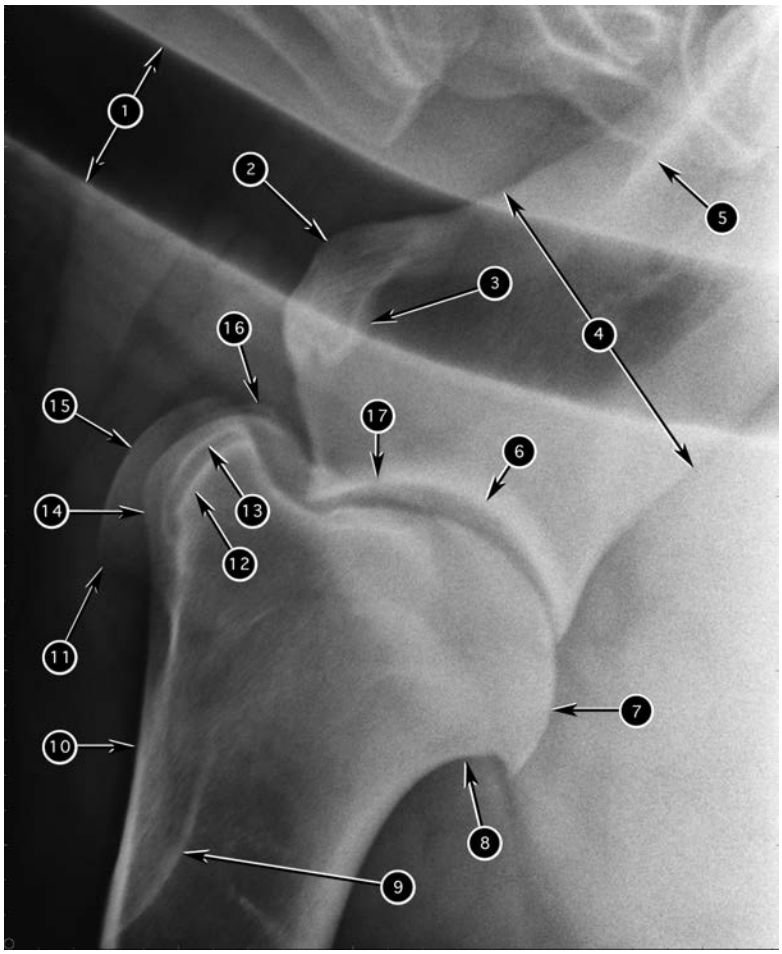


Figure 8-26. Mediolateral (ML) radiograph of equine shoulder joint: (1) air in trachea; (2) supraglenoid tubercle of scapula; (3) coracoid process of scapula; (4) neck of scapula; (5) spine of scapula; (6) medial edge of glenoid fossa of scapula; (7) head of humerus; (8) neck of humerus; (9) deltoid tuberosity of humerus; (10) cranial surface of humerus; (11) pointed distal end of intermediate tubercle; (12) compact bone forming floor of lateral (deeper) part of intertubercular groove; (13) floor of medial (more shallow) part of intertubercular groove; (14) cranial part of lesser tubercle; (15) intermediate tubercle of humerus; (16) cranial part of greater tubercle; (17) glenoid notch medial edge of glenoid fossa of scapula.

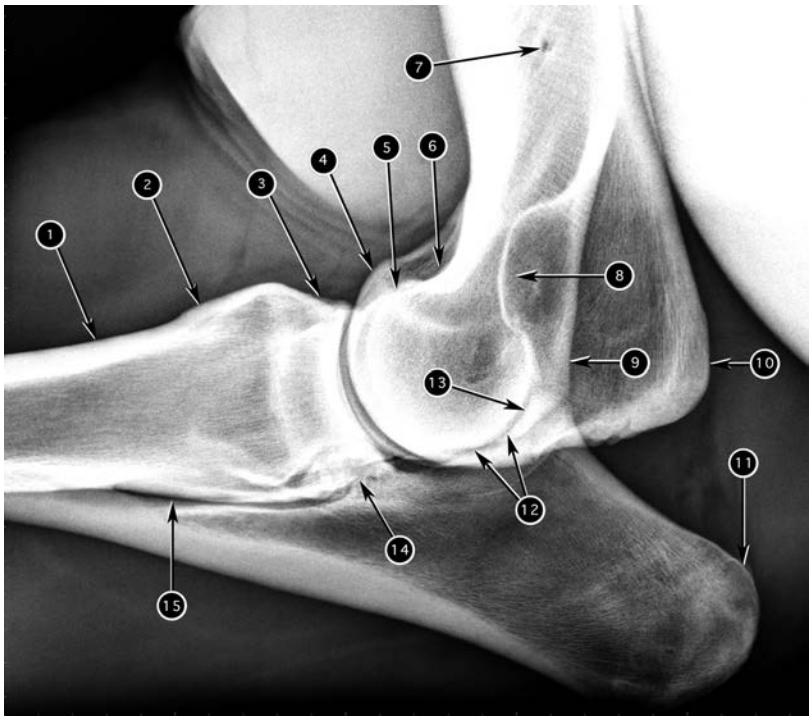


Figure 8-27. Mediolateral (ML) radiograph of equine elbow joint: (1) body of radius; (2) radial tuberosity; (3) head of radius; (4) trochlea of humeral condyle (medial); (5) capitulum of humeral condyle (lateral); (6) radial fossa of humerus; (7) nutrient canal of humerus (medial); (8) olecranon fossa of humerus; (9) lateral epicondyle of humerus; (10) medial epicondyle of humerus; (11) tuber olecranii; (12) trochlear notch of ulna; (13) anconeal process of ulna; (14) proximal radioulnar joint; (15) proximal interosseous space.

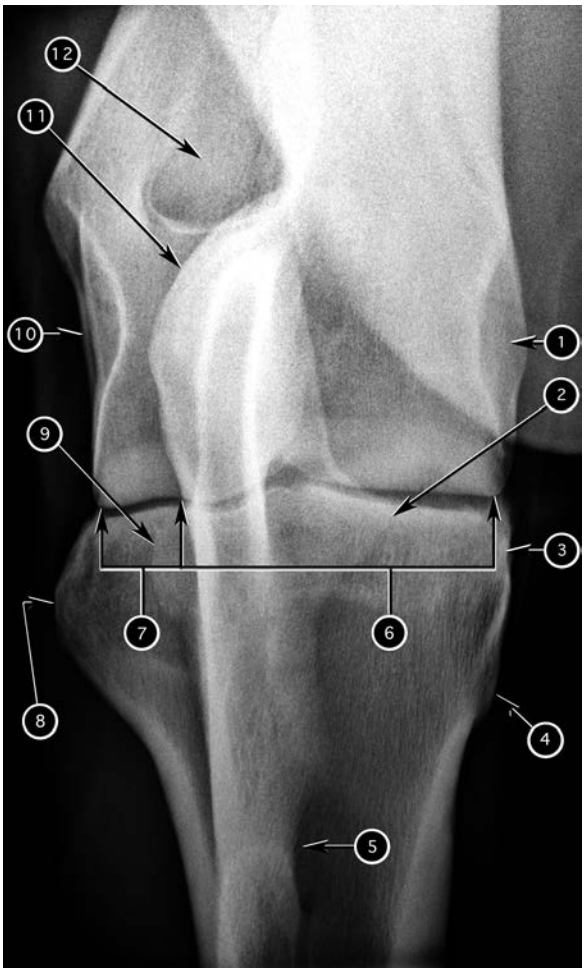


Figure 8-28. Craniocaudal (CrCd) radiograph of equine elbow joint: (1) medial epicondyle of humerus; (2) medial coronoid process of ulna; (3) head of radius; (4) radial tuberosity; (5) proximal interosseous space; (6) trochlea of humeral condyle; (7) capitulum of humeral condyle; (8) eminence for lateral collateral ligament; (9) lateral coronoid process of ulna; (10) lateral epicondyle of humerus; (11) tuber olecranii; (12) olecranon fossa of humerus.

Palpation Checklist for Thoracic Limb

Horse

1. Subclavius muscle
2. Spine of scapula; spinous tuberosity
3. Cranial and caudal parts of greater tubercle of humerus
4. Tendon of infraspinatus muscle as it crosses caudal part of greater tubercle
5. Lacertus fibrosus
6. Accessory carpal bone
7. Lateral digital extensor tendon in distal forearm and in metacarpus
8. Distal ends of the small metacarpal bones
9. Communicating branch between medial and lateral palmar nerves
10. Dorsal branch of ulnar nerve as it emerges through ulnaris lateralis tendon
11. Digital vessels and nerves as they cross proximal sesamoid bones
12. Extensor branches of interosseus
13. Medial and lateral cartilages of hoof

Ox

1. Spine of scapula
2. Greater tubercle of humerus
3. Tendon of infraspinatus muscle as it crosses greater tubercle
4. Accessory carpal bone
5. Palmar common digital artery 3 as it crosses medial branch of SDF tendon

Chapter 9 • The Carpus, Metacarpus, and Digit

Because of their anatomic complexity and clinical importance, especially in the horse, the carpus, metacarpus, and digit are covered in a separate chapter. One of the most important ways that veterinarians look at the carpus, metacarpus, and digit of the horse is by radiographic examination. Therefore, much of the information contained in this chapter is presented in that form. (Relax, you are not expected to learn all the details included in the figure legends.) The points that are of special significance are indicated in **bold print**. Although the carpus, metacarpus, and digit are certainly more than bones, the first step is to review the skeletal anatomy on the models, and the second step is to use these models as the radiographic anatomy is reviewed.

SKELETAL ANATOMY

Fusion of individual carpal bones varies with the species. Review the skeletal models, and note which bones are fused in each species (Table 9-1). Note that there is no fusion in the horse and pig. Also review the radiographic anatomy of the carpus contained in this chapter.

TABLE 9-1. Comparative carpal bone fusion in domestic ungulates*

Horse	Ruminant	Pig
Radial carpal bone (Cr)	Cr	Cr
Intermediate carpal bone (Ci)	Ci	Ci
Ulnar carpal bone (Cu)	Cu	Cu
Accessory carpal bone (Ca)	Ca	Ca
First carpal bone (C1)†		C1
Second carpal bone (C2)	(C2+3)	C2
Third carpal bone (C3)		C3
Fourth carpal bone (C4)	C4	C4

* There is no sesamoid bone in the tendon of the abductor pollicis longus in domestic ungulates
† C1 is an inconstant bone in the horse; varies in diameter from < 1mm to 15 mm.

As you recall from your study of the carnivores, the intermedioradial carpal bone represents a fusion of the radial, intermediate, and central carpal bones. No separate ossification center for the central carpal bone is seen radiographically in newborn foals (Figs. 9-1 & 9-2). Note the distinct radiolucent separation between the **lateral styloid process** and the **distal epiphysis of the radius**. Although often considered part of the radius in the horse, this structure actually represents the distal epiphysis of the ulna, which fuses to the radius. This fusion parallels that which occurs between the distal epiphyses of the equine tibia and fibula.

According to one report, fusion of the lateral styloid process to the distal epiphysis of the radius remains incomplete in about 30% of horses over 4 years old.[1] As in the pelvic limb, the "cannon bone" of the metacarpus (Mc) consists of the third metacarpal bone in the horse and of the fused third and fourth metacarpal bones in the ruminant (Fig. 9-3).

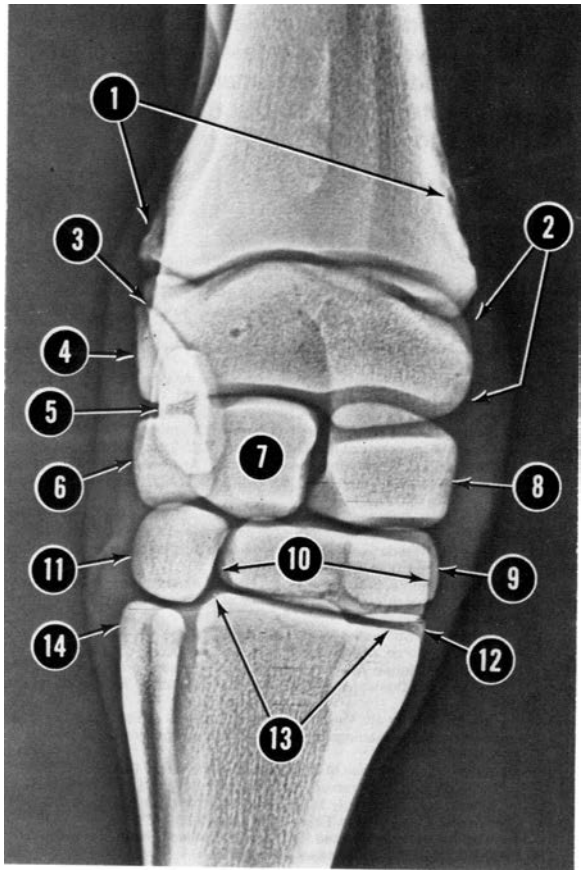


Figure 9-1. Dorsopalmar xeroradiograph of carpus of a 1-day-old female quarter horse: (1) irregular borders of distal radial metaphysis (area of active bone formation); (2) rounded edges of incompletely ossified distal radial epiphysis; (3) distinct radiolucent separation between distal ulnar and radial epiphyses; (4) lateral styloid process (distal epiphysis of ulna); (5) accessory carpal bone; (6) ulnar carpal bone; (7) intermediate carpal bone; (8) radial carpal bone; (9) C2; (10) C3; (11) C4; (12) Mc2; (13) Mc3; (14) Mc4. [With permission from Auer, J. A., Smallwood, J. E., Morris, E. L., *et al*. The developing equine carpus from birth to 6 months of age: a radiographic study. Equine Pract. 4, #4 (1982): 35-55.]

[1] Myers, V. S. Confusing radiographic variations at the distal end of the radius of the horse. JAVMA 147 1965: 1310-1312.

The pig has four complete digits; however, only the third and fourth digits are weight-bearing. The metacarpal bones resemble the metatarsals except that they are not as long. In the ox, a vestigial fifth metacarpal (Mc5) is present as a separate bone on the proximolateral aspect of the fused third and fourth metacarpals (Mc3+4). In the sheep and goat, this small metacarpal bone may be absent or fused to Mc3+4.

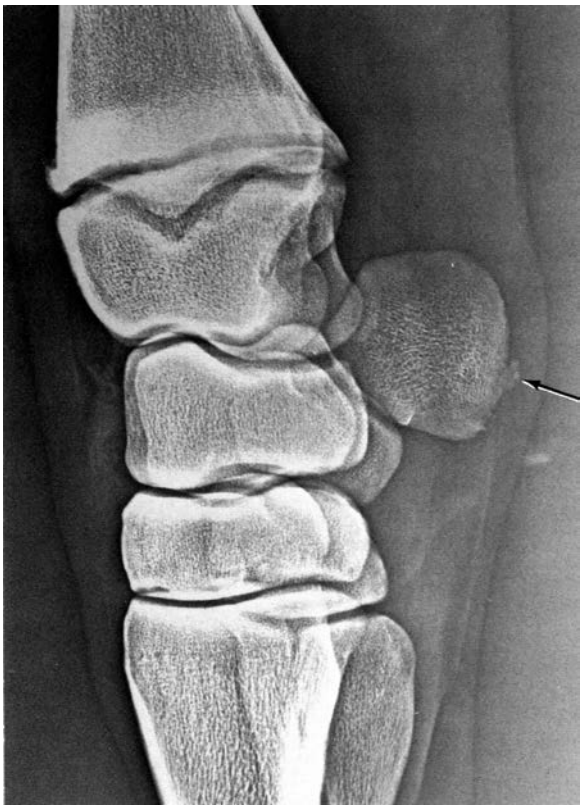


Figure 9-2. Lateromedial xeroradiograph of carpus of a 5-week-old female quarter horse. Note the multiple small foci of ossification for the secondary center of the accessory carpal bone (arrow). This is how new centers of ossification form. They start out as multiple small islands of bone that then coalesce to form a definitive center of ossification. . [With permission from Auer, J. A., Smallwood, J. E., Morris, E. L., *et al*. The developing equine carpus from birth to 6 months of age: a radiographic study. Equine Pract. 4, #4 (1982): 35-55.]

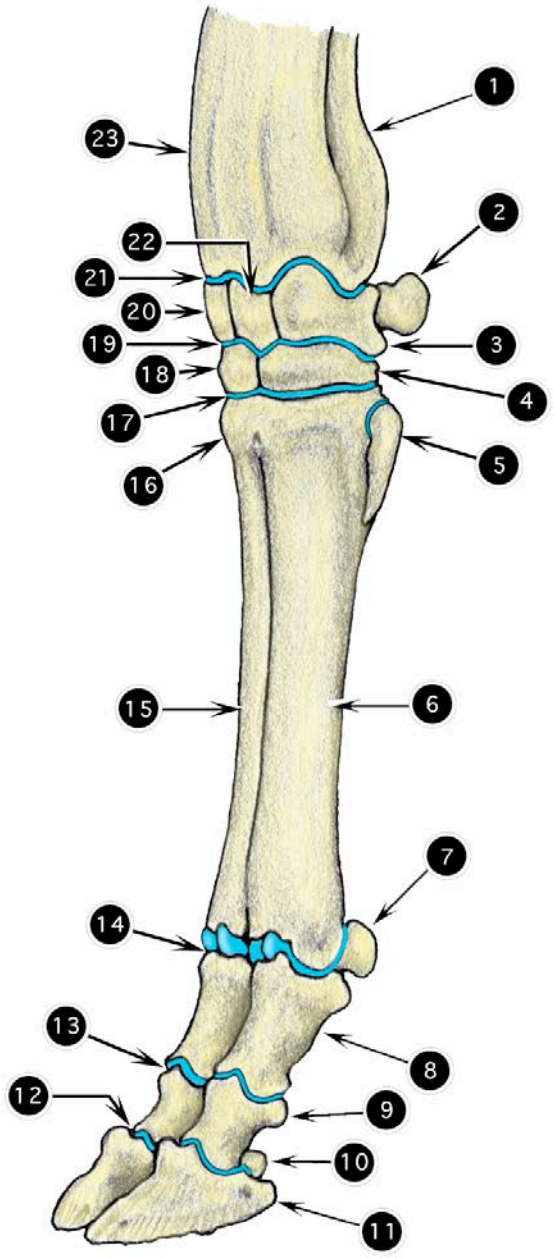


Figure 9-3. Skeleton of left carpus, metacarpus, & digits of ox, dorsolateral view: (1) ulna; (2) accessory carpal; (3) ulnar carpal bone; (4) C4; (5) Mc5; (6) Mc4; (7) abaxial proximal sesamoid bone of digit 4; (8) proximal phalanx; (9) middle phalanx; (10) distal sesamoid bone of digit 4; (11) distal phalanx; (12) distal interphalangeal joint; (13) proximal interphalangeal joint; (14) metacarpophalangeal (fetlock) joint; (15) Mc3; (16) metacarpal tuberosity; (17) carpometacarpal joint; (18) C2+3; (19) middle carpal joint; (20) Cr; (21) antebrachiocarpal joint; (22) Ci; (23) radius.

RADIOGRAPHIC ANATOMY OF EQUINE CARPUS

The equine carpus is a clinically important region that includes three major joints, seven or eight carpal bones, and five adjacent bones that articulate with one or more of the carpal elements. This area is so complex anatomically that five standard radiographic views are generally considered necessary for an adequate examination: dorsopalmar (DPa); lateromedial (LM); lateromedial with the carpus flexed; dorsolateral-palmaromedial oblique (DL-PaMO); and dorsomedial-palmarolateral oblique (DM-PaLO) views.

In addition, dorsoproximal-dorsodistal oblique (DPr-DDiO) views of the flexed carpus may be required to demonstrate certain lesions. In order for you, as a veterinarian, to be proficient in the radiographic interpretation of the equine carpus, a thorough understanding of the radiographic anatomy of this region is necessary.

The five standard radiographic views are indicated in figure 9-4. The oblique views were made at a 30° angle from the lateromedial line. The dorsoproximal-dorsodistal oblique views of the flexed carpus were obtained as indicated in figure 9-5. Because of the complexity of the carpal region, a skeletal model is helpful in identifying the overlapping and superimposed radiographic shadows.

Dorsopalmar View (Fig. 9-6): The trochlea of the radius includes the medial and lateral styloid processes to which the medial and lateral collateral ligaments of the carpus attach. The **lateral styloid process** is the **distal epiphysis of the ulna**, which fuses to the radius in the horse.

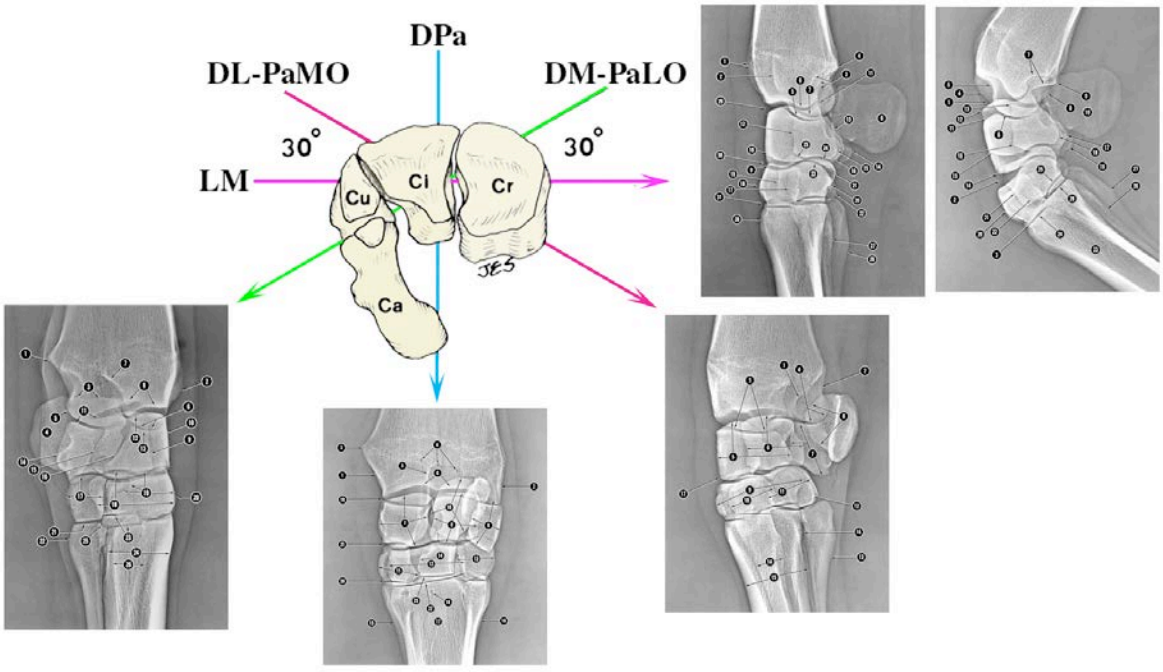


Figure 9-4. Proximal carpal bones of left limb (proximal view) illustrating orientation of central ray in five standard radiographic views: DPa, dorsopalmar; LM, lateromedial (one extended, one flexed); DL-PaMO, dorsolateral-palmaromedial oblique; and DM-PaLO, dorsomedial-palmarolateral oblique. [With permission from Smallwood, J. E., Shively, M. J., Rendano, V. T., and Habel R. E. A standardized nomenclature for radiographic projections used in veterinary medicine. Veterinary Radiology 26 (1985): 2-9.]

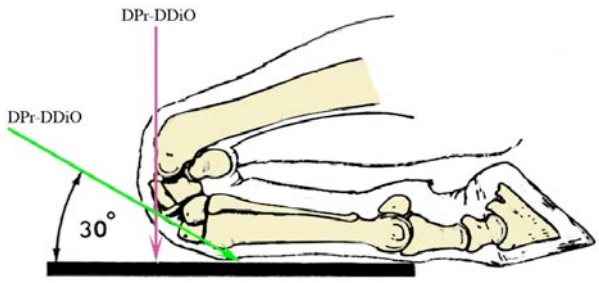


Figure 9-5. Limb, cassette, and central ray orientation for dorsoproximal-dorsodistal oblique views of flexed carpus. [With permission from Smallwood, J. E., Shively, M. J., Rendano, V. T., and Habel R. E. A standardized nomenclature for radiographic projections used in veterinary medicine. Veterinary Radiology 26 (1985): 2-9.]

The carpal articular surface may be divided into medial and lateral parts, which represent the articular surfaces of the two styloid processes, separated by an intermediate part.

There are typically seven or eight bones arranged in two rows in the equine carpus. The four in the proximal row include, from medial to lateral, the **radial carpal bone**, the **intermediate carpal bone**, and the **ulnar carpal bone**. The **accessory carpal bone** is located on the palmarolateral aspect of the carpus. Because of its size, shape, and position, it is superimposed over part of the radius and most of the intermediate carpal bone. The three bones consistently present in the distal row are the **second**, **third**, and **fourth carpal bones**. The second carpal bone is palmaromedial to the wide third carpal bone, and most of its image is superimposed on the medial aspect of the latter. In some horses, a small first carpal bone is present in one or both limbs, and a so-called "fifth carpal bone" is occasionally present.

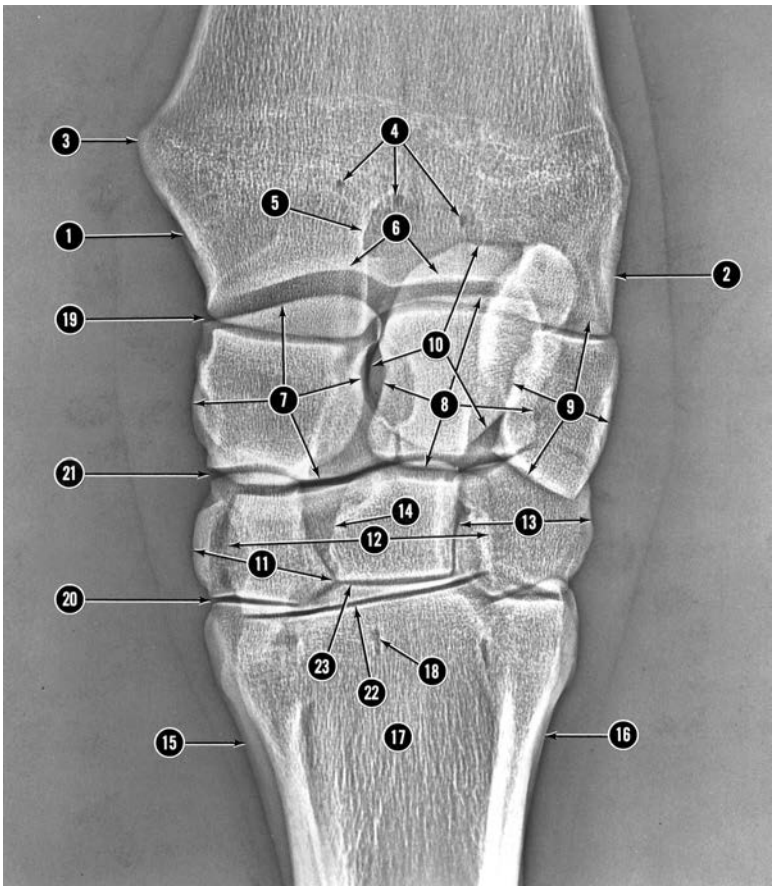


Figure 9-6. Dorsopalmar (DPa) xeroradiograph of left equine carpus: (1) medial styloid process; (2) lateral styloid process; (3) projection at proximomedial aspect of 1; (4) vascular channels; 5) caudolateral border of 1; (6) junction of carpal articular surface with cranial surface of radius; (7) radial carpal bone; (8) intermediate carpal bone; (9) ulnar carpal bone; (10) accessory carpal bone; (11) second carpal bone; (12) third carpal bone; (13) fourth carpal bone; (14) medial border of palmar process of C3; (15) second metacarpal bone; (16) fourth metacarpal bone; (17) third metacarpal bone; (18) vascular channel; (19) antebrachiocarpal joint; (20) carpometacarpal joints; (21) middle carpal joint; (22) shadow cast by dorsal aspects of carpometacarpal joints; (23) shadow cast by palmar aspects of carpometacarpal joints.

The three metacarpal bones are of unequal size, with the smaller second metacarpal (Mc2) and fourth metacarpal (Mc4) located on the palmaromedial and palmarolateral sides of the larger Mc3. The carpal joint complex includes the antebrachiocarpal joint, numerous intercarpal joints, and the carpometacarpal joints.

The **antebrachiocarpal joint** of the horse is popularly called the "radiocarpal joint" because the distal ulna fuses to and becomes inseparable from the radius. The intercarpal joints include articulations between individual carpal bones from side to side, as well as proximal to distal. The collective intercarpal joints between the proximal and distal rows of carpal bones comprise the **middle carpal joint**. The synovial cavities of the middle carpal joint and carpometacarpal joints communicate between the third and fourth carpal bones, but the antebrachiocarpal joint cavity is separate.

The joint spaces seen between the carpal elements result from the radiolucency of the cartilage on their articular surfaces. The difficulty in interpreting carpal radiographs is compounded by image superimpositions that result from the irregular shapes of the individual carpal elements. For example, the concavity of the articular surface on the base of Mc3 and the convexity of the articular surfaces of the carpal bones that articulate with it cause the dorsal aspects of the **carpometacarpal joints** to cast a radiolucent shadow distal to a second one representing the palmar aspects of the joints.

Lateromedial View (Fig. 9-7): The ridges on the cranial surface of the radial trochlea lie adjacent to and separate the extensor tendons. The ridge adjacent to the lateral border of the common digital extensor tendon forms a distinct radiopaque line. The transverse crest develops at the level of the distal radial physis, which has already closed in this horse.

The medial, intermediate, and lateral parts of the carpal articular surface of the trochlea articulate primarily with the radial, intermediate, and ulnar carpal bones, respectively. The caudolateral aspect of the trochlea also articulates with the accessory carpal bone.

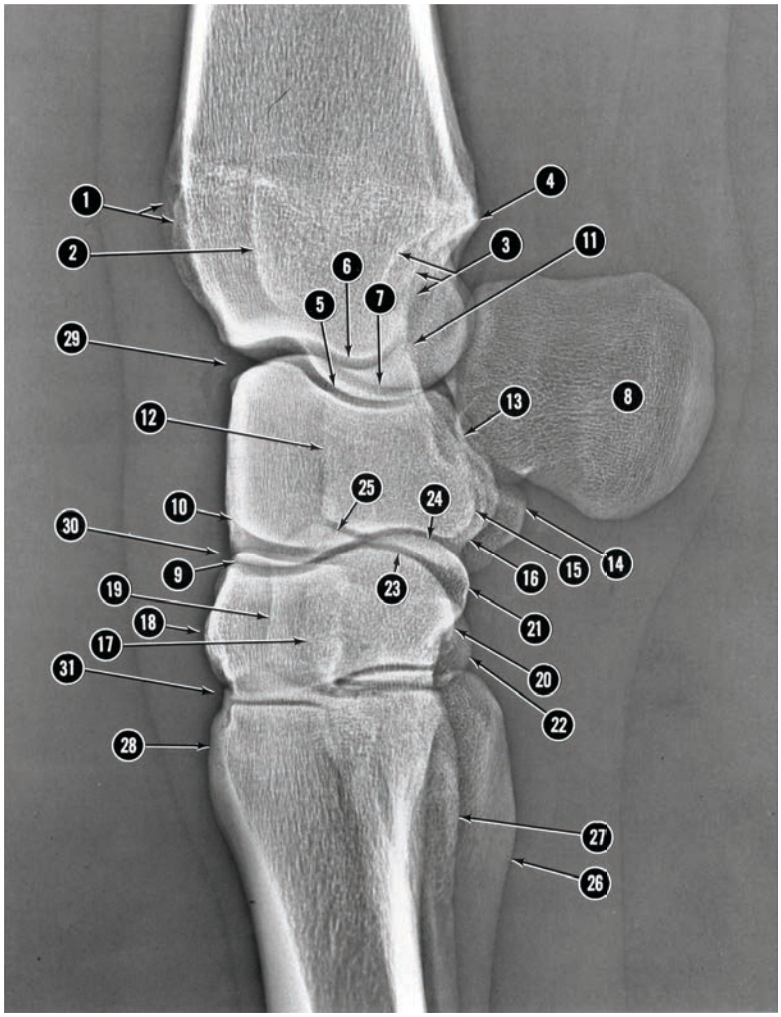


Figure 9-7. Lateromedial (LM) xeroradiograph of left equine carpus: (1) ridges on cranial surface of radius; (2) ridge adjacent to lateral border of common digital extensor tendon; (3) caudal borders of radial trochlea; (4) transverse crest of radius; (5) medial part of carpal articular surface; (6) intermediate part of carpal articular surface; (7) lateral part of carpal articular surface; (8) accessory carpal bone; (9) dorsodistal border of radial carpal bone; (10) dorsodistal border of intermediate carpal bone; (11) proximal process of Ci; (12) dorsal surface of ulnar carpal bone; (13) articulation of Ca with Cu; (14) palmar border of Cu; (15) palmar border of Ci; (16) palmar border of Cr; (17) dorsal border of C2; (18) dorsal border of C3; (19) dorsal border of C4; (20) palmar border of C2; (21) palmar border of C3; (22) palmar border of C4; (23) proximal border of C2; (24) proximal border of C3; (25) proximal border of C4; (26) fourth metacarpal bone; (27) second metacarpal bone; (28) metacarpal tuberosity; (29) antebrachiocarpal joint; (30) middle carpal joint; (31) carpometacarpal joints.

The **metacarpal tuberosity** serves as the point of termination for the extensor carpi radialis muscle. The antebrachiocarpal joint, middle carpal joint, and carpometacarpal joints appear to contain numerous bone fragments because of the shape and superimpositions of the carpal elements, which are separated by radiolucencies produced by articular cartilage.

Lateromedial View With Carpus Flexed (Fig. 9-8): As the carpal joints are flexed, almost all motion occurs at the antebrachiocarpal joint and middle carpal joint, with essentially no flexion at the carpometacarpal articulations. Note that flexion of the antebrachiocarpal joint superimposes the transverse crest of the radius on the accessory carpal bone.

This flexed positioning partially isolates the cranial aspect of the radial trochlea and also separates the superimposed images of the proximal row of carpal bones. The various images of the radial, intermediate, and ulnar carpal bones can be differentiated. Note that the radial carpal bone is shifted distally (drops) by this positioning with respect to the intermediate and ulnar carpal bones. This separation facilitates the differentiation of the dorsal aspects of these bones, which are frequently fractured.[2]

The third carpal bone articulates with Mc3 at the third carpometacarpal joint. This joint is distinct dorsally, but palmarly it is superimposed on the second carpometacarpal joint formed by C2 and Mc2. C4 and Mc4 articulate at the fourth carpometacarpal joint. The LM view of the flexed carpus has been shown to be especially valuable in demonstrating carpal fractures. In one study, 127 of 143 fractures (89%) were observed in this view.[3]

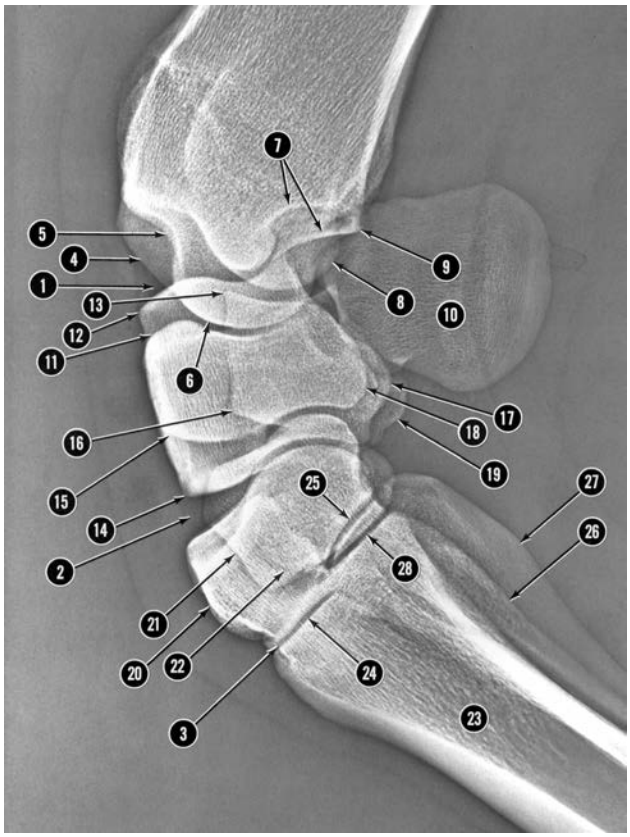


Figure 9-8. Lateromedial (LM) xeroradiograph of left equine carpus in flexed position: (1) antebrachiocarpal joint; (2) middle carpal joint; (3) carpometacarpal joints; (4) medial border of medial part of carpal articular surface; (5) lateral border of medial part of carpal articular surface; (6) medial styloid process; (7) shadows from caudal aspect of intermediate part of radial trochlea; (8) lateral styloid process; (9) transverse crest of radius; (10) accessory carpal bone; (11) dorsoproximal border of Cr; (12) dorsoproximal border of Ci; (13) dorsoproximal border of Cu; (14) dorsodistal border of Cr (isolated); (15) dorsodistal border of Ci; (16) dorsodistal border of Cu; (17) palmar border of Cr; (18) palmar border of Ci; (19) palmar border of Cu; (20) dorsal border of C3; (21) dorsal border of C4; (22) dorsal border of C2; (23) third metacarpal bone; (24) third carpometacarpal joint; (25) second carpometacarpal joint; (26) second metacarpal bone; (27) fourth metacarpal bone; (28) fourth carpometacarpal joint.

[2] Thrall, D. E., Lebel, J. L., and O'Brien, T. R. A five-year survey of the incidence and location of equine carpal chip fractures. JAVMA 158 (1971): 1366-1368.

[3] Park, R. D., Morgan, J. P., and O'Brien, T. R. Chip fractures in the carpus of the horse: a radiographic study of their incidence and location. JAVMA 157 (1971): 1305-1312.

Dorsolateral-Palmaromedial Oblique View (Fig. 9-9): A subtle radiolucency remains where the **lateral styloid process** fused to the rest of the radial trochlea. This fusion remains incomplete in about 40% of horses 2 to 4 years of age, and 30% of horses over 4 years.[4] The difference in size of the large medial part of the radial trochlea compared with the lateral portion is exaggerated, but is clearly evident in this view. The image of the radial carpal bone is superimposed across the intermediate carpal bone, which is in turn partially superimposed on the ulnar carpal bone.

The accessory carpal bone is partially isolated in this view, and its articulations with the lateral styloid process and with the ulnar carpal bone can be visualized. The **accessory carpal bone** is the only carpal bone that does not bear weight. It serves as a distal point of attachment for the ulnaris lateralis and flexor carpi ulnaris muscles, and also forms the lateral boundary of the carpal canal. The end-on ("cupped hand") perspective of the accessory carpal bone in this oblique projection is the key to recognizing it immediately as a DL-PaMO view (*versus* a DM-PaLO view).

In the distal row of carpal bones, C3 extends completely across the image of C2 and is also superimposed over much of C4. Mc4 is isolated by this positioning, but Mc2 is superimposed on Mc3. The **metacarpal interosseous ligaments**, which unite the metacarpal bones at the medial and lateral intermetacarpal joints, may become inflamed and result in the clinical condition commonly known as “splints.” These ligaments may also ossify gradually with age and without clinical signs. The DL-PaMO view is particularly valuable here because it isolates the distal aspect of the dorsomedial border of the radial carpal bone, which is the most frequently fractured part of the equine carpus. One study has shown that about 60% of all carpal fractures can be visualized in this view.[5]

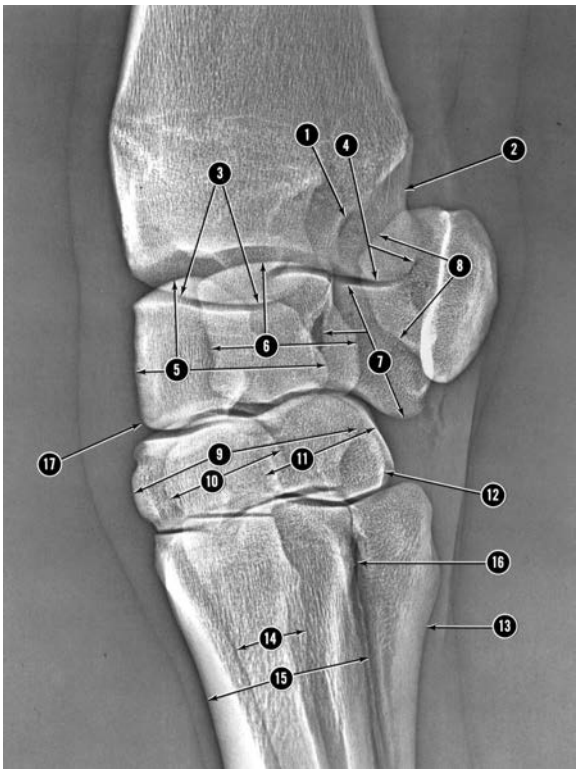


Figure 9-9. Dorsolateral-palmaromedial oblique (DL-PaMO) xeroradiograph of left equine carpus: (1) radiolucent area at line of fusion between lateral styloid process and radius; (2) lateral styloid process; (3) medial part of radial trochlea; (4) lateral styloid process; (5) radial carpal bone; (6) intermediate carpal bone; (7) ulnar carpal bone; (8) articulations of accessory carpal bone with 2 and 7; (9) third carpal bone; (10) second carpal bone; (11) fourth carpal bone; (12) palmar projection of C4; (13) fourth metacarpal bone; (14) second metacarpal bone; (15) third metacarpal bone; (16) location of metacarpal interosseous ligaments; (17) distal aspect of dorsomedial border of Cr (isolated). Note end-on ("cupped-hand") perspective of accessory carpal bone.

[4] Myers, V. S. Confusing radiographic variations at the distal end of the radius of the horse. JAVMA 147 1965: 31310-1312.

[5] Park, R. D., Morgan, J. P., and O'Brien, T. R. Chip fractures in the carpus of the horse: a radiographic study of their incidence and location. JAVMA 157 (1971): 1305-1312.

Dorsomedial-Palmarolateral Oblique View (Fig. 9-10): In this oblique view, the projection of the radius for attachment of the medial collateral ligament of the carpus is accentuated, and the ridge forming the lateral border of the groove for the common digital extensor tendon is isolated. The proximal border of the accessory carpal bone is superimposed on the medial styloid process of the radius. The superimposed "broadside" view of the accessory carpal bone in this oblique projection is the key to recognizing it immediately as a DM-PaLO view (*versus* a DL-PaMO view).

The lateral styloid process is partially superimposed on the proximal aspects of the intermediate and radial carpal bones. Various parts of the radial, intermediate, and ulnar carpal bones that can be identified include their dorsolateral borders, their proximal surfaces, and their palmaromedial borders. In the distal row, the second, third, and fourth carpal bones can be identified. The dorsolateral borders of C3 and C4 are superimposed, as are those of the intermediate and ulnar carpal bones.

Within the carpometacarpal joints, a characteristic fork-shaped radiolucency is present, with the handle representing articular cartilage between C2 and Mc2 and the upper and lower prongs representing cartilage on different planes of the articulation between C3 and Mc3. The initial part of the lower prong represents an inconstant articulation between C3 and Mc2. Mc4 is superimposed on Mc3 in this projection.

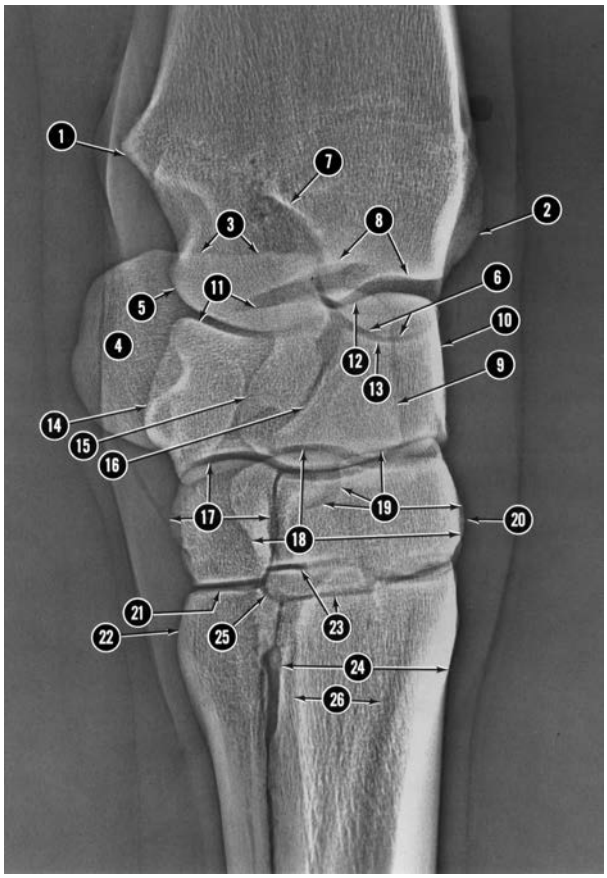


Figure 9-10. Dorsomedial-palmarolateral oblique (DM-PaLO) xeroradiograph of left equine carpus: (1) projection of radius for attachment of medial collateral ligament; (2) ridge that forms lateral border of groove for common digital extensor tendon; (3) proximal border of accessory carpal bone; (4) accessory carpal bone; (5) medial styloid process of radius; (6) lateral styloid process; (7) ridge on caudal aspect of radius; (8) ridge at junction of cranial surface of radius with carpal articular surface; (9) dorsolateral border of Cr ; (10) dorsolateral borders of Cu and Ci; (11) proximal surface of Cr; (12) proximal surface of Ci; (13) proximal surface of Cu; (14) palmaromedial border of Cr; (15) palmaromedial border of Ci; (16) palmaromedial border of Cu; (17) second carpal bone; (18) third carpal bone; (19) fourth carpal bone; (20) dorsolateral borders of C3 and C4; (21) articulation between C2 and Mc2; (22) second metacarpal bone; (23) articulation between C3 and Mc3; (24) third metacarpal bone; (25) inconstant articulation between C3 and Mc2; (26) fourth metacarpal bone. Note superimposed "broadside" view of accessory carpal bone.

Dorsoproximal-Dorsodistal Oblique View of Proximal Row of Carpal Bones (Fig. 9-11): This special view illustrates a tangential perspective of the dorsal surfaces of the radial, intermediate, and ulnar carpal bones. The radius is partially superimposed on these bones, and the carpal articular surface of its trochlea is approximately parallel to the dorsal surfaces of the proximal row of carpal bones. The dorsal surfaces of the distal row of carpal bones can be differentiated, as can Ca, Mc2, Mc3, and Mc4.

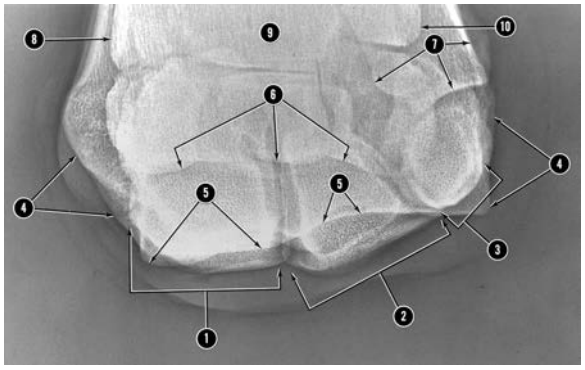


Figure 9-11. Dorsoproximal-dorsodistal oblique (DPr-DDiO) xeroradiograph of proximal row of equine carpal bones: (1) dorsal surface of radial carpal bone; (2) dorsal surface of intermediate carpal bone; (3) dorsal surface of ulnar carpal bone; (4) radius; (5) carpal articular surface of radial trochlea; (6) dorsal surfaces of distal carpal bones; (7) accessory carpal bone; (8) second metacarpal bone; (9) third metacarpal bone; (10) fourth metacarpal bone.

Dorsoproximal-Dorsodistal Oblique View of Distal Row of Carpal Bones (Fig. 9-12): This special view illustrates the tangential perspective of the dorsal surfaces of the second, third, and fourth carpal bones. Dorsal surfaces of the radial, intermediate, and ulnar carpal bones are superimposed on the distal carpal bones. The radius and accessory carpal bone can also be identified. Space between the radial and intermediate carpal bones produces a radiolucent area. This view has been shown to be especially valuable in demonstrating sagittal fractures of the third carpal bone.[6]

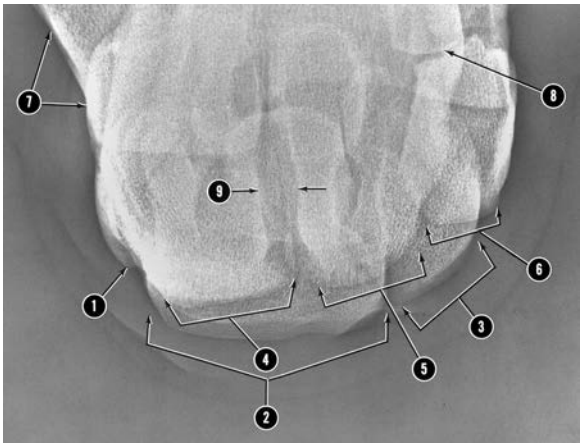


Figure 9-12. Dorsoproximal-dorsodistal oblique (DPr-DDiO) xeroradiograph of distal row of equine carpal bones: (1) dorsal surface of second carpal bone; (2) dorsal surface of third carpal bone; (3) dorsal surface of fourth carpal bone; (4) dorsal surface of radial carpal bone; (5) dorsal surface of intermediate carpal bone; (6) dorsal surface of ulnar carpal bone; (7) radius; (8) accessory carpal bone; (9) interosseous space between Cr and Ci.

First Carpal Bone of Horse: As mentioned above, the first carpal bone is a variable (inconstant) structure; *i.e.*, it's on its way out in the horse. C1 is a vestigial bone in the horse, and "vestiges vary." The first carpal lies just palmar to C2, near the base of Mc2. Because it is located on the palmaromedial aspect of the carpus, it is best isolated in the DM-PaLO (Fig. 9-13).

So-called Fifth Carpal Bone of Horse: In rare cases, another "carpal-bone-like" element is seen radiographically in the equine carpus. This osseous entity has been dubbed the "fifth carpal bone," but I have my doubts that it is actually a carpal bone at all. You have to go back to reptilians to find a fifth carpal bone, and horses (mammals) are pretty far removed from crocodiles and

[6] Gersten, K. E., Dawson, H. A. Sagittal fracture of the third carpal bone in a horse. JAVMA 169 (1976): 633-635.

alligators. When present, the so-called fifth carpal bone is located palmarolaterally in association with C4 and the base of Mc4 and is best isolated in the DL-PaMO (Fig. 9-14).



Figure 9-13. Dorsomedial-Palmarolateral Oblique (DM-PaLO) radiograph of equine carpus, illustrating first carpal bone (arrow).

One of the reasons, I doubt that this element represents C5 is shown in figure 9-15, which is the opposite limb of the same horse shown in figure 9-14. Here it can be noted that the "osseous body" seen in figure 9-14 appears to be fused with the base of Mc4 in the opposite limb. Because of this finding, I wonder if what authors have referred to as C5 actually represents the proximal epiphysis of Mc4. We normally do not see the proximal epiphyses of the metacarpal bones in the horse because they apparently fuse prenatally. Whatever this bone is, the bottom line is the same--- "it's only significance is that it is of no clinical significance, which is significant."



Figure 9-14. Dorsolateral-Palmaromedial Oblique (DL-PaMO) radiograph of equine carpus, illustrating so-called "fifth carpal bone" (arrow).

RADIOGRAPHIC ANATOMY OF BOVINE CARPUS

Because the bovine carpus is radiographed much less frequently than the equine carpus, xeroradiographs of this region are included primarily for your future reference should the need arise. Most veterinarians are less familiar with the radiographic anatomy of the bovine manus, and are thus more in need of a reference for this region in the ox.

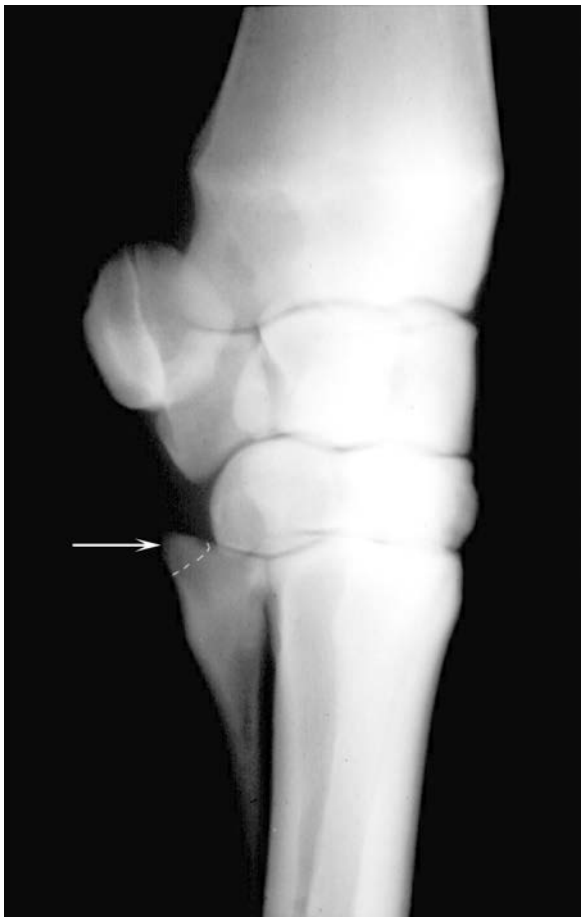


Figure 9-15. Dorsolateral-Palmaromedial Oblique (DL-PaMO) radiograph of opposite forelimb of same horse shown in figure 9-14. What ever the osseous body is in figure 9-14, it appears to be fused to the base of Mc4 on this side (arrow). Could it really represent the proximal epiphysis of Mc4?

Dorsopalmar View (Fig. 9-16): There are six carpal bones arranged in two rows in the carpus of domestic ruminants (Fig. 9-3). In the proximal row are the radial carpal bone, intermediate carpal bone, ulnar carpal bone, and accessory carpal bone. The distal row includes the fused second and third carpal bones (C2+3) on the medial side and the fourth carpal bone laterally. The first carpal bone is absent. The distal physes of the radius and ulna separate the distal epiphyses of these bones from their respective metaphyses in this young animal.

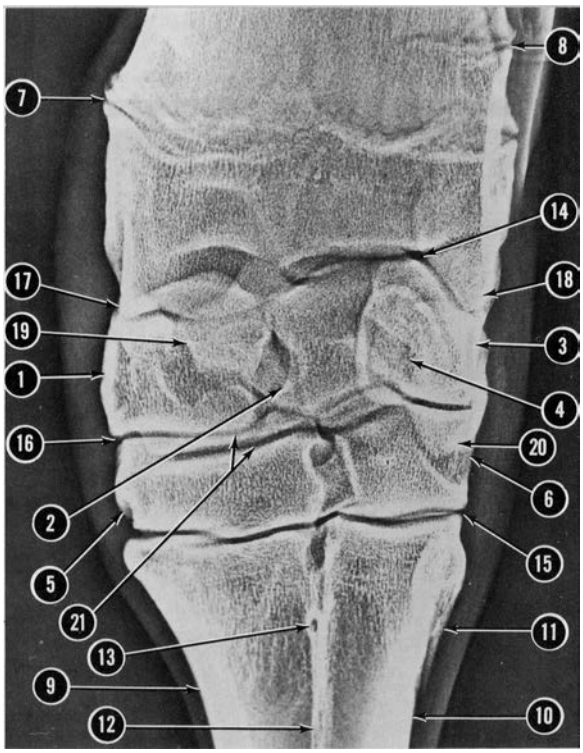


Figure 9-16. Dorsopalmar (DPa) xeroradiograph of left bovine carpus: (1) radial carpal bone; (2) intermediate carpal bone; (3) ulnar carpal bone; (4) accessory carpal bone; (5) fused second and third carpal bones (C2+3); (6) fourth carpal bone; (7) distal physis of radius; (8) distal physis of ulna; (9) third metacarpal bone; (10) fourth metacarpal bone; (11) fifth metacarpal bone; (12) dorsal and palmar grooves- division between Mc3 and Mc4; (13) proximal metacarpal canal; (14) antebrachiocarpal joint; (15) carpometacarpal joints; (16) middle carpal joint; (17) styloid process of radius; (18) styloid process of ulna; (19) palmar aspect of 2; (20) palmar process of 3; (21) middle carpal joint.

The fused third and fourth metacarpal bones (Mc3+4) are the only weight-bearing metacarpal elements. The first two metacarpal bones are absent, and the fifth metacarpal bone (Mc5) is reduced to a small vestige, which articulates with the proximolateral aspect of Mc4. In the sheep, Mc5 is often absent or is represented by a ridge on Mc3+4. The division between Mc3 and Mc4 remains obvious in the adult as shallow dorsal and palmar longitudinal grooves, which are superimposed in this projection. These grooves are vascular

impressions and are connected proximally and distally by the proximal and distal metacarpal canals.

The carpal joint complex includes the antebrachiocarpal joint, the middle carpal joint, and the carpometacarpal joint. The intercarpal joints include articulations between individual carpal bones from side to side as well as proximally to distally. The collective intercarpal joints between the proximal and distal rows of carpal bones constitute the middle carpal joint. The synovial cavities of the middle carpal joint and the carpometacarpal joint communicate, but the antebrachiocarpal joint cavity is distinct and separate.

One of the difficulties encountered in the interpretation of carpal radiographs is a result of complex superimpositions resulting from the irregular shapes of the carpal components. The styloid processes of the radius and ulna extend distally over the shadows of the radial and ulnar carpal bones, respectively.

Lateromedial View (Fig. 9-17): The antebrachiocarpal joint, middle carpal joint, and carpometacarpal joints can be identified. The distal physis of the radius is also easily observed, but the distal physis of the ulna is partially obscured by the superimposed radius. Note that the accessory carpal bone articulates only with the ulnar carpal bone. In the horse, Ca also articulates with the ulna. In the distal row of carpal bones, C2+3 projects further dorsally, whereas C4 extends further palmarly. The fifth metacarpal bone can be identified. Slight flexion of the antebrachiocarpal joint occurred because the animal was not bearing weight on the limb when the xeroradiograph was made.[7]

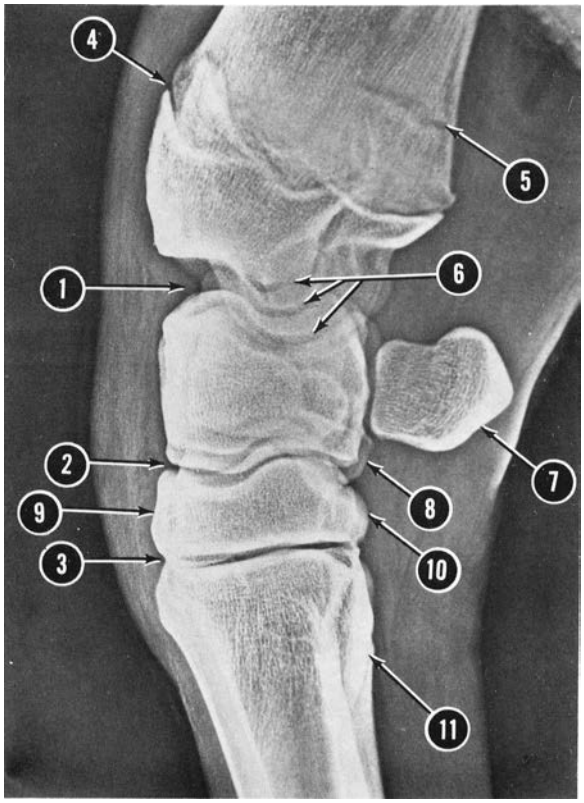


Figure 9-17. Lateromedial (LM) xeroradiograph of left bovine carpus: (1) antebrachiocarpal joint; (2) middle carpal joint; (3) carpometacarpal joint; (4) distal physis of radius; (5) distal physis of ulna; (6) multiple radiolucencies produced by 1; (7) accessory carpal bone; (8) palmar process of ulnar carpal bone; (9) fused second and third carpal bones; (10) fourth carpal bone; (11) fifth metacarpal bone.

Lateromedial View of Flexed Carpus (Fig. 9-18): This flexed position illustrates that both the antebrachiocarpal joint and the middle carpal joint have considerable mobility, whereas very little flexion occurs at the carpometacarpal articulation. The ulnar, intermediate, and radial carpal bones produce superimposed shadows that are separable along their distal and dorsal borders. In this position, C4 is rocked away

[7] This is undoubtedly related to the fact that the limb in question was detached from said bovidae at the time of radiography.

from the Mc3+4 to produce a wedge-shaped area that is filled in by the shadow of C2+3.

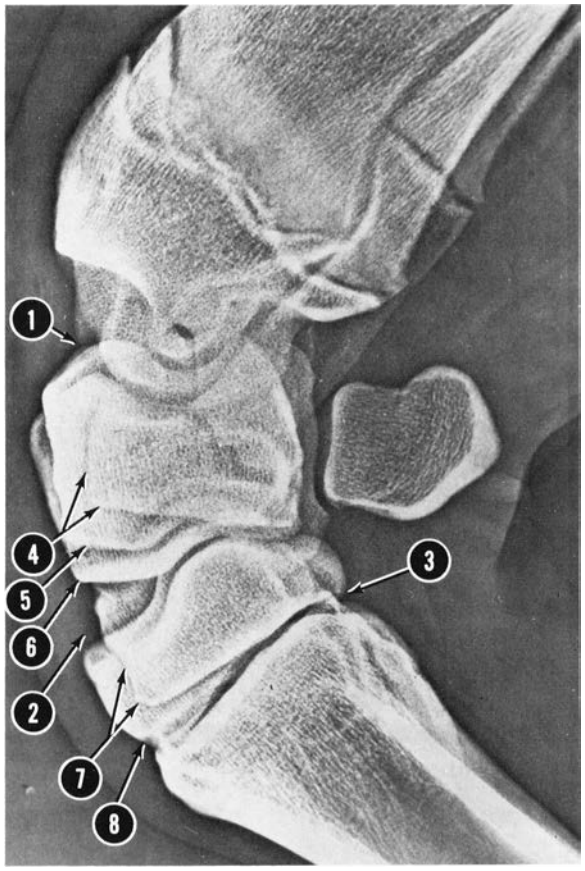


Figure 9-18. Lateromedial (LM) xeroradiograph of left bovine carpus in flexed position: (1) antebrachiocarpal joint; (2) middle carpal joint; (3) carpometacarpal joints; (4) ulnar carpal bone; (5) intermediate carpal bone; (6) radial carpal bone; (7) fourth carpal bone; (8) fused second and third carpal bones.

Dorsolateral-Palmaromedial Oblique View (Fig. 9-19): The fifth metacarpal bone and its articulation with Mc4 are well isolated in this projection. Because of its nearly end-on perspective, the accessory carpal bone appears especially opaque in this projection. The dorsomedial aspect of Cr is isolated. The distal physis of the ulna and the ulnar styloid process are also well defined. A skeletal specimen is helpful in identifying the complex, overlapping shadows along the planes of the antebrachiocarpal and middle carpal joints.

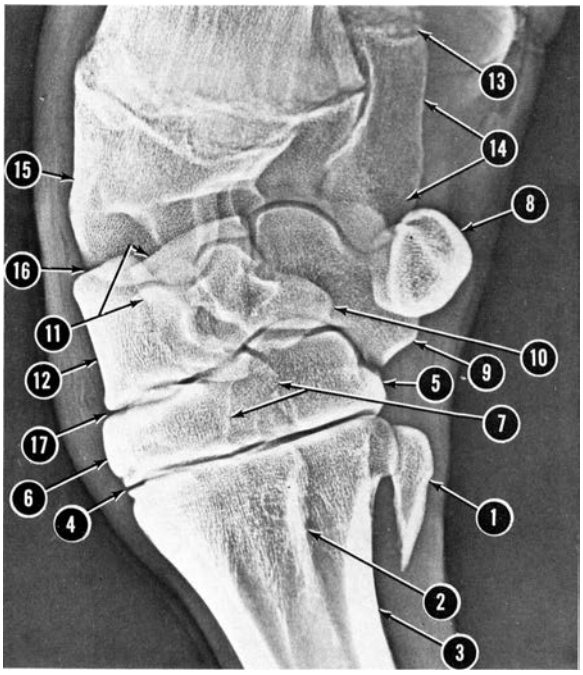


Figure 9-19. Dorsolateral-palmaromedial oblique (DL-PaMO) xeroradiograph of left bovine carpus: (1) fifth metacarpal bone; (2) palmar border of third metacarpal component of Mc3+4; (3) fourth metacarpal component of Mc3+4; (4) carpometacarpal joints; (5) fourth carpal bone; (6) fused second and third carpal bones; (7) partial superimposition of 5 on C2+3; (8) accessory carpal bone; (9) palmar process of ulnar carpal bone; (10) lateral palmar process of intermediate carpal bone; (11) borders of intermediate carpal bone; (12) dorsomedial aspect of radial carpal bone; (13) distal physis of ulna; (14) ulnar styloid process (distal epiphysis of ulna); (15) distal epiphysis of radius; (16) antebrachiocarpal joint; (17) middle carpal joint.

Dorsomedial-Palmarolateral Oblique View (Fig. 9-20): This projection superimposes the shadows of Cr and Ca. Note the distal extent of the ulnar styloid process. The image of C2+3 extends across the superimposed fourth carpal bone, and the image of the fifth metacarpal bone is superimposed on Mc3+4.

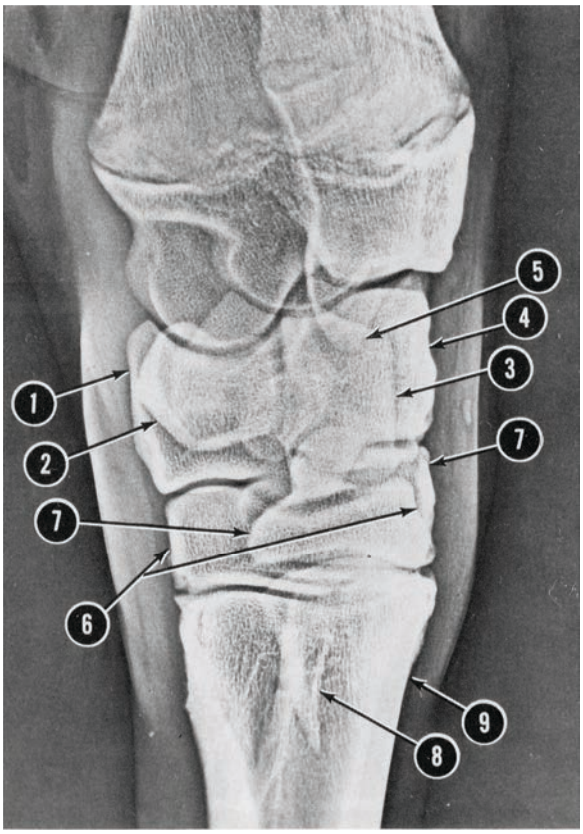


Figure 9-20. Dorsomedial-palmarolateral oblique (DM-PaLO) xeroradiograph of left bovine carpus: (1) radial carpal bone; (2) accessory carpal bone; (3) intermediate carpal bone; (4) ulnar carpal bone; (5) ulnar styloid process; (6) fused second and third carpal bones; (7) fourth carpal bone; (8) fifth metacarpal bone; (9) fused third and fourth metacarpal bones.

DISSECTION OF THE CARPUS AND METACARPUS

Carpal Joint Complex: Before we continue down the limb, let's consider a few more features of the carpal joint complex. As noted in the previous section on radiographic anatomy, most flexion at the carpus occurs at the antebrachiocarpal joint, with considerable flexion occurring also at the middle carpal joint (Figs. 9-8 & 9-18). The synovial cavity of the antebrachiocarpal joint does not communicate with the other carpal joints in any of the domestic ungulates (Fig. 9-21). The palpable accessory carpal bone can be used to locate this joint, especially in the pig, where the joint is frequently opened for postmortem examination.

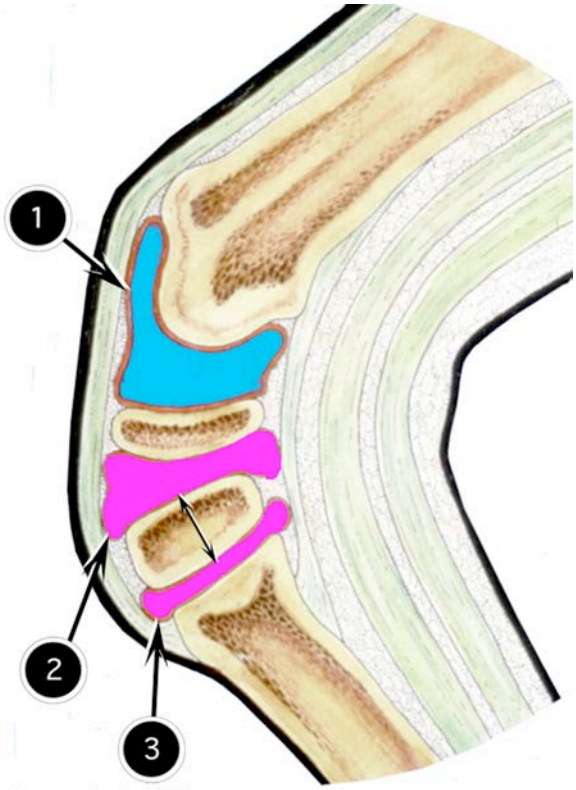


Figure 9-21. Schematic representation of equine carpal complex, sagittal section: (1) antebrachiocarpal joint cavity; (2) middle carpal joint cavity; (3) carpometacarpal joint cavity. Double-headed arrow indicates communication between 2 & 3.

Like any good hinge joint, movement is limited to flexion and extension by well-developed **medial and lateral collateral ligaments** (Fig. 9-22). Commensurate with the complexity of the carpus, these heavy ligaments are divided into several parts, the longest of which bridge the entire complex from forearm to metacarpus. To observe these ligaments without destroying your own specimen, refer to demonstration specimens.

Middle Carpal and Carpometacarpal Joints: The synovial cavities of these joints

communicate in all domestic ungulates (Fig. 9-21). Also, the synovial cavity of the small articulation between Mc4 and Mc5 in the ox communicates with the carpometacarpal joints.) In swine raised under confined conditions (concrete floors), calluses often develop over the dorsal aspect of the carpometacarpal region. This was previously mentioned with reference to the normal calluses in goats and the formation of carpal hygromas in cattle (Fig. 8-18).

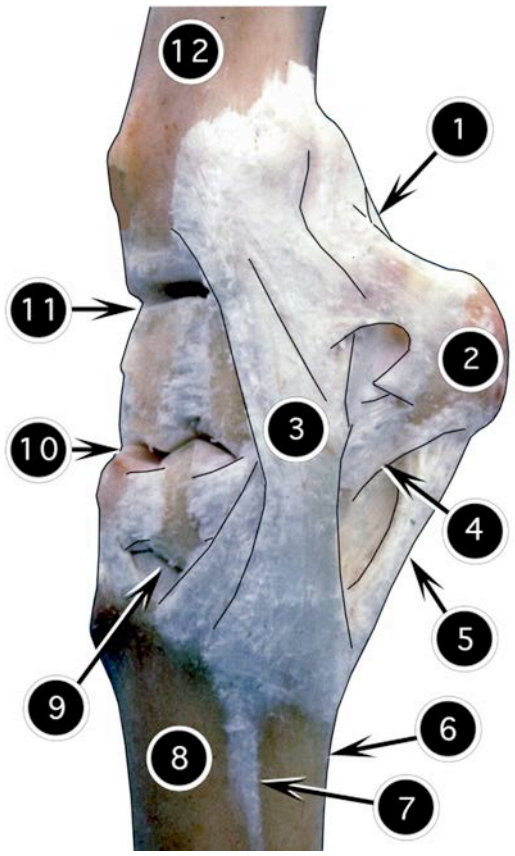


Figure 9-22. Bone ligament model of equine carpus, lateral view: (1) proximal ligament of Ca; (2) accessory carpal bone (Ca); (3) lateral collateral ligament of carpus; (4) middle ligament of Ca; (5) distal ligament of Ca; (6) Mc 4; (7) dorsal metacarpal (interosseous) ligament; (8) Mc 3; (9) carpo-metacarpal joint; (10) middle carpal joint; (11) antebrachiocarpal joint; (12) radius.

Equine Antebrachiocarpal Joint Capsule: *Open this joint on one limb only by reflecting the extensor tendons and making a transverse incision through the dorsal aspect of the joint capsule. Note the normal* ***synovial fold*** *and villi associated with the dorsal part of the joint capsule*. This fold typically envelops a variable amount of fat, which may be detected as an irregular radiolucent shadow in the lateromedial radiograph (Fig. 1-11).

Arthrocentesis of the antebrachiocarpal can be performed dorsally with the carpus flexed. Puncture of the antebrachiocarpal joint can also be done from the lateral side just proximal to the accessory carpal bone, and just caudal to the palpable lateral digital extensor tendon. The palmarolateral pouch of the joint is accessible here (Fig. 9-23). This technique has the advantage that it is performed with the limb supporting weight (*i.e.,* no moving target, less likely to damage articular cartilage). Arthrocentesis of the middle carpal joint can be done dorsally with the carpus flexed.

Equine Carpal Canal: In the preceding pages, a number of references have been made to the carpal canal. We've talked about the digital flexor tendons passing through the canal, along with the medial palmar artery and nerve, but as yet, we haven't really defined what is meant by the term. The carpal canal is the tunnel that accommodates the digital flexor tendons and the medial palmar artery and nerve as they traverse the carpal complex and continue on their way to the metacarpus. It is bounded dorsally by the relatively thick **palmar carpal ligament**, which converts the irregular palmar surface of the carpal joint complex into a smooth track for such structures as the digital flexor tendons. *Reflect the digital flexor tendons from the canal and note this ligament* (Fig. 9-24).

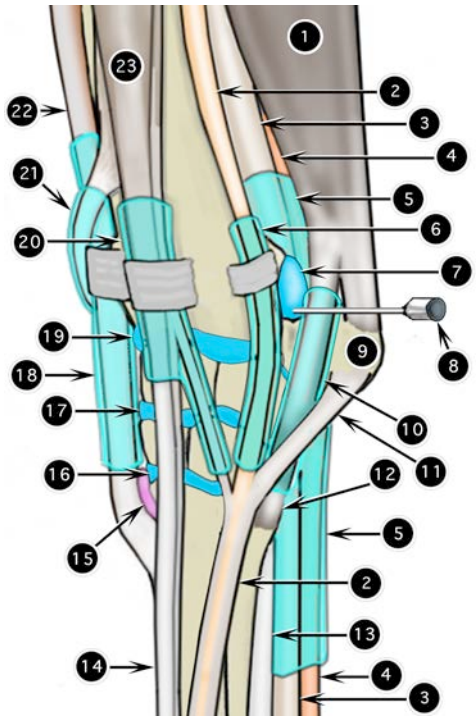


Figure 9-23. Equine carpal complex, lateral view: (1) ulnaris lateralis muscle; (2) lateral digital extensor; (3) deep digital flexor; (4) superficial digital flexor; (5) carpal sheath; (6) tendon sheath of 2; (7) palmarolateral pouch of antebrachiocarpal joint; (8) needle placement for arthrocentesis of 7; (9) accessory carpal bone; (10) tendon sheath of 1; (11) band of fibers from 9 to tendon of 2; (12) termination of 1 on base of Mc4; (13) interosseus 3 (suspensory ligament); (14) common digital extensor tendon; (15) bursa under tendon of extensor carpi radialis; (16) carpometacarpal joint capsule; (17) middle carpal joint capsule; (18) tendon sheath of extensor carpi radialis; (19) antebrachiocarpal joint capsule; (20) tendon sheath of common digital extensor; (21) tendon sheath of abductor pollicis longus; (22) extensor carpi radialis; (23) common digital extensor.

Continuous distally with the palmar carpal ligament, you should find the accessory ligament of the deep digital flexor and the interosseus (Fig. 8-21). In addition to the palmar carpal ligament, the canal is completed laterally by the accessory carpal bone and palmaromedially by the **flexor retinaculum of the carpus**.

As the digital flexor tendons pass through this canal, there is need for lubrication. Thus, *Parent Nature*[8] has provided these flexor tendons with the **carpal sheath**, one of the major tendon sheaths of the body. So as not to take any chances on friction, the sheath begins well proximal to the carpus and extends distally to mid-metacarpus (Fig. 9-23). In the spirit of efficiency, one sheath (per limb) serves both deep and superficial digital flexor tendons quite nicely.

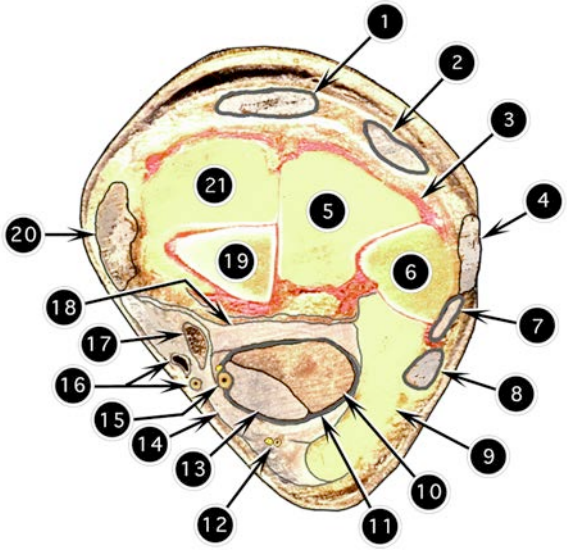


Figure 9-24. Transverse section through right antebrachiocarpal joint and carpal canal of horse, proximal view: (1) tendon sheath of extensor carpi radialis; (2) tendon sheath of common digital extensor; (3) latex filling antebrachiocarpal joint; (4) lateral collateral ligament; (5) intermediate carpal bone; (6) lateral styloid process of ulna; (7) tendon sheath of lateral digital extensor; (8) tendon sheath of long tendon of ulnaris lateralis; (9) accessory carpal bone; (10) deep digital flexor tendon; (11) carpal sheath surrounding both DDF and SDF tendons; (12) palmar branch of median artery & lateral palmar nerve; (13) superficial digital flexor tendon; (14) flexor retinaculum of carpus; (15) medial palmar artery & nerve; (16) radial artery & vein; (17) tendon of flexor carpi radialis; (18) palmar carpal ligament forming dorsal boundary of carpal canal; (19) medial styloid process of radius; (20) medial collateral ligament; (21) radial carpal bone.

[8] Parent Nature is used here as a politically correct, non-genderic equivalent of the older Mother Nature. Parent time can be substituted for Father Time for similar reasons.

Ligaments of Equine Accessory Carpal Bone: As you recall, the long plantar ligament assisted in anchoring the calcaneus of the tarsal complex to the distal part of the limb. Similarly, the accessory carpal bone is securely attached by a series of ligaments to the lateral styloid process, ulnar carpal bone, C4, and Mc4 to counteract the proximal traction exerted by the ulnaris lateralis and flexor carpi ulnaris muscles. These ligaments have rather long official names, but proximal, middle, and distal are more practical (Fig. 9-22).[9] Recall that Ca is the only carpal bone that serves as a site for muscle attachment. The pull of the ulnaris lateralis and flexor carpi ulnaris must be offset by strong ligamentous anchorage; otherwise, the bone would be pulled loose from its attachments.

Metacarpal Interosseous Ligaments of Horse: It should be obvious that all weight of the horse must ultimately be borne by Mc3. The gravitational and locomotive forces transmitted through the carpal complex are loaded onto metacarpal bones 2, 3, and 4. Mc2 and Mc4 are attached to Mc3 in their proximal parts by the **metacarpal interosseous ligaments** (Fig. 9-22), which some anatomists divide into dorsal, interosseous, and palmar parts. These short, dense ligaments allow for limited distal migration of Mc2 and Mc4 relative to Mc3 when loaded. Unfortunately, the load sometimes exceeds the resistance of these ligaments, and they are over-stretched, resulting in various degrees of injury.[10] When this over-stretching involves actual tearing of fibers (sprain), an acute inflammatory reaction occurs, typically in a localized area of the **dorsal metacarpal ligament**. Thus, there is pain and swelling in the area, and the condition is commonly referred to as a "splint" (Fig. 9-25).[11]



Figure 9-25. Medial and lateral splints (arrows) in a thoroughbred race horse. This condition results from tearing (desmitis) of the dorsal metacarpal (interosseous) ligaments between Mc2 or Mc4 and Mc3.

[9] This brings us to Smallwood's almost last Law of Veterinary Anatomic Nomenclature: "Always use correct anatomic terminology unless the term is so ridiculously long and forgettable as to be totally unacceptable to your above-average clinician."

[10] Injuries to ligaments, tendons, and muscles are generally classified as the following: (1) strains- over-stretching; (2) sprains- partial rupture or tearing of some fibers; and (3) complete rupture of the structure (*e.g.,* ruptured cranial cruciate ligament).

[11] Technically, this condition is dorsal metacarpal desmitis, which may explain why it is most often called a "splint." As you already know, the term, "splint bones," is commonly used to describe the small metacarpal and metatarsal bones of the horse.

Splints most often occur on the medial side, between Mc2 and Mc3, and there are several ideas as to why they occur more frequently on this side. Note that C2 articulates only with Mc2, whereas C4 transfers its load to both Mc3 and Mc4. Thus, all of the weight from C2 is loaded onto Mc2, whereas part of the load from C4 is transferred directly to Mc3, bypassing Mc4. Also, the center of gravity of a horse is medial to the limb, so more weight is understandably transmitted through the medial part of the limb than through the lateral part. In consideration of these facts, it is not surprising that the lesion more often involves the ligament between Mc2 and Mc3; however, in some horses tearing occurs both medially and laterally (Fig. 9-25).

The **periosteum** of the metacarpal bones is closely related to these dorsal metacarpal ligaments. When the ligaments are torn, the periosteum typically responds by smoothing things over with bone; over time, there is a synostosis or bridging with bone that results in a fusion of the bones, leaving an elevated callus resembling a "spot weld."[12]

Depending on the amount of inflammation and subsequent periosteal reaction, this can produce a bony callus between the bones that can be palpated and even observed as an enlargement in the live horse (Fig. 9-25). Because there is no longer any movement or active inflammation, there is no pain or lameness associated with these "cold" or chronic splints. They do, however, represent a "blemish" on the horse, which may be noted on a prepurchase examination and may negatively affect the value of the animal at the time of sale.

Palmar Nerves of Horse: The **medial and lateral palmar nerves** descend the metacarpus next to the deep digital flexor tendon (Figs. 8-6 & 8-22). A palmar nerve block is routinely performed along either side of the DDF tendon, at the level of the palpable distal ends of the small metacarpal bones (Fig. 9-26). This level is distal to the palpable **communicating branch** between the palmar nerves. Because the palpable communicating branch is obliquely oriented in a laterodistal direction, it is important that the medial nerve not be blocked distal to the branch and that the lateral nerve not be blocked proximal to the communicating branch. This would, of course, leave an "open pathway" for afferent (pain) information to bypass both blocks.

Recall that the medial palmar nerve is a direct continuation of the median nerve, but the lateral palmar nerve contains fibers from both median and ulnar nerves (Fig. 8-22). Blocking the palmar nerves at the level of the distal ends of the splint bones is also proximal to the level where the dorsal branch is given off (Fig. 9-26). Thus, blocking at this level would include the dorsal branch, which is typically double on the medial side.

On the live horse, palpate the communicating branch in the following manner. Using two or three fingers, press the skin against the palmar aspect of the SDF tendon in the mid-metacarpus. Move the skin proximally and distally over the tendon, and feel for the bump. That's it. *The dorsal branch of the ulnar nerve can also be*

[12] It is now time to note that a horse's distal limb is "an ossification looking for a place to happen." It doesn't take much to set off a periosteal reaction in this region, and I believe it is part of the natural survival mechanism of wild equidae. A wild horse with a sore limb is not able to keep up with the herd; it must heal itself or be left behind to die on the prairie. Thus, the horse has a "built-in" mechanism for fusing those hurting parts, stabilizing the motion, stopping the pain, and going on.

palpated by palpating proximally and distally over the ulnaris lateralis tendon, a few centimeters proximal to Ca (Fig. 8-22).

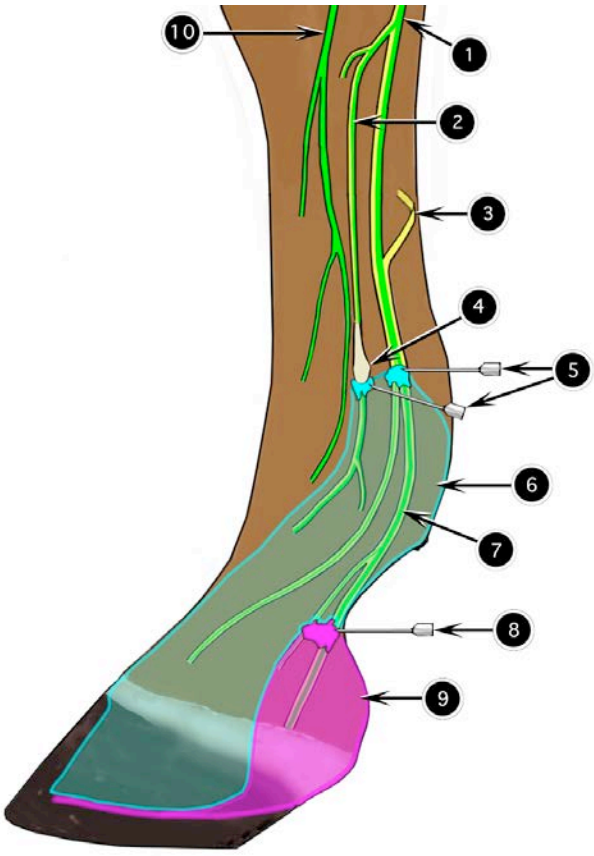


Figure 9-26. Left distal forelimb of horse showing sites of nerve blocks, lateral view: (1) lateral palmar nerve; (2) lateral palmar metacarpal nerve, from deep branch of 1; (3) communicating branch between medial & lateral palmar nerves; (4) head of Mc bone 4; (5) needle placements for blocking 1 & 2; (6) area of analgesia produced by blocking at 5, in addition to that produced at 7; (7) lateral palmar digital nerve; (8) needle placement for blocking 7; (9) area of analgesia produced by blocking at 8; (10) dorsal branch of ulnar nerve.

In addition to the palmar nerves, the small **palmar metacarpal nerves** can be blocked in the fossae just distal to the splint bones (Fig. 9-26). These nerves are derived from the deep branch of the lateral palmar nerve in the proximal part of the metacarpus.[13] Once the palmar and palmar metacarpal nerves have been blocked both medially and laterally, the horse should be completely insensitive around the coronet and pastern regions (Fig. 9-26). Because the fetlock joint capsule receives sensory fibers from the palmar metacarpal nerves before they emerge, and because the medial cutaneous antebrachial nerve may descend to this level, there is still some sensitivity in and around the fetlock joint. The most effective way of anesthetizing the fetlock joint is to inject the joint directly.

After giving off their dorsal branches, the **medial and lateral palmar digital nerves** continue across the proximal sesamoid bones, where they accompany the digital arteries and veins. They descend along side the DDF tendon into the foot. The medial and lateral palmar digital nerves can be blocked in mid-pastern next to the DDF tendon (Fig. 9-26). These are usually the first nerves to be blocked in a diagnostic procedure.

When the palmar digital nerves are blocked, the horse should be insensitive to the "ballpoint pen test" over the bulbs of the heel and palmar part of the coronet (Fig. 9-26). This block should also eliminate pain originating from the area of the frog and sole, and from the clinically important navicular bursa-bone complex. The palmar digital block does not completely anesthetize the distal interphalangeal joint or

[13] You might question the significance of discussing such small nerves- a good question. Unlike the situation with vessels, in which size is directly related to importance, this correlation is not as valid for nerves. If you think of it, nerves are merely collections of nerve fibers, each one functioning more or less independent of its neighbors, whether there are 20 or 20,000 accompanying fibers. Thus, small nerves, although visually inconspicuous, must still be considered if they contain sensory fibers from clinically important structures.

the laminar corium, because these areas are partly supplied by the dorsal branches and palmar metacarpal nerves. Unlike the arrangement in the pelvic limb, there are no dorsal digital nerves in the equine foredigit-only dorsal branches of the palmar digital nerves. This is an important difference, which should not be forgotten when you are attempting to "block out" the equine digit for diagnostic purposes.

Blood Supply to Distal Limb of Horse: As noted, the medial palmar nerve[14] accompanies the **medial palmar artery** through the carpal canal and along the medial side of the DDF tendon through the metacarpus (Fig. 8-9). As the DDF begins to separate from the interosseus in the distal metacarpus, the medial palmar artery moves into the space and inclines toward the axis of the limb (Fig. 9-27).

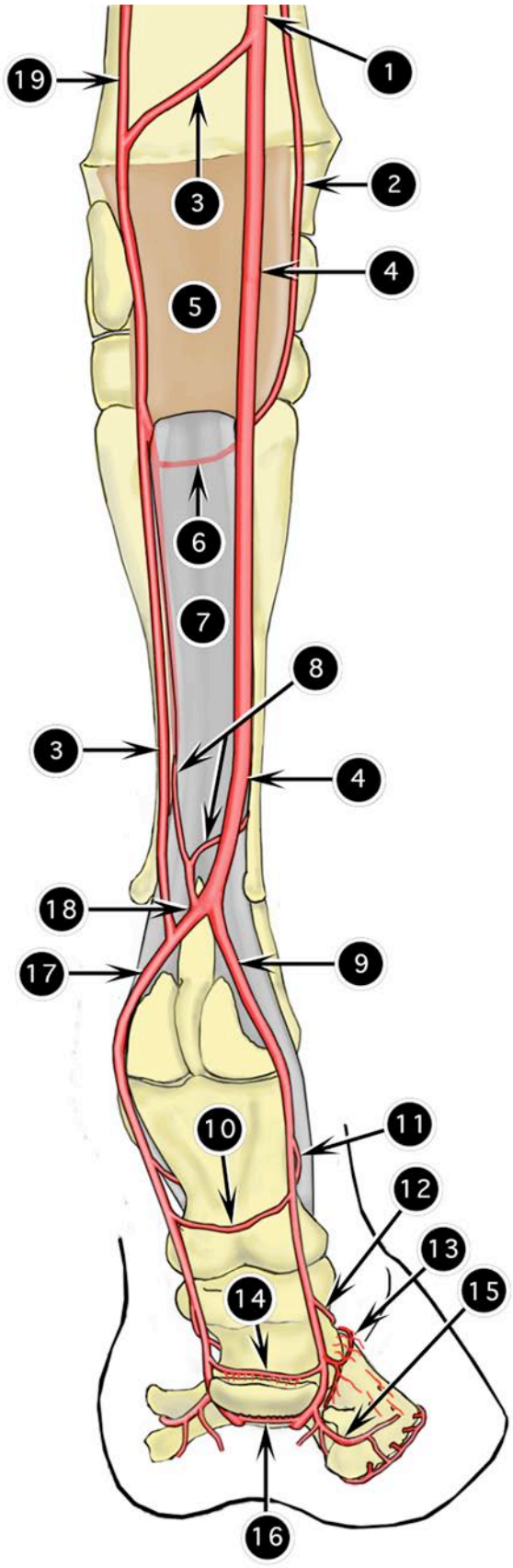


Figure 9-27. Arteries of distal limb of horse, caudomedial view: (1) median artery; (2) radial artery; (3) lateral palmar artery (palmar common digital artery 3); (4) medial palmar artery (palmar common digital artery 2); (5) palmar carpal ligament; (6) deep palmar arch; (7) interosseus 3 (suspensory ligament); (8) medial & lateral palmar metacarpal arteries; (9) medial digital artery; (10) anastomosis of palmar branches of proximal phalanx; (11) dorsal branch of proximal phalanx; (12) dorsal branch of middle phalanx; (13) coronary artery; (14) anastomosis of palmar branches of middle phalanx (minor blood supply to distal sesamoid bone); (15) dorsal branch of distal phalanx; (16) anastomosis of palmar branches of distal phalanx (major blood supply to distal sesamoid bone); (17) lateral digital artery; (18) superficial palmar arch; (19) ulnar artery.

[14] What we term the medial palmar nerve (artery, vein) is, in fact, palmar common digital nerve (artery, vein) *2*. Similarly, the lateral palmar nerve (artery, vein) represents palmar common digital nerve (artery, vein) 3. With the horse having a single digit, such a designation, although more accurate from a comparative standpoint, seems an unnecessary complication for equine clinicians. In their world, there is only one species and only one digit per limb; they like to keep things simple.

On one limb, transect the SDF and DDF tendons in mid-metacarpus, and reflect the distal stumps to follow the artery. Near the fetlock, the artery bifurcates into the **medial and lateral digital arteries**, which diverge and continue over the abaxial sides of the proximal sesamoid bones. Here they join the digital veins and palmar digital nerves (Fig. 9-27).

The vessels and nerves are palpable in the live horse as they cross the proximal sesamoid bones. Here, the digital pulse can be evaluated, and some clinicians prefer this site for blocking the nerves.

The dorsal-to-palmar relationship at this level is vein, artery, nerve (VAN). The medial and lateral digital arteries anastomose in the sole canal of the distal phalanx to form the **terminal arch**, which is functionally important if one of the arteries becomes occluded. Radiating from the sole canal are many vascular channels, which transmit vessels from the terminal arch to the parietal surface of the distal phalanx, especially to the sole border (Fig. 9-27).

Before we leave the metacarpus of the horse, we should mention another clinical problem. Note the thick periosteum over the dorsomedial aspect of Mc3. As previously mentioned, this bone comes under considerable stress during sustained athletic performance. When young horses are brought along too fast, and the training demands exceeds their conditioning, they sometimes sustain another form of injury to Mc3. Repetitive concussion in an under-conditioned animal results in the development of **stress or fatigue fractures** of this bone.

With each successive stride, Mc3 is compressed and decompressed, compressed and decompressed. Much like the skin of a jet plane, it can withstand only so many compressions and decompressions before something has to give. What usually happens is that the dorsal or dorsomedial cortex of the bone finally gives way under these repetitive concussions, and **microfractures** occur.

Many of these microfratures are undetectable with the relatively crude analysis system afforded by radiography, but that doesn't mean they didn't occur. There is hemorrhage with these fractures, and as the blood moves to the surface of the bone, it undermines the periosteum and lifts it away from the bone (Fig. 9-28). As the blood is resorbed, new bone is produced by the elevated periosteum. This produces what is commonly referred to as a "bucked shin."



Figure 9-28. Dorsolateral-palmaromedial oblique (DL-PaMO) xeroradiograph of metacarpus of 3-year-old quarter horse. Arrows indicate two areas of periosteal new bone formation. The periosteum was elevated by hemorrhage from cortical microfractures (not detected in this xeroradiograph).

Most, if not all, cases of "bucked shins" involve some form of microscopic or grossly detectable cortical fracture.[15] Stress fractures appear radiographically as characteristic 45° fracture lines in the cortex of the bone; however, they may not be detectable for several weeks following the original injury (Fig. 9-29). Those that are radiographically obvious must be considered more serious, because they can progress to a complete "saucer fracture" if the bone is stressed further before healing occurs.

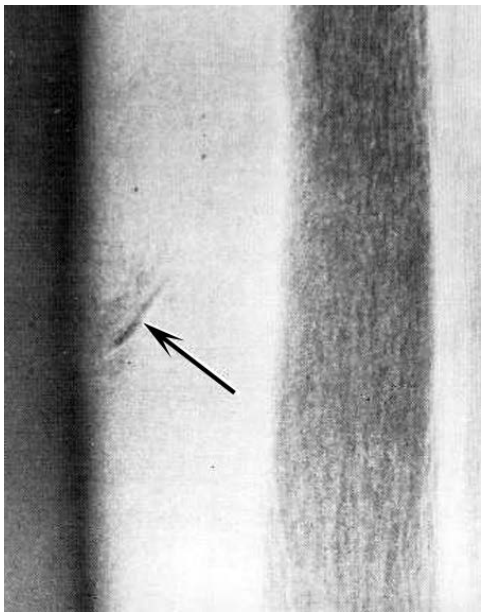


Figure 9-29. Lateromedial (LM) xeroradiograph of metacarpus of 8-year-old thoroughbred horse. Arrow indicates a characteristic 45° stress fracture in the dorsal cortex of Mc3.

Blood Supply to Distal Limb of Artiodactyls: In artiodactyls, the principal continuation of the median artery is **palmar common digital artery 3** (Fig. 8-10). Trace the **median artery** distally as it obliquely crosses the superficial digital flexor tendon to reach the interdigital space as palmar common digital artery 3.

As palmar common digital artery 3 crosses the SDF tendon, the artery is easily palpable as a large, elongated bulge. Be sure you can take the pulse of the ox at this site. Palmar common digital artery 3 bifurcates to form the **axial palmar arteries of digits 3 and 4**, which are the principal arteries of the digits. These arteries continue to enter the axial foramen of each distal phalanx (see skeletal model).

Principal Derivation of Digital Nerves in Domestic Artiodactyls: As was the case with the pelvic limb, specific knowledge about the individual nerves of the digit is most important in the horse. Diagnostic nerve blocks are rarely performed in artiodactyls. Although specific innervation of the digits in the artiodactyls does not deserve as much attention as that of the horse, students should be familiar with the general innervation pattern as outlined below. Because this list is intended to provide only a general pattern, certain communicating branches have been intentionally omitted. If specific diagnostic information were required, these communicating branches could not be disregarded.

Abaxial Dorsal Nerve of Digit 4- primarily a continuation of dorsal common digital nerve 4 from the dorsal branch of the ulnar nerve

Axial Dorsal Nerves of Digits 3 and 4- primarily continuations of dorsal common digital nerve 3 from the superficial branch of the radial nerve (Fig. 8-7)

Abaxial Dorsal Nerve of Digit 3- primarily a continuation of dorsal common digital nerve 2 from the superficial branch of the radial nerve (Fig. 8-7)

[15] Smallwood, J. E. Evaluation of the "bucked shin syndrome using xeroradiography. Equine Pract. 1, #2 (1979): 28-36.

Abaxial Palmar Nerve of Digit 4- primarily a continuation of palmar common digital nerve 4 from the palmar branch of the ulnar nerve

Axial Palmar Nerves of Digits 3 and 4- continuations of palmar common digital nerve 3 from the median nerve (Fig. 8-7)

Abaxial Palmar Nerve of Digit 3- a continuation of palmar common digital nerve 2 from the median nerve (Fig. 8-7)

SKELETAL AND RADIOGRAPHIC ANATOMY OF FETLOCK AND DIGITAL REGIONS

As you recall, we did not consider the fetlock[16] and digital regions in any detail in the pelvic limb. The bones of the distal limb are similar in both the pelvic and the thoracic limbs, and with few exceptions the features considered here are identical to those of the pelvic limb. Each principal digit consists of the three phalanges and three sesamoid bones, two proximal and one distal (Fig. 9-3 & 9-30). Common names are frequently used to describe these bones and the joints between them in the horse. The proximal phalanx is often referred to as the "long pastern bone", Pm as the "short pastern bone", and Pd as the "coffin bone." Pd is also referred to in some texts as the "pedal bone."

Similarly, the proximal interphalangeal joint (PIJ) is commonly called the "pastern joint," and the distal interphalangeal joint is referred to as the "coffin joint." Because of the complexity and clinical importance of this region in the horse, the digit will be considered in much greater detail than in the artiodactyls.

Proximal Phalanx of Horse: Pp articulates with Mc3 by conforming rather closely to the head of the latter. Note that the **sagittal ridge of Mc3** fits neatly into a groove in the base of Pp, much like a screwdriver blade fits into the slot in the head of a wood screw (Fig. 9-31). This arrangement adds mediolateral stability to the joint but also predisposes Pp to torque forces when a horse pivots on a supporting limb. In extreme cases, this can result in an oblique, spiraling fracture of Pp that originates at the slot in its base. The area on the medial side of the groove in the base of Pp is slightly larger than that on the lateral side, a difference that can be used to distinguish medial from lateral on the bone, but one that is not clear enough to provide a reliable reference in an unmarked DPa (DPl) radiograph.[17]

The digit and metacarpophalangeal region of the horse are clinically important areas that are frequently examined radiographically. Accurate interpretation and objective evaluation of these radiographs require detailed knowledge of normal radiographic anatomy, including recognition of common anatomic variations. Locate the primary nutrient foramen of Pp through its mid-dorsal cortex. This **nutrient canal** can be appreciated in radiographs and should not be mistaken for a fracture (Fig. 9-31).

[16] Some folks think that fetlock is some sort of slang term. It is not. Fetlock has the advantage in that it can be used as a collective term to describe both metacarpophalangeal and metatarsophalangeal joints. If you're interested in a good old slang (and incorrect) term for this joint in the horse, use ankle.

[17] Although there are subtle differences between the medial and lateral aspects of the distal equine limb, none can be relied on to distinguish, without doubt, medial from lateral in a radiograph. The magnification and distortion inherent in all radiographic images can mask or confuse any of the subtle differences that are present. Therefore, it is imperative that Dpa (DPl) radiographs of the distal limb be marked to indicate medial or lateral.

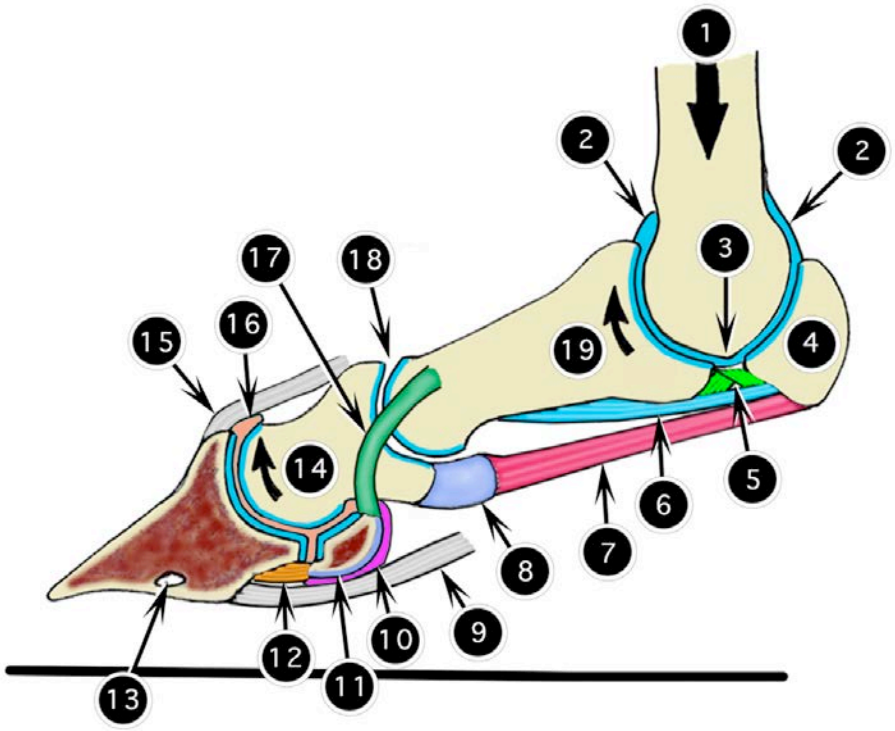


Figure 9-30. Schematic representation of movements that occur at metacarpophalangeal & distal interphalangeal joints during descent of fetlock: (1) descent of fetlock; (2) sagittal ridge of Mc3; (3) subtle transverse ridge on articular surface of Mc3; (4) proximal sesamoid bones; (5) cruciate sesamoid ligaments; (6) oblique sesamoid ligaments; (7) straight sesamoid ligament; (8) fibrocartilage of Pm; (9) deep digital flexor tendon; (10) navicular (podotrochlear) bursa; (11) distal sesamoid (navicular) bone, shown in sagittal section; (12) distal navicular (impar) ligament; (13) sole canal of Pd, Pd shown in sagittal section; (14) toe stays on ground & distal interphalangeal joint flexes; (15) termination of common digital extensor on Pd; (16) distal interphalangeal joint; (17) collateral (suspensory) ligament of navicular bone; (18) proximal interphalangeal joint does not move during descent of fetlock; (19) hyperextension of metacarpophalangeal joint during descent.

A triangular area on the dorsoproximal aspect of Pp indicates the area of attachment of the common digital extensor (CDE) tendon and, just lateral to this area, is a small prominence for termination of the lateral digital extensor tendon. During translation[18] of the fetlock at fast gaits, the joint goes into extreme hyperextension (Fig. 9-25), which may result in exostoses and chip fractures off the proximodorsal aspect of Pp. These chips are commonly referred to as "osselets."[19]

On the palmar surface of Pp, note the triangular area defined by two ridges that converge distally (Fig. 9-31). These ridges serve as attachment sites for the **oblique sesamoidean ligaments**, which help anchor the proximal sesamoid bones to the phalanges (Fig. 9-30). There are prominences at the four corners of the bone known as collateral tubercles. The medial and lateral **proximal tubercles** receive the collateral ligaments of the fetlock joint, and the medial and lateral **distal tubercles** provide origin for the collateral ligaments of the proximal interphalangeal joint.

[18] Translation of the fetlock refers to the normal sinking, rotation, and rising of this joint as the horse's weight passes over the supporting limb.

[19] osselets- little bones.

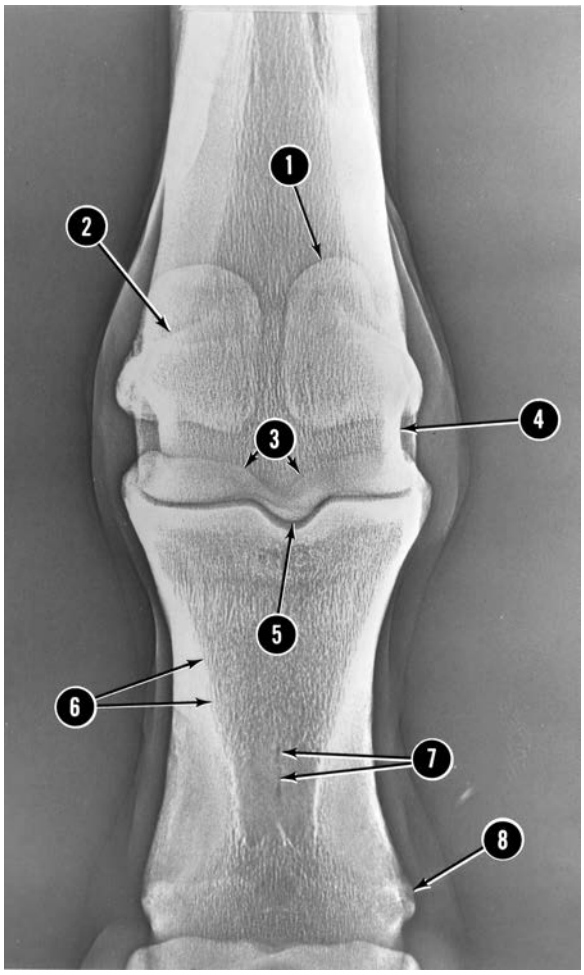


Figure 9-31.[20] Dorsoproximal-palmarodistal oblique (DPr-PaDiO) xeroradiograph of left equine metacarpophangeal joint (McPJ): (1) lateral proximal sesamoid bone- slightly taller & more pointed than medial proximal sesamoid bone; (2) depression in interosseus (abaxial) surface of medial proximal sesamoid bone for attachment of interosseus; (3) palmaroproximal edge of Pp; (4) depression in Mc3 for attachment of lateral collateral ligament of McPJ; (5) sagittal ridge on head of Mc3; (6) area of oblique ridge on palmar surface of Pp for attachment of medial oblique sesamoid ligament; (7) nutrient canal through dorsal cortex of Pp; (8) lateral distal collateral tubercle of Pp.

[20] Unless otherwise noted, the xeroradiograghs of the fetlock and digital regions in this chapter were made of the left foredigit of a 7-year-old, Swedish, warm-blood gelding with no clinical evidence of lameness. Smallwood, J.E. and Holladay, S.D. Xeroradiographic anatomy of the equine digit and metacarpophalangeal region. *Veterinary Radiology* 28 (1987): 166-173.

In addition, the distal collateral tubercles serve as termination sites for the superficial digital flexor tendon, which is unique to the horse in that the SDF terminates not only on Pm but also on Pp. It thus terminates above and below the PIJ, which resists flexion of this joint during translation of the fetlock joint (Fig. 9-30). Small depressions just dorsal to the distal collateral tubercles give origin to the collateral ligaments of the distal sesamoid (navicular) bone.

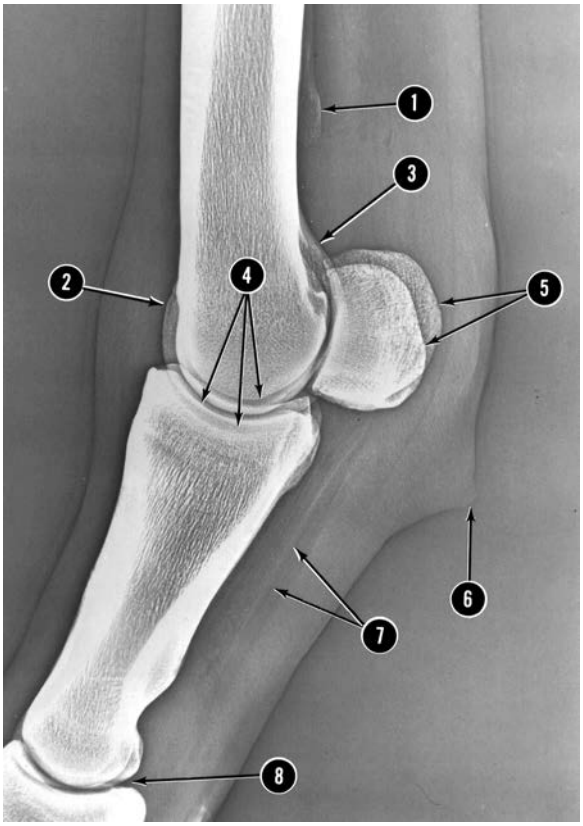


Figure 9-32. Lateromedial (LM) xeroradiograph of left equine metacarpophalangeal joint (McPJ): (1) distal end (head) of small Mc bone; (2) dorsal part of sagittal ridge of Mc3; (3) palmar part of sagittal ridge of Mc3; (4) metacarpophalangeal joint; (5) proximal sesamoid bones; (6) ergot; (7) straight sesamoid ligament; (8) proximal interphalangeal joint.

Middle Phalanx of Horse: Pm receives the bilobed head of Pp and articulates distally with Pd and the distal sesamoid bone at the distal interphalangeal joint (DIJ). Note the

large flattened area on the palmaroproximal aspect of Pm. This **flexor tuberosity** serves for the attachment of a large fibrocartilage, which extends or complements the functional articular surface of this joint (Fig. 9-30). To this fibrocartilage is attached the **straight sesamoidean ligament**. The collateral ligaments of the PIJ and the SDF tendon terminate on the medial and lateral **collateral tubercles**.

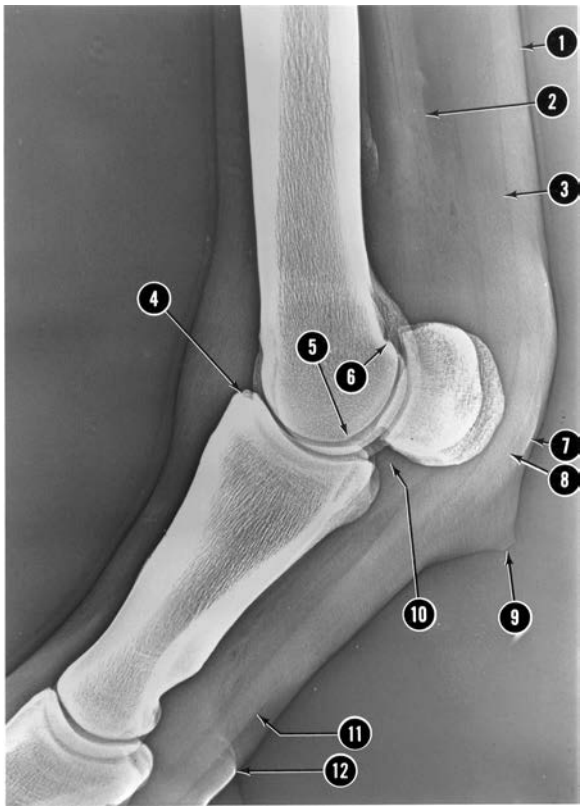


Figure 9-33. Lateromedial (LM) xeroradiograph of left equine metacarpophalangeal joint (McPJ) with right limb lifted to increase weight on left limb: (1) superficial digital flexor (SDF) tendon; (2) interosseus; (3) deep digital flexor (DDF) tendon; (4) dorsoproximal aspect of Pp; (5) subtle transverse ridge on head of Mc3; (6) distinct transverse ridge at palmar edge of articular surface; (7) palmar annular ligament of McPJ; (8) SDF tendon; (9) ergot; (10) increased distance between proximal sesamoid bones and Pp (as compared with Fig. 9-27) caused by hyperextension of McPJ and stretching of distal sesamoid ligaments; (11) DDF tendon; (12) distal digital annular ligament.

The collateral ligaments of the DIJ originate from depressions on the distomedial and distolateral aspects of the bone. Just dorsal to these depressions are eminencies that give origin to ligaments that attach to the cartilages of the hoof. In DM-PaLO and DL-PaMO radiographs of the equine digit, these normal eminencies can be mistaken for exostoses. Obviously, excessive tension on these ligaments can cause these eminencies to become accentuated. The collateral ligaments of the navicular bone are accommodated by oblique grooves across the abaxial aspects of the bone.

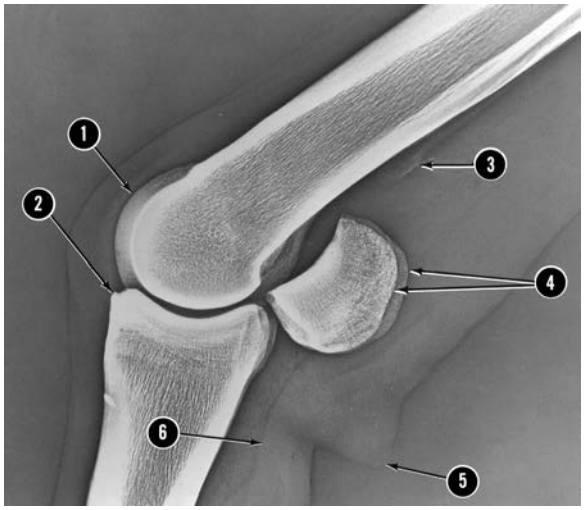


Figure 9-34. Lateromedial (LM) xeroradiograph of left equine metacarpophalangeal joint (McPJ) in flexed position: (1) sagittal ridge on head of Mc3; (2) dorsoproximal aspect of Pp; (3) distal end of small Mc bone; (4) proximal sesamoid bones; (5) ergot; (6) DDF tendon.

Distal Phalanx of Horse: The primary termination of the CDE tendon is on the **extensor process** of Pd (Fig. 9-30), but the term "extensor process" must be defined more broadly if it is to describe accurately the area of termination for this tendon. The tendon widens out and attaches over a broad area on and to either side of the apex of this process. The distal phalanx of the forelimb is broader and more rounded than that of the

pelvic limb, which is typically more pointed or plow-shaped. The articular surface receives the bilobed head of Pm, and an articular facet is provided palmarly for articulation with the navicular bone. Depressions to either side of the articular surface receive the collateral ligaments of the DIJ.

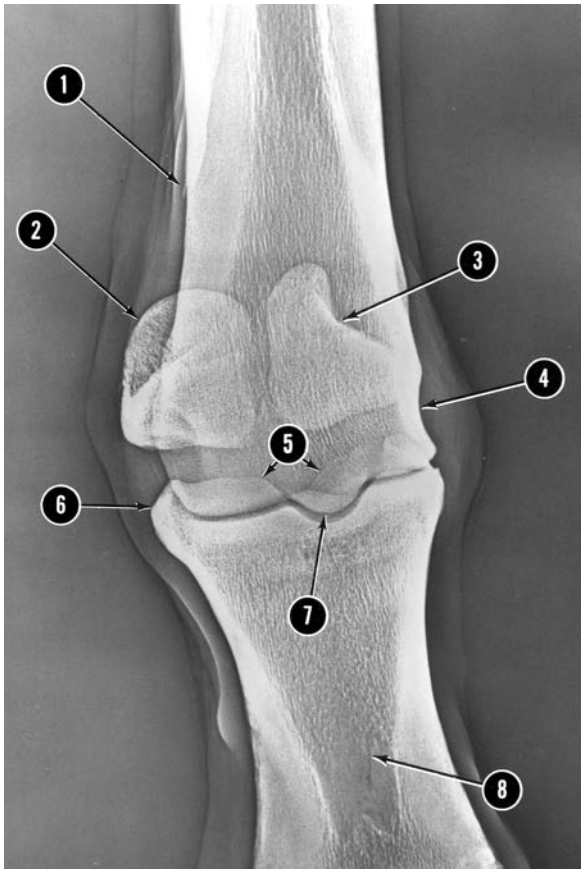


Figure 9-35. Dorsoproximomedial-palmarodistolateral oblique (DPrM-PaDiLO) xeroradiograph of left equine metacarpophalangeal joint (McPJ): (1) distal end of Mc2; (2) palmaroabaxial border of medial proximal sesamoid bone; (3) depression in interosseus surface of lateral proximal sesamoid bone for attachment of interosseus; (4) depression in Mc3 for attachment of lateral collateral ligament of McPJ; (5) palmaroproximal edge of Pp; (6) medial proximal collateral tubercle of Pp; (7) sagittal ridge on head of Mc3; (8) nutrient canal through dorsal cortex of Pp.

The surface of Pd that faces the hoof wall is the **parietal surface**.[21] It is roughened for attachment of a modified periosteal bond with the dermis (corium) of the laminar region. In addition, it is penetrated by numerous foramina (channels), which allow for the transmission of blood vessels to and from the terminal arch vessels located in the sole canal.

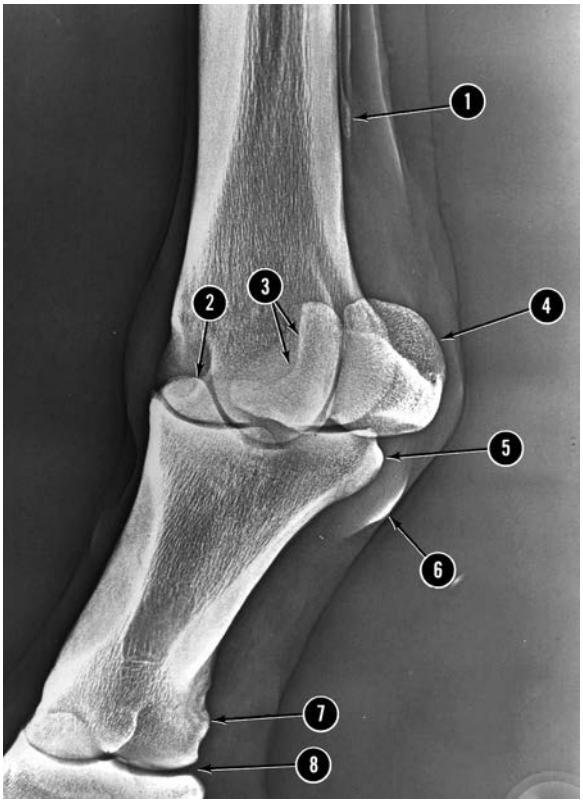


Figure 9-36. Dorsolateral-palmaromedial oblique (D45L-PaMO) xeroradiograph of left equine metacarpophalangeal joint (McPJ): (1) distal end of Mc4; (2) dorsoproximal aspect of Pp; (3) depression in interosseus surface of medial proximal sesamoid bone for attachment of interosseus; (4) palmaroabaxial border of lateral proximal sesamoid bone; (5) lateral proximal collateral tubercle of Pp; (6) ergot; (7) lateral distal collateral tubercle of Pp; (8) proximal interphalangeal joint.

[21] parietal surface- that surface related to the wall. In this case it faces dorsally, medially, and laterally, which explains why none of these terms would describe the entire surface accurately.

The parietal surface ends distally at the **sole border** of Pd, which receives many of the larger vascular channels that connect with the sole canal. This area requires additional nourishment because it is where the **terminal papillae** of the corium are located, and a large amount of hoof horn is produced over these papillae. In most forelimb specimens, you should note a variably developed mid-dorsal notch, the **crena marginis solearis**, in the sole border (Fig. 9-39). This cleft, or crena, varies from subtle to very distinct and is less commonly present in the pelvic Pd.

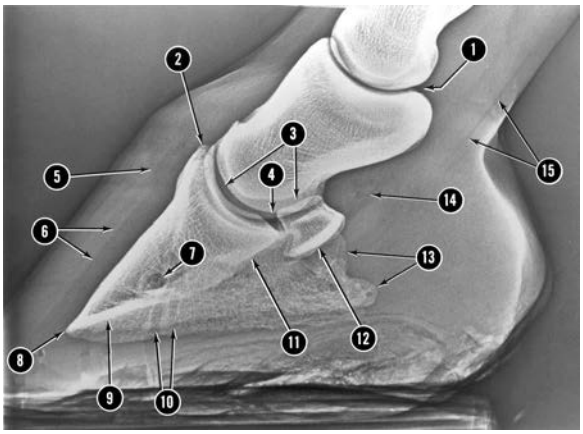


Figure 9-37. Lateromedial (LM) xeroradiograph of left equine foredigit: (1) proximal interphalangeal joint, typically more narrow than the distal interphalangeal joint; (2) extensor process of distal phalanx (Pd); (3) distal interphalangeal joint; (4) part of DIJ that extends between Pd and the distal sesamoid (navicular) bone; (5) proximal extent of tubular horn forming stratum medium of hoof wall; (6) junction of stratum medium and laminar horn of stratum internum; (7) transverse part of sole canal of Pd- accommodates terminal arch of digital vessels; (8) sole border of Pd; (9) planum cuneatum (sole surface) of Pd; (10) vascular channels extending from sole canal to sole border of Pd; (11) flexor surface of Pd- area for termination of deep digital flexor tendon and attachment of distal navicular ligament; (12) flexor surface of navicular bone- separated from DDF tendon by podotrochlear (navicular) bursa; (13) superimposed medial and lateral palmar processes of Pd; (14) radiolucent areas created by fat within synovial folds at junction of DIJ, navicular bursa, and digital sheath; (15) borders of DDF tendon- defined by fat within synovial folds of digital sheath.

Note the medial and lateral **palmar processes** to which the cartilages of the hoof[22] are attached. These processes are bipartite (a deep notch separates them into two parts); in older horses the two parts may unite, leaving a foramen for passage of the dorsal vessels of Pd. The palmar processes of Pd are sometimes referred to as "wings," but they are not wings. Fractures of the palmar processes sometimes occur.

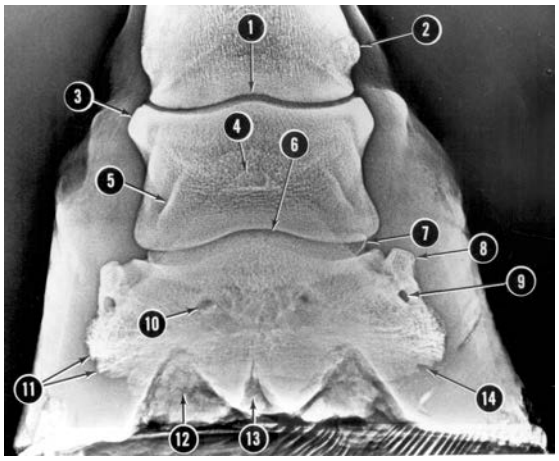


Figure 9-38. Dorsopalmar (DPa) xeroradiograph of left equine foredigit: (1) proximal interphalangeal joint; (2) lateral distal collateral tubercle of proximal phalanx; (3) medial proximal collateral tubercle of middle phalanx; (4) extensor process of Pd; (5) wall of depression in Pm for attachment of medial collateral ligament of DIJ; (6) distal interphalangeal joint; (7) lateral extremity of navicular bone; (8) lateral palmar process of Pd; (9) foramen in 8 that accommodates dorsal branches of digital vessels; (10) medial sole foramen of Pd; (11) sole border of Pd; (12) medial collateral groove of frog; (13) central groove of frog; (14) notch in sole border associated with vascular channel extending from sole canal of Pd.

[22] Cartilages of hoof is the official anatomic term, but I personally dislike this designation for the following reasons: (1) these cartilages do not attach to the hoof directly; and (2) they extend well above the hoof, and are not located completely within it. The old term, "lateral cartilage," is misleading, because only one of two is lateral; however, the alternative is just about as bad. These cartilages are most intimately associated with Pd, not with the hoof. I would propose that they should be designated the cartilages of the distal phalanx.

The **sole surface** of Pd consists of two parts, a smooth area, the **planum cuneatum**, and the **flexor surface** (Fig. 9-37), which are separated by the **semilunar line**. The sole surface provides attachment of the sole corium, and the flexor surface provides attachment for the distal ligament of the navicular bone and the DDF tendon, which also attaches along the semilunar line. Note the two **sole foramina** of Pd (Fig. 9-38). These are the medial and lateral openings of the sole canal (Fig. 9-39), which houses the terminal arches of the digital vessels.

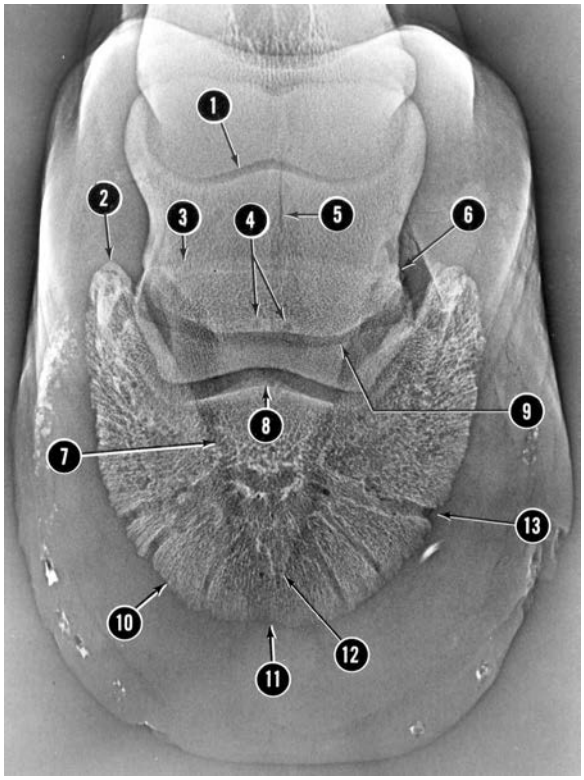


Figure 9-39. Dorsal 65° proximal-palmarodistal oblique (D65Pr-PaDiO) xeroradiograph of left equine foredigit: (1) proximal interphalangeal joint; (2) medial palmar process of Pd; (3) proximal border of navicular bone- provides for attachment of collateral ligaments of this bone; (4) vascular foramina and synovial fossae along distal border of navicular bone; (5) air within central groove of frog; (6) lateral extremity of navicular bone; (7) sole canal of Pd; (8) distal interphalangeal joint; (9) articulation of Pd with navicular bone- part of DIJ; (10) sole border of Pd; (11) crena marginis solearis; (12) apex of frog; (13) vascular channel from sole canal to sole border of Pd- transmits connection between terminal arch and circumflex artery.

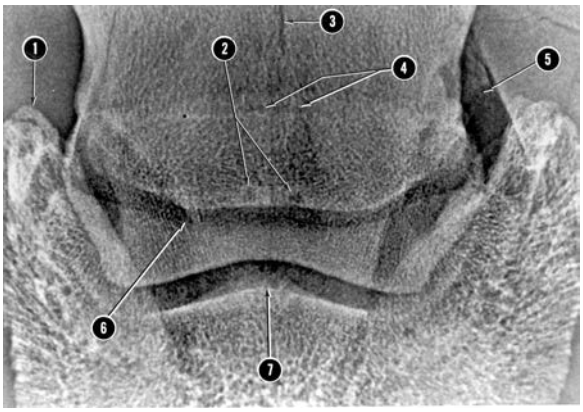


Figure 9-40. Enlargement of navicular bone area of figure 9-39: (1) medial palmar process of Pd; (2) vascular foramina and synovial fossae along distal border of navicular bone; (3) air within central groove of frog; (4) small vascular foramina along proximal border of navicular bone; (5) air within lateral collateral groove of frog; (6) articulation of Pd with navicular bone- part of DIJ; (7) distal interphalangeal joint.

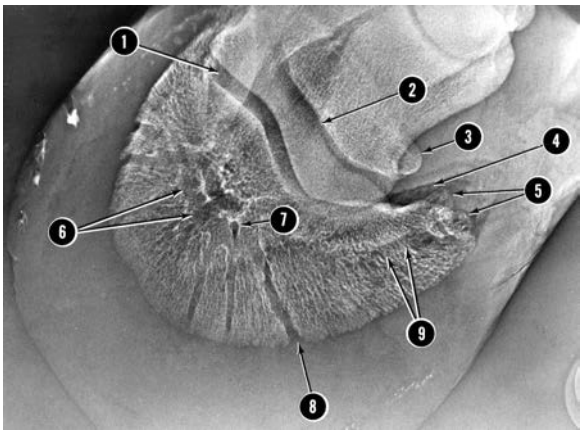


Figure 9-41. Dorsoproximolateral-palmarodistomedial oblique (D65Pr45L-PaDiMO) xeroradiograph of left equine foredigit; (1) distal interphalangeal joint; (2) articulation of Pd with navicular bone- part of DIJ; (3) lateral extremity of navicular bone; (4) air within lateral collateral groove of frog; (5) lateral palmar process of Pd; (6) sole canal of Pd; (7) end-on perspective of vascular channel from sole canal to parietal surface of Pd; (8) vascular channel from sole canal to sole border of Pd- transmits connection between terminal arch and circumflex artery; (9) lateral parietal groove of Pd- accommodates dorsal branches of digital vessels.

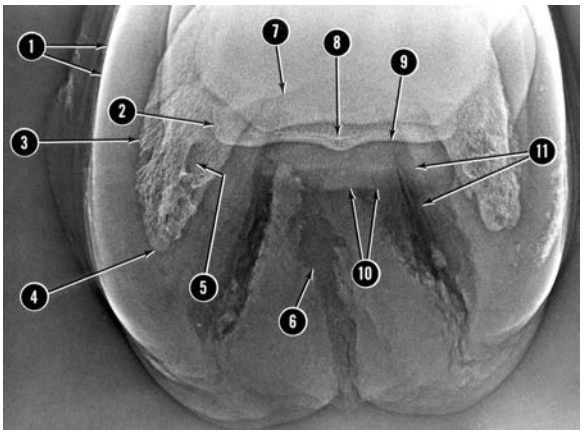


Figure 9-42. Palmaroproximal-palmarodistal oblique (PaPr-PaDiO) xeroradiograph of left fore navicular bone area: (1) proximal border of hoof wall; (2) lateral extremity of navicular bone; (3) sole border of Pd; (4) lateral palmar process of Pd; (5) foramen of lateral palmar process; (6) air within central groove of frog; (7) articulation of Pm with navicular bone- part of DIJ; (8) sagittal ridge of navicular bone; (9) flexor surface of navicular bone; (10) DDF tendon; (11) air within medial collateral groove of frog.

Proximal Sesamoid Bones of Horse: These bones are pyramidal and, like most pyramids, each has a base (distal) and an apex. The lateral sesamoid bone is slightly taller and slimmer than its more squat-bodied medial counterpart, but again this difference is subject to distortion and confusion in radiographs (Fig. 9-31). The first thing you need to understand is that these bones are embedded in a remarkable suspensory apparatus that helps support the awkward (and seemingly uncomfortable) angle assumed by the fetlock joint of the horse. How would you like to walk around on two hyperextended fingers and toes?

These bones come under extreme stress during normal weight-bearing, not to mention traveling at 40 mph, when all forces are exerted on one limb at a time. Note that these bones articulate only with the head of Mc3, not with Pp (Figs. 9-32 & 9-33). They are attached proximally by the interosseus (suspensory ligament), which divides into two strong branches, one to each bone (Fig. 9-46). These branches terminate in the concave interosseus[23] (abaxial) surfaces of the bones.

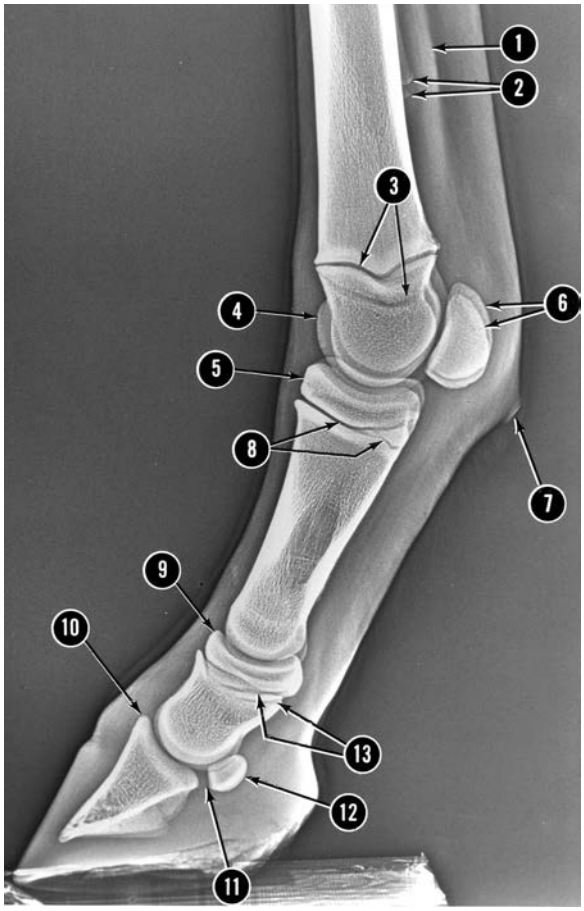


Figure 9-43. Lateromedial (LM) xeroradiograph of left foredigit of 30-day-old female quarter horse: (1) interosseus; (2) distal ends of small Mc bones- distal epiphyses have not yet ossified in this foal; (3) distal epiphyseal cartilage (physis) of Mc3; (4) sagittal ridge on distal epiphysis of Mc3; (5) proximal epiphysis of Pp; (6) proximal sesamoid bones; (7) ergot; (8) proximal physis of Pp; (9) proximal epiphysis of Pm; (10) extensor process of Pd; (11) distal interphalangeal joint between Pd and navicular bone; (12) navicular bone; (13) proximal physis of Pm.

[23] The term interosseus relates to its attachment. This is a bit confusing in that you would think that the interosseous surface would be between the two bones; that's why it's interosseus, not interosseous.

It is most important that you appreciate that these bones are interconnected by a dense fibrocartilaginous ligament, the **palmar sesamoidean ligament**, which completes the articulation with Mc3, especially with its sagittal ridge (Fig. 9-46). These bones represent a "sesamoidification" of a strong, fibro-osseous supporting sling for the fetlock joint. Distally, the proximal sesamoid bones are firmly anchored to Pp and Pm by the distal sesamoidean ligaments, which originate from their bases and the intervening palmar sesamoidean ligament (Figs. 9-30 & 9-46).

These **distal sesamoidean ligaments** (Figs. 9-30 & 9-46) consist primarily of the following: (1) the **cruciate** (deep) **sesamoidean ligaments**, which attach the base of each sesamoid bone to the opposite palmaroproximal aspect of Pp (*i.e.,* from the lateral bone to the medial aspect of Pp, and *vice versa*; thus, they cross each other, forming an "X"; (2) the **oblique (**middle) **sesamoidean ligaments**, which attach along the two oblique ridges on the palmar aspect of Pp; and (3) the **straight** (superficial) **sesamoid ligament**, which extends from the sesamoid bones and their interconnecting ligament to the fibrocartilage of Pm (Figs. 9-30 & 9-46).

Fractures of the proximal sesamoid bones are believed to occur whenever these bones are caught out of position and more than 1000 pounds of force comes crashing down and snaps over the fetlock. If they are positioned too far distally at the instant of impact, basilar fractures can occur as the bones are caught across the subtle ridge on the head of Mc3 (Figs. 9-30). If positioned too far proximally, apical fractures can result as the bones are pulled across the distinct ridge at the palmar aspect of the articular surface of Mc3 (Fig. 9-33).[24]

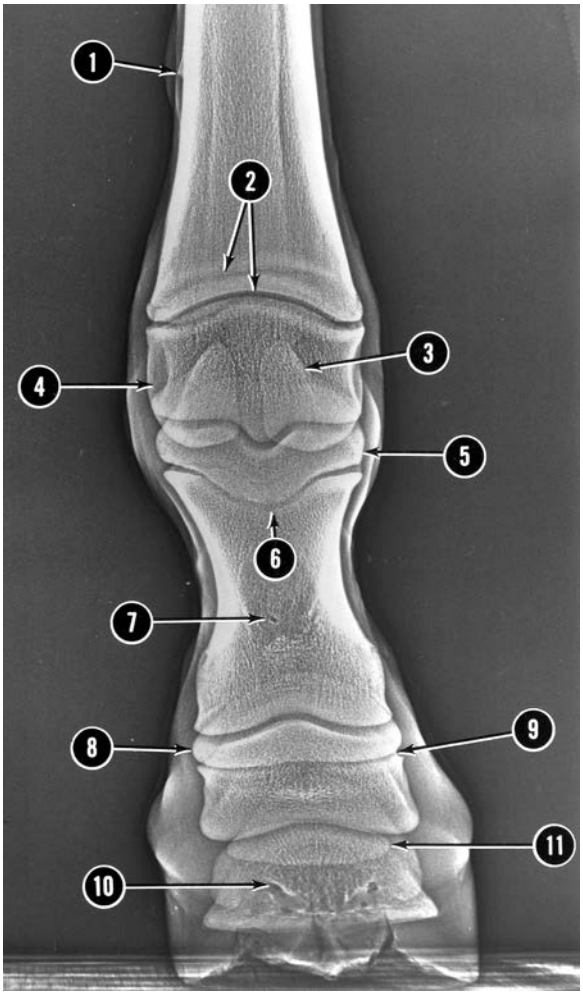


Figure 9-44. Dorsopalmar (DPa) xeroradiograph of left foredigit of 30-day-old female quarter horse: (1) distal end of Mc2; (2) distal physis of Mc3; (3) lateral proximal sesamoid bone; (4) distal epiphysis of Mc3; (5) proximal epiphysis of Pp; (6) proximal physis of Pp; (7) nutrient canal in dorsal cortex of Pp; (8) proximal epiphysis of Pm; (9) proximal physis of Pm; (10) medial sole foramen of Pd; (11) lateral extremity of navicular bone.

[24] The analogy of the race horse to the ballerina is a good one. Powerful, yet delicate, they are in fact doing a toe (finger) dance around the track. It looks graceful and easy, but that's only an illusion created by the skill and conditioning of the athlete. They are often teetering on the brink of destruction; one misstep can spell disaster.

Distal Sesamoid Bone: Because of its boat shape, the distal sesamoid[25] bone of the horse is clinically referred to as the **navicular bone**. Note that the little boat is upright, not capsized (Fig. 9-39). The navicular bone is correctly described as having articular and flexor surfaces, proximal and distal borders, and medial and lateral extremities. The bone lies over (above) the middle third of the frog, and its articular surface is divided into two parts (Figs. 9-37 & 9-42).

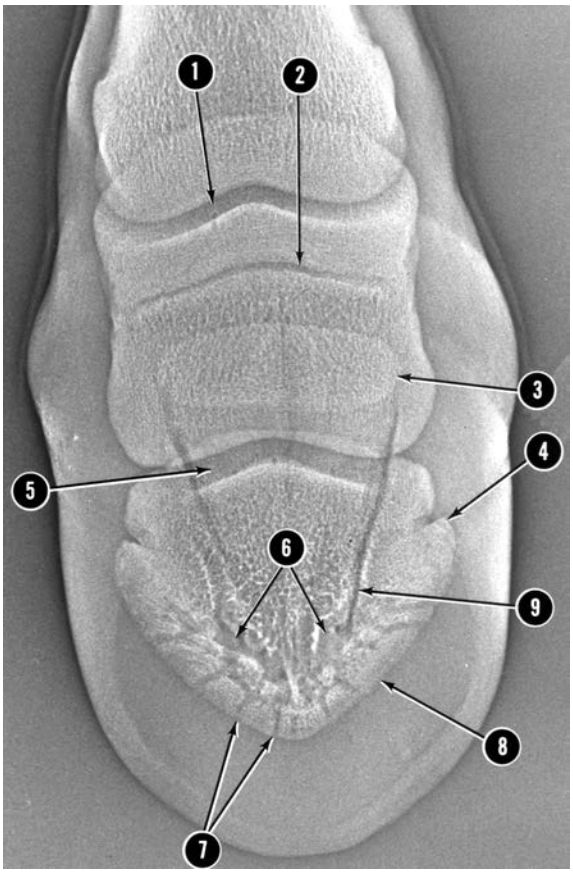


Figure 9-45. Dorsal 65° proximal-palmarodistal oblique (D65Pr-PaDiO) xeroradiograph of left foredigit of 30-day-old female quarter horse: (1) proximal interphalangeal joint; (2) proximal physis of Pm; (3) lateral extremity of navicular bone; (4) lateral palmar process of Pd; (5) distal interphalangeal joint; (6) sole canal of Pd; (7) vascular channels from sole canal to sole border of Pd; (8) sole border of Pd; (9) air within lateral collateral groove of frog.

[25] sesamoid- resembling a sesame seed.

The largest articulation is with Pm, but distally it also articulates with Pd, to which it is firmly anchored by the short, thick **distal navicular** (impar) **ligament** (Figs. 9-30 & 9-46). The **flexor surface** of the bone faces the DDF tendon, which passes over it to terminate on the flexor surface and semilunar line of Pd. In the living animal, the flexor surface is covered by fibrocartilage and has a low sagittal ridge that helps stabilize the DDF tendon, which has widened out and conforms on its deep surface to the shape of the flexor surface of the navicular bone (Fig. 9-42).

Between the flexor surface of the navicular bone and the DDF tendon is the **podotrochlear (navicular) bursa**. Note the openings along the distal border of the bone (Fig. 9-40). The primary blood supply enters the bone through these foramina (Fig. 9-27), although some of the openings represent synovial fossae associated with the DIJ. As previously noted, the navicular bone is also attached by its collateral ligaments to depressions in the dorsodistal aspect of Pp (Fig. 9-30). These ligaments pass through the oblique grooves across the medial and lateral aspects of Pm. The medial and lateral **collateral ligaments** attach all along the proximal border of the bone from extremity to extremity, and fuse with one another at the axis of the border.

Thus, the navicular bone, like a little trapeze, is suspended from Pp by its collateral ligaments and is anchored distally to Pd by its **distal ligament** (Figs. 9-30 & 9-46). There are also small foramina along the proximal border that accommodate blood vessels to help nourish the bone (Fig. 9-27); however, these foramina are much less conspicuous than those along the distal border. It has been estimated that only about 20% of the normal blood supply enters proximally.

The navicular bone is a clinically important structure because of a debilitating lameness associated with a degenerative disease involving this bone, especially in working horses over 5 years of age. Unfortunately, after years of research, I'm not sure we know much more about the etiology of so-called "navicular disease" than we did when I was in veterinary school a “few” years ago.

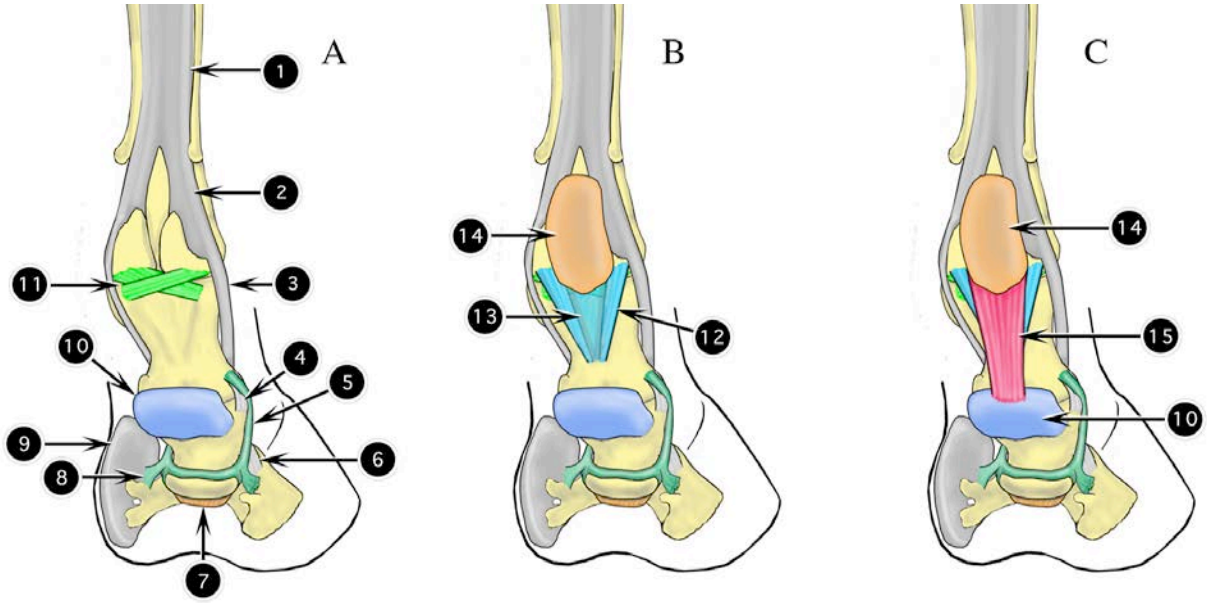


Figure 9-46. Drawings of equine suspensory apparatus and other ligaments, caudomedial view; A = deep layer; B = middle layer; C = superficial layer: (1) interosseus 3 (suspensory ligament); (2) medial branch of 1 to medial proximal sesamoid bone; (3) medial extensor branch of 2 to common digital extensor tendon; (4) medial collateral ligament of proximal interphalangeal joint; (5) medial part of collateral ligament of navicular bone; (6) medial collateral ligament of distal interphalangeal joint; (7) distal navicular (impar) ligament; (8) branch of collateral ligament of navicular bone to lateral cartilage of hoof; (9) lateral cartilage of hoof; (10) fibrocartilage of Pm; (11) cruciate sesamoidean ligament; (12) thick abaxial part of oblique sesamoidean ligament; (13) thin axial part of oblique sesamoidean ligament; (14) palmar sesamoidean ligament (fibrocartilaginous); (15) straight sesamoidean ligament.

One reason for the confusion about this "disease" is that we are not dealing with a single problem; we are dealing with a **navicular syndrome**.[26] Saying a horse has "navicular disease" is a little like saying it has pneumonia. There may well be as many variations in the syndrome as there are causes for pneumonia, but we have been slow to recognize the differences.

Part of the problem is that the overlying navicular bursa is certainly subject to inflammation (i.e., navicular bursitis). Here we have a lame horse that is sensitive to the hoof tester over the middle third of the frog, goes sound on a palmar digital nerve block, and in all likelihood has no radiographically detectable lesions. Does this horse have "navicular disease" or navicular bursitis? In no other area of the body does a bursitis, other than an infectious one, lead to destruction of the underlying bone. Thus, it is unlikely that a noninfectious navicular bursitis can progress to an osteolytic destruction of the navicular bone.

Next, consider a lame horse with a similar clinical syndrome, but upon high-

[26] syndrome- a complex of signs and/or symptoms resulting from a common cause or appearing in combination to present a clinical picture.

quality radiographic examination, has "lollipops," in which the normal cone-shaped foramina and/or synovial fossae are seen along the distal border of the bone. We recognize that when horses are worked hard, these foramina (fossae) enlarge, but their typical cone shape is maintained. If we see them change to a "lollipop" or a "light-bulb" configuration, this indicates abnormal bone resorption and is recognized by some as a radiographic indication of "navicular disease." Consider another lame horse with the same clinical findings, but this time with the classic punched-out, lytic area in the central part of the bone (Fig. 9-47).

The latter two forms may represent a relative nutrient starvation, a type of ischemic necrosis within the substance of the bone. What part (if any) thrombosis of the nutrient arteries plays is not certain, but the demand (stress) placed on this little bone, trapped between a large horse crashing down on it and the DDF, frog, and hard ground below, is just too much for its blood supply to keep up with demand. That is, demand exceeds the ability to supply and bone begins to die; this hurts and results in a chronic debilitating lameness. As long as demand exceeds supply, the condition progresses toward total destruction of the bone.

Because the bovine digits are radiographed much less frequently than the equine digit, xeroradiographs of this region are included here primarily for your future reference should the need arise. Most veterinarians are less familiar with the radiographic anatomy of the bovine digits, and are thus more in need of a reference for this region in the ox.

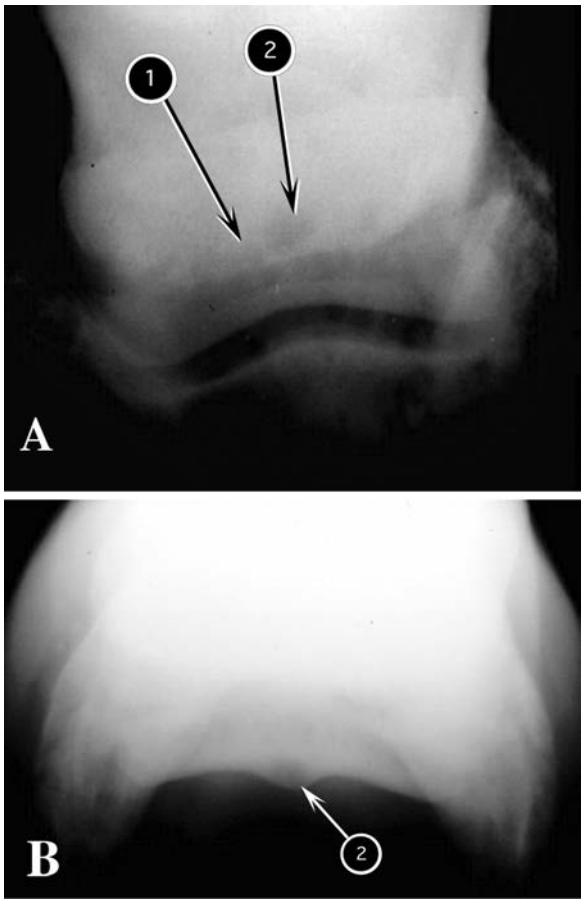


Figure 9-47. Radiographs of right fore navicular bone of an 8-year-old thoroughbred gelding with lameness clinically consistent with navicular syndrome: **(A)** D65Pr-PaDiO view; **(B)** PaPr-PaDiO view; (1) enlarged, lollipop-shaped distal foramen (synovial invagination); (2) "punched-out" lytic area, which in B is noted to involve flexor cortex of navicular bone at sagittal ridge.

Dorsopalmar View of Bovine Foredigits (Fig. 9-48)[27]: The third and fourth components of Mc3+4 are separated distally by the intertrochlear notch. The distal metacarpal canal joins the dorsal and palmar longitudinal grooves of Mc3+4. The distal physis of Mc3+4 is prominent in this young animal. The paired proximal sesamoid

[27] The xeroradiographs of the bovine digits and carpus in this chapter are from: Shively, M. J., and Smallwood, J. E. Normal radiographic and xeroradiographic anatomy of the bovine manus. Southwestern Veterinarian, 31 (1978): 220-236.

bones are located proximal to the palmar aspects of the metacarpophalangeal joints. The proximal phalanx is considerably longer than the middle phalanx or the distal phalanx.[28]

Physes separating the base and body of each proximal phalanx (Pp) are still present in this young animal. Sagittal ridges on the heads of Mc3+4 articulate with corresponding grooves in the bases of the proximal phalanges. These grooves divide the base of each Pp into two areas, with the abaxial one extending further proximally than the axial one.

The single distal sesamoid bone of each digit is superimposed on the middle phalanx (Pm) at the distal interphalangeal joint. Each distal phalanx (Pd) has four surfaces- an articular surface, an axial surface, a sole surface, and a parietal surface. Note the many vascular channels and foramina in the distal phalanges. The distal aspects of the vestigial second and fifth digits are largely superimposed on the proximal phalanges. The outline of the hoof wall is sharply delineated in this xeroradiograph.

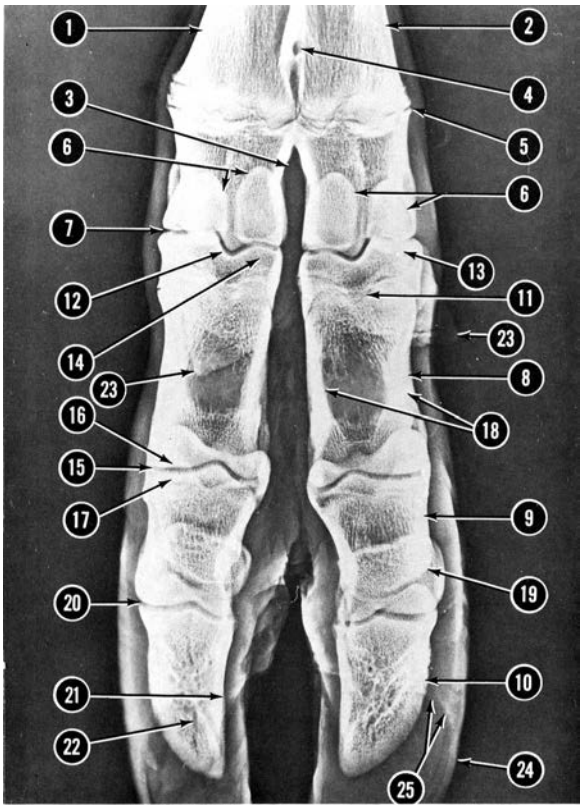


Figure 9-48. Dorsopalmar (DPa) xeroradiograph of left bovine foredigits: (1) Mc3 component of Mc3+4; (2) Mc4 component of Mc3+4; (3) intertrochlear notch; (4) distal metacarpal canal; (5) distal physis of Mc3+4; (6) proximal sesamoid bones; (7) palmar aspects of metacarpophalangeal joints; (8) proximal phalanx (Pp); (9) middle phalanx; (10) distal phalanx (Pd); (11) proximal physis of proximal phalanx; (12) groove in base of proximal phalanx; (13) abaxial part of base of Pp; (14) axial part of base of Pp; (15) proximal interphalangeal joint; (16) head of proximal phalanx; (17) base of middle phalanx; (18) axial and abaxial borders of Pp; (19) distal sesamoid bone; (20) distal interphalangeal joint; (21) axial surface of Pd; (22) vascular channels & foramina; (23) distal aspects of second and fifth digits; (24) outline of hoof wall; (25) junction of hoof sole and bulb of heel.

Dorsolateral-Palmaromedial Oblique View of Foredigits (Fig. 9-49): Rudimentary phalanges in the second and fifth digits are obvious in this xeroradiograph. The metacarpophalangeal joint, proximal interphalangeal joint, and distal interphalangeal joint of each digit are easily distinguished. The paired proximal sesamoid bones of each digit articulate

---

[28] phalanges *versus* digits: According to correct veterinary anatomic nomenclature, phalanges are named and digits are numbered. In old textbooks and, unfortunately, in some recent publications, phalanges have been referred to by number (*i.e.*, first phalanx, second phalanx, third phalanx). This unfortunate practice only leads to confusion. Similarly, using abbreviations such as PI, PII, and PIII only perpetuates the confusion. The following abbreviations are appropriate: Pp, proximal phalanx; Pm, middle phalanx; and Pd, distal phalanx.

Smallwood's *almost last* Law of Veterinary Anatomic Nomenclature: Any anatomic abbreviation should match the term it abbreviates. That is, don't abbreviate proximal phalanx with PI. It is difficult for an instructor to tell a student that PI actually stands for proximal phalanx (not first phalanx) and keep a straight face.

primarily with the head of the metacarpal bone, but also with each other and with Pp. Similarly, the distal sesamoid bone articulates primarily with Pm, but also with Pd. The physes of Mc3+4 and the proximal phalanges can be identified.

DISSECTION OF FETLOCK AND DIGITAL REGIONS

Let's get back to those big tendons that cross the fetlock joint and continue into the digit. *On the equine limb where you transected the digital flexor tendons in mid-metacarpus, reflect them to the level of the fetlock. Transect these tendons also in one limb of the artiodactyls, and reflect them to the fetlock.* Here they are held in position by the **palmar annular ligament of the fetlock** (Fig. 9-50). Much like a retinaculum, the palmar annular ligament retains the tendons in the grooves provided by the proximal sesamoid bones. Of course, these tendons divide into branches in the artiodactyls, commensurate with the number of digits that need to be flexed.

Transect the palmar annular ligament, and follow the tendons across the fetlock. Here the SDF must change lanes; after all, it's getting off at the next exit, whereas the DDF is continuing to Pd. This presents a problem that could have been solved in a number of ways. The SDF could have wrapped around the DDF medially or laterally, but this would not have been a particularly stable situation.

The best solution is for the SDF to divide and go around both sides of the DDF, which it does. In doing so, the SDF forms a sleeve or "manica" around the DDF tendon and then re-forms on the deep side. Formation of this sleeve in the ruminant is supplemented by contributing branches or tendons from the interossei, which are not present in the horse.

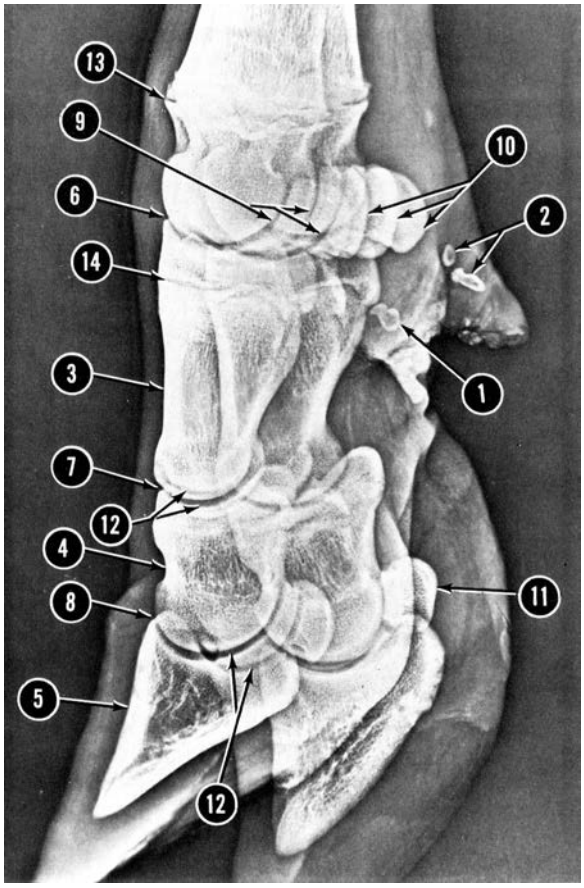


Figure 9-49. Dorsolateral-palmaromedial oblique xeroradiograph of left bovine foredigits: (1) rudimentary phalanges of digit 2; (2) rudimentary phalanges of digit 5; (3) proximal phalanx of digit 3; (4) middle phalanx of digit 3; (5) distal phalanx of digit 3; (6) metacarpophalangeal joint; (7) proximal interphalangeal joint; (8) distal interphalangeal joint; (9) sagittal ridges of heads of Mc3+4; (10) proximal sesamoid bones; (11) distal sesamoid bone; (12) paired imaging at proximal and distal interphalangeal joints; (13) physis of Mc3+4; (14) physis of proximal phalanx.

Interossei of Ruminants: The ruminant has two interossei (3 and 4), which are fused along their axial borders. In young calves the interossei are more muscular but become more fibrous with age. In the mid-metacarpus, the interossei give off fibrous branches to the SDF tendons, which assist in

the formation of the sleeves for the DDF tendons to pass through (Fig. 9-50). Above the fetlock, each muscle divides into axial and abaxial tendons. The abaxial tendons insert on the abaxial proximal sesamoid bones and give rise to abaxial extensor branches, which course obliquely dorsodistally to join the medial or lateral digital extensor tendon (Fig. 9-50). The axial tendons insert on the axial sesamoid bones and give rise to axial extensor branches, which fuse and pass dorsodistally through the interdigital space. Dorsally the axial extensor branches separate to join the medial and lateral digital extensor tendons (Fig. 9-51).

Interosseus of Horse: For once, the horse is content with a simpler arrangement, in that there is no contribution to the SDF sleeve from the interosseus. It divides into two strong branches that terminate on the concave interosseus surfaces of the proximal sesamoid bones. Medial and lateral **extensor branches** are given off that pass obliquely across the pastern to join the CDE tendon (Figs. 8-19 & 9-46).

These extensor branches are easily palpable in the live horse. During translation of the fetlock joint, the extensor branches produce traction on the extensor process of Pd, to resist the flexor tension produced by sinking of the fetlock into the DDF tendon (Fig. 9-30), which helps stop the sinking of the fetlock or "running down" in racetrack terminology. Despite this resistance, some horses do “run down,” especially in the pelvic limbs. This necessitates the use of run-down bandages or wraps to protect the ergots and palmar (plantar) surfaces of the fetlock regions from injury as the fetlock sinks into the cushion of dirt over the hard clay or asphalt base of the racetrack surface.

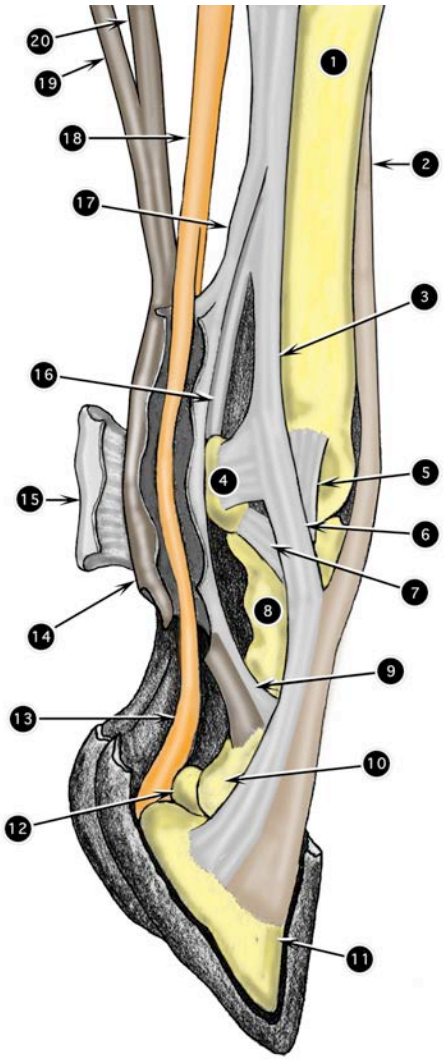


Figure 9-50. Terminations of digital flexor tendons & third interosseus of newborn calf, medial view: (1) fused metacarpal bones (Mc3+4); (2) medial tendon of common digital extensor; (3) abaxial tendon of interosseus 3; (4) abaxial proximal sesamoid bone of digit 3; (5) medial collateral ligament of fetlock joint; (6) abaxial extensor branch of interosseus 3; (7) oblique sesamoid ligament; (8) proximal phalanx (Pp) of digit 3; (9) abaxial termination of medial branch of superficial digital flexor tendon; (10) middle phalanx (Pm); (11) distal phalanx (Pd); (12) distal sesamoid bone of digit 3; (13) medial branch of deep digital flexor tendon; (14) opened sleeve formed by medial branch of superficial digital flexor tendon; (15) reflected palmar annular ligament of fetlock joint; (16) axial tendon of interosseus 3; (17) branch of interosseus 3 to superficial digital flexor tendon-assists in formation of sleeve for deep digital flexor tendon; (18) deep digital flexor tendon; (19) superficial part of superficial digital flexor tendon; (20) deep part of superficial digital flexor tendon.

When a horse is in a left lead, the first foot to catch the horse after its suspended phase of the stride is the right rear. The four-beat sequence proceeds as follows: RR-LR-RF-LF, (*i.e.,* the horse is in a left lead). This means that the LF is acting like the pole of a pole vaulter- the horse vaults over its LF as it launches its body into flight (no feet on ground) phase of its stride. The lead forelimb is thus placed under greater stress than the "off" forelimb.

In American flat racing, all turns are to the left as the horses run in a counterclockwise direction. Winning horses learn to change leads to shift the burden of fatigue between the right and left forelimbs. From a physics standpoint, it is desirable for a horse to be in a left lead on the turn, because this helps save ground. The horse can stay closer to the rail and hang closer to the lesser curvature- what you might call the "racing groove."

When in a left lead, the first foot to hit the ground following the suspended phase is RR. Thus, RR tends to push the flying horse toward the rail as the next three limbs follow suit. If the horse is in a right lead, the LR lands first, which tends to push the horse out as it continues with RR-LF-RF. Thus, the horse would drift out and "give up ground." Because of the fatigue that leading causes on the forelimb, most good horses learn to change back to a right lead as they come out of the turn and into the straight part of the track. Some horses learn to do this well and others- well, unless they are exceptional in strength and stamina, they usually finish "back in the field."

Ligaments of Ergot of Horse: Those little remnants of the metacarpal and metatarsal pads have ligaments that help hold them in place. These shiny ligaments pass distally, in an oblique fashion, from the fibrous tissue deep to the ergot to their distal anchorage. In doing so they pass obliquely across the palmar digital nerves and vessels. The ligaments are about the same size as the nerves, and can be confused with them.

If a horse lame with a foot injury or navicular disease goes completely sound with a palmar digital block, it can be "nerved" as a salvage procedure. By doing so, we "compassionate" humans are, in effect, allowing the horse to destroy itself in the process. If you're concerned about ethics, you might want to read the footnote below.[29] Palmar digital nerves can be surgically transected or frozen, through the skin, using liquid nitrogen. Cryosurgery using liquid nitrogen can be evidenced by white hair spots over the nerves, because the hair loses its pigment following freezing of the skin. After freezing, these nerves may regenerate with time, and thus the operation is not typically permanent. Please note that I am not condoning the practice of "nerving a horse," just pointing out some anatomic considerations.

If you are convinced that surgical transection of the palmar digital nerves is justified, be sure you do not confuse the ligament of the ergot and the palmar digital nerve. Note that the ligament passes superficial to the nerve and crosses the latter

[29] Nerving a horse is often a matter of ethics; in other cases, it is prohibited by law. Ethical considerations apply to situations that are not illegal, but that do not meet your standards of ethical treatment. There is, however, a tradition or standard established by our profession, which can and should guide us in this area, and those of us involved in education have a certain level of responsibility to influence (not teach) our successors in their judgment, based on our own evaluation of right and not so right. We do a grave disservice to the patient when we allow an animal to destroy itself by removing its natural protective mechanism and asking it for more. You must make your own decisions regarding these matters; some will be difficult.

obliquely. The ligament is also shinier than the nerve. If the surgeon mistakenly cuts the ligament of the ergot instead of the nerve, the result is a horse that is still lame, but that now has a "floppy ergot." Palmar digital neurectomy is no cure for any underlying problem; it only provides relief of the pain associated with the problem. In fact, if anything, you are removing the natural protective mechanism of the animal in that pain dictates rest- you are intervening to allow the animal to destroy itself. Do you want to do that?

Dewclaws: Artiodactyls do not possess ergots, but do have dewclaws. Although not homologous, ruminants have ligaments of the dewclaws, which are located in about the same location as the ligaments of the ergot in the horse. These ligaments are more substantial, though, and attach the vestigial second and fifth digits of the ruminant to the abaxial aspects of the distal phalanges and distal sesamoid bones of digits 3 and 4. Because digits 2 and 5 are much better developed in the pig, the ligaments of these non-weight-bearing digits are complex and do not deserve the attention necessary to define them.

Digital Annular Ligaments: Distal to the palmar annular ligament of the fetlock, the flexor tendons are retained by the proximal and distal digital annular ligaments (Fig. 9-51). The **proximal digital annular ligament** of the horse attaches to the four corners of Pp, and its distal attachments blend somewhat with the SDF tendon. The sling-like **distal digital annular ligament** also originates from Pp and sweeps distally around the DDF tendon, just before the latter enters the foot. The gap between the proximal and distal annular ligaments is the lowest available access to the digital sheath of the horse (Fig. 9-51).

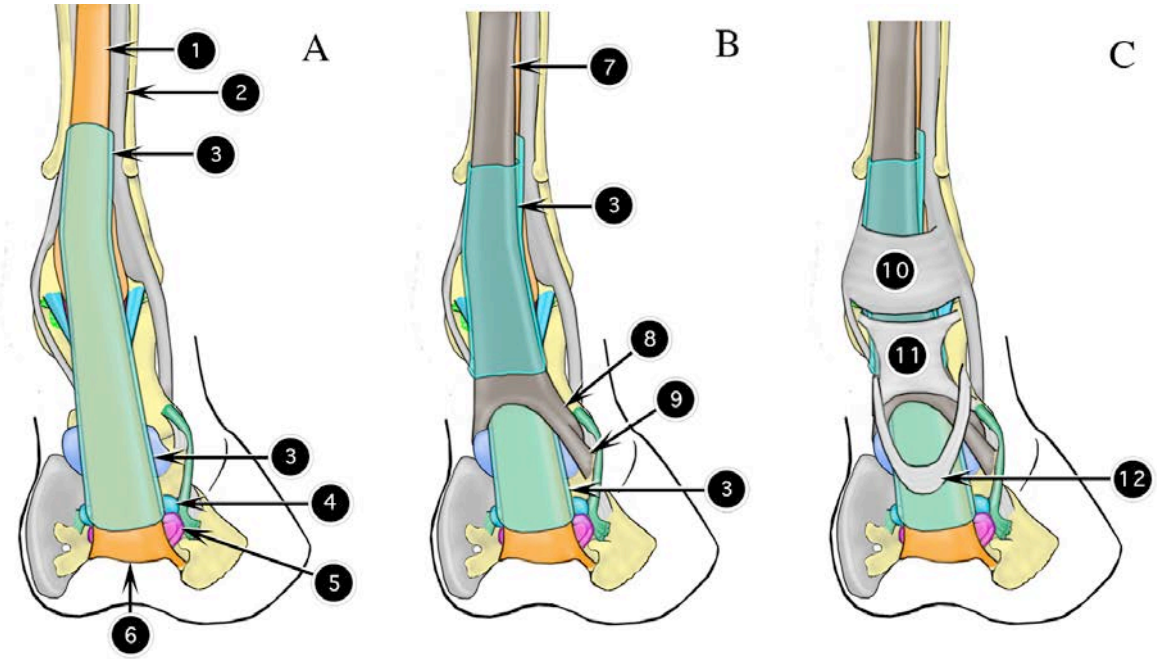


Figure 9-51. Drawings of equine digital region, caudomedial view; A = deep layer; B = middle layer; C = superficial layer: (1) deep digital flexor tendon; (2) interosseus 3 (suspensory ligament); (3) digital sheath; (4) palmar pouch of distal interphalangeal joint; (5) navicular (podotrochlear) bursa; (6) termination of 1 on Pd; (7) superficial digital flexor tendon; (8) termination of 7 on Pp; (9) termination of 7 on Pm; (10) palmar annular ligament of fetlock; (11) proximal digital annular ligament; (12) distal digital annular ligament.

Digital Sheath of Horse: With the flexor tendons reflected from the fetlock region, note the proximal extent of the digital sheath. This clinically important sheath envelops the DDF and SDF tendons in the distal fourth of the metacarpus and extends distally into the foot (Fig. 9-51). In the proximal part of the sheath, the synovial membrane forms many folds and villi that increase its surface area for production and resorption of synovial fluid, a dynamic process that is normally in equilibrium (*i.e.*, rate of production is about equal to the rate of resorption). When horses are vigorously exercised, there is sometimes an imbalance in this equilibrium, which can result in digital tenosynovitis, or "wind puffs."

Note that the digital sheath lies palmar to the interosseus and extends proximally to envelop the tendons in the distal fourth of the metacarpus (Fig. 9-51). With the flexor tendons reflected, note that there is a smooth surface provided for these tendons as they traverse the high-pressure area of the proximal sesamoid bones. You can't see the bones themselves because they are completely embedded in a fibrocartilaginous unit formed by the **palmar sesamoid** (interosseous) **ligament** (Fig. 9-46).

The palmar sesamoid ligament extends well proximal to the apices of the bones and, like the palmar carpal ligament, converts the palmar aspects of the sesamoid bones into a smooth, gliding surface (Fig. 9-46). On its dorsal surface, this fibrocartilaginous ligament is grooved to provide an additional articular area for the sagittal ridge of Mc3.

Recall that the DDF and SDF tendons are enveloped by the carpal sheath in the proximal half of the metacarpus (Fig. 9-23). Thus, the only unsheathed portion of these tendons is the third quarter, from proximal to distal (Fig. 8-19). Tenotomy of the SDF is sometimes performed in cases of flexor deformity. According to some surgeons, tendons cannot reunite if they are cut in a sheathed area. If this is true, SDF tenotomy should be performed in this third quarter of the metacarpus, between the sheaths.

Dorsal Pouch of Equine Fetlock Joint: *On the more dissected limb, transect the digital extensor tendons in the distal metacarpus, and reflect them away from the fetlock joint*. As the CDE tendon is reflected from the dorsum of the joint, a *bursa* should be opened. In the ox, the tendons of the CDE are enveloped by long tendon sheaths in this area (Fig. 8-16). The tendons of the medial and lateral digital extensors are lubricated only by bursae in the ox.

After reflection of the CDE tendon in the horse, *open the dorsal pouch of the fetlock joint capsule by making a transverse incision*. A normal *synovial fold* projects from the proximal attachment of the joint capsule to the dorsal surface of Mc3 (Fig. 6-25). As mentioned, the fetlock goes into extreme hyperextension at a fast gait, especially during racing. When this happens, the proximodorsal aspect of Pp comes right up to the top of the sagittal ridge of Mc3, and this normal synovial fold gets "beat up." In response to this repeated trauma, the fold may thicken (hypertrophy) by the accumulation of dense, fibrous connective tissue within it. This can progress to a large mass accompanied by synovial distention of the joint, producing the clinical condition known as villonodular synovitis (Fig. 9-52).

Pressure from this mass of connective tissue can erode the dorsodistal surface of Mc3, which can be detected radiographically. Confirmation of the mass, which in some cases is palpable, can be obtained by the use of positive contrast

arthrography (Fig. 9-52). Surgical removal of the mass can correct the lameness. The dorsoproximal aspect of the sagittal ridge of Mc3 is also a site for the development of osteochondrosis in the young horse, which may lead to the complete or partial detachment of cartilage flaps or bone chips. When tissue dissects away, the painful condition is known as osteochondritis dissecans.

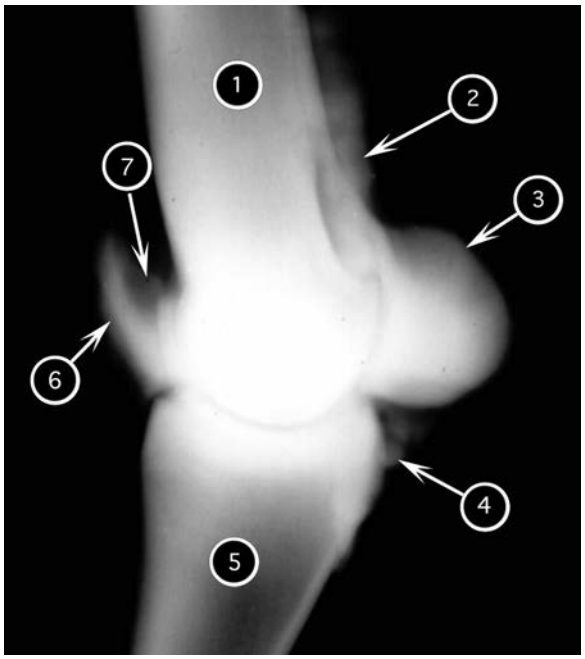


Figure 9-52. Positive contrast arthrogram of horse fetlock joint of with villonodular synovitis, LM view: (1) Mc3; (2) palmaroproximal pouch of fetlock joint; (3) proximal sesamoid bones; (4) palmarodistal pouch of fetlock joint; (5) proximal phalanx; (6) distended dorsal pouch of fetlock joint; (7) hypertrophied fibrous mass that has formed in response to repeated trauma to normal synovial fold.

Palmar Pouch of Equine Fetlock Joint: This large pouch of the fetlock joint capsule is dorsal to the interosseus, whereas the digital sheath is palmar to the interosseus (Fig. 8-19). Because the interosseus is an obvious landmark in the live horse, distention of these two important synovial structures can be differentiated according to their relationship to the interosseus. Arthrocentesis of the fetlock joint can be performed through the palmar pouch; the digital sheath can be injected either proximal to the palmar annular ligament of the fetlock or distal to the proximal digital annular ligament (Fig. 9-51).

THE EQUINE FOOT

The term "equine foot," for lack of an official name, is used to describe the epidermal hoof and all structures contained therein (*e.g.,* bones, tendons, ligaments, vessels).[30] This complex structure represents a remarkable adaptation of the horse. The horse not only supports its entire weight, but also can withstand the tremendous forces generated by locomotion while hanging from the inside of what amounts to two fingernails and two toenails. It should, therefore, come as no surprise that many equine lameness problems relate to injury or insult to one or more parts of the foot. Because of its clinical importance, all students are expected to have a detailed anatomic knowledge of the equine foot. The feet of the ruminant and pig should be studied in much less detail, primarily from a comparative approach.

The **hoof** is composed of a modified epidermis known as horn or hard keratin, as opposed to the soft keratin of skin (Fig. 9-53). The junction of hoof and skin is termed the **coronet**, the line where hair meets horn. Around this junction are some specialized transitional cells that produce a soft, flaky horn known as **periople**.[31] The periople is

[30] Stump, J. E. Anatomy of the normal equine foot, including microscopic features of the laminar region. JAVMA 151 (1967): 1588-1598.

[31] periople- the soft, gray-white material that comes down from the hairline. It becomes more obvious when the hoof is wet, and some horsepersons refer to it as the "coronary band." However, there isn't any anatomic structure known as the coronary band.

homologous to the cuticle of your fingernail and, as such, extends a variable distance down the hoof wall (typically about 1 cm), and widens over the bulbs of the heel.

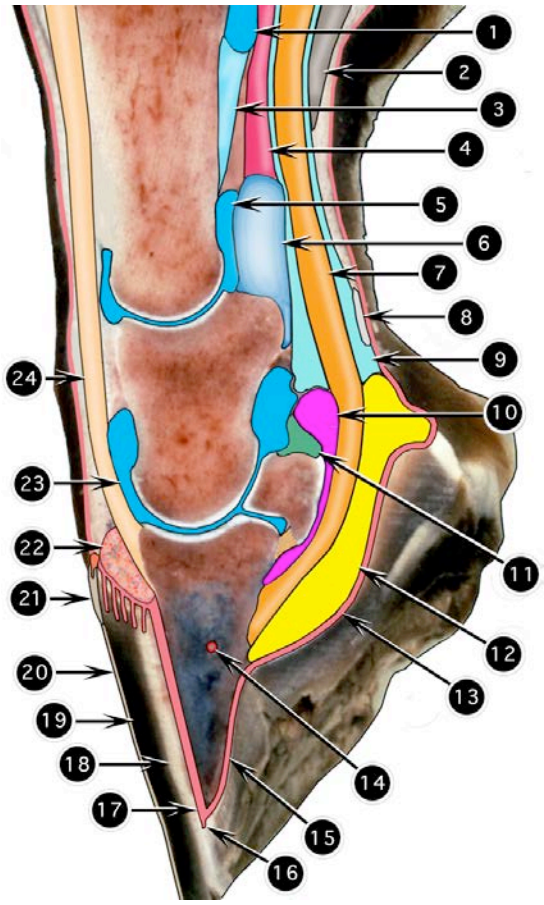


Figure 9-53. Sagittal section through digit of horse: (1) palmarodistal pouch of fetlock joint; (2) superficial digital flexor tendon forming sleeve for DDF tendon; (3) oblique sesamoidean ligament; (4) straight sesamoidean ligament; (5) palmar pouch of proximal interphalangeal joint; (6) fibrocartilage of Pm; (7) deep digital flexor tendon; (8) distal digital annular ligament; (9) distal extension of digital sheath; (10) navicular bursa; (11) collateral ligaments of navicular bone joining across proximal border of bone; (12) digital cushion; (13) corium (dermis) of frog; (14) terminal arch of digital artery within sole canal of Pd; (15) corium (dermis) of sole; (16) terminal papillae; (17) stratum internum of hoof wall; (18) inner non-pigmented part of stratum medium of hoof wall; (19) outer part of stratum medium; (20) stratum externum of hoof wall; (21) periople; (22) coronary plexus of vessels in subcutis; (23) distal interphalangeal joint; (24) common digital extensor tendon.

As the major part of the hoof wall grows distally under the periople, a thin waxy coat is pulled off the deep surface of the periople. This thin outermost layer of the hoof wall, known as the **stratum externum**, accounts for the natural sheen or glossy appearance of the hoof wall. It is the natural hoof dressing and functions as an important moisture barrier. The stratum externum retards evaporation and drying of the hoof wall during dry conditions and helps keep out excessive moisture when the horse is forced to stand in mud. It is not completely waterproof, but it does form an important moisture seal. Removal of the stratum externum by excessive, high rasping of the hoof wall can lead to excessive drying of the hoof, which predisposes it to cracking. Full-thickness cracks in the hoof wall are painful to the horse and can lead to serious complications.

Demonstration specimens should be provided for the study of the hoof.[32] Let's begin with some basic parts. The part you see when the horse's hoof is on the ground is the **wall**. The hoof wall is divided into the following regions: (1) the **toe** (most dorsal 60° or so); (2) the **quarters** (next 30° or so medially and laterally); and (3) the **heels** (most palmar part of the wall). Now, turn the hoof over so that the **sole surface** can be seen (Fig. 9-54). Here you can observe the distal (ground) surface of the wall, which is reflected dorsoaxially at the angles of the wall as the **bars**. Thus, the bars are part of the hoof wall. The innermost part of the hoof wall, where it joins the sole, is laminated- that is, characterized by many small plates that are directed toward the center of the foot. These laminae are also present on the bars. Axial to the bars are

[32] This is an area where demonstration specimens of the hoof and corresponding dermal components are almost a necessity for effective learning.

deep grooves, the paracuneal or **collateral grooves** of the frog (Fig. 9-54).

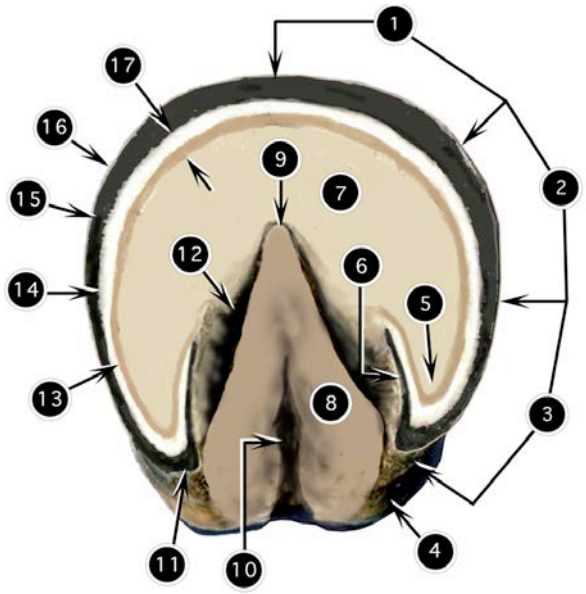


Figure 9-54. Sole surface of equine hoof: (1) toe of wall; (2) quarter of wall; (3) heel of wall; (4) bulb of heel; (5) angle of sole; (6) bar of wall; (7) sole; (8) crus of frog; (9) apex of frog; (10) central groove of frog; (11) angle of wall; (12) collateral groove of frog; (13) stratum internum of wall; (14) non-pigmented inner part of stratum medium ("white line"); (15) outer part of stratum medium; (16) stratum externum; (17) white zone between opposing arrows.

The bulbs of the horse's heel are continued as the two **crura** of the frog, which narrow and converge dorsally to the **apex** of the frog.[33] A **central groove** (sulcus) of the frog separates the two crura (Fig. 9-54). Most of the ground surface, of the hoof forms the **sole**. Within the angles of the wall, where they turn dorsally to form the bars, are the angles of the sole. The sole is normally concave, and for the most part it is non-weight-bearing. The horn of the sole is softer than that of the wall, and that of the frog is even softer than that of the sole. Although the frog becomes hardened on dried specimens, the frog of the living animal is resilient to compression.

As you examine the inner surface of the hoof wall, you should have its "reciprocal" next to it- that is, a specimen of the deeper tissues of the distal equine limb from which the hoof has been removed. In this way you can correlate the anatomy of the hoof (epidermis) with that of the horse (covered by dermis). The two go together like hand in glove, and you can appreciate their intimate, interlocking relationship best by studying the two specimens together (Figs. 9-55 & 9-56).

When you examine the inner surface of the hoof, starting at the top, you should first locate a narrow groove just inside the proximal border of the hoof wall. This **perioplic groove** accommodates the **perioplic corium**[34] that nourishes the **perioplic epithelium**, which actually produces the periople. Next, you should note the large peripheral groove that indents the proximal part of the wall. This is the **coronary groove**, which accommodates the **coronary corium** and a major vascular plexus, the **coronary plexus** (Fig. 9-53).

[33] The frog is actually the digital pad of the horse. Both the terms frog and thrush appear to have evolved from the word "frush," which was first used by Blundeville in 1566. Blundeville apparently corrupted the term from the French word, fourche (meaning fork), which would logically describe the frog's division as it blends with the heels.

[34] Corium is a name used to describe the dermis that supports the germinal epithelium, which has been genetically programmed to produce horn (not soft keratin). It is merely an extension of the dermis into the hoof, not a new anatomic structure. The hard keratin of the hoof is produced in basically the same way as the softer keratin of the skin, by replication of cells in the basal layer of the epidermis and keratinization of these cells. The hoof is not produced by the corium, any more than the epidermis over the carpus is produced by the dermis of that region.

Almost all hoof wall production occurs over this region.

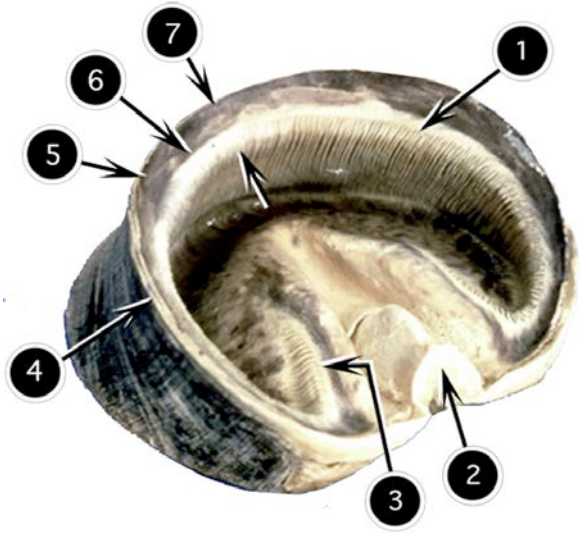


Figure 9-55. Internal features of hoof wall: (1) stratum internum consisting of epidermal laminae; (2) spine of frog (frog stay); (3) laminae of bar of wall; (4) perioplic groove (incomplete in this specimen); (5) outer part of stratum medium; (6) inner non-pigmented part of stratum medium; (7) coronary groove (between opposing arrows).

The coronary groove is characterized by many small holes, which receive the relatively long papillae of the coronary corium (Fig. 9-56A). Over these papillae is the **germinal epithelium** that is responsible for most (>90%) of hoof wall production. The part of the hoof wall that you see here is the stratum medium, which accounts for more than 80% of the hoof wall thickness (Fig. 9-54). Regardless of whether you have a dark or a relatively light hoof, you should note that the deeper part of the stratum medium is non-pigmented (Fig. 9-53). Even in a black hoof, this deeper part of the wall is white. The normal moisture content of the hoof wall is about 25%; thus, it is rather dry and represents the hardest part of the hoof.[35]

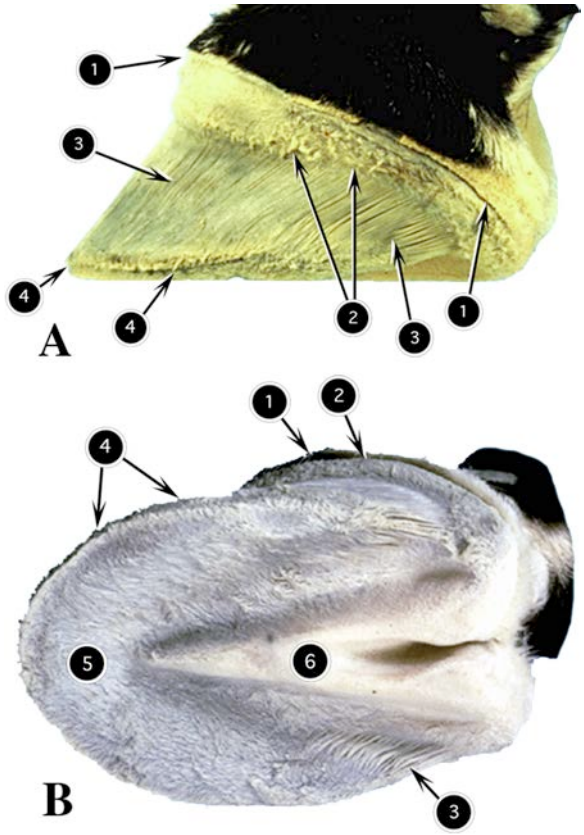


Figure 9-56. Distal digit (reciprocal) of horse with hoof removed and dermis (corium) exposed: **(A)** lateral view; **(B)** distal view; (1) perioplic papillae; (2) coronary papillae; (3) dermal laminae of laminar corium; (4) terminal papillae at distal end of laminae; (5) sole corium; (6) frog corium.

The deepest part of the hoof wall is characterized by many parallel laminae (lamellae), forming the **stratum internum**.[36] These are the **epidermal** (insensitive) **laminae** that interdigitate with

[35] Stump, J. E. Anatomy of the normal equine foot, including microscopic features of the laminar region. JAVMA 151 (1967):1588-1598.

[36] The *NAV* correct term for these structures are "lamellae." I promise to start calling them lamellae, just as soon as clinicians agree to start calling disease of these structures "lamellitis." So long as they refer to the problem as laminitis, I'll stick with laminae.

the sensitive laminae of the laminar corium, which are covered by germinal epithelium (Fig. 9-57). There are about 600 of these primary laminae in each hoof of the horse (Fig. 9-58).[37] Approximately 100,000 microscopic **secondary laminae** arise from the sides of the 600 primary laminae (Fig. 9-59) creating a large surface area (≈1 m^2) that bonds the horse to the hoof. Connective tissue fibers extend from the parietal-surface periosteum of Pd through the secondary laminae to the basement membrane of the dermoepidermal junction, thus completing the bonding of Pd to hoof wall.

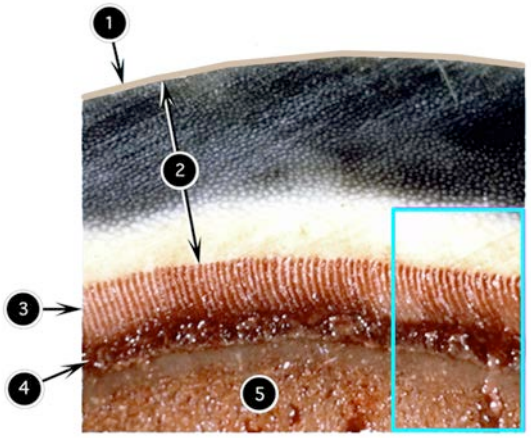


Figure 9-57. Transverse section through hoof wall including hoof-to-horse bond: (1) stratum externum of hoof wall (high-lighted here in tan); (2) stratum medium of hoof wall; (3) stratum internum of hoof wall showing interdigitation of primary epidermal (white) and dermal laminae; (4) fused laminar corium and modified periosteum of Pd; (5) distal phalanx. The rectangle indicates area shown in figure 9-58.

As you can see, the hoof wall slopes inward so that the horse is, in effect, hanging from the inside of its hoof wall. It is this large surface area produced by the complex interdigitation of the laminae that allows the system to work; the horse depends on this bond to remain suspended from its hoof.

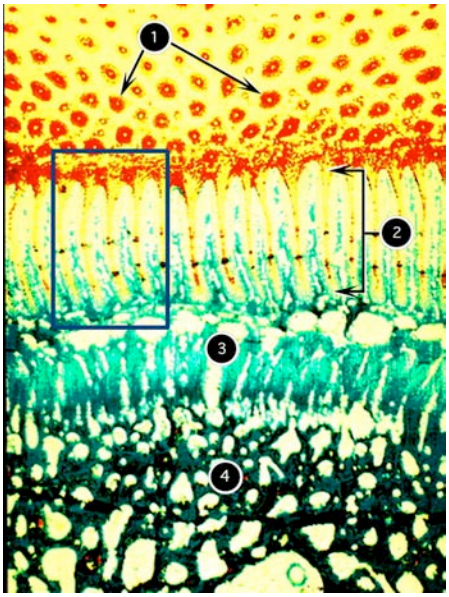


Figure 9-58. Photomicrograph of area shown in figure 9-57: (1) horn tubules in stratum medium, bonded together by intertubular horn (yellow); (2) stratum internum, composed of primary epidermal laminae (yellow) interdigitating with dermal laminae; (3) fused laminar corium and modified periosteum of Pd; (4) cancellous (trabecular) bone of Pd. The rectangle indicates area shown in figure 9-59.

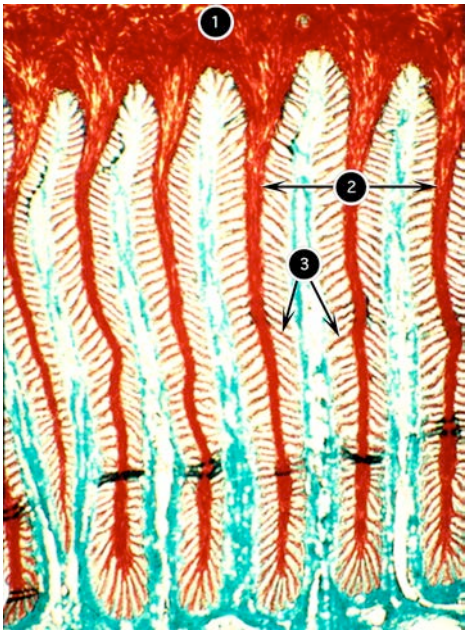


Figure 9-59. Photomicrograph of area shown in figure 9-58: (1) stratum medium; (2) primary epidermal laminae; (3) secondary epidermal laminae.

[37] de Lahunta, A. and Habel, R. E. *Applied Veterinary Anatomy*. W. B. Saunders Company. Philadelphia, 1986.

If the system breaks down, the inevitable occurs- that is, the horse falls through the bottom of its hoof. Like that of the deeper part of the stratum medium, the horn of the stratum internum, which is primarily produced in the coronary region, is non-pigmented, regardless of the outside pigmentation (Fig. 9-57).

In the normal horse, the amount of horn added to the sides of the epidermal laminae as they move distally is just sufficient to allow for the downward ("glacier-like") migration of the epidermal laminae. This generally represents an insignificant amount of hoof wall production, but it can increase under abnormal conditions.

On the inner surface of the hoof, the sole has many openings, which receive the relatively short papillae of the sole corium (Fig. 9-56B). The sole is produced by the germinal epithelium over the sole corium, and the horn of the sole contains about 33% water. On the inner surface of the hoof, the crura of the frog are obvious as depressions, and the central groove is represented by a prominent internal ridge- the spine, or frog stay (Fig. 9-55*)*.

The soft horn over the frog is produced by the germinal epithelium over the frog corium and is the softest horn of the hoof, containing about 50% water.[38] When you examine the reciprocal, you can see the bulges of the crura and the central groove that is occupied by the internal spine of the frog (Fig. 9-56B). The part of the foot that lies above the crura of the frog is occupied by a fibrofatty mass of tissue known as the **digital cushion** (Figs. 9-53 & 9-60).

From this examination, we have learned that the hoof wall is primarily produced by the germinal epithelium that covers the papillae of the coronary corium. From this region the horn of the hoof wall is produced at the rate of about 8 mm (.25 in) per month.[39] Thus, for the horn of the toe to move from the coronet to the ground surface, where in the unshod state it is worn away at about the same rate, takes about 8 to 9 months. This is the approximate rate of hoof wall production in a mature horse; it appears to be greater in the young foal (≈ 3 mm per week).[40]

At this point, you might ask what happens when the epidermal (insensitive) laminae of the wall are pushed downward to the level of the sole. What fills in between the epidermal laminae as they move beyond the dermal (sensitive) laminae? We can't just leave gaps between them, because infection could enter the sensitive tissue of the foot. Well, the distal ends of the dermal laminae form papillae, the **terminal papillae** (Figs. 9-53, 9-56A & 9-60).

Like little "caulking guns," the germinal epithelium produces a pigmented horn over these papillae that fills in the gaps between the distally moving epidermal laminae. Note that I said pigmented horn. Thus, the total horn that moves distally from this region is an alternating pattern of pigmented horn (from the terminal papillae) and non-pigmented horn (continuation of epidermal laminae). It takes a lot of horn production to keep up with the downward migration of the

[38] Stump, J. E. Anatomy of the normal equine foot, including microscopic features of the laminar region. JAVMA 151 (1967):1588-1598.

[39] de Lahunta, A., and Habel, R. E. *Applied Veterinary Anatomy*. W.B. Saunders Company. Philadelphia, 1986.

[40] Smallwood, J. E., Albright, S. M., Metcalf, M. R., *et al*. A xeroradiographic study of the developing equine foredigit and metacarpophalangeal region from birth to 6 months of age. Veterinary Radiology 30 (1989): 98-110.

epidermal laminae, which explains why the area of the terminal papillae requires a rich blood supply. Those vessels that pass through the large vascular canals from the sole canal to the sole border of Pd anastomose to form the **circumflex artery and vein** that encircle this area (Figs. 9-27 & 9-60).

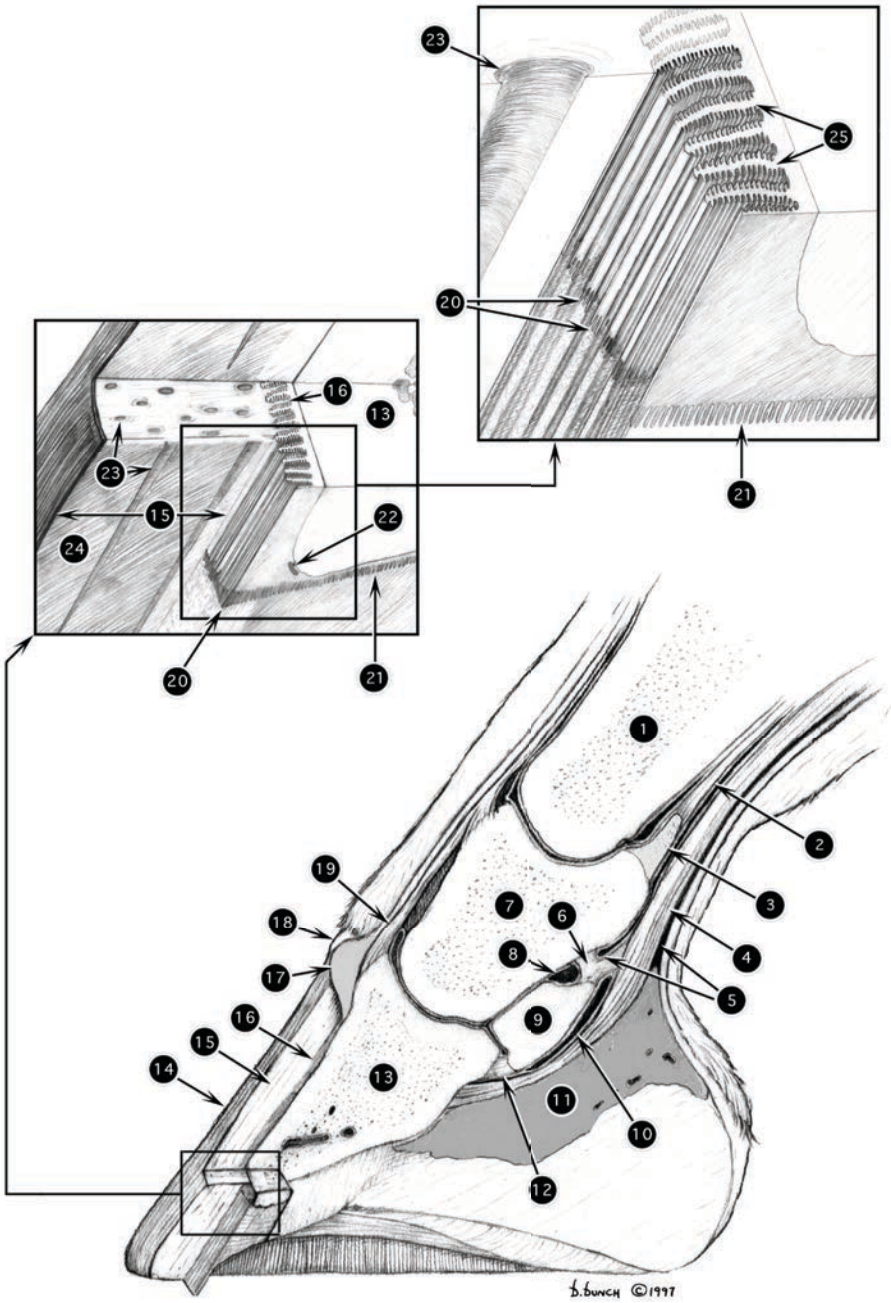


Figure 9-60. Sagittal section through foot of horse with magnified insets to illustrate details of distal hoof wall anatomy: (1) proximal phalanx; (2) straight sesamoidean ligament; (3) fibrocartilage of Pm; (4) deep digital flexor tendon; (5) digital sheath; (6) collateral ligament of navicular bone; (7) middle phalanx; (8) distal interphalangeal joint ; (9) navicular bone; (10) navicular bursa; (11) digital cushion; (12) distal navicular ligament; (13) distal phalanx; (14) stratum externum; (15) stratum medium; (16) stratum internum; (17) coronary corium; (18) perioplic corium; (19) common digital extensor tendon; (20) terminal papillae; (21) papillae of sole corium; (22) circumflex artery & vein; (23) horn tubule; (24) intertubular horn; (25) primary & secondary dermal laminae. (Drawing by Brenda Brunch).

The anatomic term, **white zone**, is applied to the area on the bottom of the horse's hoof where the wall meets the sole (Fig. 9-54). This zone is only partially white and can be appreciated best on a freshly trimmed hoof wall. Recall that the deeper part of the stratum medium and the stratum internum are non-pigmented (*i.e.*, white), but the horn produced over the terminal papillae that fills in between the epidermal laminae is consistently pigmented. This alternating pattern of pigmented and non-pigmented horn results in an off-white to brownish color. By anatomic definition, the white zone consists of the distal surface of the non-pigmented deeper part of the stratum medium and the partially pigmented area below the stratum internum.

Farriers (people who shoe horses for a living) use the expression "white line." When they trim and level the hoof wall for the shoe, the inner non-pigmented area of the stratum medium is obvious, and white. They use this white line as a guide for driving their nails into the hoof. If the nail is started inside the white line, it will likely pass too close to or even penetrate the sensitive tissue of the foot (Fig. 9-61).

Examine a horseshoe nail, and note that it is beveled only on one side. When properly inserted with the bevel toward the inside of the shoe, the nail deviates away from the sensitive tissues as it passes through the horn. It typically emerges about 1.5 cm above the ground surface of the wall. If the nail is inserted backwards (*i.e.*, bevel out), it will deviate toward the sensitive tissue, and the horse is likely be "quicked" by the misdirected nail. The head of the nail is asymmetric, so the farrier can tell by feel which way the bevel is directed.

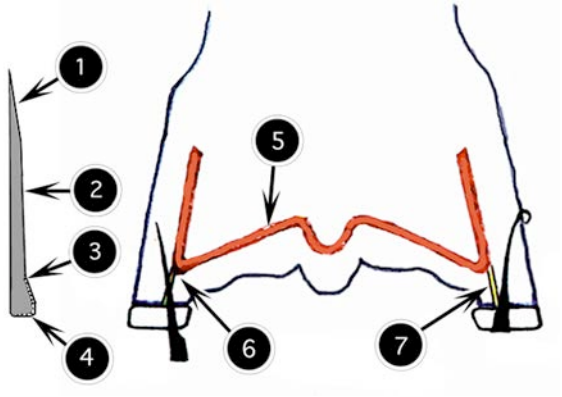


Figure 9-61. Anatomy of a horse-shoe nail and its correct and incorrect placement relative to the white line: (1) bevel of nail- always turned toward inside of shoe; (2) shank; (3) neck; (4) head of nail- asymmetric and textured so that its correct orientation can be determined by feel; (5) sensitive tissue of foot; (6) incorrect placement inside white line results in nail passing too close to 5; (7) white line- correct placement of nail.

Let's talk about holes and papillae. You might have noticed by now that wherever you have holes in the hoof, you find corresponding papillae on the reciprocal. Papillae fit into holes. In those regions of the hoof where there are papillae (periople, stratum medium, frog, and sole), horn is not produced as a uniform, homogeneous substance. Rather, it is produced as tubules of horn, bonded together by intertubular horn (Figs. 9-58 & 9-60). This configuration is known as **tubular horn**. One tubule corresponds to the presence of one papilla. More horn is produced along the sides of the papillae than over its tip, so tubular horn is naturally heterogeneous- somewhat sparse in the center of a tubule and concentrated around its periphery.

Similar to reinforcement bars in concrete, this tubular configuration adds strength, resilience, and compressibility to the structure. The tubules essentially parallel the compressive forces (weight) on the structure. Like the flexor tendons, the hoof is not totally inelastic but is designed to

"give" slightly under the compressive forces of weight-bearing (*i.e.,* the hoof wall gives slightly and then rebounds after support). When you examine the outer surface of the hoof wall, you can appreciate this tubular structure. The horn resembles[41] a bunch of hairs (tubules) stuck together with glue (intertubular horn). The tubules give the hoof its proximodistal, linear striations. In some hooves, lines of variable pigmentation accentuate the tubular pattern. Tubular horn is produced only where there are papillae; where there are laminae (stratum internum), **laminar horn** is produced.

And, speaking of laminae, let's talk about inflammation of laminae, or **laminitis**. Laminitis is a disease of the whole horse, but is manifested most severely in the highly vascular and tightly enclosed laminar region of the hoof wall. It is commonly referred to as "founder."[42] Without getting in over my head with specific causes, note that the inflammatory response can be triggered by a number of stimuli, the most common of which is a toxemia resulting from gastrointestinal stress, such as when a horse is allowed access to a grain (carbohydrate) overload. It can also be triggered by metritis or retained placenta in the mare, or by severe stress to the feet because of overwork or forcing a horse to stand for days without rest. It is also seen in horses with a contralateral lameness, where all of the weight is borne by the non-affected limb. The additional stress on this opposite limb often leads to a breakdown of the connection between horse and hoof (*viz.,* Barbaro was euthanized because of founder in his opposite hind limb).

Regardless of the initiating cause, there is a severe vascular disturbance and inflammatory reaction in the laminar corium- an intrahoof vascular engorgement and swelling. However, the hoof forms a resistant cuff over the inflamed area and cannot swell outward. Thus, intrahoof pressure goes way up, and once this pressure reaches a certain level, it prevents new blood from entering the hoof. That is, the relatively inelastic hoof, in effect, becomes a tourniquet.[43] Arteriovenous anastomoses (AVA's) open so that blood is diverted directly back to venous circulation, thus leaving the foot more or less "hung out to dry."

Because new blood can no longer enter the hoof (indicated by a pounding digital pulse and confirmed with nuclear imaging), there is a shutdown in perfusion of the laminar corium, and the clock starts to run. How long can these vital tissues go without perfusion? As a function of time, tissues of the laminar corium begin to die (ischemic necrosis), and there is a breakdown in the normal horse-hoof bond. Unless something can be done to reverse this process, the inevitable occurs. The horse begins to fall away from its hoof wall. As some of the bond breaks down, even more stress is placed on that tissue that is still there. Thus, it can quickly become a progressive breakaway (Fig 9-62).

[41] Hoof horn resembles a bunch of hairs, but it is not a bunch of hairs. If you really want to see a beautiful example of tubular horn, in which the individual tubules separate or fray distally, look at a baleen plate from a whale.

[42] founder- to sink below the water (like a ship).

[43] If you want to experience what the horse must feel like when this happens, consider the following experiment: (1) place your middle finger on a table and strike it sharply with a hammer- if it's throbbing, you've hit it hard enough; (2) next, take a thimble and quickly place it over the throbbing finger before it swells too much- tape it in place; and (3) now, place your thimbled finger back on the table and do a one-finger stand. Remain in that position for about an hour. (I said consider it- don't actually do it.)

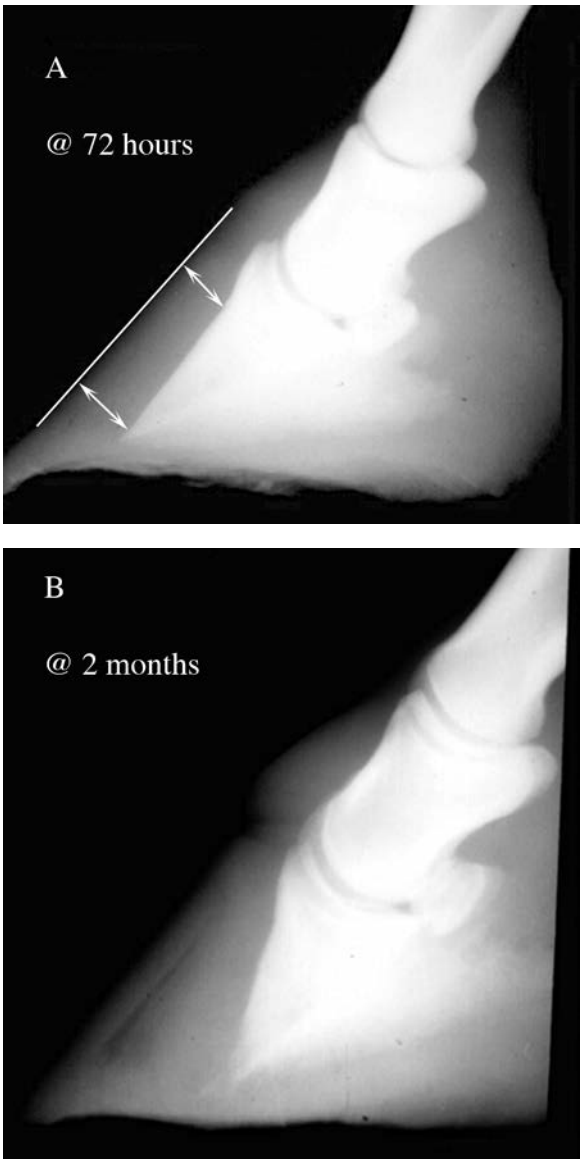


Figure 9-62. Lateromedial radiographs of a 2-year-old quarter horse with laminitis: **(A)** 72 hours following initial clinical signs; **(B)** 60 days after acute phase. Note that rotation of Pd was already detectable in this horse at 72 hours. The white line in A indicates the dorsal border of the hoof wall. In B, a large amount of "scar horn" produced over the laminar corium has filled-in the wide gap between Pd and the original hoof wall.

In the most severe cases, there is a total breakdown in the horse-hoof bond, and the toe portion of Pd pushes against the part of the sole between the apex of the frog and the dorsal wall. This causes it to bulge downward- a "dropped sole." If it continues, the dorsal part of the sole border of Pd penetrates the sole- "perforation of the sole."

When the initial separation occurs, blood seeps into the space created by the separation of the laminae and some gas may be present, probably as a result of nitrogen being pulled out of solution by the vacuum effect of the separation of horse and hoof. The break line actually occurs at about the level of the stratum spinosum, not at the dermoepidermal junction. Thus, the germinal epithelium remains with the horse, not the hoof. Once released from the tension of support, this epithelium rapidly proliferates and produces an irregular type of "scar horn," which unfortunately fills the gap between the rotated Pd and the hoof wall (Fig. 9-62B).

If you think of the normal alignment of the dermal and epidermal interdigitation of laminae as a sort of a zipper, you can understand how, when new horn produced at the coronary corium reaches this area of separation, it also jumps the track, being pushed out by the scar horn, and loses its normal relationship with the dermal tissue. Heroic attempts at removing all the abnormal horn, and then using an epoxy resin to cover the sensitive tissues have been largely unsuccessful. The reason, of course, is that as soon as the new horn reaches the area of breakdown, it also "jumps the track." In summary, rotation of Pd, as a sequel to acute laminitis, can be a devastating problem.

Whenever there is a "significant metabolic event" in the life of a horse, there is an alteration in the rate of hoof wall production. As you examine the hoof of almost any horse, you can see rings or ripples in the surface that generally parallel the coronet. These ripples indicate good

days and bad days in the life of the horse. The more distinct the ring, the more serious the metabolic event- for example, a fever, a great day of being turned out on new, high-nutrient pasture (grass rings), going without feed over the weekend, birth of a foal. The most severe rings are produced when a horse experiences laminitis (founder rings), *a* very bad day. More subtle rings indicate less marked changes in metabolic activity. Any of you who have ever used a caulking gun can appreciate how important even movement and steady trigger squeeze are to laying a smooth bead. Jerks create ripples- so it is with hoof-wall production.

Sagittal & Transverse Sections of Equine Digit: Many important structures of the foot can be examined on sagittal and transverse sections. Obtain demonstration specimens that have been so sectioned, and let's go through them. On the cut surface of the sagittal section, note the periople draping over the proximal border of the wall (Figs. 9-53 & 9-60). Observe the narrow **perioplic corium** at the junction of hair and hoof. The **coronary corium** is much wider and conforms to the coronary groove of the hoof.

There is a rich venous plexus in the subcutis of this area, the **coronary plexus**, which extends around the coronary groove of the hoof (Figs. 9-53 & 9-63). The inner, non-pigmented part of the stratum medium should be obvious and, just deep to it, the stratum internum, which is formed by the epidermal laminae that interdigitate with the dermal laminae (Fig. 9-57). These two regions extend distally to form the white zone on the ground surface of the hoof. Note that the dorsal part of the parietal surface of Pd is parallel to the hoof wall. The periosteum of this part of the bone is modified to fuse with the **laminar corium**, which contains a rich plexus of veins, the **dorsal plexus**.

At the junction of wall and sole, the sole corium continues to the apex of the frog, where it is continued as the frog corium. Remember, corium is just another name for the dermis of the foot, and adjectives (*e.g.*, perioplic, coronary, sole) are merely regional designations of this continuous layer of the integument. The corium of the frog is continued as the dermis of the skin between the bulbs of the heel (Fig. 9-53).

The wedge of tissue between the frog corium and the DDF tendon is the **digital cushion** (Figs. 9-53 & 9-60). Between the sole corium and sole surface of Pd, and continuing between the frog corium and the digital cushion, is another rich venous plexus known as the **palmar plexus.** The palmar plexus extends proximoabaxially between the digital cushion and the cartilages of the hoof (Fig. 9-63).

The digital cushion, a mass of fibrofatty connective tissue, represents a modification of the subcutis and is very important in the natural “pump action” of the equine foot, which functions to move blood out of the venous plexuses of the foot. As the horse descends into the hoof following impact, the digital cushion is compressed between the DDF tendon and frog. The digital cushion responds like a rubber ball and expands abaxially, compressing the palmar venous plexus against the more rigid cartilages of the hoof (Fig. 9-63).

As the expansion force increases, the cartilages are similarly displaced abaxially, which compresses the coronary plexus against the more rigid hoof wall (Fig. 9-63). The resulting sequential compression of these venous plexuses forces the blood abaxially and proximally into the tributaries of the digital veins.

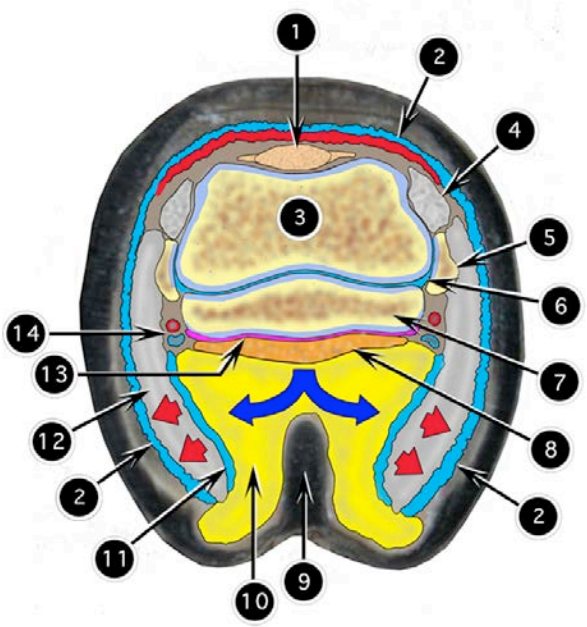


Figure 9-63. Transverse section through distal right foredigit of horse, proximal view: (1) common digital extensor tendon; (2) coronary plexus; (3) distal part of Pm; (4) lateral collateral ligament of DIJ; (5) Pd; (6) distal interphalangeal joint (DIJ); (7) navicular (distal sesamoid) bone; (8) deep digital flexor tendon; (9) spine of frog; (10) digital cushion; (11) palmar venous plexus; (12) medial cartilage of hoof; (13) navicular bursa; (14) medial digital vessels. Blue arrows indicate compression & abaxial expansion of digital cushion during weight-bearing, initially compressing palmar venous plexus. Red arrows indicate subsequent abaxial movement of cartilages of hoof, compressing coronary plexus.

To facilitate this flow, there are no valves in the plexuses themselves. However, valves are present in the veins, beginning immediately proximal to the coronary border of the hoof. In order for compression of the venous plexuses to be optimal, it is important that the cartilages of the hoof remain cartilaginous, providing resistance and flexibility. Unfortunately, they tend to ossify in response to abnormal pressures and stresses on them, sometimes as a result of poor conformation (*e.g.*, toeing in or toeing out). Like a lot of other things, they also tend to become less resilient and partially ossified with age (Fig. 9-64).

Ossification of these cartilages is commonly known as "sidebones," which, when advanced, can be detected by palpation. Less advanced cases can be detected using radiography. *Be sure you can palpate these cartilages in the live horse. They should give under firm pressure of your fingers, indicating that they are still cartilaginous and are not osseous.*

On an intact equine hoof, observe the design of the proximal surface of the frog (Fig. 9-55). The highly vascular corium conforms to this mold of the hoof (Fig. 9-56B). From this view, you can see how the digital cushion saddles the **spine of the frog**. The latter acts not only as a stabilizer but also as a wedge to spread the compressed digital cushion abaxially (Fig. 9-63). Not only are the venous plexuses compressed, providing a sort of "fluid suspension," but also the hoof itself is expanded at the heels by this force, which provides additional shock absorption. If you examine the upper surface of a used horseshoe immediately after its removal, you should observe that it has been polished at the heels by the alternate expansion and contraction of the hoof wall. This expansion is necessary for the normal function of the hoof and explains why the shoe is not normally nailed at the heels.



Figure 9-64. Distal phalanx of horse with advanced ossification of cartilages of hoof ("sidebones").

Digital Sheath, DIJ Capsule, and Navicular Bursa of Horse: On the sagittal section of the equine digit, note the close proximity of these three synovial structures (Fig. 9-53). Only a small, T-shaped connective tissue bridge separates them proximal to the fused collateral ligaments of the navicular bone. Injection studies have demonstrated that direct communication between the navicular bursa and the DIJ are rare.[44]

Despite the fact that few, if any, direct communications have been demonstrated between the DIJ capsule and navicular bursa, the thin membranes between these structures are apparently permeable to anesthetic solutions.[45] Because of this diffusion from joint to bursa, it is possible to anesthetize the bursa indirectly by injecting a sufficient volume (6-10 ml) of anesthetic into the DIJ, which is considerably easier than injecting the bursa directly.[46]

Termination of Equine Superficial Digital Flexor: In other species of domestic mammals, the SDF terminates on the middle phalanx only. Its additional termination on Pp is unique to the horse. By attaching both proximal and distal to the PIJ, it assists in preventing the joint from flexing when the limb is bearing weight. Other structures are also involved in this stabilization, and as a result, there is virtually no movement in the joint during the support phase of the stride (Fig. 9-30). As the fetlock sinks under the weight of the horse, the metacarpophalangeal joint hyperextends and the DIJ flexes, but the PIJ does neither. As the fetlock rises following its descent, the metacarpophalangeal joint flexes and the DIJ extends, but again the PIJ does neither. Only after the limb leaves the ground does the PIJ flex. Therefore, of the three major joints of the digit, the PIJ is the least important to the limb's natural function in weight-bearing. Consequently, in some cases of degenerative osteoarthritis ("high ring bone"), the PIJ can be surgically fused (arthrodesis), with return to functional soundness.

Suspensory Apparatus of Horse: Note that the interosseus, proximal sesamoid bones and their distal ligaments (straight, oblique, cruciate) form a strong, fibro-osseous support for the normal angulation of the fetlock joint (Fig. 9-65).

These structures are under a good deal of tension, even when the horse is standing still. Obviously, this tension is greatly increased during high-speed exercise, which explains why these structures are so vulnerable to damage during racing or other types of athletic activity. The straight sesamoidean ligament also crosses the PIJ, which it helps stabilize during weight-bearing (Figs. 9-30 & 9-46).

In addition to the suspensory apparatus, both the DDF and SDF help support the fetlock. Because of their accessory (check) ligaments and the large amount of fibrous tissue in the muscle bellies, this support is also partly passive (Fig. 9-65). Passive support is particularly important at rest and, after the muscles have fatigued, during exercise. These tendons must stretch under load and then should return to their unloaded

---

[44] Calislar, T., and St. Clair, L. E. Observations on the navicular bursa and the distal interphalangeal joint cavity of the horse. JAVMA 154 (1969): 410-412.

[45] Bowker, R. M., Rockershouser, S. J., *et al*. Immunocytochemical and dye distribution studies of nerves potentially desensitized by injections into the distal interphalangeal joint or the navicular bursa of horses. JAVMA 203 (1993): 1708-1714.

[46] Schebitz, H. On navicular disease- long-term results after neurectomy of the rami volares. As abstracted by Habel, R. E., Cornell Veterinarian 55 (1965): 518-520.

state. The elastic recoil of these stretched fibrous structures provides energy to aid in lifting and accelerating the horse during ascent of the fetlock.

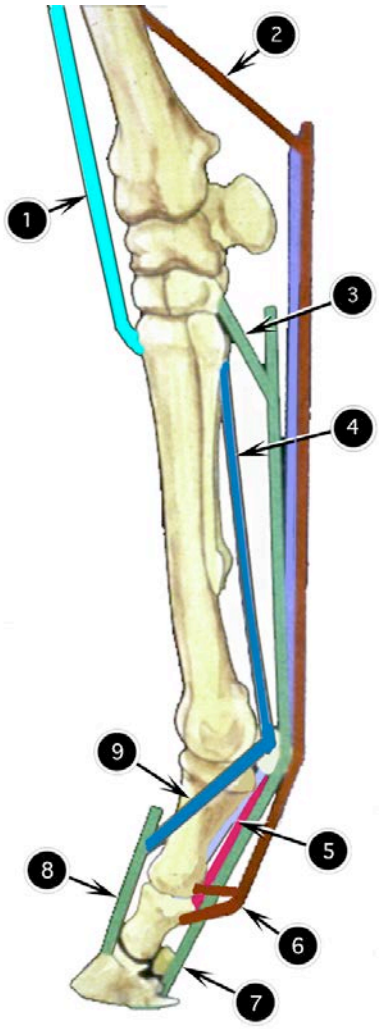


Figure 9-65. Schematic representation of distal components of equine thoracic stay apparatus: (1) extensor carpi radialis tendon; (2) accessory ligament of SDF; (3) accessory ligament of DDF; (4) interosseus (suspensory ligament); (5) distal sesamoidean ligaments; (6) termination of SDF on Pp & Pm; (7) termination of DDF on Pd; (8) common digital extensor tendon; (9) extensor branch of interosseus.

Stretching of the equine suspensory apparatus, DDF, and SDF is evident in slow-motion cinematography of the running horse. As the fetlock descends under the weight and tremendous acceleration forces of the fast-moving horse, these structures are severely tested. Over-stretching is common in racehorses, producing various degrees of damage to one or more of these three supporting structures. Such injuries include fracture of the sesamoid bones, tearing at the fibro-osseous junctions (often resulting in exostoses), and tearing of the tendons ("bowed tendon"), which is often accompanied by inflammation of the carpal and/or digital sheath (Fig. 9-66).

The racehorse shown in figure 9-66 has been subjected to a "medieval" form of therapy referred to in polite circles as "therapeutic cautery," but more commonly called "pin firing." Although I trust none of you will ever be taught how to burn holes in a horse's skin with a cautery as a form therapy, it is something that is still being done in some places. "Therapeutic cautery" was still being taught in veterinary school when I went through in the late 1960s, but to my knowledge, no US veterinary schools teach it anymore. At least I hope not. Pin firing is mentioned here only so that you can say you've heard of it, and so that if you do see a horse that has been pin fired, you will know what caused that dot pattern of scars on its limb. The idea ("rationale") behind pin firing was to convert a chronic or subacute inflammatory process into a really acute one in the "hope that it will heal faster." [47]

Firing was undoubtedly one of the most abused and misused forms of therapy ever devised, and many complications arose from firing horses, especially by persons who were not skilled at doing it. Not to mention

[47] If burning holes in the skin wasn't enough to heat things up, some veterinarians even rubbed caustic "blisters" such as mercuric oxide into the wounds after firing. Perhaps they took the abbreviated version of the Veterinarian's Oath.

the pain and suffering of the horse after the local anesthetic wears off, other complications of "therapeutic cautery" include: open wounds, infection, sloughing of skin, laminitis, suppurative arthritis, and tetanus.

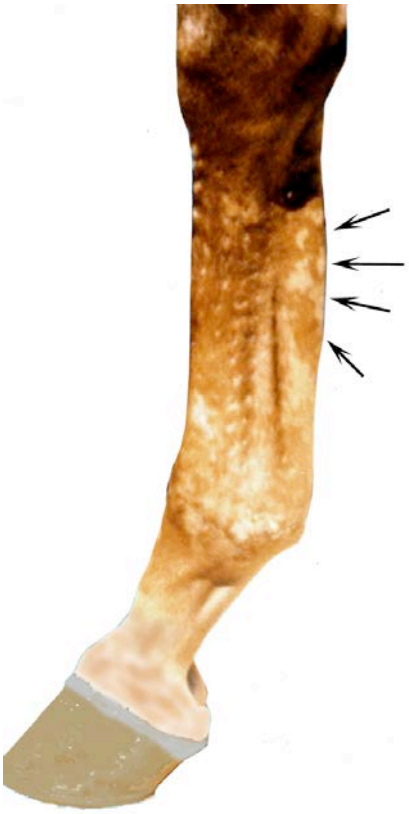


Figure 9-66. Thoroughbred racehorse with tendosynovitis or "bowed tendon." Note the distension (arrows) of the carpal sheath surrounding the SDF and DDF tendons to the level of mid-metacarpus. The cannon region of this racehorse has been subjected to "therapeutic cautery" or "pin firing," resulting in the dotted-scar pattern.

Ligaments of Digits in Artiodactyls: Because these structures are of less clinical importance in artiodactyls, a detailed study is not necessary here. The ox has no straight sesamoidean ligaments, but does possess cruciate and oblique ligaments.

Two ligaments are especially important in the ox, the proximal and distal interdigital ligaments, which should be observed on a specimen or demonstration model (Fig. 9-67). The **proximal interdigital ligament** is a short, thick ligament that connects the proximal halves of the proximal phalanges. The **distal interdigital ligament** provides additional support by preventing spreading of the distal digits (Fig. 9-67).

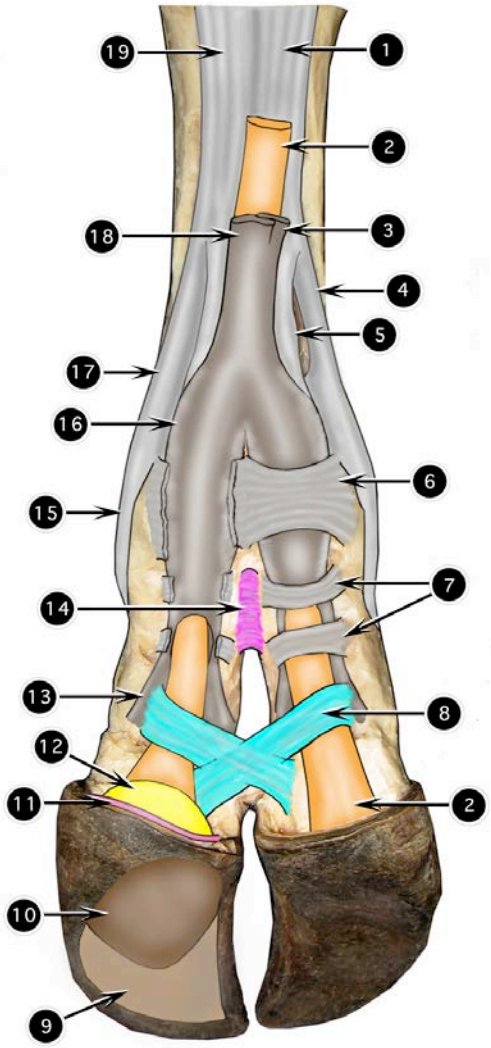


Figure 9-67. Left distal forelimb of ox, palmar view: (1) interosseus 3; (2) deep digital flexor tendon; (3) deep part of superficial digital flexor tendon; (4) abaxial tendon of 1; (5) band from interossei to SDF tendon; (6) palmar annular ligament of fetlock; (7) digital annular ligaments; (8) distal interdigital ligament; (9) sole of hoof; (10) bulb of heel; (11) dermis (corium) of hoof; (12) digital cushion; (13) termination of lateral tendon of SDF on Pm; (14) proximal interdigital ligament; (15) abaxial extensor branch of interosseus 4; (16) sleeve for DDF formed by SDF & interossei; (17) abaxial tendon of interosseus 4; (18) superficial part of SDF tendon; (19) interosseus 4.

In severe cases of osteomyelitis of a digit (foot rot), surgical amputation of the affected digit may be performed. Digital amputation is usually done with a gigli wire saw, cutting obliquely (proximoabaxially) through the distal half of Pp. The proximal interdigital ligament is thus preserved to provide important stabilizing support for the stump of the amputated digit.

Using a large knife or scalpel, cut upward between the digits, transecting the distal digital annular ligament. Insert a gigli-wire saw between the digits and position it just above the proximal interphalangeal joint. Now, cut obliquely through the proximal phalanx of one digit so as to remove the digit. Congratulations, you have just performed a "claw amputation." If done correctly, the **proximal interdigital ligament**, which connects the proximal halves of the two proximal phalanges, should has been left intact. With one digit removed, you should also be able to follow the principal arterial supply, the axial palmar (proper) digital artery along the digit to the foot.

Foot of Ox: The hoof wall is divided into axial and abaxial parts that meet dorsally at the toe. The toe of each bovine hoof is directed somewhat axially (toward the interdigital space) as a result of the curvature of the abaxial part of the wall (Fig. 9-67). This curvature is generally more pronounced on the medial hoof. The hooves of the thoracic limb are broader and somewhat shorter than those of the pelvic limb. In the newborn calf, an extension of soft, yellow horn is present on the sole surface of the hoof. This **eponychium** dries quickly and, as the calf walks, is usually worn away within a few hours.

When the interior of the bovine hoof is compared with that of the horse, some substantial differences can be noted. The **coronary groove** is wider but shallower than that of the horse. Many holes in this region receive the papillae of the coronary corium. The **primary epidermal laminae** are shorter than those of the horse. No secondary laminae are present in the ox, but the primary laminae are more numerous. The periople spreads out and merges with the horn of the bulb.

The **bulb of the hoof** is large and, with the digital cushion, forms the **digital pad**, which corresponds to the bulbs and frog of the equine hoof. The bulb covers much of the supporting surface of the hoof and bears a larger share of the weight than the bulbs of the equine hoof. There are no bars or frog in the bovine hoof. The **sole** is a relatively small area surrounding the apex of the bulb and extending to the white zone (Fig. 9-67).

Foot problems are one of the primary causes of lameness in cattle. Modern dairy cows are large, heavy (1500 lbs. or more) animals that must support a great deal of weight on their feet. Hard surfaces (concrete) compound the trauma of weight-bearing and predispose dairy cattle to foot problems. Among the more common clinical conditions of bovine feet are: (1) interdigital necrosis, which results from an infection (*Fusiformis necrophorus*) originating in the interdigital space; (2) pododermatitis, which is an inflammation of the sole that often progresses to ulceration; (3) so-called "white line disease," which results in separation of the wall and sole; and (4) laminitis.[48]

Foot of Pig and Small Ruminants: The hooves of the pig and small ruminants are similar and resemble those of the ox. Note that the lateral hoof of the pig is slightly

[48] Webster, A. J. In *Bovine Practice*. W. B. Saunders Company, Philadelphia, 1991.

larger than the medial one, and that digit 3 is somewhat shorter than digit 4. These differences may be more obvious on the pelvic limb. Most foot problems in pigs involve the lateral digit. The bulb of the porcine hoof is large and bulges beyond the supporting surface.

The sole of the pig hoof is relatively larger than that of small ruminants. In the latter, the bulb covers almost the entire supporting surface. The axial part of the wall covers only the more dorsal part of the digit. As in the ox, there are no secondary laminae in the pig and in the small ruminants. Similarly, the wall bears a much smaller percentage of the body weight than in the horse.

Stay Apparatus of Equine Forelimb: Now that we've seen most of the parts, let's consider how the stay apparatus of the horse functions in the passive support of the animal's weight. In contrast to the pelvic limb, in which everything centers around locking the patella and involves shifting the support alternately between limbs, the stay apparatus of the thoracic limbs functions concurrently. When standing squarely, horses support more weight on their thoracic limbs, largely because the head and neck are heavy, and their forward overhang moves the center of gravity of the horse to a level about 38 cm (≈16 inches) caudal to the tuber olecrani.[49] By centering weight over this area, the jockey becomes more in balance with the horse, which allows the horse to move most efficiently (naturally).

Body weight is transferred to the forelimb primarily at the serrated face of the scapula by way of the attachment of the serratus ventralis (Fig. 9-68). The thoracic part of the serratus ventralis has a thick epimysium, and the muscle itself contains considerable connective tissue, making the transfer largely passive. This point of weight transfer is caudal to the shoulder joint. Flexion (collapse) of the shoulder is prevented by the fibrous band of the biceps, supplemented by a fibrocartilaginous mold over the intermediate tuberosity of the intertubercular groove (Figs. 8-2 & 9-68). Continuation of this fibrous band through the lacertus fibrosus-extensor carpi radialis tendon pulls a tight, stabilizing band across the dorsum of the carpus, which helps the horse resist buckling forward into flexion (Fig. 9-68).

The digital flexor tendons, with their accessory ligaments, are pulled tightly across the palmar surface of the carpus and provide additional resistance to flexion of this joint complex. As these tendons continue around the fetlock, they help form a fibrous sling for this joint to fall back into. Of course, the fibro-osseous sling provided by the interosseus, proximal sesamoid bones and the distal sesamoidean ligaments provides great support for the fetlock. The weight-induced traction provided by the extensor branches of the interosseus to the CDE to the extensor process of Pd offsets the flexion pull on the DIJ produced by the DDF tension (Fig. 9-68).

The only joint subject to question is the elbow. Although the triceps brachii muscle is necessary to set the elbow in its weight-bearing position, it does not appear to do much once everything is set. *You can demonstrate this in the standing horse by palpating the triceps muscle*. It's not exactly overworking itself.

Once set, initial flexion of the elbow joint in the weight-supporting limb is resisted by the following: (1) the digital and

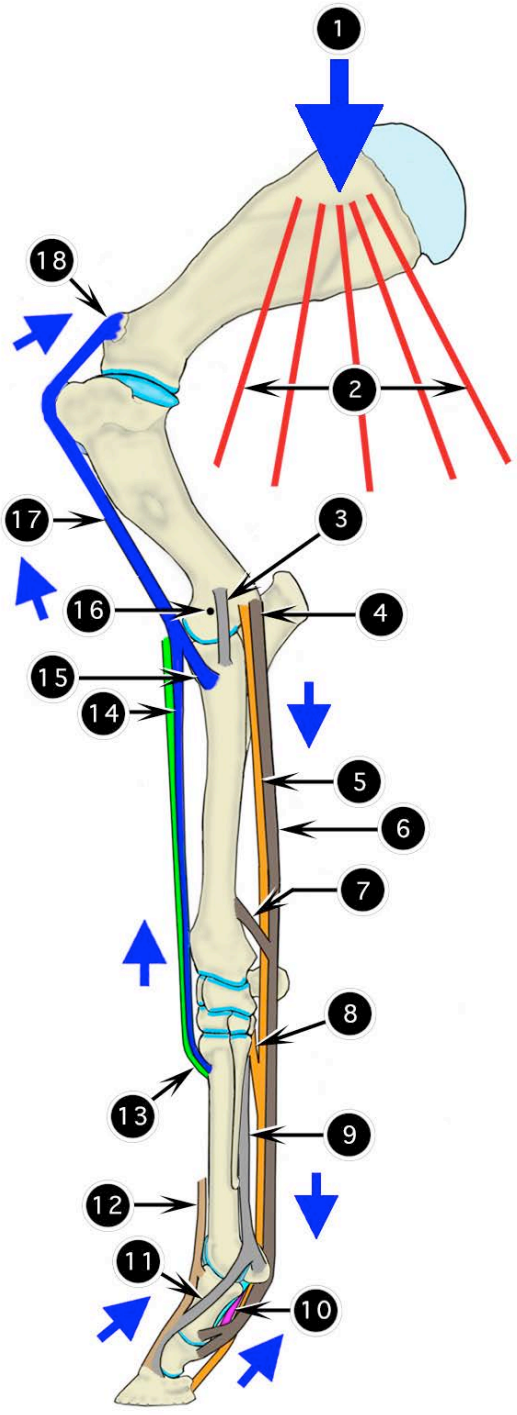
[49] de Lahunta, A. and Habel, R. E. *Applied Veterinary Anatomy*. W. B. Saunders Company. Philadelphia, 1986.

carpal flexor muscles, which contain much fibrous tissue, originate primarily from the medial epicondyle of the humerus and thus resist flexion by pulling down on the lever provided by the epicondyle; and (2) the collateral ligaments of the elbow, which pass caudal to the center of rotation of the joint. Thus, initial flexion of the joint is resisted because, at the onset of flexion, these ligaments must be stretched a little as their proximal attachments rotate up and over the center of rotation (Fig. 9-68).

With their well-developed stay apparatus, adult horses can remain standing for days if need be; however, given their choice, they don't. Although horses can sleep in the standing position, it's more or less comparable to the kind of sleep first-year veterinary students get during an anatomy lecture. Some of you can do pretty well, but it's not as restful as you would prefer. If the only sleep you got was during anatomy class, you would get pretty strung out by week's end.

Most adult horses, given a choice, sneak in a couple of hours of good old laterally recumbent, REM snoozing every night, but they're hard to catch doing it. Sneak into a darkened stable at about 2:30 A.M., turn on the lights real fast, and run down the alley. You'll probably catch some drowsy horses trying to get to their feet (or maybe they'll just sleep right through your bothering them).

Figure 9-68. Stay apparatus of equine forelimb, medial view: (1) weight transferred to limb at serrated face of scapula; (2) fibrous components in serratus ventralis thoracis; (3) medial collateral ligament of elbow, caudal to center of rotation; (4) origin of digital & carpal flexors from medial epicondyle of humerus, contain considerable fibrous tissue; (5) deep digital flexor tendon; (6) superficial digital flexor tendon; (7) accessory ligament of SDF; (8) accessory ligament of DDF; (9) interosseus 3 (suspensory ligament); (10) distal sesamoidean ligaments; (11) medial extensor branch of 9; (12) common digital extensor tendon; (13) termination of extensor carpi radialis; (14) lacertus fibrosus joining with 13; (15) short tendon of termination of biceps brachii; (16) dot indicates center of rotation for flexion of elbow joint; (17) fibrous component of biceps brachii; (18) origin of biceps brachii from supraglenoid tubercle of scapula. Blue arrows indicate direction of force applied to limb.



Chapter 10 • The Head

EXTERNAL FEATURES

Infraorbital Pouch of Sheep: The sheep is the only domestic mammal that possesses this structure, which is better developed in some wild ruminants such as deer. The pouch is represented by a narrow slit near the rostral angle (medial canthus) of the eye. Associated with the pouch, which is better developed in males, are both apocrine and large sebaceous glands. These glands produce a sticky, yellowish-brown secretion, which, when brushed off on objects in the environment (*e.g.,* foliage) is believed to serve as a marker substance. The lacrimal bone of the ovine skull is characterized by a fossa that accommodates this pouch.

Cornual (Horn) Gland of Goat: This gland, which is present in both sexes, is located just caudomedial to the base of each horn. It consists of both apocrine and sebaceous glands and is apparently responsible for the strong odor of the buck. The secretion is believed to act as a territorial marker.

Mental (Chin) Gland of Pig: This structure, which is present in both wild and domestic pigs, consists of a tactile elevation about 1.5 cm in diameter on the ventral surface of the mandibular region (Fig. 10-1). Unlike the porcine carpal glands, there are typically a few vibrissae (tactile hairs) as well as eight to ten duct orifices associated with the mental gland. In addition to both apocrine and sebaceous glands, there are numerous pressure receptors present, indicating both marker and tactile functions.

Veins of Porcine and Bovine Ear: Note that there are several superficial veins on the convex surface of the pinna of the pig's ear. These veins, particularly the **lateral auricular vein** (Fig. 10-1), are used for intravenous injections in pigs. Hint: a butterfly catheter, with a small (≈ 22-gauge), short-beveled needle, works much better than a syringe connected directly to the needle. The **intermediate auricular vein** has been used as a site for in-dwelling catheter placement in cattle. Auricular vein catheters are reported to be a convenient, safe, and low-cost alternative to jugular vein catheters in cattle.[1]

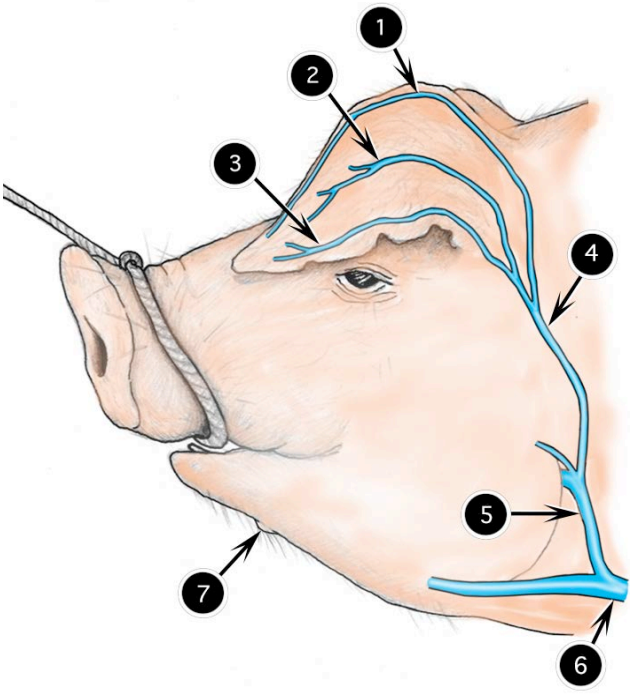


Figure 10-1. Veins of the porcine ear, lateral view: (1) medial auricular vein; (2) intermediate auricular vein; (3) lateral auricular vein; (4) caudal auricular vein; (5) maxillary vein; (6) external jugular vein; (7) mental (chin) gland.

[1] Roussel A. F., Talioferra, L., *et al*. Catherization of the auricular vein in cattle: 68 cases (1991-1994) JAVMA 208 (1996): 905-907.

Splitting of Heads: One of the first steps in dissection of the head is to split it down the median plane so as to provide two halves. As with the limbs, *one side should be dissected more deeply, and the other should be used to preserve the more superficial structures. In preparation for splitting the heads, make a separation between the central incisor teeth by prying them apart wide enough to accommodate the band saw blade.* The enamel of the teeth is very hard on band saw blades. *After passing inspection, the heads are to be split on the band saw by the laboratory staff.*

SUPERFICIAL STRUCTURES

Carefully reflect the skin from the head, leaving a rim of skin around the eye, nostril, and mouth, and leaving the skin on the pinna of the ear. When studying the two halves of the head, it is a good idea to work together. Because the cuts are usually slightly off center, some structures are better demonstrated on one side than the other.

Cutaneous Muscles: The cutaneus facei and the cutaneus colli muscles together form the **platysma**, which, as previously noted, is well developed in the pig. In addition to the cutaneus facei muscle, note the well-developed **frontalis muscle** of the ruminant (Fig. 10-2).

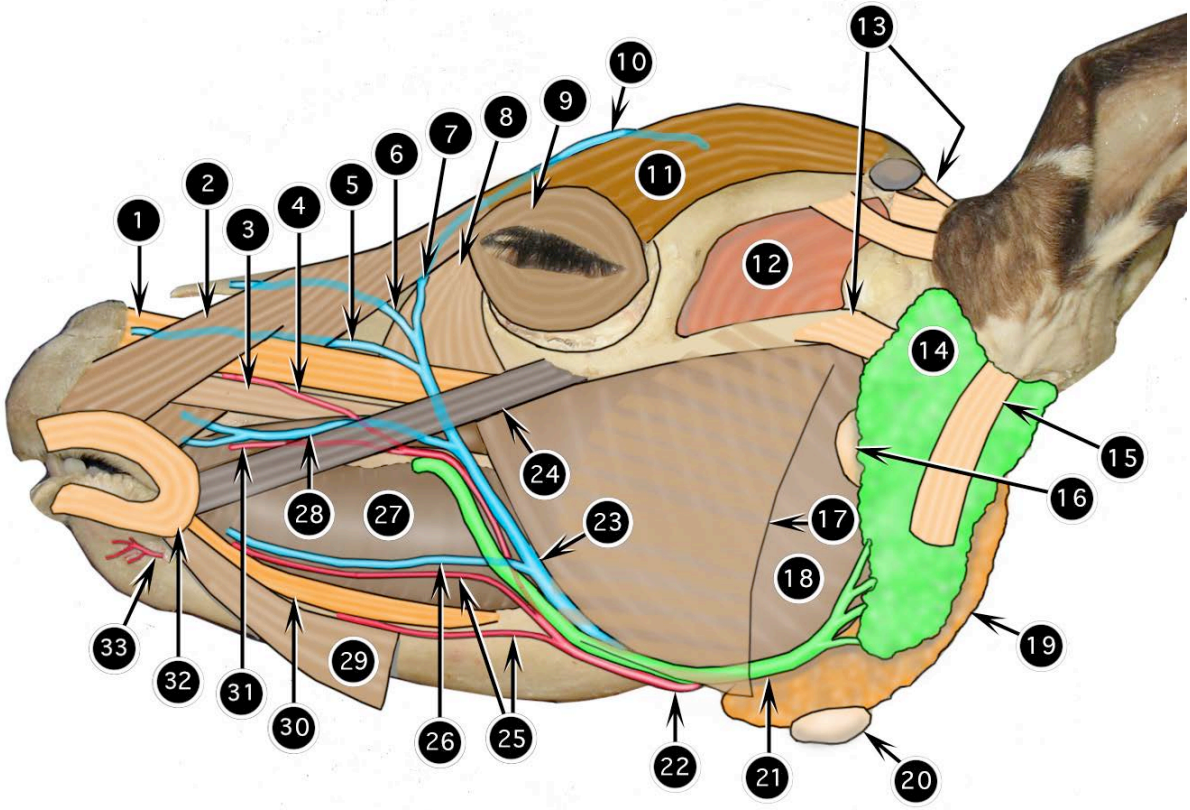


Figure 10-2. Head of calf, lateral view: (1) levator labii superioris; (2) levator nasolabialis; (3) caninus muscle; (4) rostral lateral nasal artery; (5) lateral nasal vein; (6) dorsal nasal vein; (7) angular vein of eye; (8) malaris muscle; (9) orbicularis oculi muscle; (10) frontal vein; (11) frontalis muscle; (12) temporalis muscle; (13) rostral auricular muscles; (14) parotid salivary gland; (15) parotidoauricularis muscle; (16) parotid lymph node; (17) cutaneus facei muscle (partially removed); (18) masseter muscle; (19) mandibular salivary gland; (20) mandibular lymph node; (21) parotid duct; (22) facial artery; (23) facial vein; (24)) zgomaticus muscle; (25) inferior labial arteries; (26) inferior labial vein; (27) buccinator muscle; (28) superior labial vein; (29) depressor anguli oris muscle (part of 17); (30) depressor labia inferioris muscle; (31) superior labial artery; (32) orbicularis oris muscle; (33) mental artery.

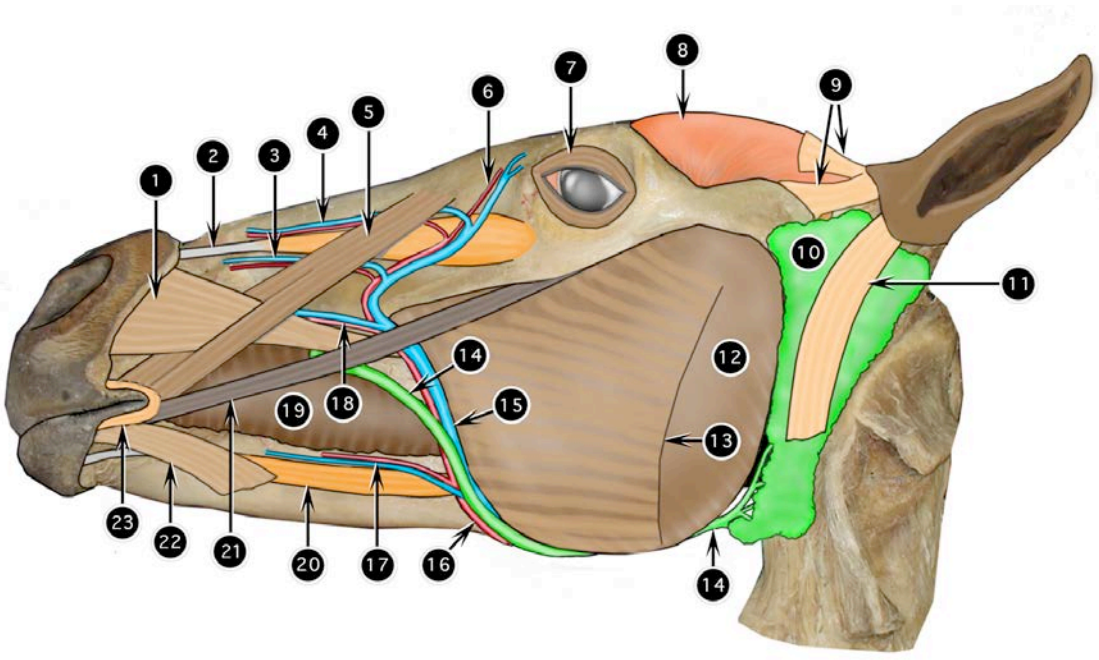


Figure 10-3. Head of horse, lateral view: (1) caninus muscle; (2) levator labii superioris; (3) lateral nasal vessels; (4) dorsal nasal vessels; (5) levator nasolabialis; (6) angular vessels of eye; (7) orbicularis oculi muscle; (8) temporalis muscle; (9) rostral auricular muscles; (10) parotid salivary gland; (11) parotidoauricularis muscle; (12) masseter muscle; (13) cutaneus facei muscle (partially removed); (14) parotid duct; (15) facial vein; (16) facial artery; (17) inferior labial vessels; (18) superior labial vessels; (19) buccinator muscle; (20) depressor labia inferioris muscle; (21) zgomaticus muscle; (22) depressor anguli oris muscle (part of 13); (23) orbicularis oris muscle.

The muscle that crosses the superficial surface of the parotid gland is the parotidoauricularis, which functions to pull the ear down (Figs. 10-2 & 10-3). *In the pig, the thick platysma muscle needs to be reflected to examine the salivary glands and other structures*.

One facial muscle that is well developed in the horse is the **caninus muscle** (Fig. 10-3), which functions to dilate the nostril, an important action for an athletic animal such as the horse. Dilation of the equine nostril is also assisted during high-speed exercise by a passive mechanism. Note that the lateral edge of the nostril has no cartilaginous support (palpate). *Insert a finger into the lateral part of the nostril, and define a cutaneous pouch*, the **nasal diverticulum**, which extends caudally lateral to the skull. This arrangement allows the nostrils of the horse to catch air like an air scoop during high-speed exercise, thus providing passive dilation of the nostril.[2] In the artiodactyls, there is no nasal diverticulum, and the nostrils have more complete cartilaginous support. Consequently, the caninus has less effect on nostril dilation, especially in the ox (Fig. 10-2).

Buccal Branches of Facial Nerve: As you recall, the facial nerve is motor to the muscles of facial expression. In the horse, the **dorsal and ventral buccal branches of the facial nerve** cross the masseter muscle, where they are vulnerable to injury from a lateral blow to the head or from pressure to the side of the face (Fig. 10-4). Damage to

[2] Again, the horse has devised a way of doing an important job and still getting out of doing any work. By the way, the nasal diverticulum is a warm and protected place for ticks to take up residence.

these nerves can produce various degrees of facial paralysis, which is most conspicuous by drooping of the lips on the affected side. These branches, which show considerable variation in their branching pattern, are palpable in the live horse and can sometimes be observed without palpation, particularly when the horse is chewing. Communicating branches of the **auriculotemporal nerve** join the dorsal buccal branch of the facial nerve (CN VII) to supply sensory fibers to the side of the face (Fig. 10-4).

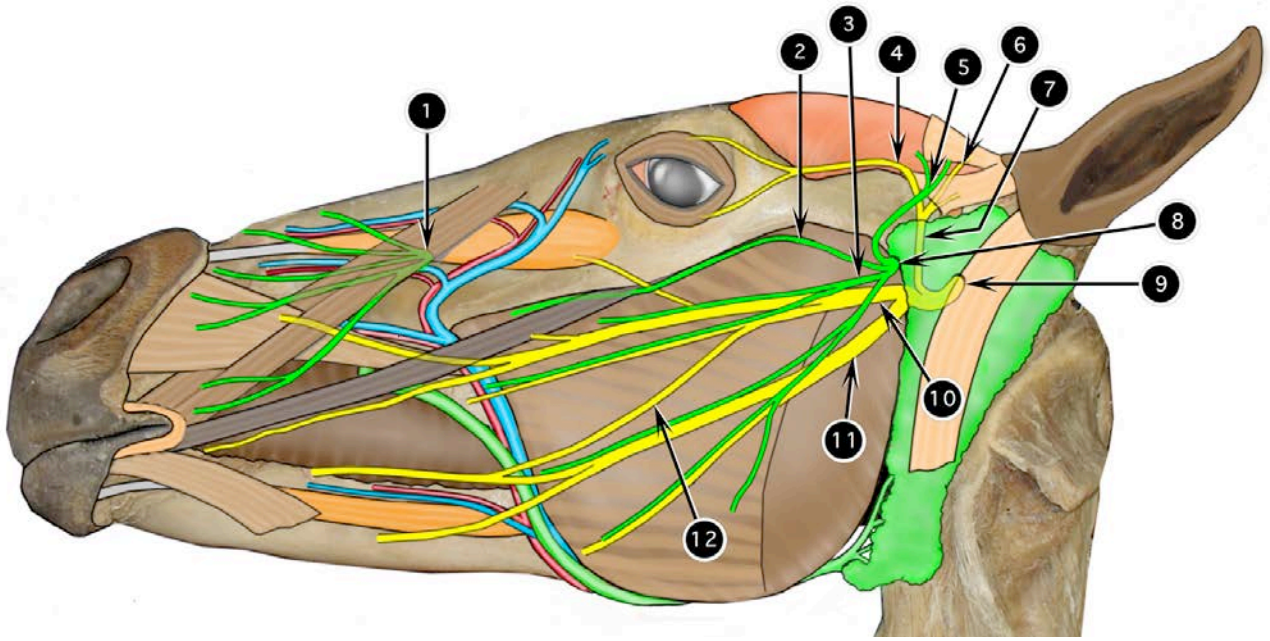


Figure 10-4. Superficial branches of facial (yellow) and trigeminal (green) nerves of horse, lateral view: (1) infraorbital nerve (from maxillary branch of CN V), exiting *via* infraorbital foramen; (2) transverse facial branch of auriculotemporal nerve; (3) communicating branch of auriculotemporal nerve; (4) palpebral branch of auriculopalpebral nerve (palpable as it crosses zygomatic arch); (5) rostral auricular nerves; (6) rostral auricular branches of auriculopalpebral nerve; (7) auriculopalpebral nerve; (8) auriculotemporal nerve emerging around caudal border of mandible; (9) facial nerve (CN VII) emerging from stylomastoid foramen; (10) dorsal buccal branch of 9; (11) ventral buccal branch of 9; (12) variable communicating branches between 10 & 11.

In the ox and pig, the facial nerve divides into dorsal and ventral buccal branches, under cover of the parotid salivary gland (Fig. 10-5). Only the **dorsal buccal branch** crosses the masseter muscle, whereas the smaller ventral buccal branch (to be seen later) courses ventrally along the border of the masseter muscle. Follow the dorsal buccal branch of the ox caudally to where it emerges from behind the **parotid lymph node**. Here, it is joined by a more dorsal branch emerging from around the caudal border of the mandible.

This is a branch of the **auriculotemporal nerve** (Figs. 10-4 & 10-5), from the mandibular branch of the trigeminal nerve (CN V), which joins the dorsal buccal branch and provides sensory innervation to much of the lateral surface of the head. In the sheep, the ventral buccal branch, like that of the horse, crosses the surface of the masseter muscle ventral to the dorsal buccal branch. In the goat, the buccal branches of CN VII are routed similar to those of the ox.

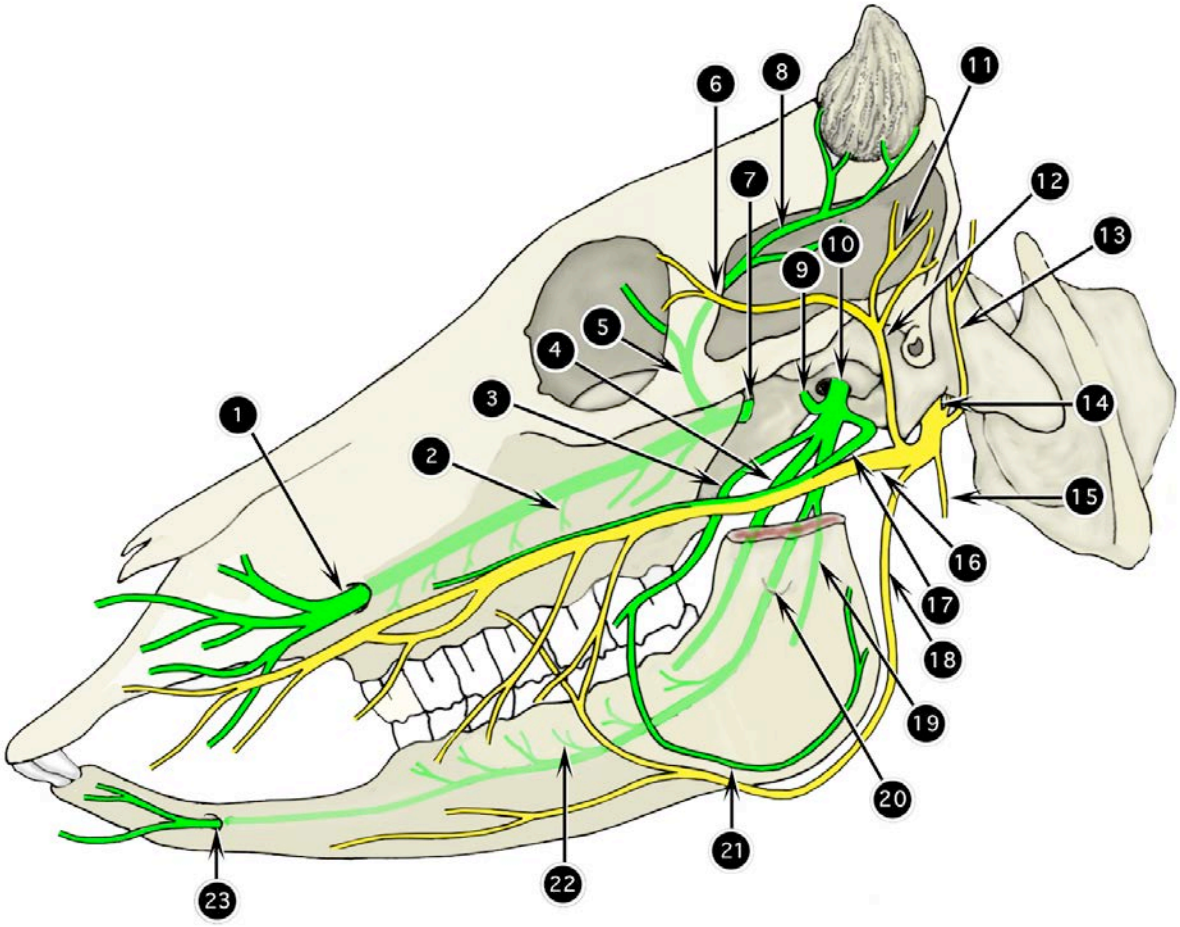


Figure 10-5. Branches of the facial (yellow) and trigeminal (green) nerves of the ox, lateral view: (1) infraorbital nerve- exiting *via* infraorbital foramen; (2) superior dental branches of 1 to superior cheek teeth; (3) buccal nerve- sensory nerve to mucous membrane of oral cavity; (4) lingual nerve- sensory to body & apical part of tongue; (5) zygomatic nerve; (6) palpebral branch of auriculopalpebral nerve; (7) maxillary nerve- exiting *via* foramen orbitorotundum; (8) cornual branch of 5; (9) stump of masticatory nerve to masseter & temporalis muscles; (10) mandibular nerve- exiting *via* oval foramen; (11) rostral auricular branches of auriculopalpebral nerve; (12) auriculopalpebral nerve- can be blocked at arrow this location; (13) caudal auricular nerve; (14) facial nerve- exiting *via* stylomastoid foramen; (15) branch of 14 to digastricus muscle; (16) dorsal buccal branch of 14; (17) auriculotemporal nerve- joins dorsal buccal branch of CN VII; (18) ventral buccal branch of 14; (19) mylohyoid nerve; (20) inferior alveolar nerve- entering mandibular foramen; (21) parotid branch of buccal nerve; (22) inferior dental branches to inferior cheek teeth; (23) mental nerve- exiting *via* mental foramen.

Salivary Glands and Superficial Lymph Nodes: Commensurate with their high-fiber diet, the salivary glands of ungulates are relatively larger than those of carnivores. In addition, the lymph nodes of the head are important because they are frequently involved in infections and are examined as part of routine carcass inspection of food animals. Note the large **parotid gland** in the pig (Fig. 10-6).

While you are examining this gland in the pig, identify the **lateral retropharyngeal**, the **mandibular**, and the **parotid lymph nodes** (Fig. 10-6). Also, recall that the superficial cervical lymph nodes are numerous in the pig, and that the ventral nodes of this group are closely related to the parotid gland (Fig. 10-6). The parotid glands of the horse (Fig. 10-3) and ruminant are also well developed and, in the

ox, the large **parotid lymph node** should be identified and separated from the salivary tissue. Also, define the **mandibular lymph nodes** in the ox, which lie near the linguofacial vein (Fig. 10-2).

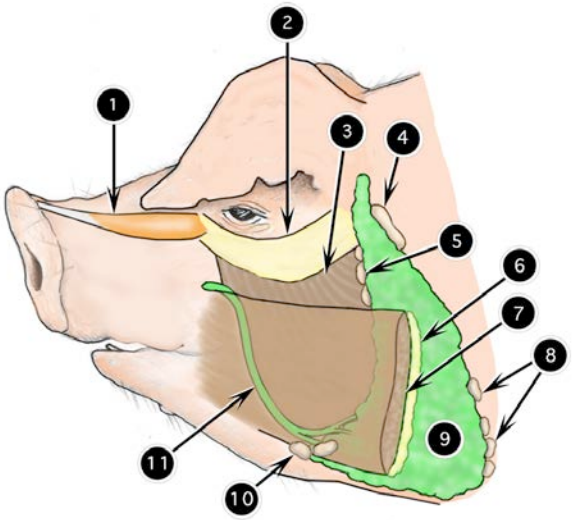


Figure 10-6. Selected structures of porcine head, lateral view: (1) levator labii superioris muscle; (2) zygomatic arch; (3) masseter muscle; (4) lateral retropharyngeal lymph node; (5) parotid lymph nodes; (6) fat; (7) cutaneus facei (part of platysma muscle); (8) ventral superficial cervical lymph nodes; (9) parotid salivary gland; (10) mandibular lymph nodes; (11) parotid duct.

The **mandibular lymph nodes** of the horse are about the only lymph nodes that are routinely palpated in the live animal. As is typical for equidae, these nodes are pea-sized and form a cluster medial to the body of the mandible. The right and left clusters converge rostrally to form a V-shaped mass in the intermandibular space (Fig. 10-7). *Palpate these nodes in the live horse*.

Parotid Duct: The course and termination of the parotid duct varies with the species (Figs. 10-2, 10-3 & 10-6). In the carnivores and sheep, it crosses the masseter muscle, whereas in the horse, ox, goat[3], and pig, it follows a curving course around the ventral part of the muscle. The duct terminates on the parotid papilla, which is located opposite a superior cheek tooth and varies somewhat among species. In the horse, small ruminant, and pig the duct opens opposite the 3rd or 4th superior cheek tooth, while in the ox it opens more caudally opposite the 5th superior cheek tooth.

The parotid duct may become occluded in the ox and horse by the formation of salivary calculi or stones (sialoliths). These may develop around a small foreign body (*e.g.*, grass seed) that gets lodged in the duct after entering through the oral opening. Various salts in the saliva precipitate around this nidus and the resulting sialoliths can become very large in the horse. Surgical removal of the calculus can be performed.

Locate the parotid duct of the horse and ox and follow it around the masseter to where it crosses the mandible. Here it is accompanied by several other structures (Fig. 10-7). The most rostral of these is the facial artery. *As the artery crosses the mandible, the pulse can be taken in the horse and ox*. Caudal to the artery lies the facial vein, and caudal to the vein is the parotid duct. In addition to these structures in the ox, you should identify the ventral buccal branch of CN VII between the facial artery and vein (Fig. 10-5).

Facial Artery and Vein: Note that the **facial artery**, which is frequently used to take the pulse in the horse and ox, is the most rostral of these structures as they cross the mandible. This fact is helpful when attempting to take the pulse from the facial artery as it is hard to get a pulse from the parotid duct. *Take the pulse from the facial artery in the horse and ox by compressing the vessel against the ventromedial border of the mandible*.

[3] Note: A goat is not a hairy sheep, and a sheep is not a wooly goat.

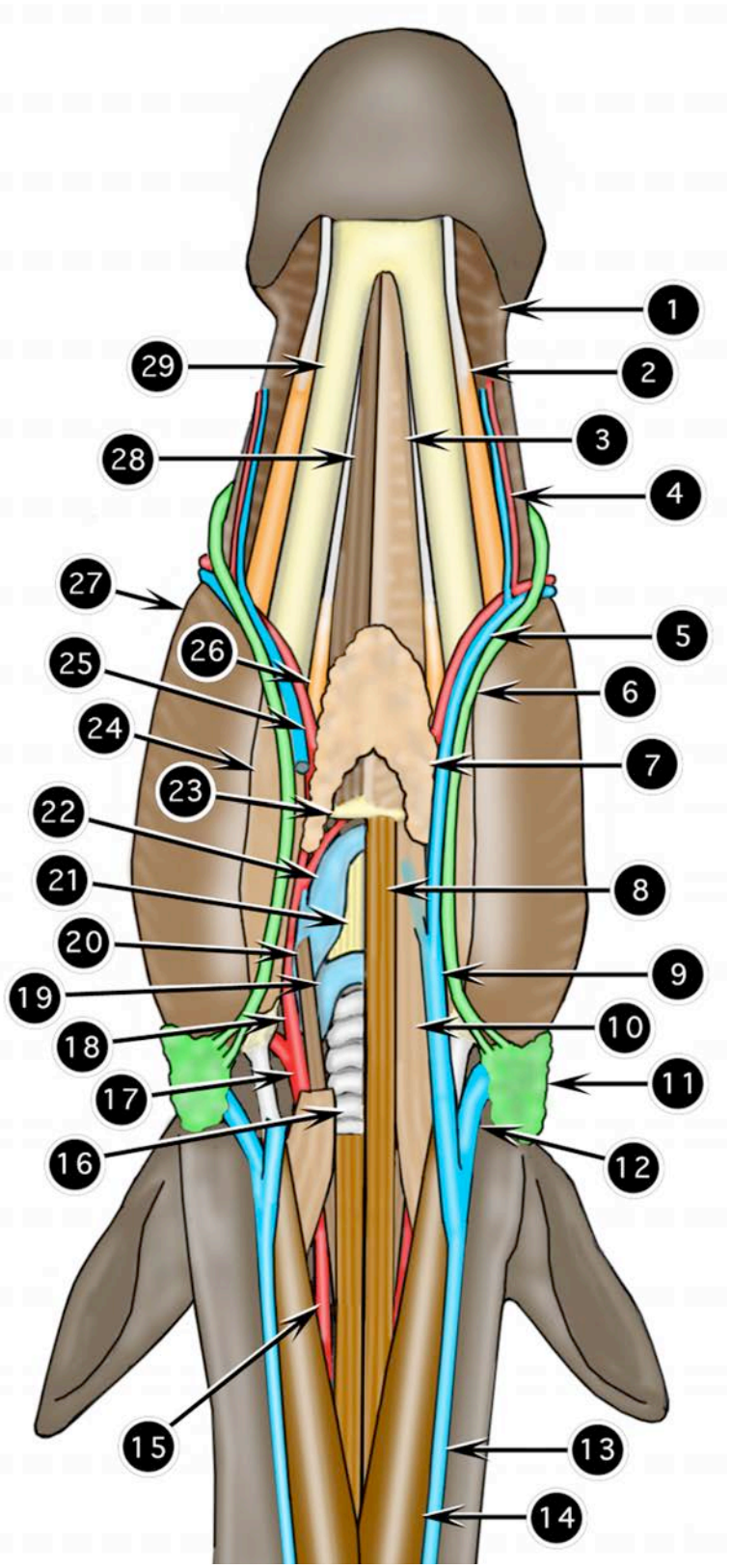


Figure 10-7. Selected structures of equine head, ventral view: (1) buccinator muscle; (2) depressor labii inferioris muscle; (3) mylohyoideus muscle (removed on right side of head); (4) inferior labial vessels; (5) facial vein; (6) parotid duct; (7) mandibular lymph nodes; (8) sternohyoideus muscle; (9) linguofacial vein; (10) omohyoideus muscle; (11) parotid salivary gland; (12) maxillary vein; (13) external jugular vein; (14) sternocephalicus muscle; (15) common carotid artery; (16) trachea; (17) external carotid artery; (18) linguofacial trunk; (19) cricoid cartilage; (20) sternothyroideus muscle; (21) cricothyroid ligament; (22) thyroid cartilage; (23) basihyoid bone; (24) medial pterygoid muscle; (25) facial artery; (26) rostral belly of digastricus muscle; (27) masseter muscle; (28) geniohyoideus muscle; (29) body of mandible.

In the horse, the facial artery continues dorsally, after crossing the mandible, giving rise to the inferior labial to the lower lip, the superior labial to the upper lip, the lateral nasal, and finally the dorsal nasal artery (Fig. 10-3).

Also in the horse, if you trace the **facial vein** dorsally from where it crosses the mandible, you can see that it is joined by several large veins that emerge from under the masseter muscle. The first of these (from ventral to dorsal) is the **buccal vein**, next is the **deep facial vein**, and just below the facial crest, the **transverse facial vein** (Fig. 10-8).

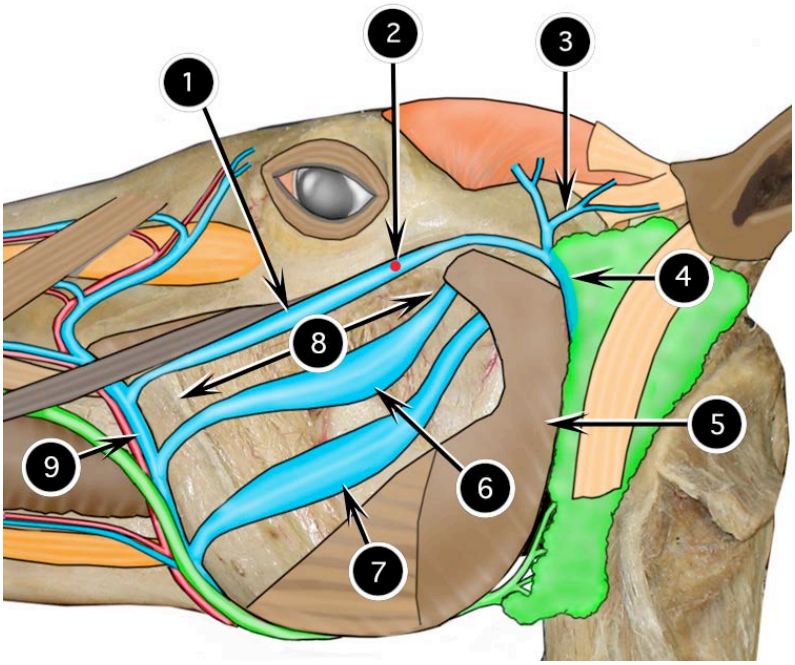


Figure 10-8. Selected veins of equine head, lateral view: (1) transverse facial vein; (2) site for venipuncture; (3) rostral auricular vein; (4) superficial temporal vein; (5) masseter muscle, partially removed; (6) deep facial vein; (7) buccal vein; (8) lack of valves in these haustrated veins allows for flow in either direction; (9) facial vein.

The transverse facial vein can be used as a site for venipuncture, using a small gauge needle inserted just below the facial crest (Fig. 10-8). A small blood sample can thus be obtained sufficient for PCV, total protein, etc.

The facial artery is shorter in the ox and terminates as the rostral lateral nasal artery (Fig. 10-2). The bovine caudal lateral nasal and dorsal nasal arteries emerge from the orbit as branches of the malar artery. There is no facial artery in small ruminants; the lateral and dorsal nasal arteries arise from the malar artery, and the arteries of the lips are branches of the large transverse facial artery.

In the pig, the facial artery is short, and the arteries of the lips arise from the more deeply located buccal artery. Don't get too bogged down in these variations, but then don't try to take the pulse from the facial artery in a sheep, goat, or pig, either.

Levator Labii Superioris Muscle of Horse: This is a prominent (and active) muscle in the horse (Fig. 10-3). In addition to covering the infraorbital foramen (easily pushed dorsally for palpation of foramen), this is the "horse laugh muscle." *Tickle the nose of the live horse and watch the contraction of the muscle in elevating the upper lip*. It is also active when the horse is eating, because the lips are the primary organs of food prehension in the horse. This is also true in small ruminants, allowing them to graze more closely than cattle.

The lips of the ox and pig are thick, heavy, and relatively immobile. The bovine levator labii superioris isn't much to brag about (Fig. 10-2), and their principal organ of food prehension is the tongue, which is why cattle can't graze as closely as small ruminants.

In the pig, the well-developed levator labii superioris muscle functions more in moving the rostrum or snout than the lip (Fig. 10-6). This is important in the characteristic rooting activity of the pig, such as when searching for truffles or digging a nice terrestrial fossa. To facilitate good rooting, the rostrum of the pig is supported by a bone, the **os rostri**, on which the muscle attaches (see skeletal model).

SKELETAL ANATOMY

You are expected to have acquired a general knowledge of the individual bones that form the skull from your study of the dog and cat, so we will not consider these bones in great detail here. Demonstration models of color-coded painted skulls, sculptured skulls, and "exploded" skulls should be used to review the basic arrangements and relationships of the bones, as well as the excavations and communications of the paranasal sinuses.

Unlike that of the carnivore and pig, the **orbit** of the equine (Fig. 10-9) and bovine skull (Fig. 10-10) has a completely osseous rim across the caudolateral aspect of the orbit. As previously noted, the pig's rostrum is stiffened by the **os rostri**.

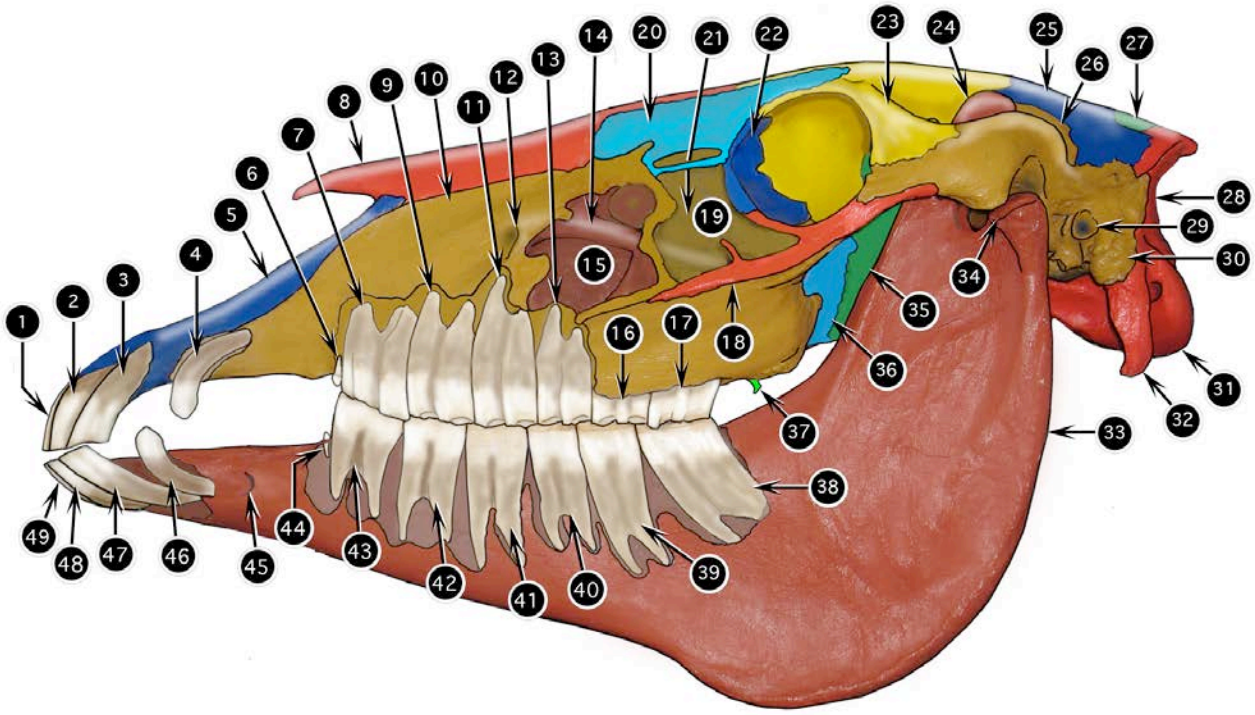


Figure 10-9. Skull of horse, about 8 years old, lateral view: (1) superior central incisor; (2) superior intermediate incisor; (3) superior corner incisor; (4) superior canine tooth; (5) incisive bone; (6) superior premolar 1 (wolf tooth); (7) superior premolar 2; (8) nasal bone; (9) superior premolar 3; (10) maxillary bone; (11) superior premolar 4; (12) infraorbital foramen; (13) superior molar 1; (14) infraorbital canal; (15) rostral maxillary sinus; (16) superior molar 2; (17) superior molar 3; (18) facial crest; (19) caudal maxillary sinus; (20) conchofrontal sinus; (21) frontomaxillary opening; (22) lacrimal bone; (23) zygomatic process of frontal bone; (24) coronoid process of mandible; (25) parietal bone; (26) squamous temporal bone; (27) interparietal bone; (28) occipital bone; (29) external acoustic meatus; (30) mastoid process; (31) occipital condyle; (32) paracondylar process; (33) ramus of mandible; (34) head of mandible; (35) sphenoid bone; (36) palatine bone; (37) hamulus of pterygoid bone; (38) inferior molar 3; (39) inferior molar 2; (40) inferior molar 1; (41) inferior premolar 4; (42) inferior premolar 3; (43) inferior premolar 2; (44) inferior premolar 1 (rarely erupts); (45) mental foramen; (46) inferior canine tooth; (47) inferior corner incisor; (48) inferior intermediate incisor; (49) inferior central incisor.

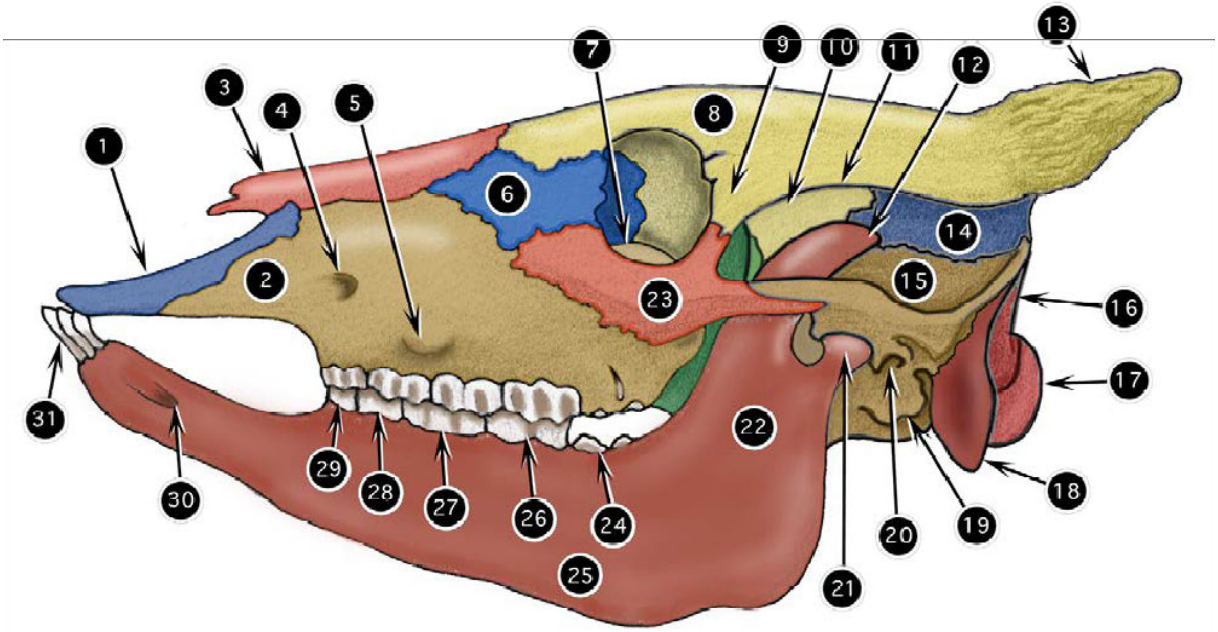


Figure 10-10. Skull of Holstein steer, about 14 months old, lateral view: (1) incisive bone; (2) maxilla; (3) nasal bone; (4) infraorbital foramen; (5) facial tuberosity; (6) lacrimal bone; (7) lacrimal bulla- thin-walled extension of maxillary sinus; (8) frontal bone; (9) zygomatic process of frontal bone; (10) temporal part of frontal bone; (11) temporal line- forms dorsal border of temporal fossa; (12) coronoid process of mandible; (13) cornual process of frontal bone; (14) parietal bone; (15) squamous part of temporal bone; (16) occipital bone; (17) occipital condyle; (18) paracondylar process of occipital bone; (19) tympanic bulla; (20) external acoustic meatus; (21) head of mandible; (22) ramus of mandible; (23) zygomatic bone; (24) inferior molar 2; (25) body of mandible; (26) inferior molar 1; (27) deciduous inferior premolar 4; (28) deciduous inferior premolar 3; (29) deciduous inferior premolar 2; (30) mental foramen; (31) deciduous incisor teeth.

Skull and Paranasal Sinuses of Horse: Related to the large mandible of the horse, the **temporomandibular joint** is located much further dorsally than you might have expected; *it is palpable and observable in the live horse*, and lies caudal to the orbit (Fig. 10-9). The horse possesses a distinct **facial crest**, which extends rostrally from the zygomatic arch and provides for attachment of the powerful masseter muscle. *The facial crest is palpable in the live horse, and is an important clinical landmark.*

Its rostral end is used to help locate the **infraorbital foramen**, from which the **infraorbital nerve** emerges to provide sensory fibers to the muzzle and upper lip (Figs. 10-4 & 10-9). *To locate the infraorbital foramen in the live horse, place your thumb on the rostral end of the facial crest and your middle finger at the palpable* **nasoincisive notch**. *Now, let your index finger fall naturally into position on the horse. By nudging the levator labii superioris dorsally, you can palpate the edge of the foramen with your index finger.*

The **supraorbital foramen**, from which the supraorbital nerve and artery emerge, is located near the zygomatic process of the frontal bone (Fig. 10-11). The **temporal lines** converge dorsally to form the prominent **external sagittal crest**. The temporal lines form the rostromedial boundaries of the **temporal fossae**, which house the massive temporalis muscles.

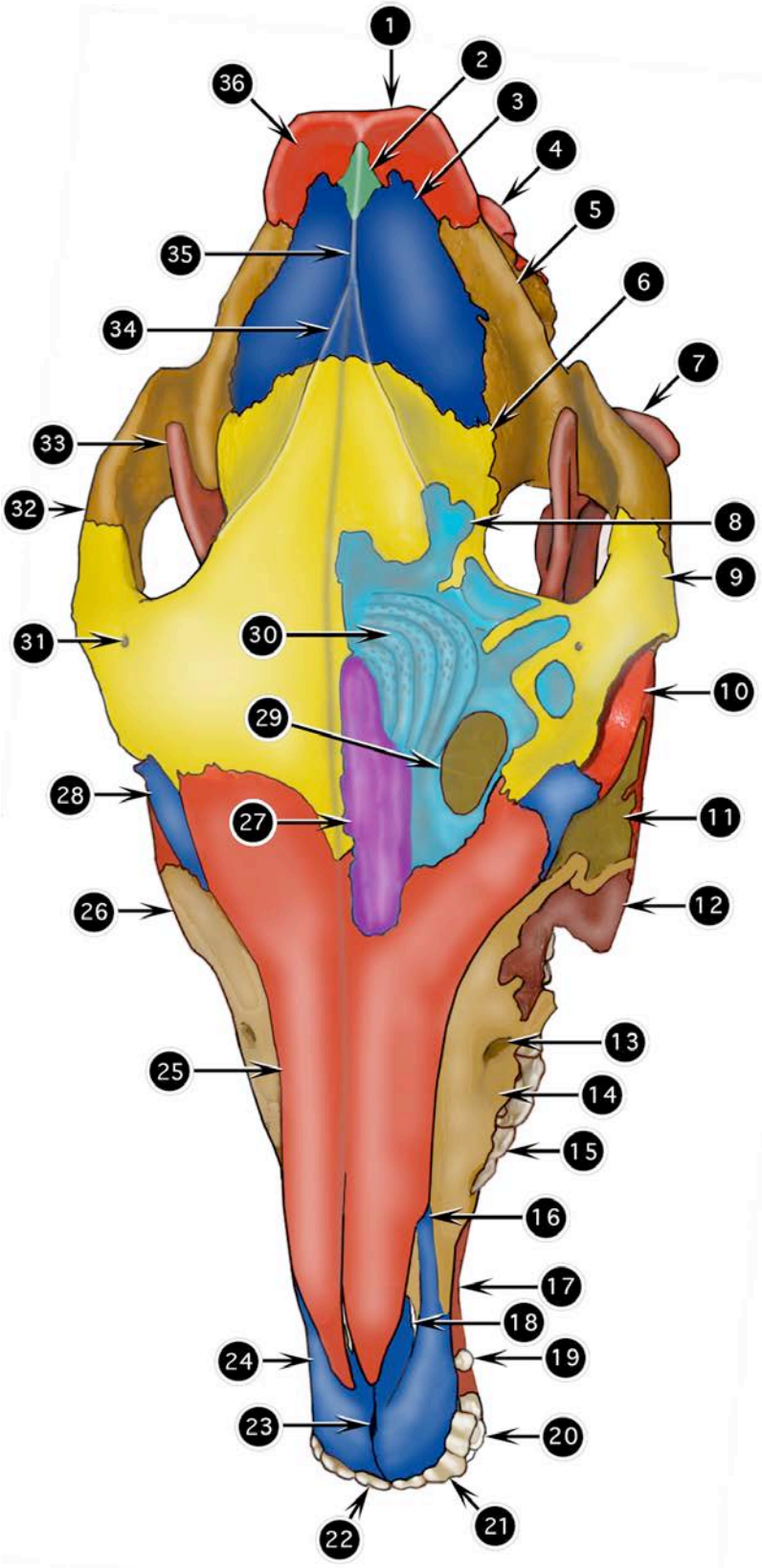


Figure 10-11. Skull of horse, about 8 years old, dorsal oblique view: (1) nuchal crest; (2) interparietal bone; (3) parietal bone; (4) occipital condyle; (5) temporal bone; (6) frontal bone; (7) head of mandible; (8) frontal sinus; (9) zygomatic process of frontal bone; (10) zygomatic bone; (11) caudal maxillary sinus; (12) rostral maxillary sinus; (13) infraorbital foramen; (14) maxillary bone; (15) superior premolar 2; (16) nasoincisive notch; (17) body of mandible; (18) palatine process of incisive bone; (19) inferior canine tooth; (20) inferior corner incisor (I3); (21) superior intermediate incisor (I2); (22) superior central incisor (I1); (23) interincisive canal; (24) incisive bone; (25) nasal bone; (26) facial crest; (27) dorsal conchal sinus (forms conchofrontal sinus with 8; (28) lacrimal bone; (29) frontomaxillary opening; (30) ethmoidal labyrinth; (31) supraorbital foramen; (32) zygomatic arch; (33) coronoid process of mandible; (34) temporal line; (35) external sagittal crest; (36) occipital bone.

The temporalis muscles are most obvious in the stallion and can be observed moving the *palpable* **coronoid process** of the mandible as the horse chews. Like that of the cat, the equine skull possesses a prominent, transversely oriented **nuchal crest**, which forms the skeletal basis of the "poll" in the horse (Fig 10-11).

The **paranasal sinuses** should be studied on a sculptured demonstration skull. Of primary clinical importance is the divided **maxillary sinus** of the horse (Figs. 10-9 & 10-11). As with all paranasal sinuses, they enlarge as the foal matures, and the specific relationships of the **rostral and caudal maxillary sinuses** to the upper cheek teeth change with maturity. In the adult, the thin-walled osseous alveoli over the roots of the cheek teeth are enveloped by the maxillary sinuses.

Note that the **oblique septum**, which separates the rostral and caudal sinuses, is located about 5 cm (2 inches) caudal to the rostral end of the facial crest (Figs. 10-9 & 10-11). Trephination of the maxillary sinuses is sometimes necessary to treat an **infectious sinusitis** and/or to repel an infected molar tooth.[4] It should be obvious that, whenever you're going to be drilling through bone, it's a good idea to know exactly where you are, and what lies under your trephine. There are specific **surgical boundaries** for trephination of the equine maxillary sinuses, as follows:[5]

- **Ventral boundary**- facial crest
- **Rostral boundary**- line from rostral end of facial crest to infraorbital foramen
- **Dorsal boundary**- line from infraorbital foramen to orbit, parallel to facial crest
- **Caudal boundary**- cranial margin of orbit, below dorsal boundary

It is most important that you not violate the dorsal boundary because of the presence of two important structures. High trephination, near the infraorbital foramen, would endanger the infraorbital nerve and vessels, located within the **infraorbital canal** (Fig. 10-9). In addition, the **nasolacrimal canal**, which transmits the nasolacrimal duct, lies just dorsal to the dorsal boundary. Damage to the nasolacrimal duct could produce a tearful, post-surgical situation not only for the horse, but probably for the veterinarian as well.

The **frontal sinus** communicates freely with a cavity within the more caudal part of the dorsal concha, the **dorsal conchal sinus**, and the combined sinus is referred to in the horse as the **conchofrontal sinus** (Fig. 10-11). Another peculiarity of the horse is that the conchofrontal and caudal maxillary sinuses freely communicate through a large hole, the **frontomaxillary opening**. This natural opening can come in handy when it is necessary to repel the last cheek tooth (M3). The horse also has a **sphenopalatine sinus** that extends caudally, ventral to the cranial cavity (Fig. 10-12). This sinus can be seen on the medial surface of your split equine head extending caudally, ventral to the brain.

---

[4] Trephination is a surgical procedure in which a hole is cut in a bone. After surgical exposure of the bone, a hand-powered instrument known as a trephine, which resembles a circle or hole saw, is used to cut a circular hole through the bone. Trephination of sinuses allows for drainage and flushing of an infected sinus and for surgical access to cheek teeth that need to be removed by repelling them into the oral cavity.

[5] Surgical boundaries are the absolute limits of the "safe area;" in practice, stay well inside the boundaries just to be safe. If you mess up here, it could cause some serious consequences *(primum non nocere)*.

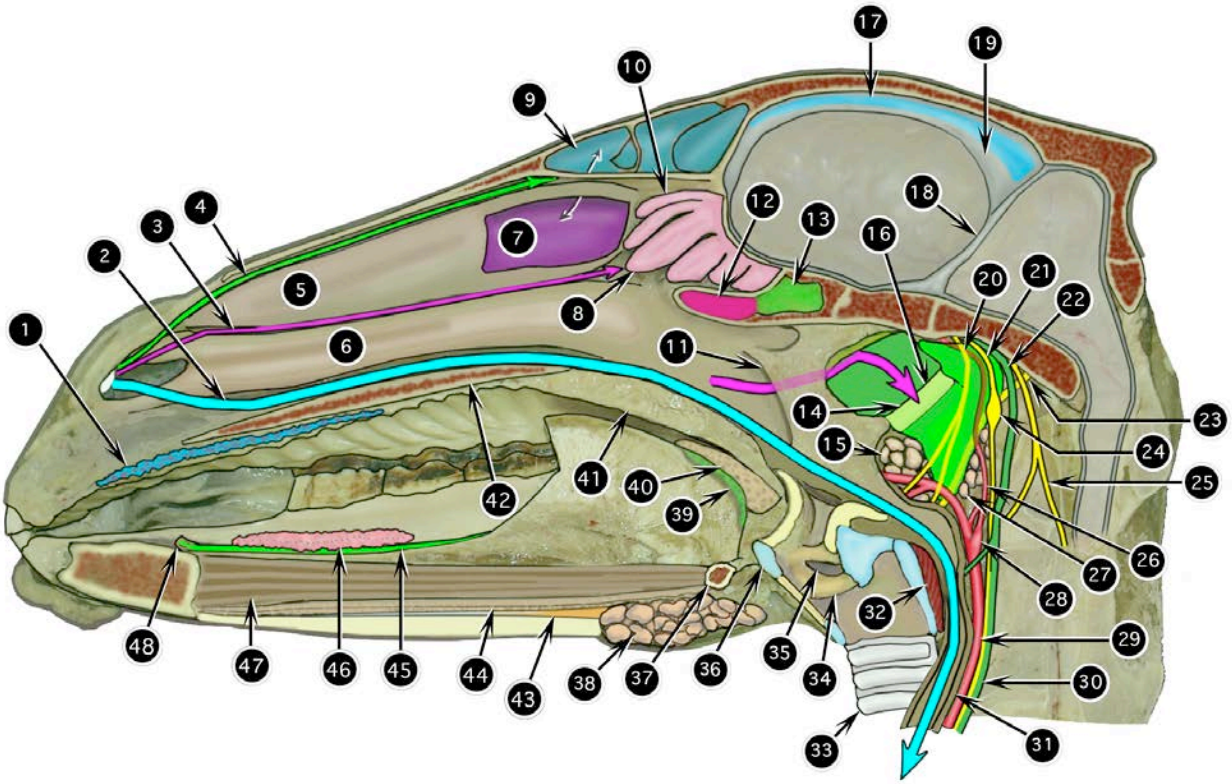


Figure 10-12. Sagittal section of horse head: (1) palatine venous plexus; (2) path of nasogastric tube through ventral nasal meatus, nasopharynx, & laryngopharynx to esophagus; (3) middle nasal meatus; (4) dorsal nasal meatus; (5) dorsal nasal concha; (6) ventral nasal concha; (7) dorsal conchal sinus; (8) middle nasal concha; (9) frontal sinus, forms conchofrontal sinus with 7; (10) ethmoidal labyrinth (conchae); (11) nasopharyngeal opening of auditory tube; (12) palatine sinus; (13) sphenoidal sinus, forms sphenopalatine sinus with 12; (14) stylohyoid bone, partly dividing medial & lateral compartments of guttural pouch; (15) medial retropharyngeal lymph nodes; (16) lateral compartment of guttural pouch; (17) dorsal sagittal sinus; (18) tentorium cerebelli; (19) falx cerebri; (20) glossopharyngeal nerve (CN IX); (21) cervical sympathetic trunk; (22) vagus nerve (CN X); (23) hypoglossal nerve (CN XII); (24) cranial cervical ganglion; (25) accessory nerve (CN XI); (26) internal carotid artery; (27) lateral retropharyngeal lymph nodes; (28) carotid sinus, at origin of 26; (29) common carotid artery; (30) vagosympathetic trunk; (31) esophagus; (32) cricoarytenoideus dorsalis muscle; (33) trachea; (34) vocal fold; (35) laryngeal ventricle; (36) body of thyroid cartilage; (37) basihyoid bone; (38) mandibular lymph nodes; (39) lingual tonsil; (40) palatine tonsil; (41) soft palate; (42) hard palate; (43) rostral belly of digastricus muscle; (44) mylohyoideus muscle; (45) mandibular salivary duct; (46) polystomatic sublingual salivary gland (monostomatic part absent in horse); (47) geniohyoideus muscle; (48) sublingual caruncle, with opening of 45.

Skull and Paranasal Sinuses of Ox: Artiodactyls do not have a facial crest, but only a **facial tuberosity** (Figs. 10-10 & 10-13). The **infraorbital foramen** lies dorsal to the first superior cheek tooth (P2), which is *palpable through the cheek*, and can be used as a landmark for locating the foramen. The **supraorbital foramen** is large and located medial to the orbit in the ox (Fig. 10-13). The large **frontal vein** should be identified as it emerges from the foramen and courses rostrally in a groove. This large vein should be avoided when trephination of the frontal sinus is performed.

The frontal bones of the ox expand greatly as the calf matures into the adult, which accounts for the drastic change in head shape from the dome-like, "puppy skull" of the calf to the larger, more angular shape of the adult ox skull.

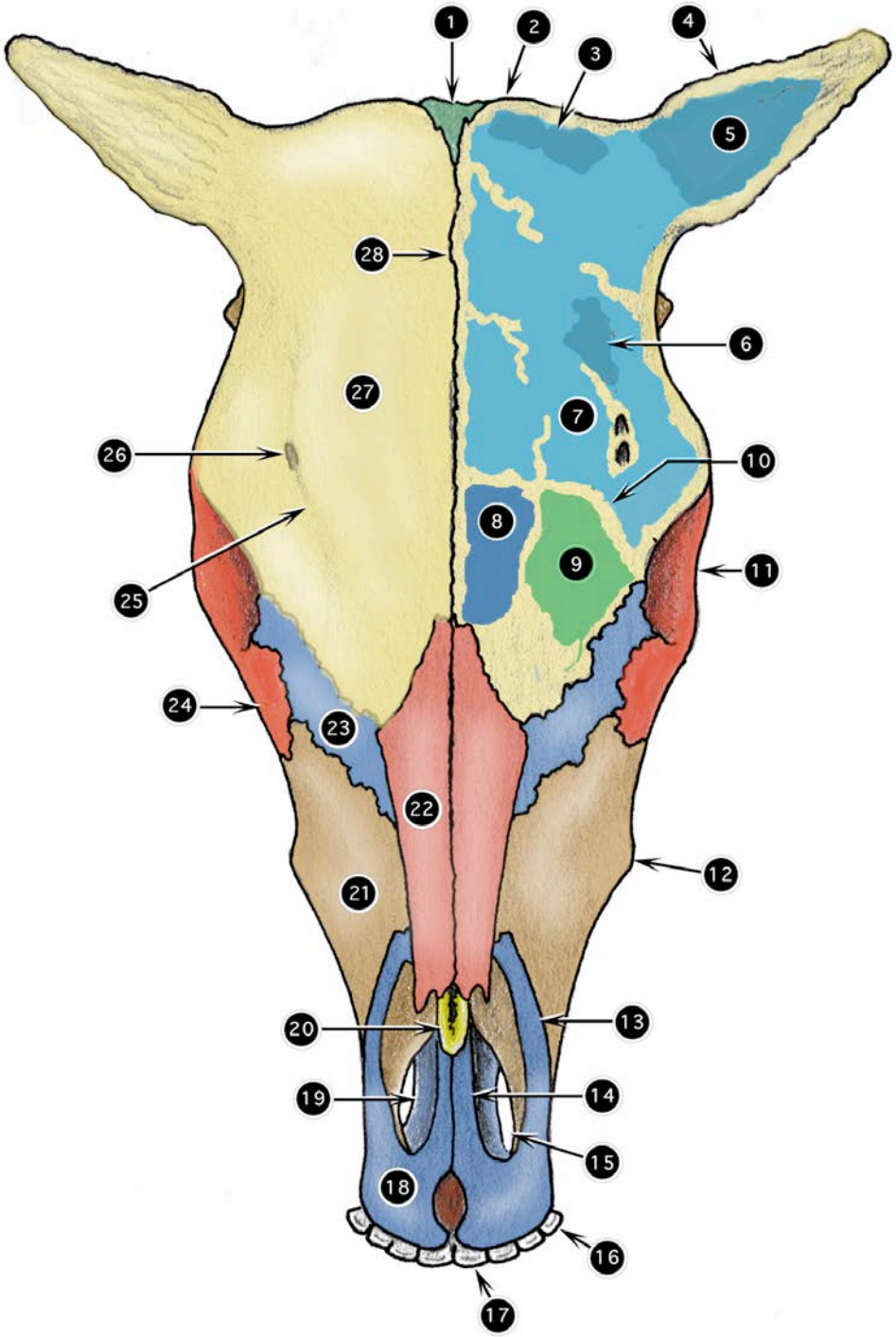


Figure 10-13. Skull of a Holstein steer, about 14 months old, dorsal view with paranasal sinuses superimposed on left side: (1) interparietal bone; (2) intercornual protuberance; (3) nuchal diverticulum of caudal frontal sinus; (4) cornual process of frontal bone; (5) cornual diverticulum of caudal frontal sinus; (6) post-orbital diverticulum of caudal frontal sinus; (7) caudal frontal sinus; (8) medial rostral frontal sinus; (9) lateral rostral frontal sinus; (10) oblique septum separating rostral and caudal frontal sinuses; (11) zygomatic arch; (12) facial tuberosity; (13) nasal process of incisive bone; (14) palatine process of incisive bone; (15) palatine fissure; (16) deciduous incisor 4; (17) deciduous incisor 1; (18) incisive bone; (19) mandible; (20) vomer; (21) maxillary bone; (22) nasal bone; (23) lacrimal bone; (24) zygomatic bone; (25) supraorbital groove- accommodates frontal vein; (26) supraorbital foramen; (27) frontal bone; (28) interfrontal suture.

This frontal expansion is related to the development of the large frontal sinuses, which continue to enlarge somewhat as the animal ages. As the frontal bones expand laterally, the **temporal lines** are pushed over the sides of the skull so that they end up on the lateral sides (Fig. 10-10). Thus, the **temporal fossa** is relegated to a more or less concealed lateral position, between the zygomatic arch and temporal line. Note: The temporal line of the ox is often misidentified as the so-called "frontal crest."

The temporal line is palpable and is an important landmark in blocking the cornual nerve for dehorning (Fig. 10-5). The ox does not have a nuchal crest, but the **intercornual protuberance** forms the "poll."[6] In horned animals, the **cornual process** of the frontal bone forms the osseous base for the horn, and the **frontal sinus** invades this process as the **cornual diverticulum** (Fig. 10-13).

On the demonstration skulls, note that the frontal sinus of the ox is divided into several compartments, which are usually considered as separate sinuses. The largest of these is the **caudal frontal sinus**, which is the one that extends into the cornual process (Fig. 10-13). Infectious sinusitis of the ox is a potential sequela of dehorning when done after the cornual diverticulum has invaded the cornual process. The **oblique septum**, which separates the caudal frontal sinus from the **rostral frontal sinuses** begins about the middle of the orbit and continues at about a 45-degree angle to the median septum (Fig. 10-13). Trephination of the caudal sinus must be done caudal to this septum if the caudal sinus is to be accessed and drained. Also, note the **post-orbital and nuchal diverticula** (Fig. 10-13), which are difficult to drain. The medial and lateral **rostral frontal sinuses** are located rostral to the septum (Fig. 10-13).

The **maxillary sinus** of the ox is not divided into rostral and caudal compartments, but has a clinically important diverticulum that extends caudally under the eye. This is the **lacrimal bulla**, which is an extremely thin-walled (eggshell) extension of the maxillary sinus (Fig. 10-10). Because of its location, it is vulnerable to damage during radical enucleation of the bovine eye. A radical enucleation is usually carried out because of an advanced malignancy, typically squamous cell carcinoma or "cancer eye" in cattle. The lacrimal sinus is a completely separate structure; it has nothing to do with the lacrimal bulla. The maxillary sinus communicates freely over the top of the infraorbital canal with the **palatine sinus**, a large excavation in the hard palate. The palatine sinus can be seen on the medial surface of the split bovine heads.

Skull and Paranasal Sinuses of Small Ruminants and Pig: There is no caudal frontal sinus in small ruminants. In horned sheep and goats, it is the **lateral frontal sinus** that extends into the cornual process (see demonstration specimens).

Although poorly developed or absent in the newborn pig, the extensive paranasal sinuses of the adult form a complex of air-filled spaces that almost completely surrounds the cranial cavity. The frontal sinuses are divided into rostral and caudal parts, and a large sphenoid sinus develops. The maxillary sinuses even invade the rostral parts of the zygomatic arches. Refer to a demonstration specimen and note the many complicated diverticula in the paranasal sinuses of the adult pig.

[6] Even if there aren't any cornuals to be between, as is the case with polled breeds.

What purpose do paranasal sinuses serve, besides causing problems when they get congested or infected? Because of their communication with the nasal cavity, they are usually considered with the respiratory system, even though they do not have any recognized respiratory function. In essence, these sinuses allow for substantial expansion (growth) of the head, without a commensurate increase in the weight of the head. Paranasal sinuses develop, to a large degree postnatally, as excavations between the inner and outer compact tables of the cranial and facial bones. Thus, they represent a type of "pneumatization" of bone similar to that which occurs in most birds. By expanding the bones through this pneumatization, the head becomes larger to accommodate more "things" (*viz*. teeth, glands, tongue, etc.) and to provide a collapsible, non-vital protective shell around the brain. In other words, the sinuses allow for the head to get big and strong, without becoming so heavy that the animal could not hold it up.

Mandibular Salivary Gland: The mandibular gland of the pig more closely resembles that of the carnivores, but it is larger in the ruminants (Fig. 10-2). In the horse, the gland is considerably smaller than the parotid gland. If you haven't already done so, identify the mandibular lymph nodes (Figs. 10-2, 10-5, 10-7, & 10-12) and isolate them from the salivary tissue.

Sternomandibularis Muscle: Recall that this muscle is absent in the sheep (lack of ventral boundary of jugular groove). In the goat, the tendon blends with the aponeurotic covering of the masseter (not to the mandible), and fibers continue to the zygomatic arch.

Lateral Retropharyngeal Lymph Node: This node is related to the wing of the atlas and should be identified (Fig. 10-6). Knowledge of the lymph nodes of the head has special significance in food animals. Lymph nodes provide an index to the health of the animal and are therefore examined on the carcass and offal (viscera). Lymph nodes of the head receive considerable attention during meat inspection.

Auriculopalpebral Nerve: In the ox, trace the dorsal buccal branch of CN VII into the parotid gland and identify the origin of the **ventral buccal branch** in the substance of the gland (Fig 10-5). Note the separation of the **auriculotemporal nerve** (from CN V) and identify the origin of the **auriculopalpebral nerve** (Figs. 10-4 & 10-5). Trace the latter branch of the facial nerve toward the eye and ear, noting where it crosses the zygomatic arch.

In the horse, the nerve passes almost straight dorsally to near the base of the ear, and then turns rostrally to cross the zygomatic arch (Fig. 10-4). *Palpate the auriculopalpebral nerve in the live horse by running your fingers rostrally and caudally along the arch, just caudal to its highest point*. Here the palpebral branch of the nerve can be blocked. Although blocking the auriculopalpebral nerve does nothing to anesthetize the eye, this block paralyzes the **orbicularis oculi muscle**, which prevents the animal from clamping the palpebral fissure shut. This can greatly facilitate examination and treatment of the eye.

Transverse Facial Vessels of Ruminant: Trace these vessels caudally and identify the large parotid lymph node (Fig. 10-2), which is partially covered by the parotid salivary gland. Continue tracing the artery caudally to identify the superficial temporal artery (Fig. 10-14).

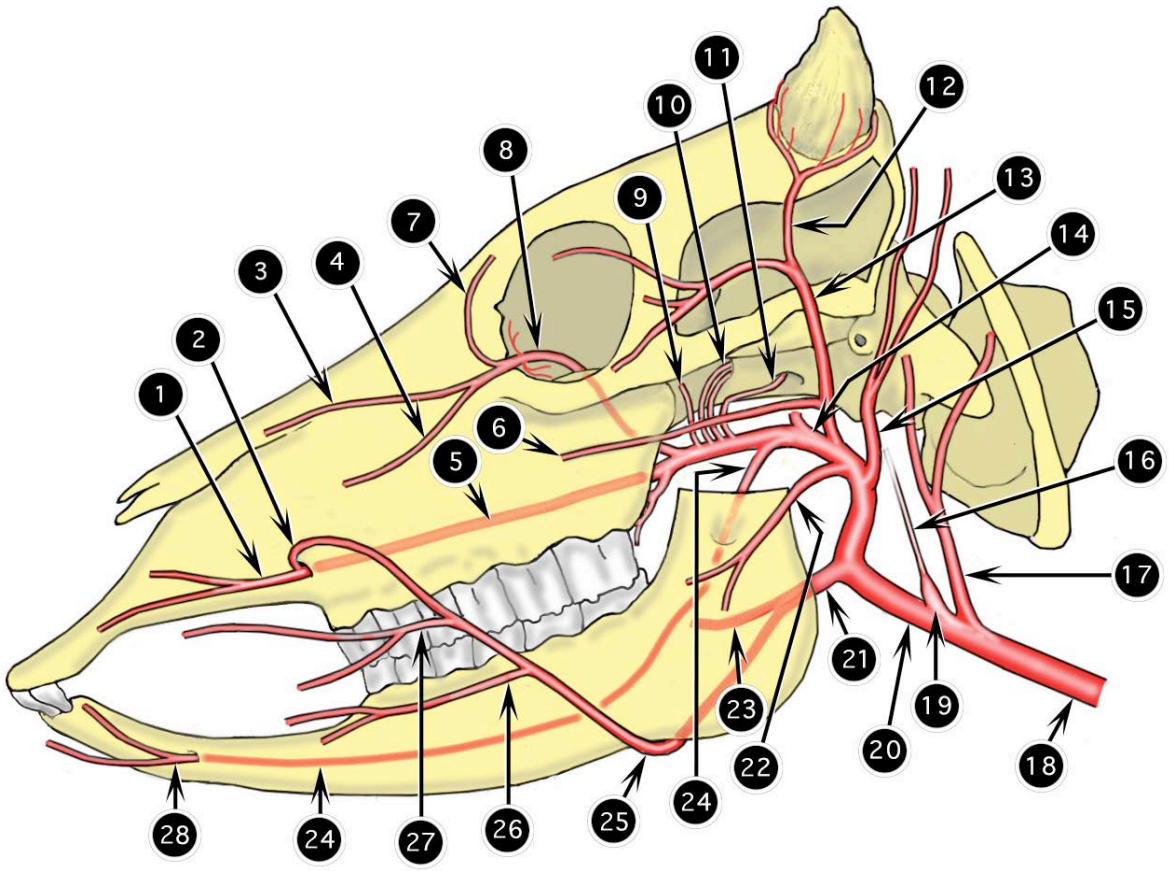


Figure 10-14. Branches of common carotid artery of ox, lateral view: (1) rostral lateral nasal artery; (2) anastomosis of infraorbital & facial arteries; (3) dorsal nasal artery; (4) caudal lateral nasal artery; (5) infraorbital artery within infraorbital canal; (6) transverse facial artery; (7) angular artery of eye; (8) malar artery; (9) external ophthalmic artery; (10) rostral branches to epidural rete mirabile, entering foramen orbitorotundum; (11) caudal branch to epidural rete mirabile, entering oval foramen; (12) cornual artery; (13) superficial temporal artery; (14) maxillary artery; (15) caudal auricular artery; (16) internal carotid artery, extracranial part degenerates shortly after birth; (17) occipital artery; (18) common carotid artery; (19) carotid sinus at origin of 16; (20) external carotid artery; (21) linguofacial trunk; (22) masseteric artery; (23) lingual artery; (24) inferior alveolar artery; (25) facial artery; (26) inferior labial artery; (27) superior labial artery; (28) mental artery, emerging from mental foramen as continuation of 24.

Superficial Temporal Artery of Ox: After this vessel has been identified, follow the superficial temporal artery dorsally across the zygomatic arch and identify the **cornual artery**, which is given off toward the horn as the superficial temporal turns rostrally toward the eye (Fig. 10-14). Follow the cornual artery to observe its division into dorsal and ventral branches, and continue tracing these branches to the base of the horn. Branches of the cornual artery are cut during dehorning and may be clamped to reduce hemorrhage.

Occipitomandibular Part of Digastricus Muscle in Horse: As the name implies, the digastricus muscle typically consists of two bellies (stomachs). In the carnivores, the two bellies are fused and indistinct. In the ungulates, the rostral and caudal bellies are separated by an intermediate tendon; however, the horse has an additional part. This occipitomandibular part of the

digastricus does not attach to the intermediate tendon of the muscle, but extends from the large paracondylar process of the occipital bone directly to the caudal border of the mandible. It thus forms an obstacle to a lateral surgical approach to the guttural pouch.

Termination of Common Carotid Artery: Division of the common carotid artery can usually be better observed from the medial surface of your specimen. The **internal carotid artery** branches from the common carotid at the level of the atlas, and the **external carotid artery** continues toward the mandible (Figs 10-14 & 10-15). The internal carotid artery arises in close association with the **occipital artery**, which is directed more dorsolaterally toward the atlas. The internal carotid courses more rostromedially to the **foramen lacerum** (Fig. 10-15). In some horses, the two arteries arise by a short common trunk.

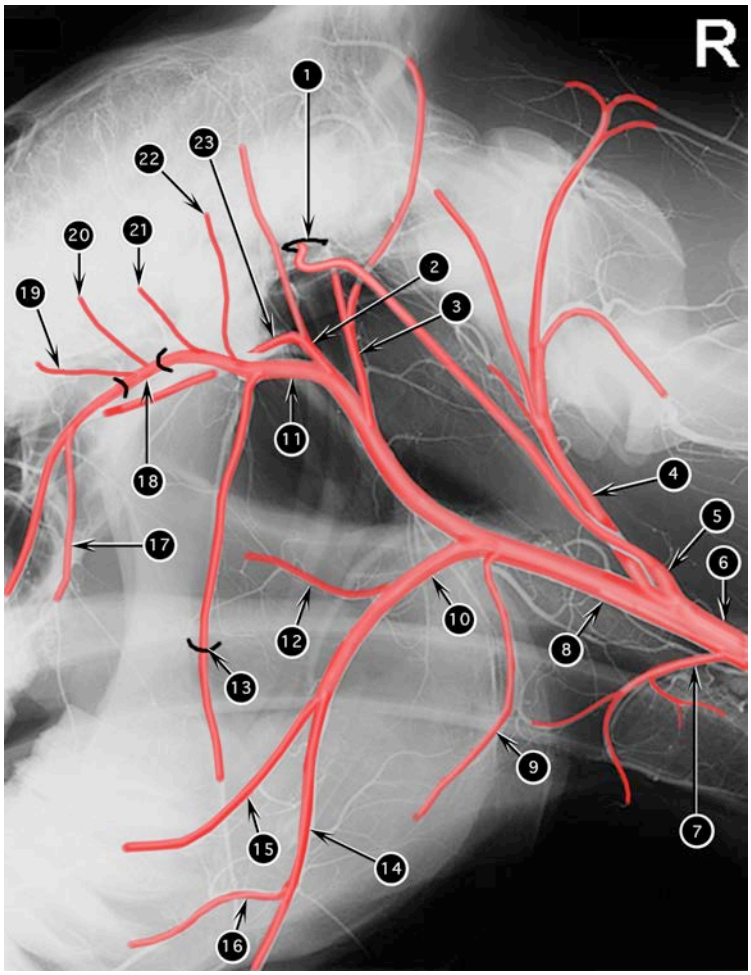


Figure 10-15. Left-right lateral arteriogram of common carotid artery of horse, with major arteries highlighted: (1) internal carotid artery entering foramen lacerum; (2) superficial temporal artery; (3) caudal auricular artery; (4) occipital artery; (5) carotid sinus at origin of 1; (6) common carotid artery; (7) cranial thyroid artery; (8) external carotid artery; (9) masseteric artery; (10) linguofacial trunk; (11) maxillary artery; (12) ascending palatine artery; (13) inferior alveolar artery entering mandibular foramen; (14) facial artery; (15) lingual artery; (16) sublingual artery; (17) buccal artery; (18) maxillary artery passing though alar canal; (19) external ophthalmic artery; (20) rostral deep temporal artery; (21) caudal deep temporal artery; (22) middle meningeal artery; (23) transverse facial artery. (Arteriogram courtesy of Dr. Anthony Pease.)

The division and subsequent ramification of the equine internal carotid artery is similar to the pattern observed in the dog. One point of interest, however, is the important relationship of the internal carotid artery to the guttural pouch. The artery curves through the caudodorsal wall of the pouch, where it is enveloped by a mesentery-like fold of the pouch wall (Figs. 10-12 & 10-19).

In the ruminant, the extracranial part of the internal carotid artery degenerates postnatally, leaving only a thin, fibrous remnant (Fig. 10-14). The intracranial part remains patent, however, and is supplied indirectly by branches of the maxillary artery through the rostral epidural rete mirabile (Fig. 10-14). This postnatal degeneration of the extracranial part of the artery is similar to that which occurs in the cat. In the ruminant, degeneration is thought to be related to a physiologic adaptation for grazing. When the ruminant lowers its head for grazing, the sudden change in head position from above the heart to several feet below it results in a high-pressure rush of arterial blood to the internal carotid artery because of the abrupt reduction in hydrostatic ("hemostatic") pressures.

If the internal carotid artery were patent, this high-pressure surge would be directly transmitted through the cerebral circle to the cerebral arteries, which could result in significant stress (if not rupture) of the cerebral arteries. Thus, to remove this direct route to the cerebral arteries, the ruminant simply closes off the expressway and detours the blood through a meshwork of small arteries, the **epidural rete mirabile** (Fig. 10-18). This mesh of small vessels acts a sort of "surge protector" by capturing the high-pressure rush and releasing it as a more moderate, more even flow to the cerebral circle. If this surge protector were not present, imagine what might happen when say a giraffe lowered its head to drink. As the head is moved rather quickly from about 6 feet above the heart to 6 feet below it, an "intracranial incident" could occur. This adaptation, therefore, is for the immediate changes in hemostatic pressures, before the reflex lowering of pressure can be effected by the carotid body-baroreceptor mechanism.[7]

Guttural Pouches of Horse: Please note that the correct spelling is guttural, not gutteral. Although present in several wild species of perissodactyls (*e.g.,* zebra, tapir, rhinoceros), these peculiar dilatations of the auditory tubes are unique, among our domestic species, to equidae (Fig. 10-19). Each pouch normally contains about 300 ml of air. They are related dorsally to the base of the skull, atlas, axis, and several muscles, the largest of which is the **longus capitis**.

The two pouches are separated by a thin *septum* (sort of a "mediastinum gutturalis") formed by the adjacent walls of the right and left pouches (Fig. 10-16). Note how they saddle the dorsolateral aspect of the pharynx (Fig. 10-19). Enlargement (distention) of one or both pouches can compress the pharynx and result in dyspnea and/or

[7] It is my opinion that most quadrupeds have devised some mechanism to regulate immediate fluctuations in intracranial blood pressure resulting from sudden changes in head position relative to the heart. Postnatal closing off of the extracranial part of the internal carotid artery is an obvious solution that serves the ruminant and cat. The surge protectors of the dog and horse are less conspicuous, but present nevertheless. In the dog, the little loop of internal carotid artery that just sticks out through the foramen lacerum (external carotid foramen) and then turns back inside the cranial cavity serves this same purpose. By acting like a slide on a trombone, this loop catches the pulsations, dampens them like a spring, and converts the highly pulsate pre-loop flow to a more even post-loop flow. As for the horse, this may well be what the guttural pouches are about.

dysphagia. Note also that each pouch is subdivided into medial and lateral compartments by the **stylohyoid bone**, which indents the pouch ventrally (Figs. 10-16 & 10-19).

The medial compartment is considerably larger than the **lateral compartment**, and extends much further ventrally and caudally. Because of this difference, the two compartments, although superimposed, can be differentiated in lateral radiographs of the equine head (Fig. 10-17).

The guttural pouches are clinically important in the horse because they frequently become involved in upper respiratory infections that enter the pouches through their openings to the nasopharynx. One type of infection (guttural pouch mycosis) is caused by an opportunistic fungus (*Aspergillus fumigatus*)[8] and can have serious consequences. This fungal infection has a predilection for the dorsal part of the pouch, which is intimately related to the internal carotid artery. Such fungal infections can erode the thin wall of the pouch and wall of the artery, which can cause rupture of the artery and subsequent flooding of the pouch with arterial blood. When the pouch is full, blood runs out of its opening into the nasopharynx and then through the nasal cavity to the outside, producing severe epistaxis (nosebleed).

Remove the rostral part of the longus capitis muscle on one side of the head. Note the many vital structures that are closely associated with the wall of the guttural pouch. The **glossopharyngeal nerve** closely parallels the **hypoglossal nerve**, which can be observed passing lateral to the **external carotid artery** at about the level of origin of the **linguofacial trunk** (Fig. 10-19). The glossopharyngeal nerve crosses the medial aspect of the artery at about the same level. In addition, the **occipital and internal carotid arteries**, the **vagus nerve**, the **sympathetic trunk**, **cranial cervical ganglion**, and the **accessory nerve** all are closely related to the pouch in this area (Fig. 10-19). As you may recall, Viborg's triangle is used as one avenue of approach for surgical drainage of the guttural pouch (Fig. 2-5). Consider the potential consequences of accidentally damaging one of the aforementioned structures during such an operation. With the advent of the flexible fiberoptic scope, clinical examination of the guttural pouches of the horse has been greatly enhanced.

Both medial and lateral retropharyngeal lymph nodes are associated with the wall of the guttural pouch, and the two groups coalesce at the division of the common carotid artery (Fig. 10-19). The larger **medial retropharyngeal lymph nodes** are those most closely associated with the wall of the pharynx, whereas the **lateral nodes** lie more on the caudodorsal aspect of the pouch near the internal carotid artery and wing of the atlas. Because of the close relationship of these two groups in the horse, they can be considered collectively as retropharyngeal lymph nodes.

What's the Purpose of the Guttural Pouches Anyway? For hundreds of years, people have known about, and some have even described in exquisite detail, the guttural pouches of the horse, but good luck on trying to find out what purpose they serve. Because of their direct communication with the nasopharynx, most explanations try to tie them in some way with the respiratory system. But what respiratory function do they serve? I submit that the guttural pouches may have little, if anything, to do with the respiratory system,

[8] Barakzai, Safia: Handbook of equine respiratory endoscopy. Saunders/Elsevier, Philadelphia, 2007.

but serve primarily a cardiovascular function.

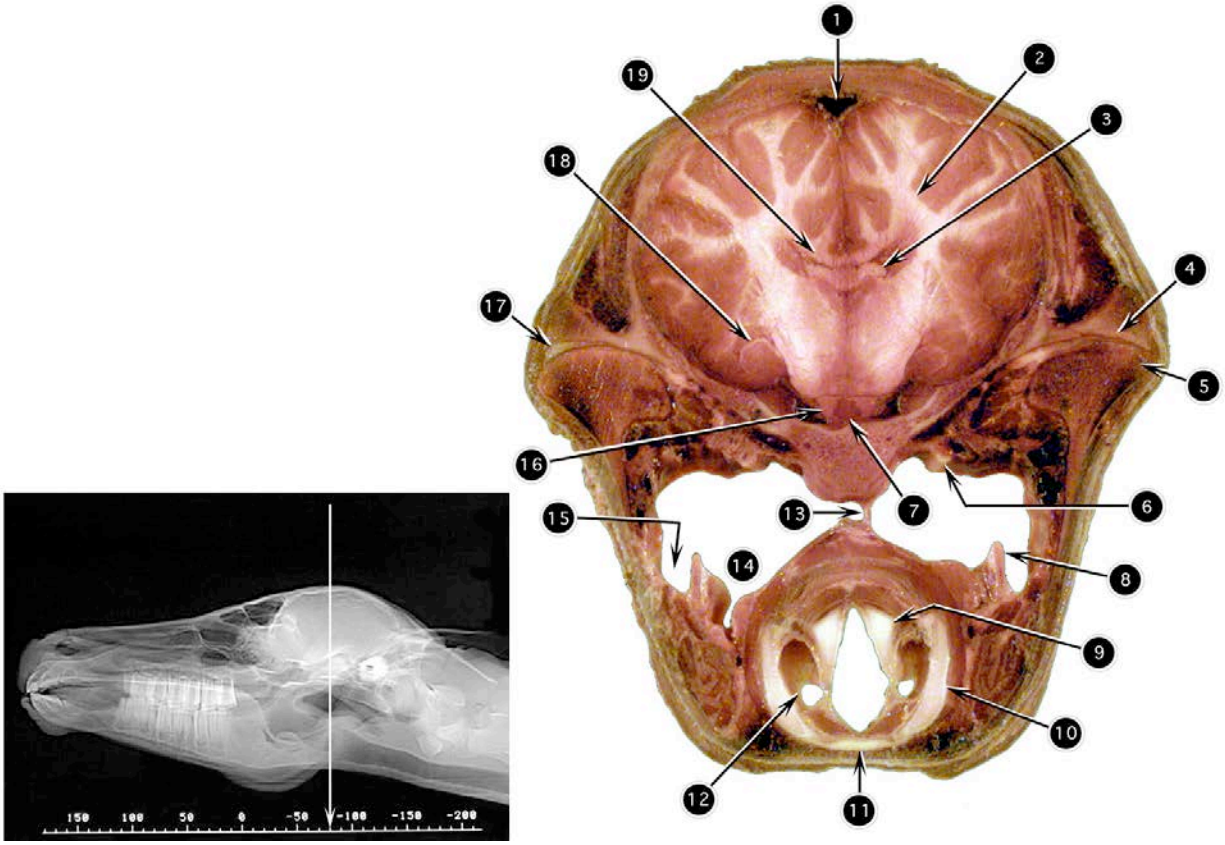


Figure 10-16. Transverse section through head of 5-week-old foal at level indicated in reconstructed CT image, caudal view: (1) dorsal sagittal sinus within falx cerebri; (2) corona radiata; (3) body of fornix; (4) mandibular fossa; (5) head of mandible; (6) internal carotid artery; (7) neurohypophysis of pituitary gland; (8) stylohyoid bone dividing guttural pouch into medial and lateral compartments; (9) arytenoid cartilage; (10) thyroid cartilage; (11) cricothyroid ligament; (12) laryngeal ventricle; (13) septum between right and left guttural pouches; (14) medial compartment of guttural pouch; (15) lateral compartment of guttural pouch; (16) adenohypophysis of pituitary gland; (17) articular disc of temporomandibular joint; (18) hippocampus; (19) corpus callosum.

In addition to cooling the arterial blood prior to reaching the brain, the pouches also function to regulate intracranial blood pressure through their intimate relationship with the internal carotid artery. My hypothesis is that the guttural pouches of the horse serve as “pneumatic cuffs” around the internal carotid arteries, and work in the following way. When a horse lowers its head to graze or drink, the abundant soft tissues on the caudodorsal aspect of the pouch (lymph nodes, salivary tissue, etc.) fall forward and compress the pouch. Assuming the horse can concurrently close off the pharyngeal opening, air pressure within the pouch goes up (like in a blood pressure cuff) and the artery, suspended in its little "mesartery" and surrounded by air, is compressed. This compression reduces the diameter of the artery, thereby increasing resistance and serving to prevent a high-pressure surge of blood pressure into the cerebral circulation until the baroreceptor reflex can accommodate for the change in hemostatic pressure. In essence, the horse has solved the same problem as the ruminant and cat with their rete mirabile (plan A), by

using an entirely different strategy (plan B).
(The dog chose plan C.)

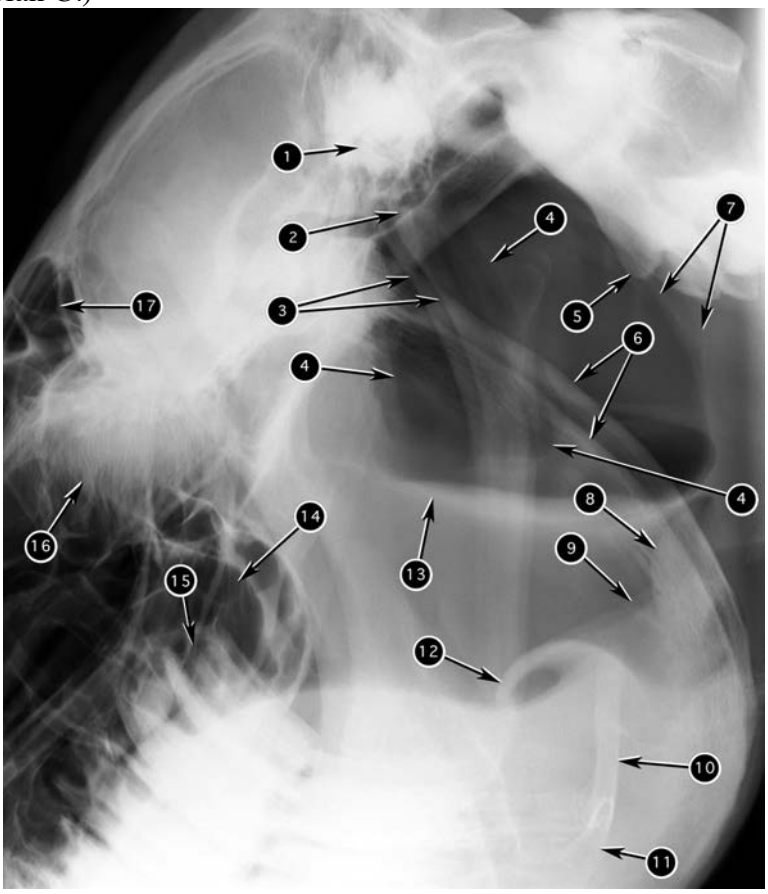


Figure 10-17. Left-right lateral radiograph of equine guttural pouch region: (1) petrous temporal bones; (2) tympanohyoid cartilage; (3) stylohyoid bones; (4) lateral compartments of guttural pouches; (5) ventral tubercle of atlas; (6) caudal borders of mandibles; (7) medial compartments of guttural pouches; (8) corniculate process of arytenoid cartilage; (9) aryepiglottic fold; (10) thyrohyoid bone; (11) basihyoid bone; (12) epiglottis; (13) dorsal wall of nasopharynx; (14) caudal maxillary sinus; (15) superior molar 3; (16) ethmoidal conchae; (17) conchofrontal sinus.

Medial Retropharyngeal Lymph Nodes of Ox: Locate these important lymph nodes in the fat caudodorsal to the pharynx (Fig. 10-18). The right and left nodes lie adjacent to one another on the caudodorsal wall of the nasopharynx. When these nodes become enlarged, which can occur when there is infection being drained from the pharynx, they can compress the nasopharynx, resulting in dyspnea and/or dysphagia (effect comparable to guttural pouch distention in the horse).

Nasal Cavity: There is only one nasal cavity per animal (not right and left, as is often stated). The two sides are separated by a substantial **nasal septum** (Fig. 10-18), which is formed primarily of hyaline cartilage, covered on each side by a highly vascular mucous membrane. The cartilaginous septum is supported ventrally by a trough provided by the **vomer**. It extends caudally to the level of the nasopharynx, where in the ruminant and pig, it is continued by the pharyngeal septum.

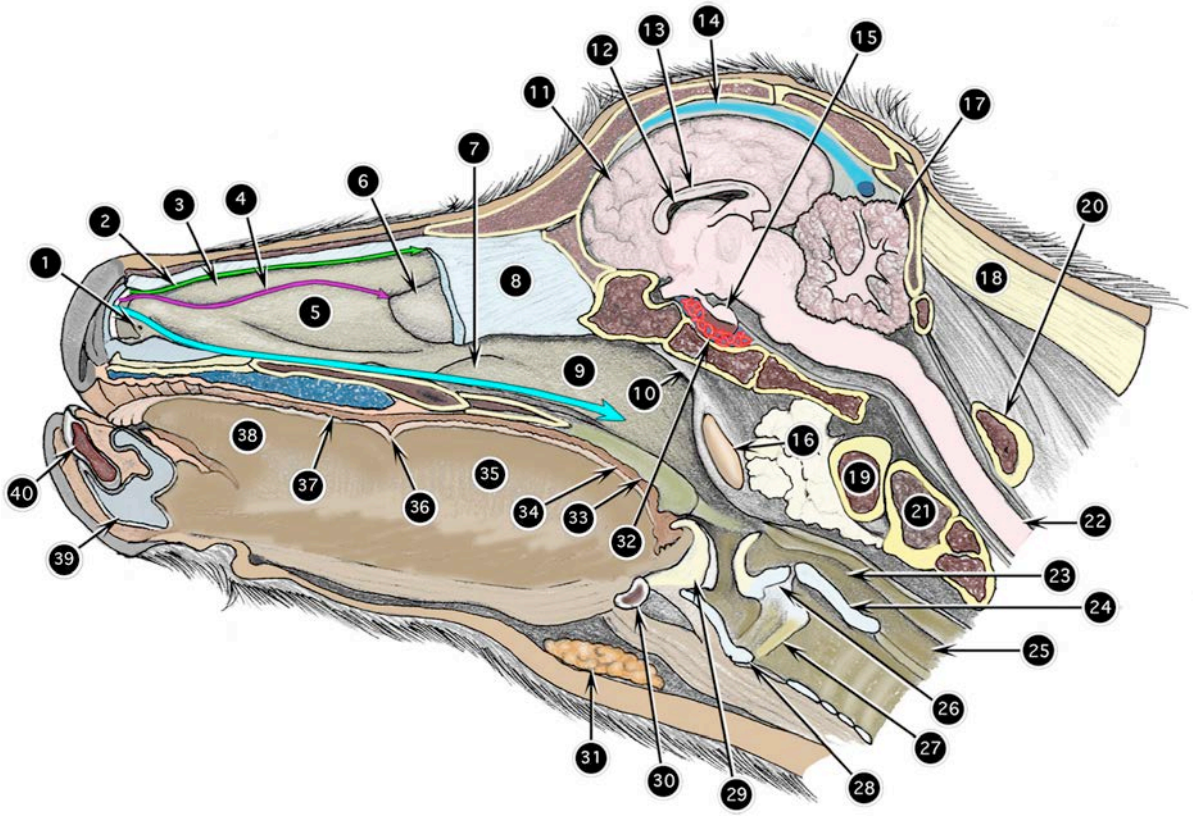


Figure 10-18. Sagittal section of newborn calf head: (1) nasal orifice of nasolacrimal duct; (2) dorsal nasal meatus; (3) dorsal nasal concha; (4) middle nasal meatus; (5) ventral nasal concha; (6) middle nasal concha; (7) ventral nasal meatus; (8) nasal septum, mostly removed; (9) nasopharynx; (10) location (hidden) of pharyngeal opening of auditory tube; (11) right cerebral hemisphere; (12) right lateral ventricle; (13) corpus callosum; (14) falx cerebri, enclosing dorsal sagittal sinus; (15) hypophysis (pituitary gland); (16) right medial retropharyngeal lymph node; (17) cerebellum; (18) funiculus nuchae; (19) ventral arch of atlas; (20) dorsal arch of atlas; (21) dens of axis; (22) spinal cord; (23) laryngopharynx; (24) cricoid cartilage; (25) esophagus; (26) right arytenoid cartilage; (27) right vocal fold; (28) thyroid cartilage; (29) epiglottis; (30) basihyoid bone; (31) mandibular salivary gland; (32) epidural rete mirabile; (33) soft palate; (34) oropharynx; (35) body of tongue; (36) fossa linguae; (37) oral cavity; (38) apical part of tongue; (39) intermandibular joint; (40) deciduous incisor teeth.

Depending on how accurately your head was split, the septum may be confined to only one side of the divided head. If the saw-blade divided the septum, *you should now remove it from one side of the head in order to expose the structures of the nasal cavity* (Fig. 10-18).

Nasal Conchae and Meatuses: Each half of the nasal cavity is mostly filled with the delicate, shell-like nasal conchae,[9] which, like the septum, are covered with a highly vascular mucous membrane. Although the relative size and shape of the conchae vary among species, their designation is the same. Between the nasal bones and the **dorsal concha** is the small **dorsal nasal meatus**, between the dorsal and ventral conchae is

[9] concha- resembling a shell or a conch. In clinical usage, these structures are often referred to as turbinates because of their apparent function of swirling the inspired air like a turbine, thus slinging a lot of material out of the polluted air and up against the walls of the nasal cavity. Here the dust, or whatever, sticks to the mucous film and, by ciliary action, is moved to the pharynx, where it is swallowed.

the **middle nasal meatus**, and below the **ventral concha** is the large **ventral nasal meatus** (Fig. 10-18). Next to the nasal septum is a vertical slit, the **common nasal meatus**, which connects the other three meatuses along side the septum (Fig. 10-20).

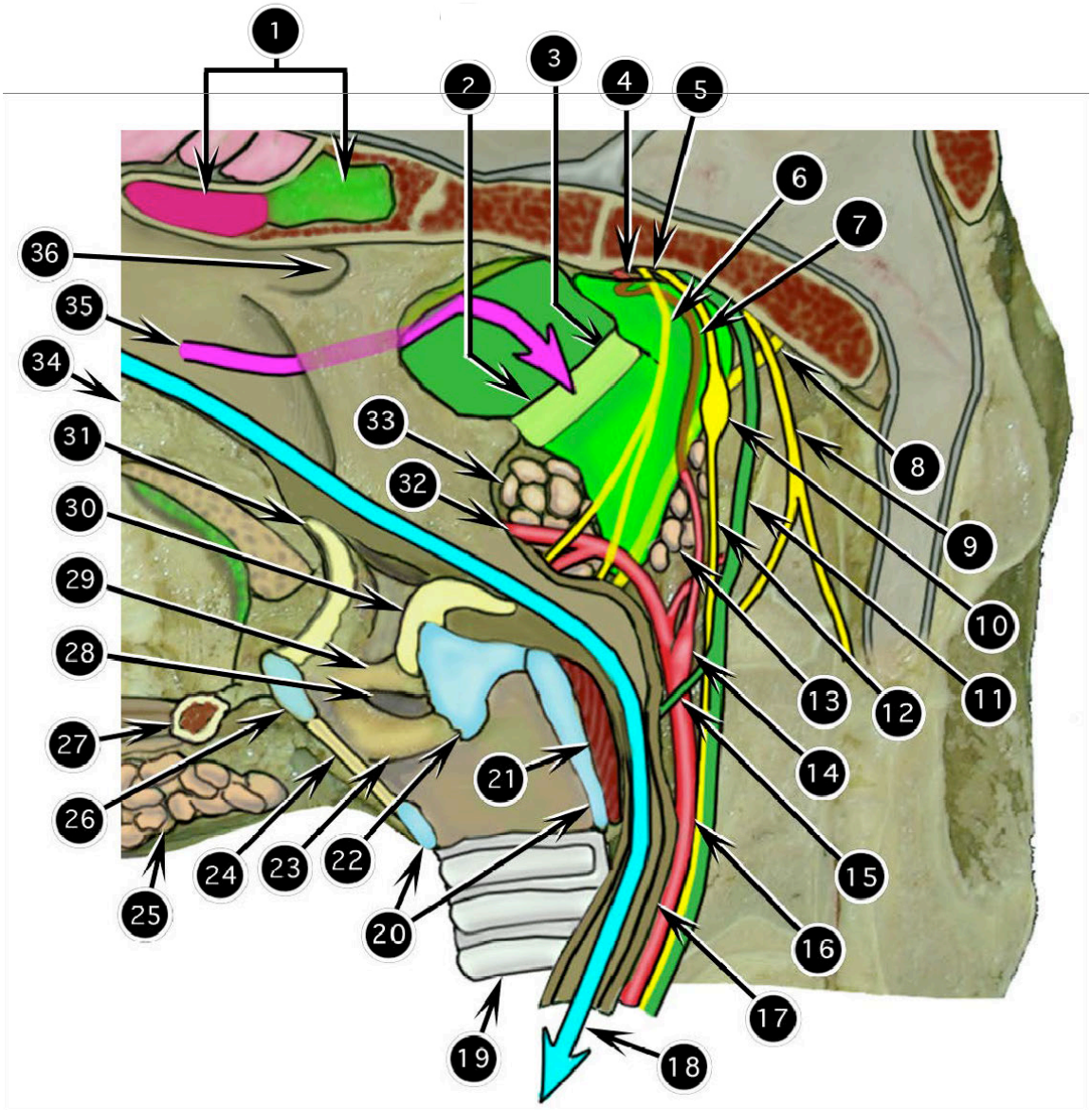


Figure 10-19. Sagittal section of equine pharyngeal region: (1) sphenopalatine sinus; (2) stylohyoid bone, partly dividing guttural pouch into medial & lateral compartments; (3) lateral compartment of guttural pouch; (4) sigmoid flexure of internal carotid artery; (5) location of tympano-occipital fissure; (6) glossopharyngeal nerve (CN IX); (7) internal carotid artery enveloped by fold of guttural pouch mucosa; (8) hypoglossal nerve, emerging from hypoglossal canal; (9) accessory nerve (CN XI); (10) cranial cervical ganglion; (11) vagus nerve (CN X); (12) cervical sympathetic trunk; (13) lateral retropharyngeal lymph nodes; (14) carotid sinus, at origin of internal carotid artery; (15) cranial laryngeal nerve; (16) common carotid artery; (17) esophagus; (18) path of nasogastric tube; (19) trachea; (20) cricoid cartilage; (21) cricoarytenoideus dorsalis muscle; (22) vocal process of arytenoid cartilage; (23) vocal fold; (24) cricothyroid ligament, filling thyroid notch; (25) mandibular lymph nodes; (26) body of thyroid cartilage; (27) basihyoid bone; (28) laryngeal ventricle; (29) vestibular fold, contains cuneiform process of epiglottic cartilage; (30) corniculate process of arytenoid cartilage; (31) epiglottic cartilage; (32) external carotid artery; (33) medial retropharyngeal lymph nodes; (34) soft palate; (35) path of flexible fiberoptiscope passing through pharyngeal orifice of auditory tube into guttural pouch; (36) pharyngeal recess.

The nasal cavity is separated from the oral cavity by the **hard palate**. At the caudal border of the hard palate, the **soft palate** extends caudally and similarly divides the nasopharynx above, from the oropharynx below (Fig. 10-18). As noted, the hard palate of the ruminant is excavated to house the **palatine sinus**. The right and left openings of the nasal cavity into the nasopharynx, which are separated by the vomer, are the **nasal choanae**.[8]

The **dorsal concha** of the horse is large and is invaded caudally by the **dorsal conchal sinus** (Fig. 10-12). The **ventral concha** extends rostrally to the **vestibule** of the nasal cavity, where it is continued by alar and basal folds. The **middle concha** of the horse is short and extends only slightly more rostral than the ethmoidal concha to which it is closely related.

The **ethmoidal conchae** form a complex labyrinth, and are limited to the more caudal part (fundus) of the nasal cavity. Note that the middle nasal meatus leads to the middle nasal concha, where it divides into dorsal and ventral channels around that concha (Fig. 10-12). If a nasogastric tube is directed incorrectly into the middle meatus, it inevitably ends up crunching the conchae and abrading the vascular mucosa. This can have dire results: hemorrhage, a snorting shower of blood, and a liberal sprinkling of the attending personnel. The stomach tube should always be directed ventromedially along the more accommodating and open-ended **ventral nasal meatus** so that it can continue over the soft palate and be swallowed by the horse (Figs. 10-12).

Before we leave the nasal cavity, let's consider its association with the outside world. The entrance to each side of the nasal cavity is through the **nostril**. Inside the nostril is a "reception area" known as the **nasal vestibule**. It is here that the stratified squamous epithelium of the skin extends caudally to join the ciliated epithelium of the nasal cavity proper. The alar and basal folds of the ventral concha pass rostrally through the nasal vestibule to become associated with the nostril. At or very near the mucocutaneous junction is the nasal orifice of the nasolacrimal duct.

Nasal Orifice of Nasolacrimal Duct: In the horse, this is a conspicuous opening in the floor of the nasal vestibule. This opening can be easily seen and cannulated in the live horse. When grazing, horses can get a grass seed or other foreign object pulled into one of their lacrimal canaliculi, thus partially occluding the normal drainage of the conjunctival sac. When the nasolacrimal system becomes occluded in the horse, a soft polyethylene catheter can be inserted into the nasal orifice and the system gently back-flushed with an appropriate solution. Be sure you can locate this normal opening in the live horse.

In the donkey, this opening has been found near the lateral margin of the nostril (Fig. 10-21). Also, the nasolacrimal duct of the horse should not be overlooked as a possible source of hemorrhage in cases of epistaxis, particularly if it is unilateral.[9] For your interest only, an opening of the nasolacrimal duct is present near the nostril in the young pig. After birth, a second opening typically develops on the lateral surface of the ventral concha near its caudal end (relatively inaccessible). Subsequently, the more rostral opening and the rostral part

[8] choanae- (plural of choana; from Latin, Greek *choana* funnel). Choanae should not be confused with the nasal conchae.

[9] Shoemaker, J., Dean, P., and Welch, B. Epistaxis in two horses with dacryohemorrhea. JAVMA 200 (1992): 366-367.

of the duct degenerate, leaving only the more caudal opening.

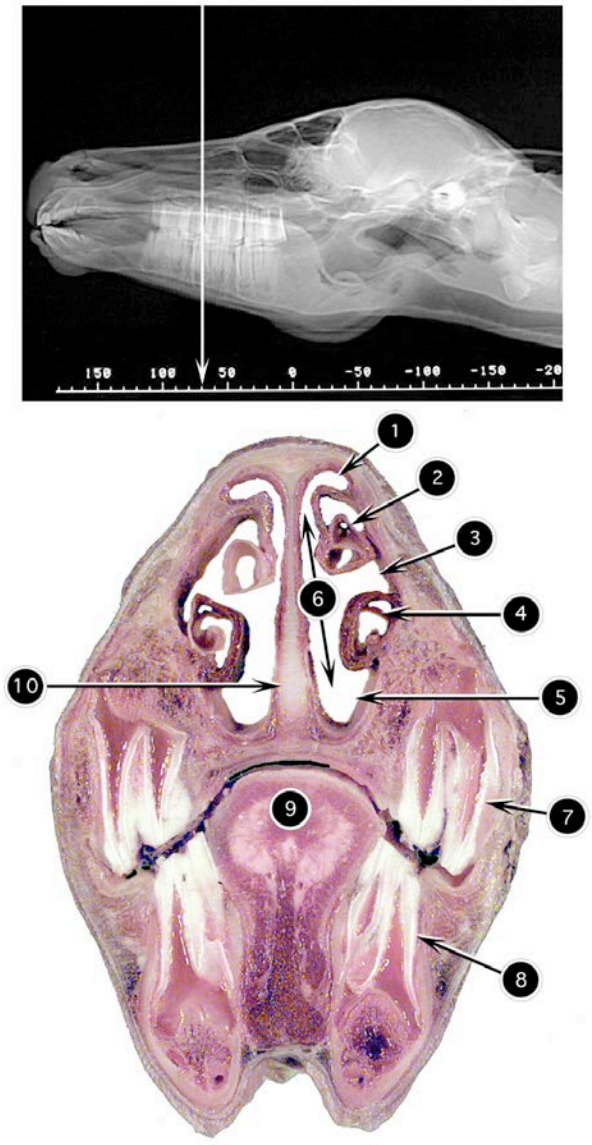


Figure 10-20. Transverse section through head of 5-week-old foal at level indicated in reconstructed CT image, caudal view: (1) dorsal nasal meatus; (2) dorsal concha; (3) middle nasal meatus; (4) ventral concha; (5) ventral nasal meatus; (6) common nasal meatus; (7) deciduous superior premolar 3; (8) deciduous inferior premolar 3; (9) tongue; (10) nasal septum.

In the ox, the nasal opening of the nasolacrimal duct is located on the ventromedial aspect of the alar fold, so it is not easily accessible for back-flushing the nasolacrimal duct system (Fig. 10-18). Locate this opening, which is in a location similar to that of the dog. In the goat the opening has been found at the about the fork of the alar and basal folds of the ventral concha.

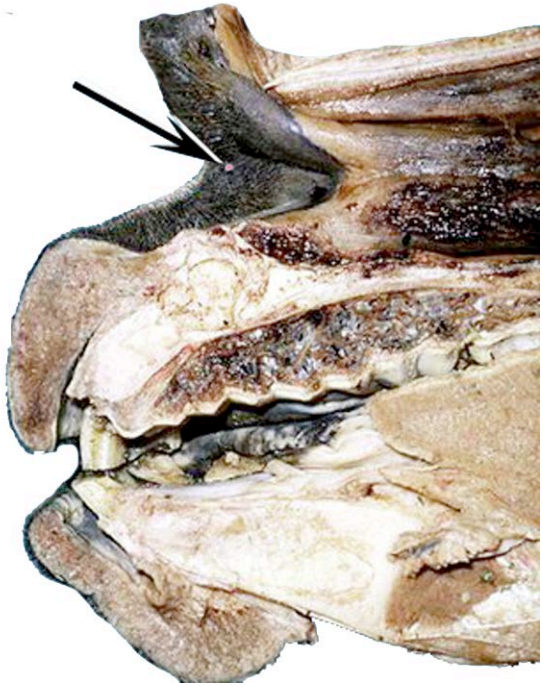


Figure 10-21. Sagittal section of donkey head with right nostril opened, medial view. The nasal opening of the nasolacrimal duct (accentuated) was found near the lateral margin of the nostril (arrow).

The nostrils of the ox are separated by a broad, thick plate of connective tissue, covered by a tough, cornified epithelium. This heavy plate is relatively immobile and is called the **planum nasolabial**. If you've never noticed, the ox uses its tongue to clear its nostrils of food material when eating grain from a trough. The apex of the tongue fits neatly within the nostril for this purpose. It is a very efficient, if somewhat socially unacceptable, cleaning process.

Pharynx: The first thing to be said about the pharynx is that it is a Y-shaped (when viewed on median section) crossroads of the

respiratory and digestive systems (Figs. 10-12 & 10-18). The respiratory system starts on top, but crosses the digestive tract at the pharynx to become ventrally located. The "Y" falls over so that its two arms face rostrally, and the stem is directed caudally over the larynx. Thus, the pharynx consists of three parts. The **nasopharynx** (dorsally) is separated from the **oropharynx** (ventrally) by the soft palate (Fig. 10-18). Around the caudal edge of the soft palate, termed the **palatopharyngeal arch**, these two parts join to form the **laryngopharynx**, which extends above and around the projection of the larynx to funnel into the esophagus (Fig. 10-12).

Nasopharynx: The nasopharynx is the cavity that is immediately caudal to the nasal cavity and communicates with the latter through the nasal choanae. Caudally, it is functionally continuous with the larynx through the **aditus laryngis**, an opening formed by the epiglottic cartilage, the aryepiglottic folds, and the arytenoid cartilages of the larynx (Fig. 10-19). Once air enters the aditus laryngis, it flows caudally through the rima glottidis[10] and larynx to the trachea. The nasopharynx is separated from the oropharynx by the soft palate and communicates with the cavities of the middle ear through the auditory tubes. In the pig and ruminants, the nasopharynx is partially divided by a **pharyngeal septum** (Fig. 10-18).

In the pig, the pharyngeal septum is complete in the rostral part of the nasopharynx, whereas in the ruminants, it is a prominent, highly vascular median fold that projects from the dorsal wall of the pharynx. A collection of lymphoid tissue in the caudodorsal wall of the nasopharynx represents the pharyngeal (adenoid) tonsil.

Pharyngeal Recess of Equidae: In the caudodorsal part of the nasopharynx in the horse, identify the pharyngeal recess (Fig. 10-22). This recess is much deeper in the donkey and mule than in the horse. A misdirected nasogastric tube could lodge in this recess.

Soft Palate: The relative length of the soft palate varies among species (Figs. 10-18 & 10-19) and only the pig possesses a rudimentary uvula. The exceptionally long soft palate of the horse essentially eliminates the possibility of mouth breathing in this species and also explains why a nasogastric tube is routinely used in the horse. Additionally, in the rare (and typically grave) situation in which a horse does vomit, the gastric contents emerge through the nostrils, not the mouth.

Pharyngeal Orifice of Auditory Tube: Be sure you can identify this opening in each species. In the artiodactyls, this slit-like opening is more easily identified on the side of the head without the pharyngeal septum (Fig. 10-18). The clinical condition known as tympanites of the guttural pouch, which is usually unilateral, is believed to be related to a congenital defect in the pharyngeal orifice of the auditory tube. It is thought that the cartilaginous flap on the affected side folds into the tube and acts as a one-way valve, allowing air to enter but not escape the guttural pouch. Surgical fenestration of the septum between the two pouches has been used in the past to treat this problem.[11]

[10] rima glottidis- the foramen (opening) formed by the glottis. The glottis is formed by the vocal folds ventrally and the arytenoid cartilages dorsally.

[11] Milne, D.W. and Fessler, J.F. Tympanites of the guttural pouch in a foal. JAVMA 161 (1972): 61-64.

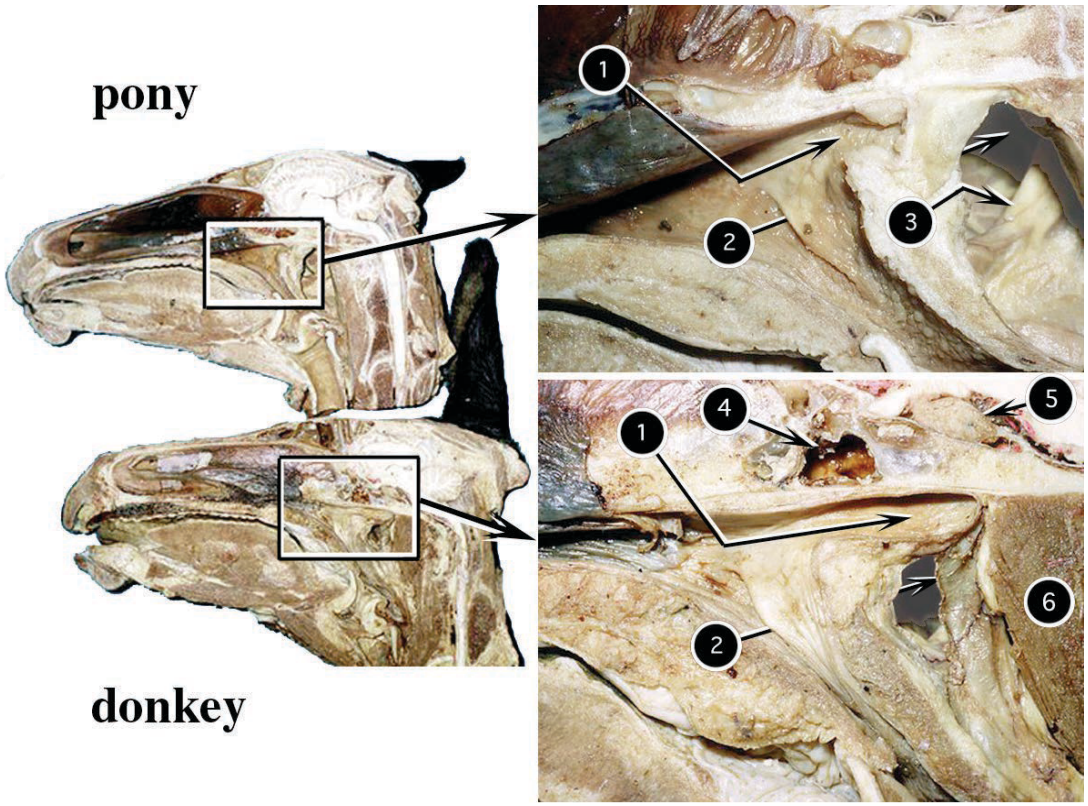


Figure 10-22. Sagittal sections of pony and donkey heads with magnified insets to illustrate details of pharyngeal recess areas, medial view: (1) pharyngeal recess; (2) pharyngeal opening of the auditory tube (arrow ends in guttural pouch); (3) stylohyoid bone dividing guttural pouch into medial and lateral compartments; (4) sphenopalatine sinus; (5) hypophysis (pituitary gland); (6) longus capitis muscle.

With the advent of fiberoptic-guided laser surgery, an alternative method of treatment involves creating a new pharyngeal opening into the affected pouch.[12] Do not confuse the pharyngeal orifice of the bovine auditory tube in the nasopharynx with the entrance to the sinus of the palatine tonsil, which is located in the oropharynx.

Oral Cavity and Oropharynx: The size and shape of the **sublingual caruncles**, which serve as the termination sites for the **mandibular** and **major sublingual salivary ducts**, vary considerably among species (Fig. 10-12). Actual caruncles are often absent in the pig. Because a **monostomatic sublingual gland** is absent in the horse, only the mandibular duct opens on the sublingual caruncle in this species. Multiple small ducts of the equine **polystomatic sublingual gland** open along the **sublingual fold** (Fig. 10-12).

As you recall from your study of the dog and cat, the polystomatic part of the gland is located rostral to the monostomatic part in carnivores. This is also true in the pig. In ruminants, the polystomatic part is located caudodorsal to the monostomatic part. The only reason for mentioning this difference is that, due to their reversed relationship, these glands are prone to misidentification in the ruminants.

[12] Tate, L. P., Blikslager, A. T., Little, E. D. E. Transendoscopic laser treatment of guttural pouch tympanites in eight foals. Veterinary Surgery 24 (1995): 367-372.

Tongue: As noted previously, the tongue serves as an important organ of food prehension in the ox. Note the distinctive **fossa linguae** of the ox (Fig. 10-18), which can trap a sharp foreign object and result in penetration and subsequent infection. The body of the bovine tongue forms a prominence, caudal to the fossa, known as the **torus linguae**.

There are various types of papillae on the tongue. Most of the papillae are purely mechanical (filiform), while others (fungiform and vallate) have taste buds associated with them. The **filiform papillae** create a uniform covering over the dorsum of tongue, much like the grass of a lawn. Scattered among the filiform are the **fungiform papillae**- those pesky mushrooms that pop-up in the lawn of filiform. The large **vallate papillae** are found more caudally at the junction of the body and root of the tongue. In the ruminant, some of the mechanical papillae become highly cornified, and take on various shapes, including conical (pointed) and lenticular (flattened) types. Also, in cattle, there are many large conical papillae on the inside of the rostral part of the cheek.

Palatine Tonsil: Note that the word is palatine, not palantine. The shape, size, and exposure of the palatine tonsil vary considerably among the domestic ungulates. It is embedded in the wall of the oropharynx in the ox and small ruminants, and is superficially located in the horse (Figs. 10-12 & 10-23). This tonsil is reportedly absent in the pig. Note: When a lymph node is "absent," it means that there is no grossly identifiable, consolidated body of lymphoid tissue; it does not mean that there is no diffusely arranged lymphoid tissue in the area.

On one side of the ruminant head, dissect out the palatine tonsil. Note the small opening into the **tonsilar sinus** (Fig. 10-23). Be sure you do not confuse the bovine palatine tonsil with the medial retropharyngeal lymph node (Fig. 10-23). Note that the tonsil is related to the oropharynx and that the lymph node is related to the nasopharynx.

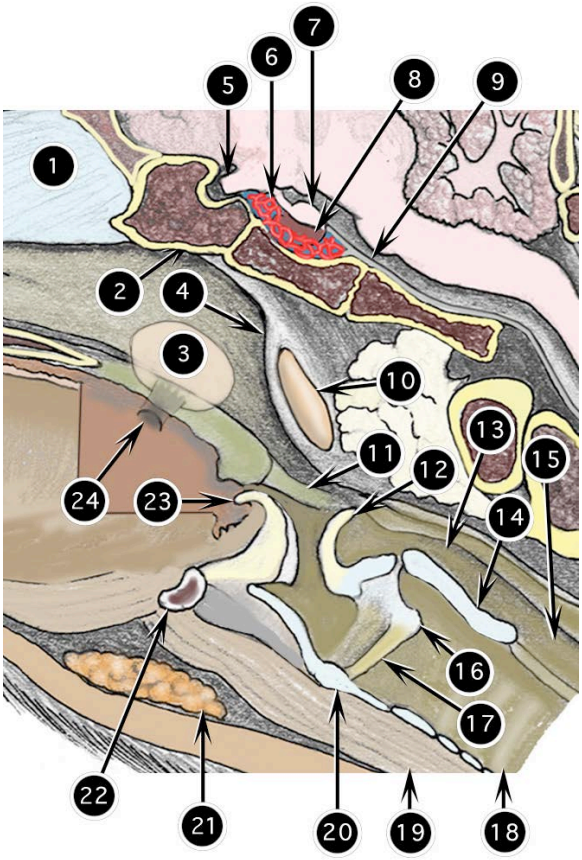


Figure 10-23. Sagittal section of bovine pharyngeal region: (1) nasal septum; (2) pharyngeal opening of auditory tube (hidden); (3) palatine tonsil, embedded in dorsolateral wall of oropharynx; (4) pharyngeal septum; (5) optic chiasm; (6) epidural rete mirabile; (7) neurohypophysis (posterior pituitary); (8) adenohypophysis (anterior pituitary); (9) dura mater; (10) medial retropharyngeal lymph node; (11) palatopharyngeal arch; (12) corniculate process of arytenoid cartilage; (13) laryngopharynx; (14) cricoid cartilage; (15) esophagus; (16) vocal process of arytenoid cartilage; (17) vocal fold; (18) trachea; (19) sternohyoideus muscle; (20) body of thyroid cartilage; (21) mandibular salivary gland; (22) basihyoid bone; (23) epiglottic cartilage; (24) opening of tonsilar sinus in dorsolateral wall of oropharynx.

Lingual Tonsil of Horse: This is a collection of lymphatic tissue located at the very back (root) of the tongue and closely related to the palatine tonsils, which flank the root of the tongue on either side (Fig. 10-12). The lingual tonsil is confined to the dorsum of the tongue, whereas the palatine tonsils are slightly off to the sides (*i.e.*, if it is on the tongue, call it lingual; if not, call it palatine.

Larynx and Laryngopharynx: Refer to demonstration specimens for a comparative study of the laryngeal cartilages. Note particularly the differences in the **thyroid notch** of the various species. Because of the deep thyroid notch of the horse, the junction of the two laminae (thyroid body) is very narrow (Figs. 10-7 & 10-19). This area frequently becomes ossified in the horse and, in lateral radiographs, may be confused with the basihyoid bone. Only the dog and horse possess cuneiform processes. In the dog, they are obvious projections of the arytenoid cartilages, while in the horse they are part of the epiglottic cartilage and are inconspicuous processes contained within the vestibular folds of the larynx.

It is important that you understand the **cricoarytenoid articulation**, especially the rotational movement that occurs as the glottis is dilated by the **cricoarytenoideus dorsalis muscle** or closed by other laryngeal muscles (Fig. 10-24). Note that the cricoid, thyroid, and the body of the arytenoid cartilage are made of hyaline cartilage, whereas the corniculate processes and the epiglottis are made of elastic cartilage (Figs. 10-19 & 10-23). Both the dog and the horse have well-developed **laryngeal ventricles** (Fig. 10-19), the entrance of which is bounded rostrally by the **vestibular fold** and caudally by the **vocal fold**. The pig also possesses a **laryngeal ventricle**, but its entrance is formed by a split in the vocal fold. Also, both the pig and the horse have a median laryngeal recess. Neither the cat nor ruminants have a laryngeal ventricle (Fig. 10-23).

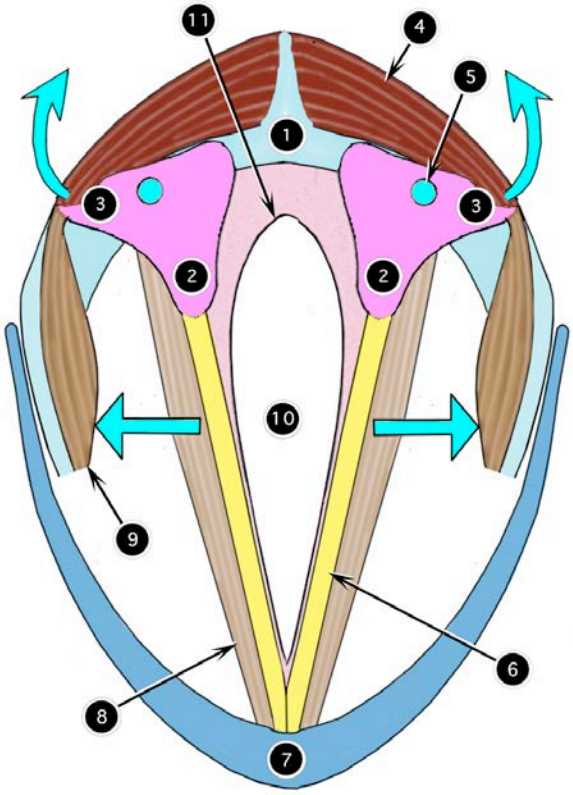


Figure 10-24. Schematic cross-section of larynx: (1) cricoid cartilage; (2) vocal process of arytenoid cartilage; (3) muscular process of arytenoid cartilage; (4) cricoarytenoideus dorsalis muscle; (5) location of cricoarytenoid joint; (6) vocal ligament within vocal fold; (7) body of thyroid cartilage; (8) vocalis muscle (caudal part of thyroarytenoideus muscle; (9) cricoarytenoideus lateralis muscle; (10) rima glottidis; (11) laryngeal mucosa. Curved arrows indicate rotation produced by contraction of 4, resulting in abduction of vocal folds (straight arrows) & dilation of glottis. (Modified from *Textbook of Veterinary Anatomy*, Dyce, Sack, Wensing, 3rd ed., W. B. Saunders Co., 2002, p. 156)

Refer to a demonstration specimen to appreciate the ligamentous support of the larynx. Corresponding to their well-defined vestibular folds, both the dog and the horse have distinct vestibular ligaments, whereas in the artiodactyls, this ligament is more fanned-shaped. The thyroarytenoideus

muscle of artiodactyls is not distinctly divided into a ventricularis and vocalis, as in the dog and horse. The normal resting (breathing) configuration of the larynx is dictated by the supporting cartilages and interconnecting ligaments. The laryngeal muscles function only to alter this shape *(e.g.,* dilation of glottis, closure of glottis).

Cricothyroid Ligament of Horse: This ligament connects the cricoid and thyroid cartilages, and in so doing fills the area of the large thyroid notch of the horse (Figs. 10-7 & 10-19). A median incision in this ligament provides surgical access to the laryngeal lumen. Such an approach (laryngotomy) can be used to remove the laryngeal ventricle (ventriculectomy) in cases of laryngeal hemiplegia.

Laryngeal Hemiplegia in Horse: Laryngeal hemiplegia is a clinical condition in the horse, with affected animals being known around the barn as "roarers." The roaring sound is produced by flapping of tissue within the larynx caused by paralysis of most of the intrinsic muscles on the left side. With the exception of the cricothyroideus muscle, all other intrinsic muscles of the larynx are innervated by the **caudal** (recurrent) **laryngeal nerve**.

When paralysis of these muscles occurs, two major problems result. First, there is loss of tone in the lateral wall of the larynx because the vocalis and ventricularis muscles are affected. Second, there is an inability to dilate the glottis completely because the important **cricoarytenoideus dorsalis muscle** is paralyzed. According to the laws of physics, the faster air passes through a tube, the more it tries to pull its walls inward.[13] With paralysis of the left cricoarytenoideus dorsalis muscle, the left arytenoid cartilage cannot be abducted and it falls inward, thereby reducing the size of the rima glottidis (opening through glottis).

When the horse attempts to breathe in, especially after some exercise, the air rushes through this partially closed glottis, turbulence is created, and negative pressure pulls on the tissues in the lateral wall of the larynx. Because it is poorly supported by the paralyzed muscles, the left vocal fold falls inward and flaps, initially during inspiration, but later during both phases of respiration. The more the vocal fold is in the way, the smaller the opening, and the greater the negative the pressure. Thus, more tissue, including the wall of the laryngeal ventricle, is pulled out into the lumen; everything now flaps, creating more sound and a further reduction in diameter, and the condition continues to worsen. It's one of those vicious cycles you hear so much about.

Treatment is directed at correcting one or both of the problems. Ventriculectomy is merely the surgical removal of the edematous laryngeal ventricle that has been everted into the laryngeal lumen. This helps by opening the airway somewhat, and the resulting scar tissue helps tighten up the lateral wall of the larynx. It does nothing, however, to address the droopy left arytenoid cartilage. Another procedure, which may be done in combination with the ventriculectomy, has been developed to correct the other problem. This involves tying the arytenoid cartilage back into a more abducted position. A permanent suture is passed through the muscular process of the arytenoid cartilage and then tied back to the cricoid cartilage, which in effect simulates the tone of the cricoarytenoideus dorsalis muscle.

[13] You know, the kind of aggravation you experience when you suck too hard on a straw, trying to get that thick chocolate malt out of the cup.

The fact that this problem occurs consistently on the left side raises some interesting questions about how, where, and even if the left recurrent nerve is damaged. Various mechanisms, ranging from inflammation of the caudal deep cervical lymph nodes to the throbbing of the aortic pulse against the nerve and trachea, have been proposed. Some have suggested that the lesion is central, not peripheral.

My current state of "relative confusion"[14] about the problem is as follows. Remember wavy nerves and the vacuum cleaner? Both recurrent nerves have just about the right amount of slack in them to allow for the normal range of motion in the long equine neck. Stay within that range and everything is fine; go beyond that range, and the nerve gets stretched and damaged.

Picture, if you will, a horse tied to a trailer with a nylon halter and lead shank. Suddenly, something "spooks" the horse and it jumps back, and jerks its head violently to the one side. If the head and neck are jerked violently to the left, the right forelimb probably comes off the ground and swings forward. This would allow the right subclavian artery to move forward and give the right recurrent nerve a little extra slack. Not so, however, when the head is jerked to the right. Even if the left forelimb does come forward, it does not help; the heart-aortic arch unit is not going to give very much. Thus, the left nerve is stretched, and the right nerve is spared. The same thing could happen if a horse falls and does a roll; head to left *versus* head to right.

Pharyngeal Diverticulum of Pig: This diverticulum of the laryngopharynx lies dorsal to the opening of the esophagus and, among our domestic mammals, is present only in the pig. Misdirected stomach tubes or metal syringes can lodge here. Note that the pharyngeal diverticulum of the pig is not homologous to the pharyngeal recess of the horse, which is a blind pocket off the nasopharynx, not the laryngopharynx.

Hyoid Apparatus: The small **epihyoid** fuses to the **stylohyoid bone** in the horse (Fig. 10-25). Also note the well-developed, blade-shaped **lingual process** of the equine **basihyoid**. The **thyrohyoid** is attached to the rostral cornu of the thyroid cartilage at the thyrohyoid joint. The epihyoid also fuses to the stylohyoid in the pig, but there is no appreciable lingual process of the basihyoid. In the ox, the epihyoid remains as a distinct bone and the lingual process is represented only by a blunt, rostral projection from the basihyoid. The **ceratohyoid** attaches the basihyoid to the epihyoid. The **tympanohyoid** is a short, partly cartilaginous attachment of the stylohyoid to the temporal bone (see skull for attachment site).

Constrictor Muscles of Laryngopharynx: The three pharyngeal constrictor muscles, **hyopharyngeus**, **thyropharyngeus**, and **cricopharyngeus** (Fig. 10-26), are important in swallowing. When a bolus is "flipped" into the laryngopharynx by the root of the tongue, it must be caught like a baseball is caught in a glove. First, you have to open the glove to receive the ball and then close it quickly to capture it.[15] This is in effect what must occur for the laryngopharynx to catch the bolus and deliver it immediately to the esophagus.

The muscles must be able to relax to receive the bolus, and then must contract

[14] "You see, we all operate from a state of relative confusion about most complex matters; it's just that some folks are more confused than others."

[15] Pointers on athletic competition are an added attraction of this book.

quickly and synchronously in a rostral-to-caudal "milking" manner. Otherwise, they drop the ball, and some of the food falls forward and into the aditus laryngis, which typically results in coughing and, in some cases, aspiration pneumonia. Failure of the more caudal muscles to relax properly when the bolus is delivered to the laryngopharynx is seen as a clinical problem in the dog known as “cricopharyngeal achalasia.” To my knowledge, this problem has not been reported in domestic ungulates, but a review of the muscles should be worth a few minutes of your time.

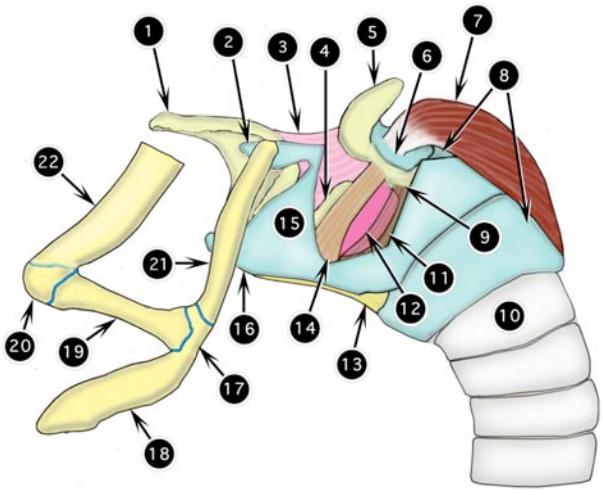


Figure 10-25. Larynx & hyoid apparatus of horse, lateral view: (1) epiglottis; (2) rostral cornu of thyroid cartilage; (3) aryepiglottic fold; (4) cuneiform process of epiglottic cartilage within vestibular fold; (5) corniculate process of arytenoid cartilage; (6) muscular process of arytenoid cartilage; (7) cricoarytenoideus dorsalis muscle; (8) lamina of cricoid cartilage; (9) vocal process of arytenoid cartilage; (10) trachea; (11) vocalis muscle within vocal fold; (12) laryngeal ventricle; (13) cricothyroid ligament; (14) ventricularis muscle within vestibular fold; (15) lamina of thyroid cartilage (section removed); (16) body of thyroid cartilage; (17) basihyoid; (18) lingual process of 17; (19) ceratohyoid bone; (20) epihyoid (fused to stylohyoid); (21) thyrohyoid; (22) stylohyoid.

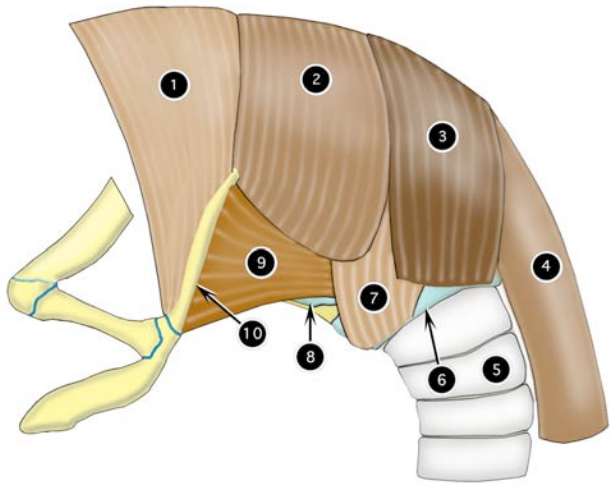


Figure 10-26. Pharyngeal constrictor muscles of horse, lateral view: (1) hyopharyngeus muscle; (2) thyropharyngeus muscle; (3) cricopharyngeus muscle; (4) esophagus; (5) trachea; (6) cricoid cartilage; (7) cricothyroideus muscle; (8) thyroid cartilage; (9) thyrohyoideus muscle; (10) thyrohyoid.

TEETH OF HORSE

Both the incisor and cheek teeth of the horse are of the **hypsodont** type. Hypsodont teeth have no clearly distinguishable crown and neck. These teeth consist of a body and root, and continue to grow and erupt long after they come into wear. Thus, the entire tooth is never present at any given time because part of it has already worn away before the deeper part of the tooth has been formed (Fig. 10-12).

Certain terms are (or should be) used with respect to teeth. The surface of a tooth that faces its antagonist is its **occlusal surface**, that toward the tongue is its **lingual surface**, and that toward the lips or cheek is its **vestibular surface** (sometimes called labial surface). The surfaces toward adjacent teeth in the same dental arch are **contact surfaces**. On the first incisor (I1) that contact surface toward the median plane is its **mesial surface**; on all other teeth that contact surface toward I1 is the mesial surface. The contact surface opposite the

mesial surface is the **distal surface** on all teeth (Fig. 10-27).

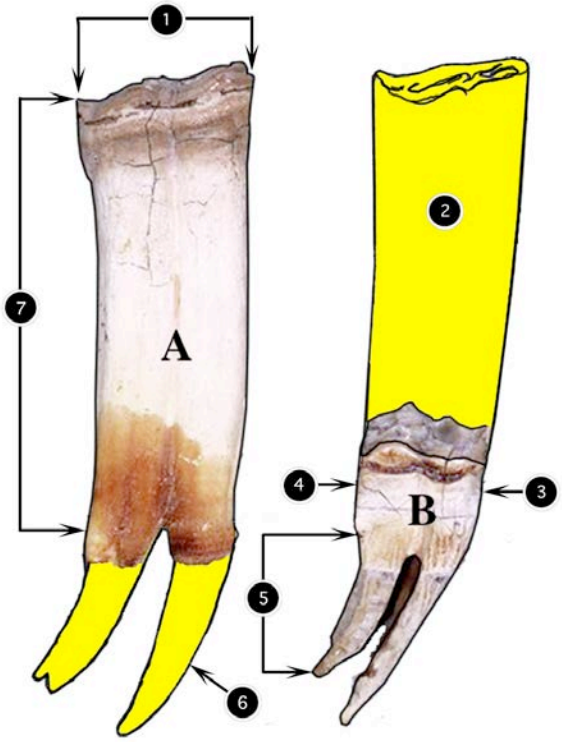


Figure 10-27. Inferior molar 1 of young horse **(A)** and aged horse **(B)**, vestibular surface view: (1) occlusal surface; (2) most of body has been worn away in aged horse; (3) mesial contact surface; (4) distal contact surface; (5) root of tooth; (6) roots not yet formed in young horse; (7) body of tooth. (Modified from slide set, *The Dissected Horse*, by W. O. Sack and L. L. Sadler, Cornell University.)

The dental formula for the horse is typically listed as:

2 (I 3/3, C 1/1, P 3-4/3, M3/3) = 40-42

This listing denotes variability in the presence of superior premolar 1. My opinion is that superior premolar 1 typically erupts, but is not consistently present in horses over 3 years old. Superior premolar 1 is a small tooth, and is frequently lost in young horses, especially when permanent P2 erupts at about 2.5 years. Not only does permanent P2 push out its deciduous predecessor (cap), but it also takes out the small P1. Furthermore, this formula completely disregards the presence of inferior P1 (Fig. 10-9). The truth is that inferior P1 does rarely erupt (Fig. 10-28), and ignoring it in the dental formula implies that it is not present.

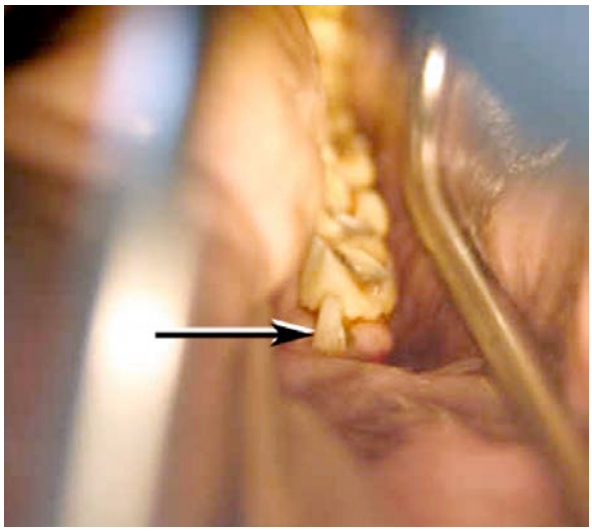


Figure 10-28. Photograph of horse with fully erupted inferior P1 (arrow). Photograph courtesy Dr. Bryan Taylor, Taylor Mobile Veterinary Dentistry, Mocksville, NC.)

Because inferior P1 is a real tooth (not imaginary), and superior P1 typically does erupt, my preference is to consider the real equine dental formula to be:

2 (I 3/3, C 1/1, P 4/4, M3/3) = 44

I would rather list it and not see it than not list it and be confused when it “pops up.”

Equine incisor teeth are often referred to as the **central** (I1), **intermediate** (I2), and **corner** (I3) **incisors**. Canine teeth develop more completely in the male, but sometimes are fully erupted in the female. Contrary to what might be assumed, the canines are not the so-called "wolf teeth." The **wolf tooth** is the small first superior (and rarely inferior) premolar. In some cases wolf teeth are removed in the young horse so as not to "interfere with the bit."

Note that the inferior arch is much narrower than the superior arch. Thus, the horse is **anisognathous**. When the mouth is closed in the resting position (centric occlusion), only about a third of the occlusal surfaces are in contact (Fig. 10-20). When the horse brings one side into more complete contact during mastication, the other side is not in contact at all. This situation often leads to uneven wear of the teeth, which is characterized by prominent sharp edges or points that develop on the cheek teeth.

Because the occlusal surfaces naturally slope ventrolaterally, the sharp edges most often form along the lingual edge of the inferior teeth and the vestibular edge of the superior teeth. These sharp edges and points can lacerate the tongue and cheek, respectively, causing pain and reluctance to masticate, as well as creating potential avenues for infection. Treatment of this condition involves filing these sharp enamel edges (points) away using a rasp-like instrument known as a float; the process is referred to as "floating the teeth."

Estimation of Age of Horse by Examination of Incisor Teeth: Although it is generally considered impolite to peruse visually the oral cavity of a gratuitous equidae, veterinarians are sometimes asked to "age a horse" by examining its teeth. However, the estimate may not be accurate. Surprisingly, many horses hold at 6 years of age for a long time- the same horse may be bought and sold as a 6-year-old for quite a few years.

There are two basic criteria that can be used to estimate the age of a horse by examination of its teeth. Eruption is a reliable criterion, and the age of a young horse that is still in the process of erupting incisor teeth can be estimated fairly accurately. However, once a horse has all of its permanent incisor teeth in wear, this criterion is no longer available, and the only remaining determinant is the amount of wear on these teeth.

Unfortunately, wear of teeth is not a reliable criterion because of the considerable variation in this process produced by different diets, different soil types, and different habits of gnawing or cribbing on nonfood objects (*e.g.*, fences, troughs, water pipes, etc.). It is not unusual to find a horse that is one age according to eruption, but is considerably older according to wear. When such conflicting information is present, wear should be disregarded, and the estimation of age should be based on the more reliable eruption status.

Estimation of a horse's age by examining its teeth is an art, and to become proficient requires considerable practice on horses of known ages. Because eruption is reliable, all students are expected to know when the deciduous and permanent incisor teeth erupt (incisors, not all teeth). Although eruption of cheek teeth can be used, the difficulty in examining these teeth in a live horse markedly reduces the practicality of obtaining this information. The eruption of the **deciduous incisors** can be simplified as 6 days, 6 weeks, and 6 to 8 months (I1, I2, I3, respectively). Most people with a horse less than a year old know when the horse was born, and, with the help of a calendar and a small calculator, you can figure out the age without looking at the teeth. Because it takes about 6 months from the time of eruption for a new tooth to protrude far enough to reach its antagonist, the corner incisors are usually not in wear until the horse is about a year old.

From about 12 months until about 2.5 years, when the permanent central incisors erupt, there is a sort of "twilight period,"

during which age estimation is based on wear of the deciduous incisors. During this period, it is especially important to look at the whole horse- that is, its size, condition, and so forth, which may help provide a more accurate overall estimation. During this period, the small deciduous incisors are worn down more and more. To understand what happens as an incisor tooth is worn, one must know the anatomy of the tooth (Fig. 10-29).

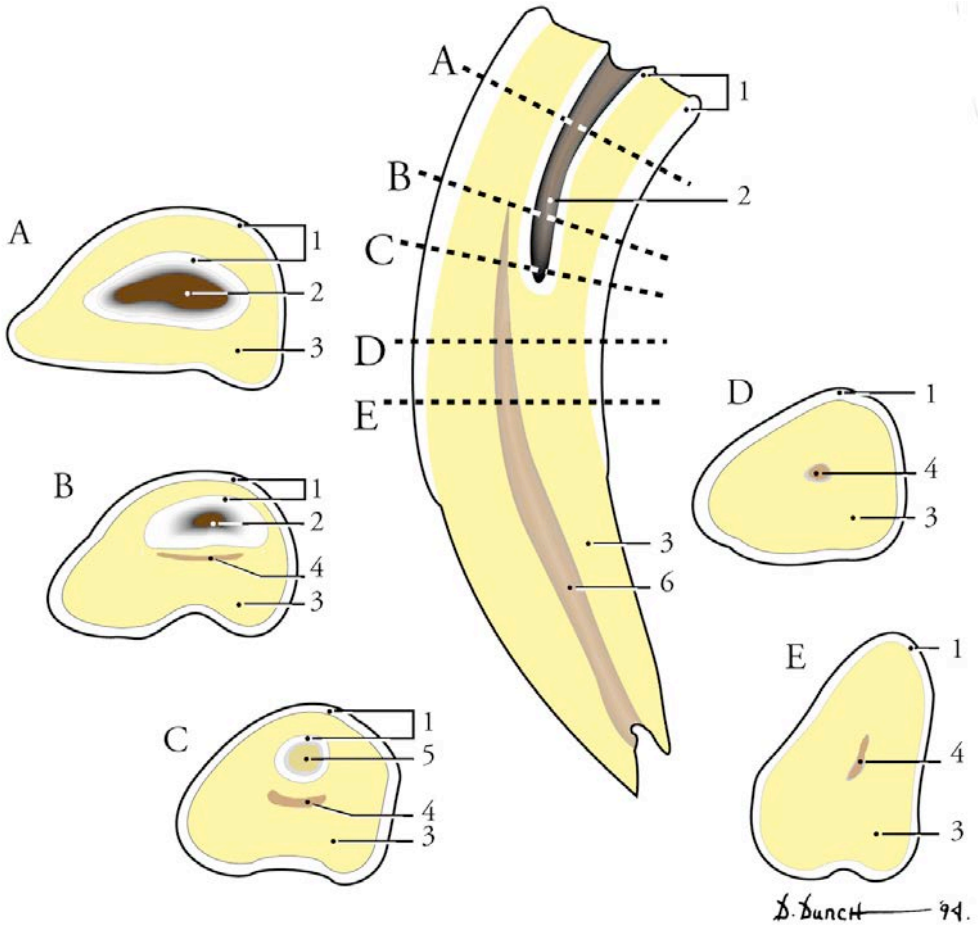


Figure 10-29. Longitudinal section of equine incisor tooth with occlusal views of transverse sections at levels A-E: (1) enamel; (2) infundibulum (cup)- containing dark-colored cementum; (3) dentine; (4) dental star- new dentine filling in old dental cavity as it recedes away from occlusal surface; (5) enamel spot- enamel lining fundus (bottom) of cup; (6) dental cavity; (A) tooth in wear, cup present, oval shape; (B) tooth becoming more round, cup still present, appearance of dental star on vestibular (labial) side of cup; (C) cup gone, tooth round, enamel spot and dental star present; (D) enamel spot gone, tooth sill round, dental star now in center of tooth; (E) tooth triangular, dental star present. (Drawing by Brenda Bunch.)

When the tooth first erupts, the external enamel and the central enamel, which lines the infundibulum (cup), are continuous at the occlusal surface; no dentine is exposed. As the tooth begins to wear, the cutting-edge enamel is worn away, and dentine is exposed. This produces two enamel crests, completely separated by dentine; the occlusal surface has flattened and the tooth is said to be "level." Leveling of the deciduous incisors progresses from central to corner as the horse passes through this twilight period, and by about 2 years of age, all of them have been leveled.

Between 2 and 2.5 years, the deciduous incisors are almost worn completely down. It is during this period, when these teeth are worn very short and the permanent central incisors are nearing eruption, that inflammation and swelling of the palate just caudal to the superior incisors may occur, producing a clinical condition referred to as palatitis or "lampas." Although some archaic surgical treatments have been used for this problem, the condition resolves itself as soon as the permanent central incisors erupt and protrude far enough to relieve the pressure on this area. Soft feed during this period has been recommended as a humane treatment if the condition occurs.

Another problem in aging a horse during this twilight period is that deciduous incisors may be confused with permanent incisors, which would make a big difference in the estimated age. Thus, it is important to be able to differentiate deciduous from permanent incisors (Fig. 10-30). First, deciduous incisors are smaller, but this may not be obvious without a permanent tooth present for comparison. Deciduous incisors have a sort of "neck" (more of a constriction between exposed and embedded parts), while permanent incisors do not. The most reliable distinction is that a deciduous incisor initially has many fine longitudinal grooves on its vestibular surface; a permanent incisor has only one large central groove on its vestibular surface (Fig. 10-30).

From about 2.5 to about 5 years, it is relatively easy to estimate age fairly accurately. The permanent incisors erupt at about 2.5, 3.5, and 4.5 years (I1, I2, and I3, respectively), and each takes about 6 months to protrude to the wear position. A horse usually has all permanent incisors in wear (a full mouth) by 5 years. The canine teeth usually erupt at about 4 years (range, 3.5 to 5), but remember that these may not erupt at all, especially in the mare. Every veterinary student should be able to age a horse up to 5 years.

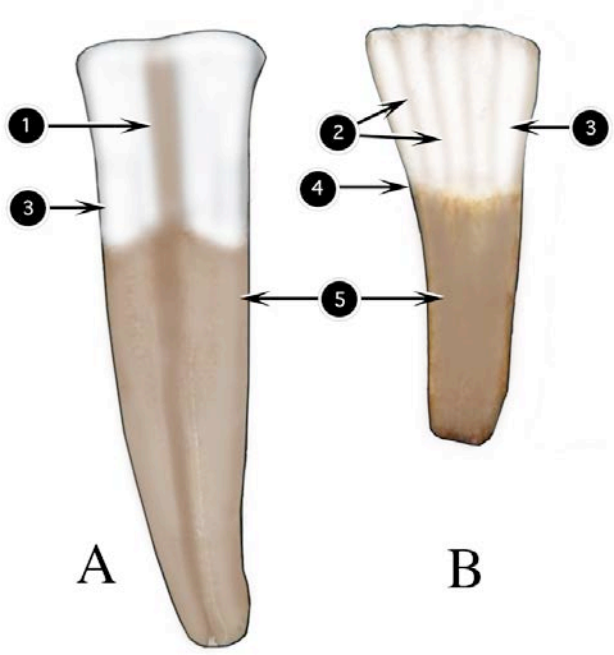


Figure 10-30. Comparison between permanent (A) & deciduous (B) incisors of horse, vestibular surface: (1) cementum within large central groove; (2) cementum in multiple fine grooves; (3) enamel revealed by wearing off cementum from exposed part of tooth; (4) more of a constriction between exposed & embedded parts of tooth; (5) cementum covering embedded part of tooth.

After 5 years, wear of the permanent incisors is the only remaining criterion, and as mentioned, this is not very reliable. For example, can you tell how many miles the tires on my pick-up have on them by looking at the amount of tread wear? These later estimations should really be called "guesstimations." A detailed reference, *Official Guide for Determining the Age of the Horse* is available from the American Association of Equine Practitioners.[16] If you really need to provide an accurate age determination of a horse over 5 years, you

[16] American Association of Equine Practitioners. *Official Guide for Determining the Age of the Horse*. Fort Dodge Laboratories, Fort Dodge, IA, 1966.

should use this guide as a reference and cite it on any official insurance or other form you might sign "certifying" the age of the horse.

As with the deciduous incisors, interpretation of the wear changes that occur with permanent incisors is based on the anatomy of the tooth (Fig. 10-29). Remember that the incisors of the horse are hypsodont teeth, and that the entire tooth is never present at any given time (Fig. 10-27*)*. Be sure you understand the relationship of the different parts of the tooth. Note that the original dental cavity overlaps the deepest part of the infundibulum, and that the former is on the vestibular (labial) side of the latter. As the tooth is worn down to near the level of the original dental cavity, the vessels and nerves recede. New dentine is produced to fill-in (patch) this part of the cavity as the vessels and nerves withdraw.

Much like new asphalt filling a pot-hole, this new dentine is darker than the surrounding old dentine, and when viewed on the occlusal surface, the dark area is called the "**dental star**." In most cases, it doesn't look much like a star, but that's what it's called. It is important to note that the infundibulum has an enamel liner (the central enamel), but that the dental cavity (star) does not. As the tooth is worn down to the deepest part of the infundibulum, the dark material (cementum and decaying food material) is cleaned away, and the cup is said to be "lost."[17] The remaining enamel at the bottom of the cup forms the **enamel spot**, which is at first oval and later round (Fig. 10-29). Although a cup is technically lost when the dark material is gone, the presence or absence of a cup may be a point of contention between seller and potential buyer of said horse. <u>There is no reason why a veterinary student should confuse an enamel spot with a dental star</u>. As the name implies, the enamel spot is enamel (white); the dental star is new dentine (brown).

Although wear obviously occurs on both superior and inferior incisors, the inferior incisors wear more rapidly, and therefore similar changes occur at different ages in the two arches. With the exception of Galvayne's groove, I prefer to disregard the superior incisors and concentrate on the inferior incisors. The cups are typically lost from the inferior incisors at about 6, 7, and 8 years (I1, I2, and I3, respectively). Thus, at 8 years, a horse has lost all cups from its inferior incisors and is affectionately referred to as a "smooth mouth." (For those who insist on searching for superior incisor cups, which are of little value in age guesstimation, some usually remain until about 11 or 12 years. Thus, some people say a horse is a smooth mouth at about 12; whether a horse is considered a smooth mouth at 8 or 12 years is probably related to whether one is buying or selling said horse.

After the inferior cups are lost (at about 8 years), the shape of the occlusal surface is considered. Originally, these incisors are distinctly oval, with the long dimension in the mesial-to-distal direction; as the tooth is worn and new tooth is protruded, this shape changes to round (sort of) and then to triangular. In very old horses (more than 21 years) it even becomes more or less oval again, but with the long dimension in the lingual-to-vestibular direction (Fig. 10-29). By this time, accurate age is probably a moot point, because the horse is at least old enough to vote.

Rounding of the teeth occurs at about 9 and 10 years (I1 and I2, respectively; I3 doesn't really round up until about 13 years). The transition from round to triangular

[17] The horse didn't actually lose it you understand; it just got worn away.

occurs at about 16 and 17 years (I1 and I2, respectively). Other factors can be considered, like appearance of dental stars and disappearance of enamel spots, but to me this is like trying to apply a complicated system to something that is only a semi-informed guesstimation to begin with. Therefore, the whole process can be simplified by considering only the loss of cups- 6, 7, 8; rounding 9 and 10; and then looking at the superior corner incisor and checking out **Galvayne's groove**.

This groove retains cementum and thus appears as a dark line on the vestibular surface of superior I3. According to Galvayne, this groove appears at the gum line at about 10 years, extends halfway down the tooth at 15 years, and all the way down by age 20 years (please extrapolate for other years, such as 12 or 17). If Galvayne's groove is on one side, check it on the other to see if it is the same. If not, average the two sides. This groove begins to disappear at the gum at 21 years, is halfway gone at 25 years, and is gone at 30 years. Some say Galvayne's groove alone is an unreliable indicator. I certainly wouldn't argue with that, but I doubt that calculating enamel spot loss and dental star appearance adds a great deal to the accuracy. Comparing the rounding and triangular factors with the Galvayne factor can help confirm your guesstimation (although it probably does not make the guess any more reliable).

Although in this day and age I doubt that anyone does it any more, for historical interest I suppose you should know about a fraudulent practice whereby a horse's teeth are altered to make it appear younger *(caveat emptor)*, a technique known as "Bishoping."[18] By cutting grooves in the dentine of the incisors, "pseudocups" are produced, complete with dark staining to make them look authentic. However, any veterinary student should immediately detect such "pseudocups" by two telltale signs: (1) a round or triangular tooth does not have a cup; and (2) true infundibula are enamel-lined, "pseudocups" are not.

Because the teeth of the horse are often examined radiographically, several equine dental radiographs follow (Figs. 10-31, 10-32, 10-33).

TEETH OF RUMINANTS

Although primordia of superior incisor teeth have been demonstrated embryologically, ruminants do not have superior incisor teeth. Instead of superior incisors there is a tough, connective tissue structure, the **dental pad**, against which the inferior incisors press.

Unlike those of the horse, the incisor teeth of ruminants are of the **brachydont** type, which means that they are almost completely formed at the time of eruption. Each consists of a distinct crown, neck, and root (Fig. 10-34). Because the teeth are not protruded continually over a long period, like those of the horse, they may wear down to the roots and become the limiting factor in the animal's ability to survive as a productive individual. This is especially true for range cattle that graze in areas of sandy soil, where the abrasion of the sand accelerates wear.

Ruminants have what appear to be four inferior incisors on each side, whereas other domestic mammals (carnivores, horse, pig) have only three. The dental formula for domestic ruminants is typically written as:

2 (I 0/4, C 0/0, P 3/3, M3/3) = 32

[18] I understand Mr. Bishop's descendents are keeping up the family tradition by rolling back odometers on used cars.

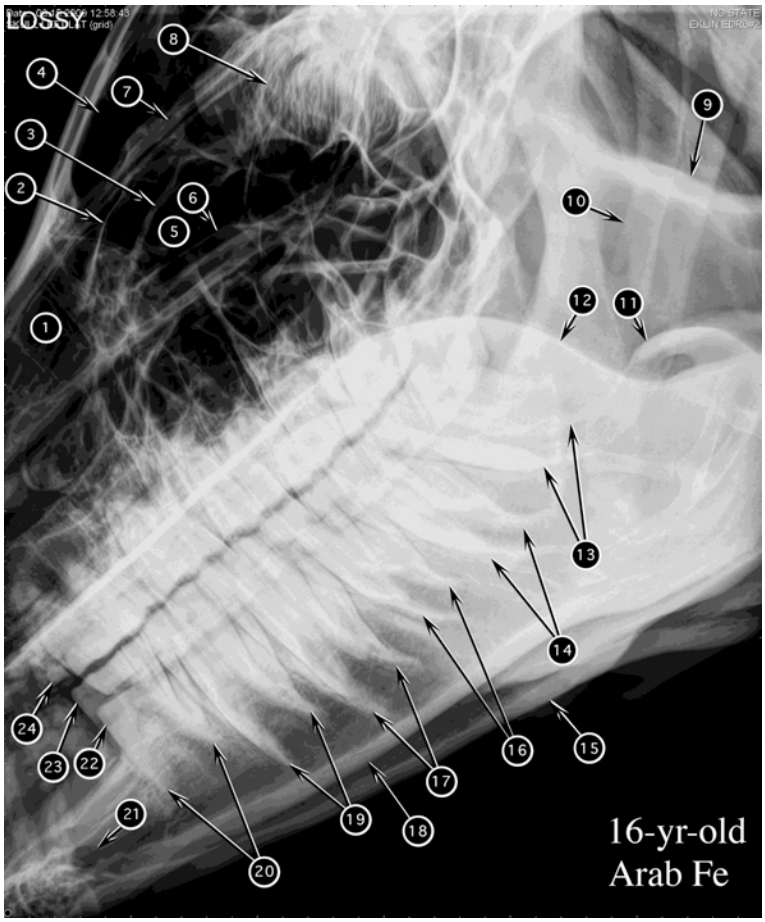


Figure 10-31. Right-Left Lateral (Rt-LeL) radiograph of middle region of equine head: (1) dorsal conchal sinuses; (2) septum between left rostral & caudal maxillary sinuses; (3) septum between right rostral & caudal maxillary sinuses; (4) frontal sinuses (communicate with 1); (5) caudal maxillary sinuses; (6) left infraorbital canal; (7) nasolacrimal ducts; (8) ethmoidal labyrinth; (9) dorsal wall of nasopharynx; (10) left stylohyoid bone; (11) epiglottic cartilage; (12) soft palate resting on root of tongue; (13) roots of right inferior molar 3 (tooth #411); (14) roots of right inferior molar 2 (tooth #410); (15) ventral border of right mandible; (16) roots of right inferior molar 1 (tooth #409); (17) roots of right inferior premolar 4 (tooth #408); (18) ventral border of left mandible; (19) roots of right inferior premolar 3 (tooth #407); (20) roots of right inferior premolar 2 (tooth #406); (21) left mental foramen; (22) right inferior premolar 2 (tooth #406); (23) left inferior premolar 2 (tooth #306); (24) left superior premolar 1 (tooth #205).

Although the ruminant dental formula expresses four inferior incisors, the corner incisor represents the inferior canine tooth, which has become modified to function as an incisor (evolutionary translocation and transformation). Another interesting feature of ruminant incisors is that they are not rigidly fixed in their alveoli, so that limited movement of these teeth is normal.

The cheek teeth of ruminants, like those of the horse, are of the **hypsodont** type; however, the bodies of these teeth never reach the length of their equine counterparts. There are only three premolar teeth (P2, P3, P4), because P1 is absent in ruminants (Fig. 10-10). The cheek teeth become progressively larger from P2 through M3, and the serrated arrangement of the occlusal surfaces produces an interdigitating type of occlusion (Fig. 10-10).

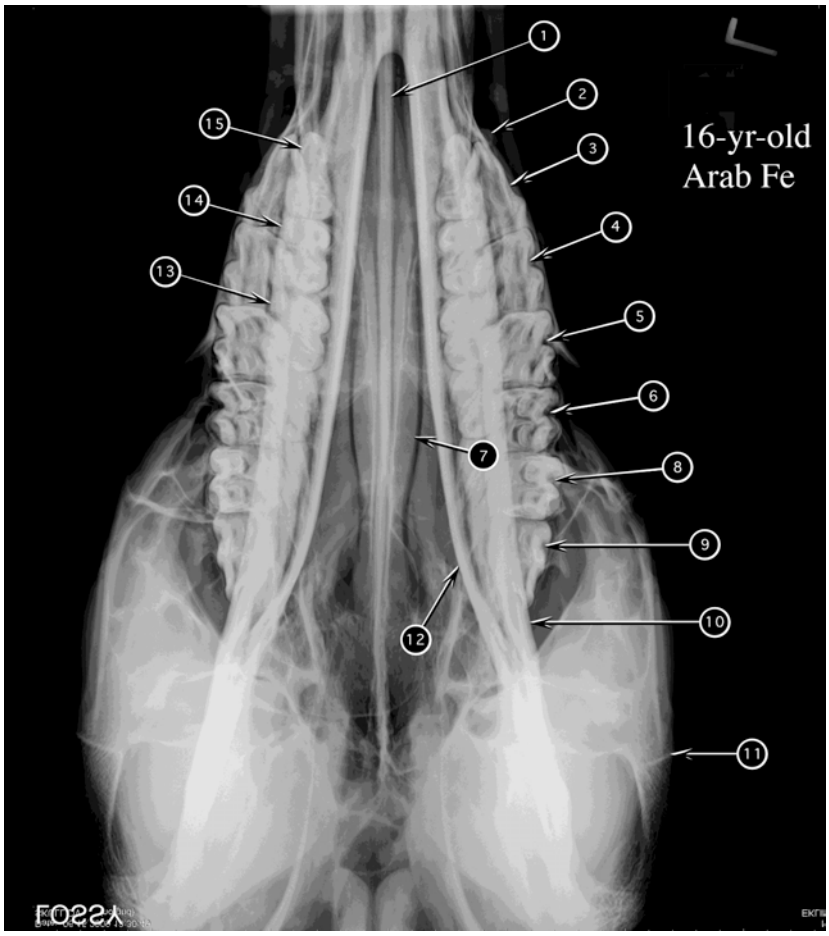


Figure 10-32. Dorsoventral (DV) radiograph of middle region of equine head: (1) cartilaginous nasal septum superimposed on vomer; (2) left superior premolar 1 (tooth #205); (3) left superior premolar 2 (tooth #206); (4) left superior premolar 3 (tooth #207); (5) left superior premolar 4 (tooth #208); (6) left superior molar 1 (tooth #209); (7) vascular mucosa covering side of nasal septum; (8) left superior molar 2 (tooth #210); (9) left superior molar 3 (tooth #211); (10) lateral surface of left mandible; (11) zygomatic arch; (12) medial surface of left mandible; (13) right inferior premolar 4 (tooth #408); (14) right inferior premolar 3 (tooth #407); (15) right inferior premolar 2 (tooth #406).

Like the horse, ruminants are severely **anisognathous**, and the occlusal surfaces slope in a ventrolateral direction, especially in the small ruminants. At centric occlusion, only a small part of the occlusal surfaces are in contact; full contact on one side removes contact on the other, so that chewing is unilateral at any given time.

Estimation of Age of Ruminants by Examination of Incisor Teeth: As with the horse, eruption is a more reliable criterion than wear. However, one study has indicated that in cattle there is a surprisingly wide variation in eruption ages of the incisors.[19] The deciduous incisors erupt about the time of birth or shortly thereafter. By 3 to 4 weeks, the complete crowns of all

[19] Andrews, A. H. A survey of the relationship between age and the development of the anterior teeth in cattle. Veterinary Record 92 (1973): 275-282.

these teeth are exposed. From this age until the permanent central incisors erupt, wear is the only available criterion; however, other factors, such as size or horn development, can often provide an experienced cattleperson (sheep or goat raiser) with a fair indication of age.

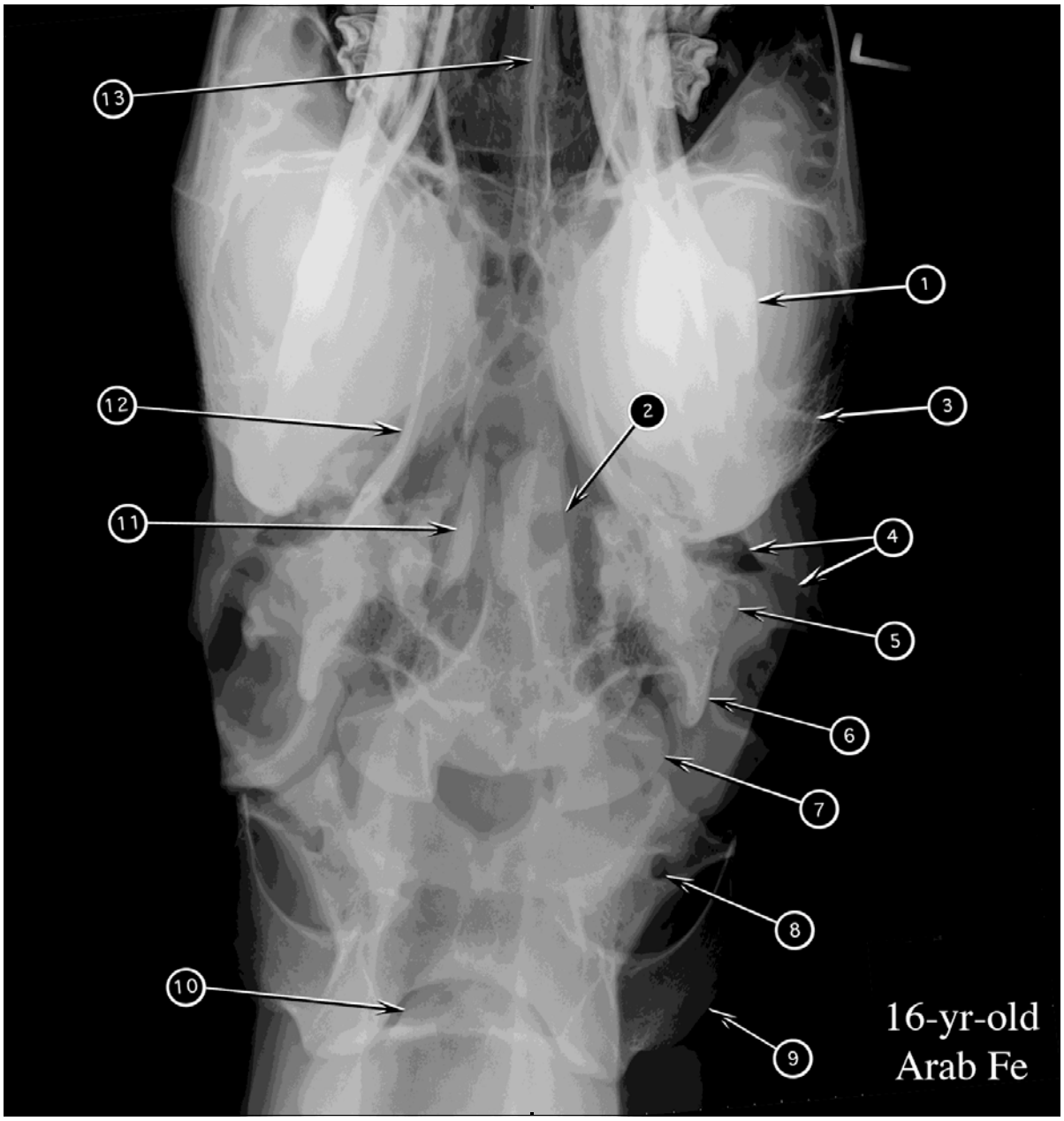


Figure 10-33. Dorsoventral radiograph of caudal region of equine head: (1) coronoid process of left mandible; (2) left laryngeal ventricle; (3) left temporomandibular joint; (4) external ear canal; (5) mastoid process of temporal bone; (6) paracondylar process of occipital bone; (7) occipital condyle; (8) alar foramen of atlas; (9) wing of atlas; (10) dens of axis; (11) right arytenoid cartilage of larynx; (12) right stylohyoid bone; (13) nasal septum.

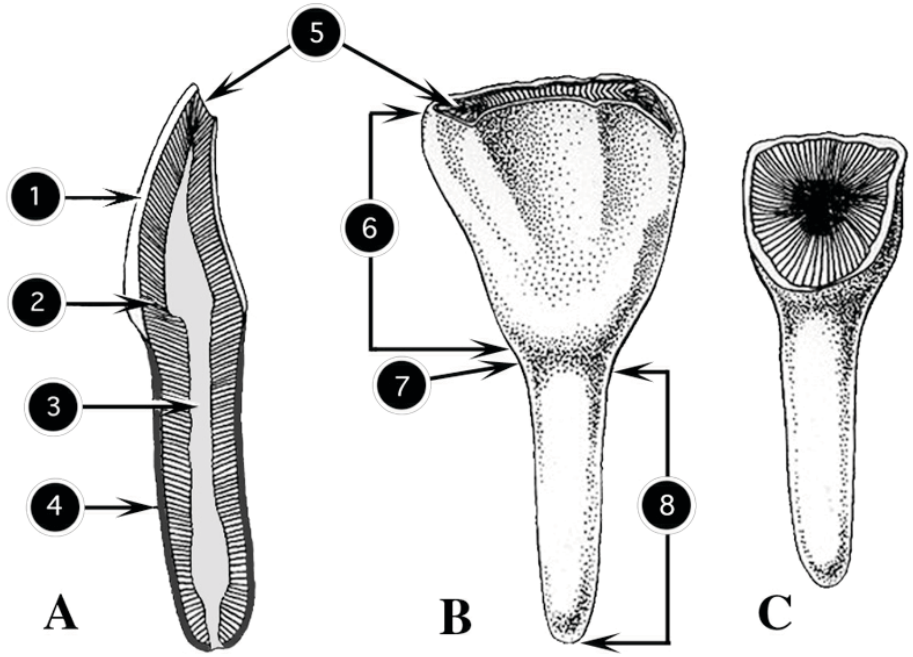


Figure 10-34. Bovine permanent incisor teeth: (A) longitudinal section; (B) lingual surface of tooth in wear; (C) lingual surface of tooth that has been leveled; (1) enamel; (2) dentine; (3) dental cavity; (4) cementum; (5) dentine exposed by wearing away of "cutting-edge" enamel; (6) crown; (7) neck; (8) root. (Modified from *Applied Veterinary Anatomy*, de Lahunta and Habel, W. B. Saunders, Co., 1986, p. 10.)

Wearing of the enamel cutting edge of the tooth progresses, so that dentine over the lingual surface of the tooth is exposed (Fig. 10-34). In a calf about five months old, the dentine is exposed over about half of the lingual surface of the first deciduous incisor (Di1). By about 10 months, dentine is seen over the entire lingual surface of Di1, and the other incisors show considerable wear. The entire lingual surface of Di4 is worn by about 15 months.

Eruption of the permanent incisors in the ox occurs at about 1.5, 2.5, 3, and 4 years of age. Thus, an ox is said to have a full mouth at about 4-5 years. As in the horse, it takes about 6 months for a newly erupted incisor to reach the wear position. The permanent incisors can be distinguished from the smaller deciduous ones by their broad, shovel-like shape as compared to the more triangular deciduous incisors. As for eruption of permanent incisors in the small ruminants, my preference is to simplify it as 1, 2, 3, and 4 years for "everyday" use.

Leveling of Bovine Teeth: When a permanent bovine incisor first erupts, the enamel cutting-edge of the tooth is complete and forms a sharp occlusal surface or border. On the lingual surface of a bovine incisor are several longitudinal enamel ridges (Fig. 10-34/B). As the tooth comes into wear the enamel cutting-edge is worn off, exposing the darker dentine of the tooth. Because of these ridges, the area of exposed dentine initially has a “scalloped” lingual border. As wear progresses, these ridges are worn away so that the area of exposed dentine develops a smooth, convex, lingual border. When this occurs, the tooth is said to be “level” (Fig. 10-34/C).

After an ox has reached about 4 to 5 years old (full mouth), wear of the incisor teeth is the only remaining dental criterion

for age estimation. In addition to leveling, the gum recedes away from the crown, which exposes the neck and part of the root. Again, emphasizing that wear is not a reliable criterion, at about 6 years I1 is level and part of the neck is exposed. Similar changes occur in I2 to I4 at about 7, 8, and 9 years, respectively.[20] Beyond 9 years, more and more of the crown is worn off, leaving only the roots of the teeth as small round pegs during the teenaged years. It is not uncommon for some teeth to fall out when worn down to the root. It is probably not as important to be able to determine the age of an older ox as it is to evaluate the general condition of the teeth themselves. This evaluation is probably more relevant to the animal's expected productive life than whether the ox is 6 or 10 years old.

TEETH OF PIG

According to most anatomy books, the pig is the only domestic mammal with a so-called "full dentition," with a dental formula of:

2 (I3/3, C1/1, P4/4, M3/3) = 44

Of course, I would argue that the horse also has a full dentition, with the admission that inferior P1 only rarely erupts.[21] Like the ruminant, the **incisor teeth** of the pig are of the **brachydont** type. The **cheek teeth** are also **brachydont** in type, but because of their flattened, multi-tuberculate shape, are referred to as bunodont teeth, characteristic of omnivores. Like those of the ruminant, the cheek teeth increase in size from mesial to distal. But, unlike the ruminant and horse, centric occlusion of the cheek teeth in the pig is **isognathous** and bilateral mastication is possible. The **canine teeth** or "tusks" of the pig are similar to the incisors of rodents because they continue to grow throughout life, at least in the boar. These teeth are kept sharp and can become formidable defensive and offensive weapons. The canines of the sow are smaller than those of the boar, and apparently cease to grow after several years.

The deciduous canines and Di3 are present at birth and are commonly referred to as "needle teeth." Because these sharp teeth can cause injury to the sow during nursing, they are often removed (cut off) shortly after birth as a routine husbandry practice. This may be done at the same time that the tails are docked to prevent tail biting (cannibalism) in confined pigs. Selective breeding for early maturation has undoubtedly altered the replacement ages in modern pigs with complete replacement (permanent dentition) present by about 1.5 years.

Modified Triadan Numbering System for Teeth: As veterinary dentistry has become recognized as a specialty in our profession, an alternate system of dental nomenclature has been adapted from human dentistry. This system involves numbering of all teeth rather than using I1, I2, etc. Here is the way it works (Fig. 10-35). Starting with upper right I1, this tooth is designated as # 101, continuing distally to upper right M3, which is #111. Moving next to the upper left arcade, I1 is designated as #201 through M3, which is #211. Next, the lower left arch is designated as #301 (I1) through #311 (M3). Lastly, the lower right arch is numbered #401 (I1) through #411 (M3). For deciduous teeth, the same order is used with upper right Di1 being #501 through lower right P4 being #808.

---

[20] de Lahunta, A. and Habel, R. E. *Applied Veterinary Anatomy*. W. B. Saunders Company, Philadelphia, 1986.

[21] Regardless of my argument, the pig does not have the most teeth of any mammal; the Virginia opossum has 50 (very sharp) teeth.

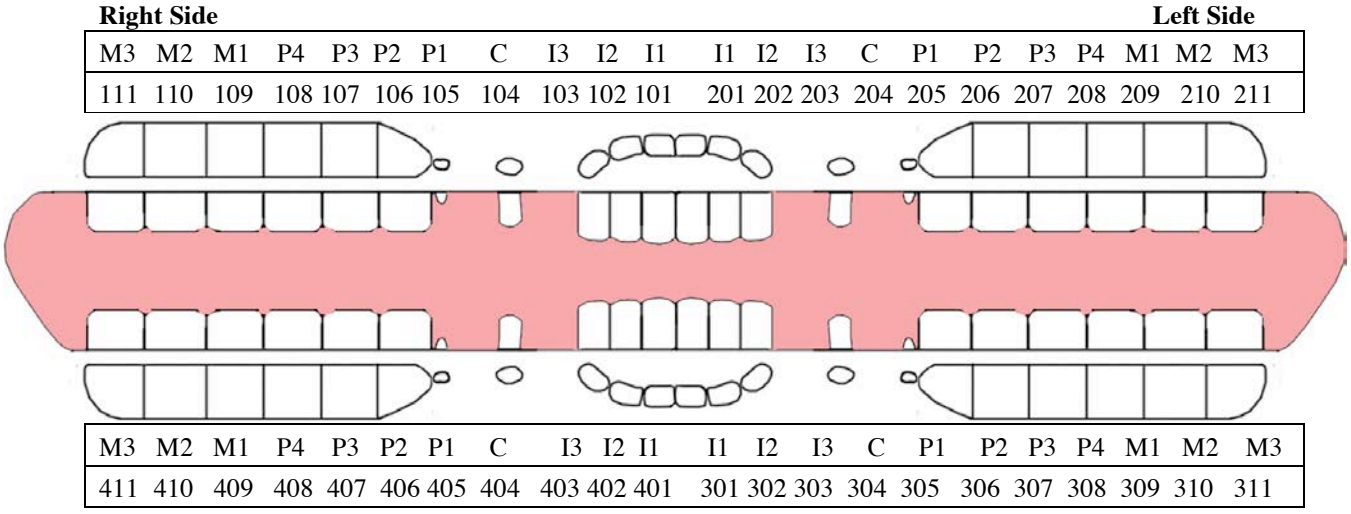


Figure 10-35. Schematic representation of modified triadan system of numbering teeth, equine teeth shown. (Chart courtesy of Dr. Bryan Taylor, Mocksville, NC).

ADNEXA OF EYE

The adnexa of the eye includes the eyelids, the conjunctiva, the lacrimal apparatus, the bulbar muscles, and other structures associated with the eyeball. The eyelids function to protect and clean the exposed surface of the eye. The anatomically correct terms for the upper and lower eyelids are the **superior** and **inferior palpebrae**, and the opening between them, through which the eye is visible, is the **palpebral fissure** (Fig. 10-36). The upper and lower eyelids come together at the medial and lateral **palpebral commissures**, and the medial and lateral **angles** of the eye, formed by these commissures, are referred to clinically as the medial and lateral canthi (singular- canthus) of the eye. In order to increase surgical access to the eyeball, the palpebral fissure can be enlarged *via* a surgical incision of the lateral commissure, called a lateral canthotomy.

Eyelids: The eyelids (palpebrae) serve to open and close the palpebral fissure and, in so doing, spread the protective tear film across the eye to clean away dust and debris. The free edges of the lids are supported by thin fibrous plates known as **tarsi**, and the lids have **cilia** (lashes) near their margins (Fig. 10-37). The cilia are better developed along the upper (superior) lid margin. As noted, the palpebral fissure is closed by action of the **orbicularis oculi muscle**, which is located within the upper and lower lids and, in effect, forms a sphincter around the palpebral fissure. In addition, the upper lid is raised or elevated by the **levator palpebrae superioris** (Fig. 10-38). At the lid margins, the skin of the anterior surface of the eyelid is continued over the posterior surface by the **conjunctiva**, which is the mucous membrane that lines the recess around the eyeball, forming the **conjunctival sac** (Fig. 10-36).

Many glands are associated with the eyelids and, in human medical terminology, each gland has been named after someone, a sort of "eponymic epidemic." If you carefully examine the area just inside the lid margins you should note a line of small orifices, about 40 or so altogether. These are the openings of large sebaceous glands,

the **tarsal glands**,[22] which in the horse can be observed as a conspicuous row of yellowish glands just deep to the palpebral conjunctiva (Fig. 10-36). Those of the ruminant and pig are more deeply embedded in the eyelids, and are not as evident as those of the horse.

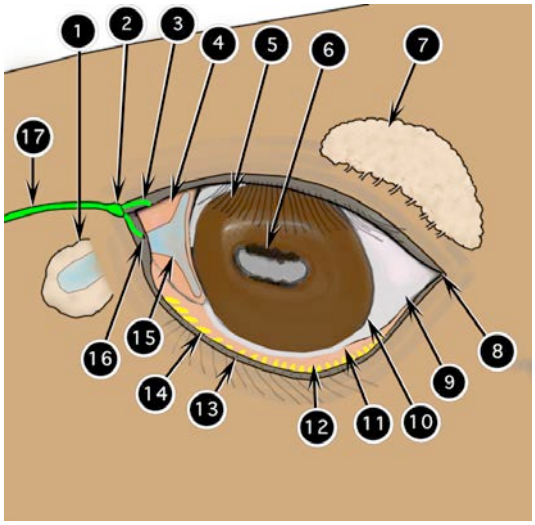


Figure 10-36. Adnexa of eye of horse, inferior lid partially everted to expose palpebral conjunctiva: (1) superficial gland of 3rd eyelid; (2) lacrimal sac; (3) superior lacrimal canaliculus; (4) 3rd eyelid covered by palpebral conjunctiva; (5) iris; (6) iridic granules projecting through pupil into anterior chamber; (7) lacrimal gland with ducts opening into dorsolateral fornix of conjunctival sac; (8) lateral palpebral commissure; (9) sclera of eyeball covered by bulbar conjunctiva; (10) corneal limbus; (11) conjunctival fornix; (12) palpebral conjunctiva; (13) openings of tarsal glands; (14) tarsal glands seen through 12; (15) T-shaped supporting cartilage of 3rd eyelid; (16) inferior lacrimal punctum; (17) nasolacrimal duct leading to nasal opening.

The secretion of the tarsal glands provides lubrication along the lid margins, sort of like coating them with a thin layer of petroleum jelly. In addition to lubrication, this oily film helps prevent the less viscous portion of the tear film from spilling over the lid margins. After prolonged periods of palpebral closure (*i.e.,* sleep), the dried tarsal gland secretion forms what is loosely termed "sleep." Occlusion and inflammation of a tarsal gland is called a **chalazion**.[23] Other small sweat and sebaceous glands[24] are associated with the cilia and lid margins (Fig. 10-37). Occlusion and infection of one or more of these lid margin glands is known as a **hordeolum**, commonly called a “sty.”

That region of the conjunctiva that covers the posterior surface of the palpebrae and the entire third eyelid is logically designated the **palpebral conjunctiva** (Fig. 10-36 & 10-37). Upon reaching the deepest part of the conjunctival sac, the **conjunctival fornix** the mucous membrane reflects back onto the anterior aspect of the eyeball as the **bulbar conjunctiva**. The bulbar conjunctiva is only loosely attached to the underlying sclera, except along the **corneal limbus**,[25] where the conjunctiva becomes continuous with the anterior epithelium of the cornea. When the conjunctiva is inflamed (**conjunctivitis**), it typically becomes hyperemic, and the conjunctival vessels become congested.

Although vestigial in the human, the **third eyelid** (palpebra tertius, nictitating membrane) is well developed in the horse and ruminant (Fig. 10-36). Movement of this extra "eye-shield wiper" is activated by retraction of the eyeball into the orbit by the **retractor bulbi muscle**, which is absent in the human. Whenever we wish to examine the third eyelid, we can protrude it by simply pushing the eyeball back into the orbit by slight digital pressure through the upper eyelid. The third eyelid is supported more substantially than the other lids in that it contains a T-shaped "stay" of hyaline cartilage (Fig. 10-36).

[22] Also called the meibomian glands.

[23] chalazion (kah-la'ze-on) - a small lump.

[24] Moll's and zeisian glands.

[25] corneal limbus: the edge of the cornea where it becomes continuous with the sclera.

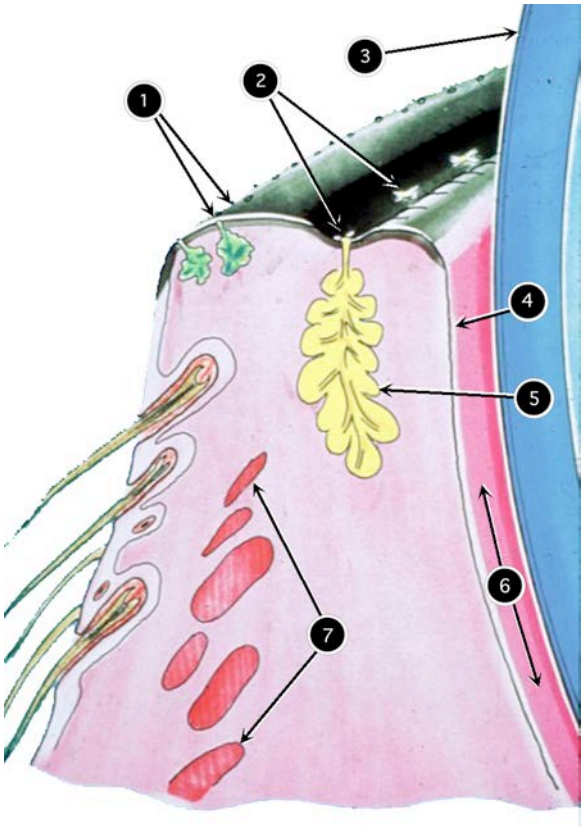


Figure 10-37. Drawing of section through eyelid, conjunctival sac, and cornea: (1) small sebaceous & sweat glands associated with eyelid margin; (2) openings of tarsal glands along eyelid margin; (3) cornea; (4) palpebral conjunctiva lining posterior surface of eyelid; (5) tarsal gland; (6) conjunctival sac; (7) fibers of orbicularis oculi muscle cut in cross-section.

Lacrimal Apparatus: The lacrimal apparatus consists of numerous glands that function in the production of the important **tear film**.[26] Not only does this essential fluid layer prevent the exposed surface of the cornea from drying out, it also functions bacteriostatically by maintaining a hostile environment for potential invaders. Although we usually credit tear production to the lacrimal gland, the tear is actually a "cocktail" of fluids derived from numerous adnexal glands, including the lacrimal gland and one or more glands of the third eyelid (Fig. 10-36). The **lacrimal gland** consists of flattened lobules congregated into an elliptical unit, and its secretion is delivered *via* multiple ducts into the dorsolateral fornix of the conjunctival sac (Fig. 10-36). The lacrimal gland is large in the ox and horse (Fig. 10-38).

The tear film washes across the cornea assisted by movement of the lids, and tends to collect in the medial part of the conjunctival sac. Here there is a small pooling area, which is of variable size and is known as the **lacrimal lake** (really, more like a pool). There is, however, an island in this pool formed by the **lacrimal caruncle**. This caruncle displaces the fluid back out of the pool when the lids are closed, delivering it to the vicinity of two openings just inside the lid margins. These are the openings of the lacrimal drainage system, the **lacrimal puncta**. These puncta, one superior (upper lid), the other inferior (lower lid), are the orifices of the **lacrimal canaliculi** (Fig. 10-36).

These canaliculi (little canals) conduct the tears to the medial aspect of the orbit, where they unite to form the **nasolacrimal duct** (Fig. 10-36). At the union of the canaliculi there is, in some species, a small dilatation known as the **lacrimal sac**, which is accommodated by the lacrimal fossa of the skull. The nasolacrimal duct passes rostrally, partly within a small but important osseous canal, to one or more nasal openings of the canal, the location of which varies considerably among species. As the tears evaporate through air movement across the nasal opening(s), a siphon is created that helps aspirate new fluid into the drainage system.

Inflammation and/or other occlusion of the nasolacrimal duct results in a "stopped-up sewer pipe," and just like with your

[26] Sometimes called "pre-corneal" tear film; like it would be somewhere else?

toilet, the fluid backs up into the conjunctival sac and spills over the lower lid, resulting in a condition known as **epiphora**.

Supernumerary lacrimal puncta have been reported as a congenital anomaly in Brown Swiss and Holstein calves. These accessory openings vary in number and occur on the face near the medial canthus of the eye.[27] Although both superior and inferior lacrimal puncta and canaliculi are present in the pig, the inferior canaliculus usually becomes occluded and is thus nonfunctional. On the porcine skull note that, instead of a fossa for the lacrimal sac (absent in pig), there are two lacrimal foramina to accommodate the superior and inferior canaliculi.

Use a skull for orientation during the following dissection. On one side of the head, carefully cut completely through the lids around the internal rim of the orbit, staying as close to the bone as possible. Isolate the caudolateral part of the orbit, which is formed by the zygomatic and frontal processes. Using an appropriate bone cutter, cut through the zygomatic process of the frontal bone as far dorsally as possible (Fig. 10-38). Now, isolate the ventral border of the orbit and, using bone cutters, cut through it as far rostrally as possible. Isolate the zygomatic arch caudal to the frontal process, and cut through it. If done correctly, the above cuts should isolate a Y-shaped bony segment that accesses the orbit when removed. Some of the temporalis muscle, retrobulbar fat, and part of the coronoid process of the mandible also need to be removed to expose the periorbital cone completely (Fig. 10-38).

Periorbita: The eyeball and many of its adnexal structures (*e. g.,* lacrimal gland, bulbar muscles, vessels, and nerves) are enclosed and neatly packaged in a tough fibroelastic cone of connective tissue known as the **periorbita** (Fig. 10-38). The periorbita attaches caudally to the orbital wall around the optic canal and orbital fissure, extends rostrally to attach around the rim of the orbit, and is fused medially with the periosteum of the orbital bones. Analgesia of the eye can be accomplished by the injection of a sufficient volume of local anesthetic into the periorbital cone.

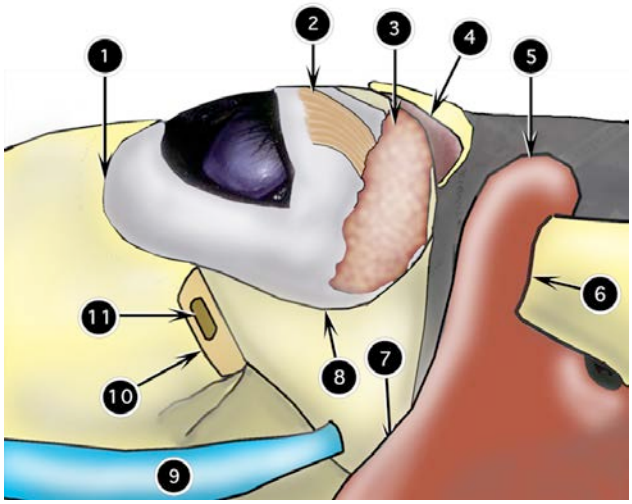


Figure 10-38. Periorbital cone of horse, exposed by removal of lateral & ventral walls of orbit: (1) rostroventral edge of orbit; (2) levator palpebrae superioris muscle; (3) lacrimal gland; (4) cut edge of zygomatic process of frontal bone; (5) coronoid process of mandible; (6) cut edge of zygomatic arch; (7) attachment of periorbita around orbital fissure & optic canal; (8) cut edge of periorbita that attached to removed section of orbit; (9) deep facial vein; (10) cut edge of zygomatic & maxillary bones; (11) caudal maxillary sinus opened by cut.

Although Peterson originally described (1951) a specific technique for depositing the anesthetic near the **foramen orbitorotundum** (Peterson eye block for cattle), this method is difficult, unnecessary, and potentially dangerous. On the bovine skull, note the deep and protected location of

[27] Heider, L., Wyman, M., Burt, J., *et al.* Nasolacrimal duct anomaly in calves. JAVMA., 167 (1975): 145-147.

the **foramen orbitorotundum** (fused orbital fissure and round foramen; Fig. 10-14) and its proximity to the **optic canal**. Recall that the optic nerve, which emerges through the optic canal, is surrounded by extensions of the meninges and subarachnoid space to the level of the sclera. If, in an attempt to perform the Peterson block, anesthetic is accidentally injected into this extension of the subarachnoid space, the results could be fatal to the patient. Today, informed surgeons prefer a simpler and safer technique of retrobulbar, intraperiorbital infusion of anesthetic, which effectively blocks the ophthalmic, trochlear, abducent, zygomatic, and oculomotor nerves, and has little or no risk of a subarachnoid injection.

Identify the **lacrimal bulla** (Fig. 10-10) on the bovine skull. Recall that this thin-walled extension of the maxillary sinus is vulnerable to damage during enucleation of the eye. The malar artery crosses the dorsal surface of the lacrimal bulla to exit rostrally through a notch on the medial wall of the orbit (Fig. 10-14).

Open and reflect the periorbita as shown in figure 10-39. Continue the reflection, and carefully remove the periorbital fat until the bulbar muscles are completely exposed.

Bulbar Muscles: The bulbar (extraocular) muscles consist of three antagonistic pairs of muscles, designed to rotate the eyeball around three axes, and an additional muscle capable of retracting the eyeball into the orbit. All four of the **rectus muscles** originate caudally from around the optic canal and orbital fissure and extend rostrally to insert into the sclera, anterior to the equator of the eyeball (Fig. 10-39). The dorsal and ventral rectus muscles rotate the eyeball around a horizontal axis, and the medial and lateral rectus muscles rotate the eyeball around a vertical axis.

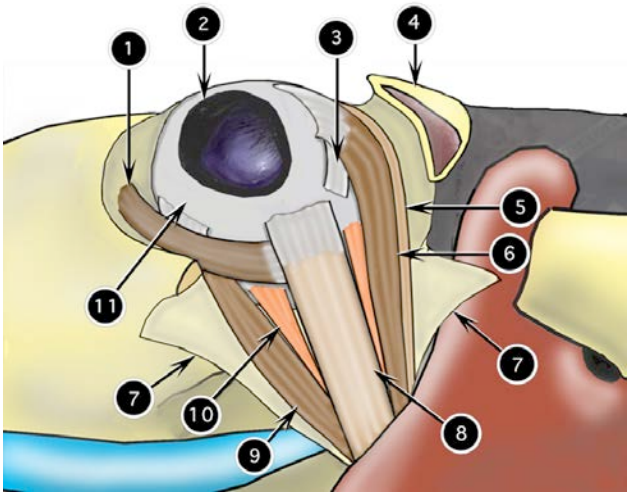


Figure 10-39. Reflection of periorbita to expose bulbar muscles: (1) origin of ventral oblique muscle from rostromedial wall of orbit; (2) corneal limbus; (3) termination of dorsal oblique tendon; (4) zygomatic process of frontal bone; (5) dorsal oblique muscle; (6) dorsal rectus muscle; (7) reflected periorbita; (8) lateral rectus muscle; (9) ventral rectus muscle; (10) retractor bulbi muscle; (11) sclera.

The **ventral oblique muscle** is unique in that it originates from the rostromedial wall of the orbit and passes directly ventral to the eyeball to attach laterally. It is beautifully designed for its job of rotating the eyeball around an anteroposterior axis so that the top of the eye moves laterally, while the ventral part moves medially.

Its antagonist is not so well designed and appears to be somewhat of a "problem child" for “Parent Nature” in that an entire cranial nerve had to be dedicated to innervation to this one little muscle. In any case, the **dorsal oblique muscle** starts off like it wants to be a rectus muscle, originating with them, then realizes it is heading in the wrong direction. In order for it to work in opposition to the ventral oblique, the dorsal oblique muscle must change direction. This problem is solved by the insertion of a little pulley-like, cartilaginous device in the dorsomedial orbital wall known as a **trochlea**. The

tendon of the dorsal oblique loops over the trochlea and turns abruptly laterally to cross the dorsal aspect of the eyeball and oppose the action of the ventral oblique (Fig. 10-39). That may be doing it the hard way, but it gets the job done none-the-less.

The last bulbar muscle is the **retractor bulbi**, which as previously mentioned has been dropped from the team in the case of the human.[28] This muscle consists of four separate slips, originating at the orbital fissure and extending rostrally to insert into the sclera, posterior to the equator of the eyeball (Fig. 10-39). As the name implies, its job is to retract the eyeball into the orbit, which is why you can't do that. In retracting the eyeball, the superficial gland of the third eyelid slips anteriorly, and the third eyelid is passively protruded. The eyeball is thus "doubly protected" from impending danger by moving back and by "flipping up" a protective shield. Our domestic mammals have a built-in "eye-shield wiper" to wipe away any annoying debris that gets on the eye-shield.

The innervation of the bulbar muscles is easy to remember using a little common sense. The muscle that is associated with the trochlea (dorsal oblique) is innervated by the **trochlear nerve**. The muscle that abducts the axis of the eyeball (lateral rectus) is innervated by the **abducent nerve**. The latter also innervates the **retractor bulbi muscle**, which is not present in the human. (You'll just have to remember this one.) All remaining bulbar muscles and the levator palpebrae superioris are innervated by the **oculomotor nerve**.

Using this information, one can identify branches of these nerves by association with their respective muscles. Sensory innervation to the eye and surrounding area can be summarized by noting that this area is supplied by multiple branches of the **ophthalmic branch of CN V** and by one branch of the maxillary branch of CN V (the **zygomatic nerve**).

Glands of Third Eyelid: All the common domestic mammals possess the **superficial gland** of the third eyelid, which is closely associated with the cartilage of the lid (Fig. 10-36). In addition, the ox and pig have the **deep gland** of the third eyelid (or Harder's gland). Only in the pig is this deep gland well developed and distinctly separated from the superficial gland. Identify this deep gland on a porcine specimen. It is surrounded by an orbital venous plexus from which a blood sample can be obtained. The orbital face of the porcine lacrimal bone is excavated to accommodate this deep gland and surrounding venous plexus.

EYEBALL *(Bulbus oculi)*

The **eyeball** consists of the sclera and cornea, and all structures and spaces contained therein (Fig. 10-40). As is already evident, the terms anterior and posterior are used here just as in human anatomy.[29] Much like your better quality trash tissue, the wall of the eyeball is a three-ply structure, consisting of fibrous, vascular, and internal layers or tunics.

The **fibrous tunic** is formed by the opaque **sclera** (≈ 70%) and the transparent **cornea** (≈ 30%). The scleral component has a slightly greater radius of curvature than the cornea, which explains why the cornea

[28] retractor bulbi: I'm not sure when he/she was cut from the human line-up. It must have been before early anatomists named cranial nerves.

[29] In the case of the eye, these terms present no confusion, because they have the same meaning as in human anatomy; unfortunately this is not the case with 90+% of the body parts, which is why they are not used in most regions of quadrupeds.

bulges slightly from the scleral sphere (Fig. 10-40). The **optic axis** is a line drawn through the geometric (optical) centers of the cornea and lens and extending posteriorly through the back of the eyeball.

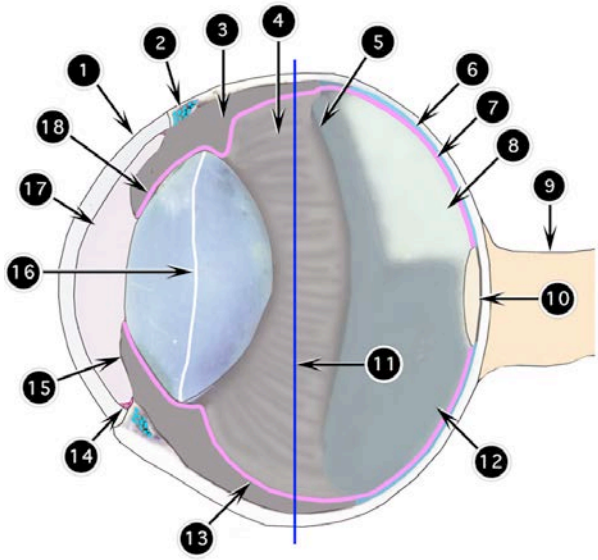


Figure 10-40. Meridional section of eyeball: (1) cornea; (2) scleral venous plexus; (3) ciliary body; (4) ciliary processes; (5) ciliary ring (ora serrata); (6) choroid; (7) pars optica retinae; (8) tapetum lucidum; (9) optic nerve; (10) optic disc; (11) equator of eyeball; (12) non-tapetal fundus (tapetum nigrum); (13) pars ciliaris retinae; (14) pectinate ligament in iridocorneal angle; (15) iris; (16) equator of lens; (17) anterior chamber; (18) pars iridica retinae.

The **cornea**, which forms the transparent, anterior part of the fibrous tunic, is clinically important because it is subject to many types of disease and injury. The cornea is normally avascular and is nourished by loops of capillaries at the corneoscleral junction. Additional nourishment is provided by the constantly changing aqueous humor on the posterior surface and the tear film on the anterior surface. The anterior limiting (Bowman's) membrane is usually much thinner in domestic mammals than in humans, and is apparently nonexistent in the dog and cat.

Both the **anterior and posterior epithelia** (especially the latter) are important in regulating the degree of hydration of the **proper substance**.[30] Disruption of either epithelium results in **corneal edema** (and opacity). Although avascular, the cornea as you know, is very well innervated so that anything that insults the cornea is accompanied by considerable discomfort and down-right pain. Ophthalmologists typically refer to the proper substance as the corneal stroma and to the posterior epithelium as the corneal endothelium.

Transparency and health of the cornea also depends on the tear film, which as previously noted, is composed of a complex mixture of secretions from the various glands associated with the conjunctival sac. Similarly, in order for the tear film to function in the nourishment, lubrication, and protection of the cornea, the normal blinking action of the lids and proper drainage of the tears are essential. The cornea of the domestic mammals plays a major role in the convergence of light rays so that images are focused on the retina.

The **vascular tunic** of the eyeball consists of the choroid, the ciliary body, and the iris (Fig. 10-40). Clinically, the vascular tunic is more frequently referred to as the **uvea**[31] or uveal tract, and inflammatory change in any or all of the above structures is called **uveitis**. Because this layer contains most of the blood vessels of eyeball, it makes sense that the uvea is subject to manifesting inflammatory change related to a multitude of etiologies, both local and systemic in nature.

---

30 To put it bluntly, the anterior and posterior epithelial cells are continuously working like little sump pumps to keep the proper substance dehydrated.

31 uvea (u've-ah); from u'vae [L. grape]; if you were to strip the fibrous tunic away, the remaining, dark-colored spheroid, covered by the choroid, ciliary body, and iris, would resemble a grape.

Equine Recurrent Uveitis: Recurrent uveitis is a leading cause of blindness in horses. Clinical signs include blepharospasm, conjunctivitis, corneal edema, aqueous flare (protein and cells in the anterior chamber), and miosis (Fig. 10-41). Ophthalmic examination may reveal cataract formation, subluxated lens, vitreous degeneration, retinal degeneration or detachment, or glaucoma.

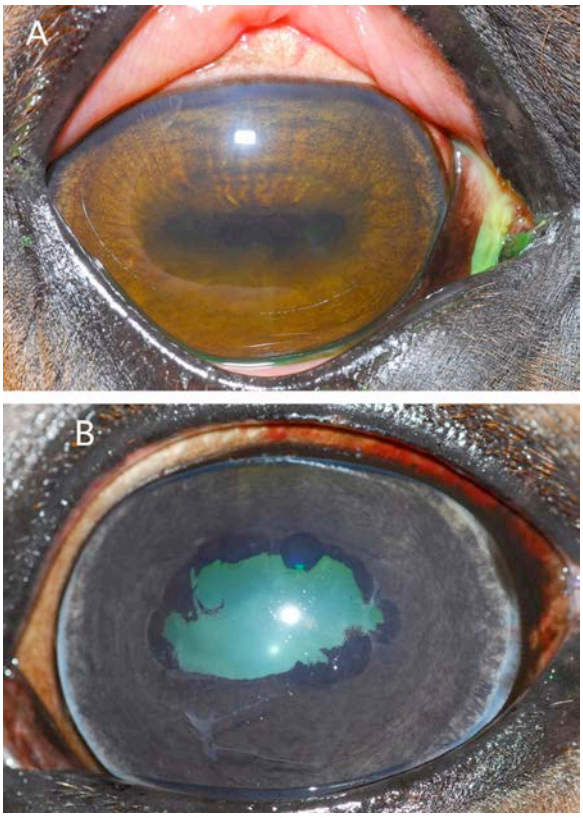


Figure 10-41. Acute (A) & chronic (B) cases of equine recurrent uveitis. (Photographs courtesy of Dr. Brian Gilger, Professor of Veterinary Ophthalmology, NC State University)

The initial insult in any uveitis is tissue damage and breakdown of the blood-aqueous barrier. Although most cases are idiopathic, various infections have been associated with recurrent uveitis in horses. Regardless of the initiating insult, it is thought that the problem results from a primary immune mediated etiology.

Most of the vascular tunic, on a real estate basis, is formed by the **choroid**, which encloses most of the vitreous chamber (Fig. 10-40). Its primary function is to provide vascular supply (nutrition) to the eyeball; however, it typically contains pigment,[32] which masks its important vascular components and helps to limit the amount of scattered light within the eyeball.

In most domestic mammals, "Parent Nature" adds a little something extra to the choroid. During the first few months of life a specialized reflective area, the **tapetum lucidum**[33], develops within the choroid (Fig. 10-40). Generally considered to represent an adaptation for improved night vision, it is typically present in carnivores but is sometimes absent in toy breeds of dogs. (They never go outside after dark anyway.) In the carnivores, it is a cellular structure, but in the horse and ruminant, it is more fibrous in nature.

There is a lack of retinal pigment in the area of the tapetum lucidum, which allows this part of the choroid to be observed directly with the ophthalmoscope (Figs. 10-42 & 43). There is no tapetum lucidum in the pig. Here again, this omnivorous creature most closely resembles the human, and its ocular fundus[34] typically appears red-orange on ophthalmic examination.[35] The typically pigmented, non-reflective part of

[32] Pigment is absent in the choroid and iris in true albino eyes (*e.g.,* white rats/rabbits, and the true vascular nature of the uvea shines through.

[33] Ophthalmologists rarely use the full name, and refer to this area simply as the tapetum or tapetal fundus.

[34] fundus- generic term meaning the deepest part of something; in this case, the ocular fundus is the back of the eye, which can be examined through an ophthalmoscope.

[35] Absence of the tapetum lucidum also explains that annoying red-eye phenomenon so often observed in flash photographs of pigs at a dinner party.

the choroid is termed the non-tapetal fundus (Fig. 10-40).

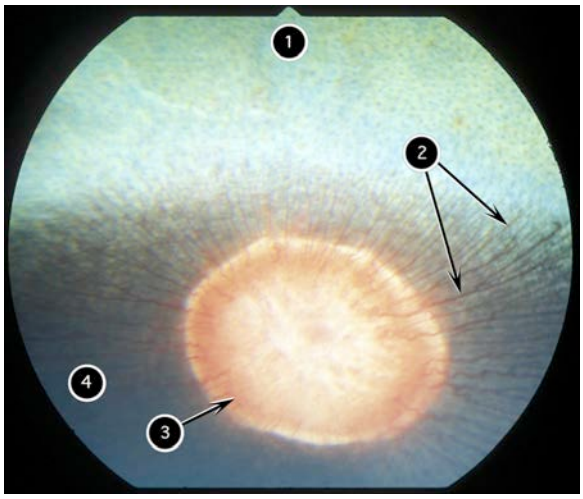


Figure 10-42. Fundus of equine eye as viewed through ophthalmoscope: (1) tapetum lucidum; (2) retinal vessels emanating from peripheral part of optic disc (3) optic disc; (4) non-tapetal fundus. (Photograph courtesy of Dr. Brian Gilger, Professor of Veterinary Ophthalmology, NC State University)

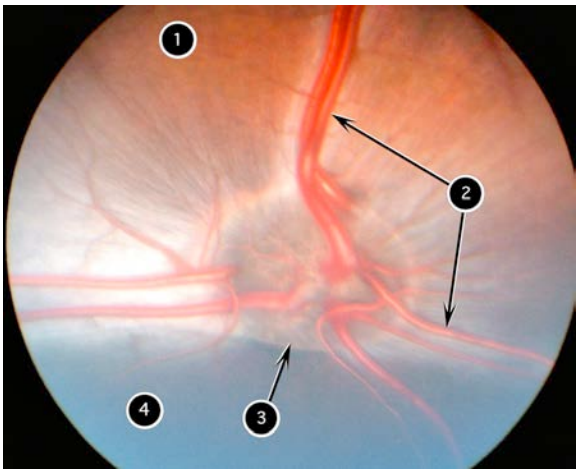


Figure 10-43. Fundus of bovine eye as viewed through ophthalmoscope: (1) tapetum lucidum; (2) retinal vessels emanating from central part of optic disc (3) optic disc; (4) non-tapetal fundus. (Photograph courtesy of Dr. Brian Gilger, Professor of Veterinary Ophthalmology, NC State University)

Moving anteriorly from the choroid, the next division of the vascular tunic is the **ciliary body**, which is a thickened annular ridge between the choroid and iris (Fig. 10-18). When viewed from within the eyeball, the most prominent feature of the ciliary body is its **ciliary processes** (Fig. 10-44). These fibroelastic ridges (≈ 100 in number) radiate from very near the edge of the lens to the junction (ciliary ring) between the choroid and ciliary body (Fig. 10-40). If you examine these processes closely, you will note that there is basically an alternating pattern of major (larger, longer) and minor (smaller, shorter) processes (Fig. 10-21).

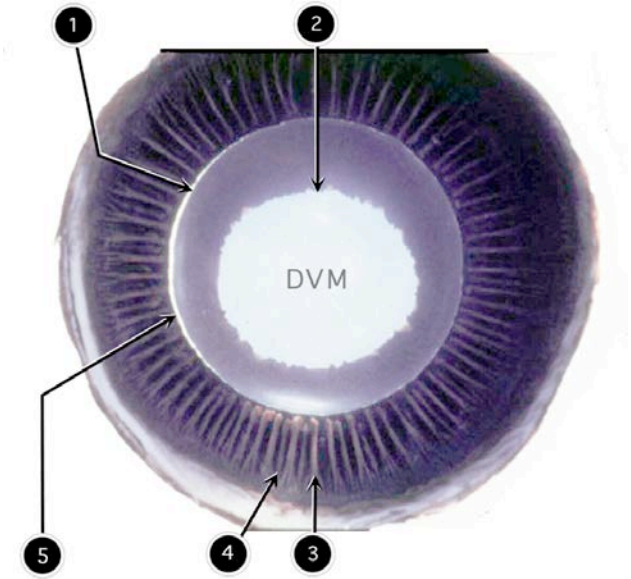


Figure 10-44. Posterior view of anterior hemisphere of eyeball, looking out through pupil: (1) equator of lens; (2) pupillary margin, edge of iris as seen though lens; (3) major ciliary process; (4) minor ciliary process; (5) zonular fibers attaching lens capsule to ciliary processes.

Intimately associated with the sides of the ciliary processes are the delicate fibers that form the suspensory apparatus of the lens. In effect, the ciliary processes act as supporting guides for these **zonular fibers**, which originate further posteriorly and collect into folds of fibers immediately adjacent to the ciliary processes.[36] Those

[36] Zonular fibers do not originate from the tips of the ciliary processes, as incorrectly depicted in many drawings.

zonular fibers associated with the major ciliary processes attach to the anterior lens capsule, while those associated with the minor processes attach posteriorly to the capsule (Fig. 10-45).

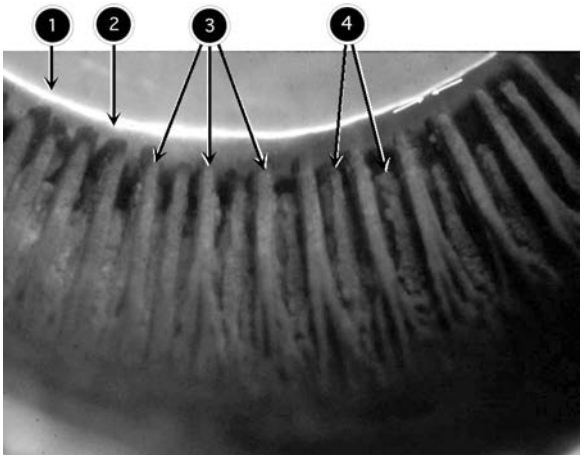


Figure 10-45. Close-up posterior view of ciliary body: (1) equator of lens; (2) zonular fibers attaching lens capsule to ciliary processes (3) major ciliary process supporting fibers to anterior lens capsule; (4) minor ciliary process supporting fibers to posterior lens capsule.

The **ciliary muscle** is a ring of smooth muscle fibers located within the ciliary body that functions in accommodation[37] of the lens. The ciliary muscle consists of both meridional and circular fibers (Fig. 10-46). When the muscle is relaxed, the zonular fibers are under tension, and the lens is more flattened (less convergent) for far vision. Contraction of this muscle draws the ciliary body anteriorly, away from the equator, and in so doing relaxes tension on the fibers of the zonula ciliaris[38], which allows the lens to assume a more spherical shape.

This naturally reduces the focal length of the lens, thereby accommodating for near vision.[39] In comparison with that of primates, the ciliary muscle of common domestic mammals is much less developed, and because of this, it is generally thought that these animals have poor accommodative ability.

The most anterior division of the uvea is the **iris**, which is the adjustable diaphragm that regulates the amount of light allowed to reach the fundus of the eyeball. Of course, the **pupil** is the opening in the center of the iris, the diameter of which is controlled by muscles within the iris. Two distinct and antagonistic muscles within the iris are responsible for dilation and constriction of the pupil.

Mydriasis (dilation of pupil) is effected by contraction of the **dilator pupillae muscle**, which consists of radially-oriented smooth muscle fibers near the posterior surface of the iris. The dilator muscle receives sympathetic post-ganglionic fibers from neurons located in the cranial cervical ganglion, which reach the iris *via* the ophthalmic nerve. The dilator muscle also receives parasympathetic innervation. Sympathetic stimulation causes contraction of the dilator muscle, while parasympathetic stimulation inhibits this action.

Miosis (constriction of pupil) is produced by action of the **sphincter pupillae muscle**, which consists of an annular band of smooth muscle within the central portion of the iris, immediately surrounding the pupil. The sphincter muscle receives parasympathetic innervation from

[37] accommodation: process by which lens changes shape (degree of convexity) for near and far vision.

[38] zonula ciliaris: suspensory apparatus of lens; formed by the zonular fibers and intervening spaces.

[39] As I'm looking at the computer screen through my bifocal lenses, I am reminded that in people the lens begins to lose its elasticity so that by about the age of 40 years, relaxation of the zonular fibers is not accompanied by a more spherical lens. Thus optometrists prosper prescribing corrective lenses for those of us in the 40+ age group afflicted with presbyopia.

neurons located in the ciliary ganglion. The preganglionic fibers reach the ganglion *via* the oculomotor nerve, with the post-ganglionic fibers continuing to the iris *via* short ciliary nerves.

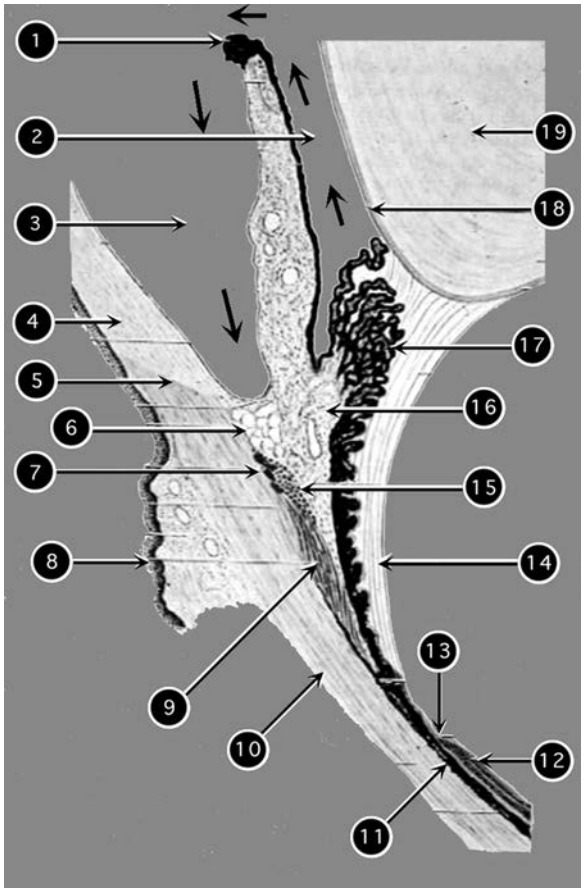


Figure 10-46. Drawing of iridocorneal angle of eye, black arrows indicate flow of aqueous humor: (1) pars iridica retinae; (2) posterior chamber; (3) anterior chamber; (4) proper substance (stroma) of cornea; (5) corneoscleral junction; (6) pectinate ligament; (7) scleral venous plexus; (8) bulbar conjunctiva; (9) meridional fibers of ciliary muscle; (10) sclera; (11) choroid; (12) pars optica retinae; (13) ora serrata; (14) zonular fibers; (15) circular fibers of ciliary muscle; (16) ciliary body; (17) pars ciliaris retinae covering ciliary processes; (18) lens epithelium; (19) cortex of lens formed by lens fibers. (Modified from *The Anatomy of the Domestic Animals*, Nickel, Schummer, Seiferle, Vol. 4, 1984).

Iridic Granules: Although most conspicuous in the horse (Figs. 10-36, 10-41, 10-46), these projections of the iris through the pupillary opening are also present in the ruminant eye, but not in the pig. These highly vascular structures, covered by pigmented epithelium, are normal for these species. Please don't mistake the iridic granules (formerly known as corpora nigra) for abnormal growths.

The **internal tunic** of the eyeball is formed by the retina with its pigmented epithelium. The **retina**, which extends from the pupil to the optic disc, consists of three divisions: (1) the light-sensitive part, the **pars optica retinae**, which covers the choroid; (2) the **pars ciliaris retinae**, which covers the ciliary body and its processes; and (3) the **pars iridica retinae**, which covers the posterior surface of the iris (Fig. 10-40). The junction of the thicker pars optica and thinner pars ciliaris is demarcated by an edge, the ciliary ring, which is serrated in humans, and is called the ora serrata. Although anatomically divisions of the retina, ophthalmologists typically refer to the pars ciliaris retinae and pars iridica retinae as the ciliary epithelium and iris epithelium, respectively.

Histologically the **pars optica retinae** is a complex layer consisting of an outermost epithelium and three neuron cell layers, which includes the actual photosensitive layer of rod and cone cells, located immediately inside the epithelium.[40] Ophthalmologists typically consider the retina as only two layers- the sensory retina (consisting of 9 histologic layers) and the retinal pigmented epithelium (RPE). In the area of the tapetum lucidum, there is no pigment in the external retinal epithelium,

[40] pars optica retinae: classically divided into 10 layers in histologic descriptions; see histologist for details.

and the light is reflected back through the photoreceptor cells, giving them sort of a "double bang" for the "photon buck." Axons from the neurons within the pars optica retina all converge to form the **optic disc** (Figs. 10-42 & 10-43), at which they turn outward, penetrating the wall of the eyeball, and emerging on the outside as the **optic nerve** (Fig. 10-40*)*. Because there are no photoreceptive cells overlying the optic disc, there is a small "blind spot" created by this deficit.

Over 90% of the photoreceptor cells in the dog are **rods**; however, the **cones** that are present are apparently able to respond differently to at least two different wave-length ranges of light. This type of "dichromatic" response indicates that the dog should be capable of distinguishing between predominantly long- and short-wave-length colors (*e.g.*, blues from reds).[41] When we view the retina through an ophthalmoscope, we are examining the **ocular fundus** (Figs. 10-42 & 10-43).

From the optic disc, we should note the emergence of the primary **retinal arterioles and venules**[42], although the typical pattern of these vessels varies considerably among domestic species. We might also note that there is a somewhat poorly defined area lateral and slightly dorsal to the optic disc, that is "avoided" by these vessels. This area, known as the **macula** or **area centralis**, represents the region of greatest concentration of photoreceptor cells and is considered to be the area of most acute vision.[43]

Although the photoreceptive layers of the retina end anteriorly at the ciliary ring, a much thinner epithelium continues onto the ciliary body as the **pars ciliaris retinae**, and then onto the posterior surface of the iris as the **pars iridica retinae** (Fig. 10-40). The retinal epithelium covering the ciliary body consists of two layers of cuboidal cells, an outer heavily pigmented layer and an inner non-pigmented layer, which is responsible for the production of aqueous humor.

Aqueous humor is actively secreted by the epithelium covering the ciliary body into the **posterior chamber** of the eye, flows centrally, passes through the pupil, and fills the **anterior chamber** (Fig. 10-46). Aqueous humor is a clear, colorless fluid that is secreted continuously and serves as a source of nutrition for the avascular lens and cornea. Aqueous humor is also responsible for maintaining the normal turgor or intraocular pressure within the anterior and posterior chambers. Because it is being continuously secreted, aqueous humor must also be continuously resorbed in order to maintain a relatively constant intraocular pressure (≈ 20 mm Hg).

In other words, the rate of secretion and resorption must be in balance to maintain this "dynamic equilibrium" of pressure. Anytime this balance is upset, typically by an impedance to flow or reduction in the rate of resorption, there will be an increase in intraocular pressure, a condition known as **glaucoma**. Glaucoma is a potentially disastrous condition, which if severe and left

[41] To my knowledge, no human knows *for sure* what colors non-human animals really see or don't see. It's all based on circumstantial evidence, which may or may not hold up in court. I personally doubt a dog can distinguish, say between raw umber and burnt sienna. I don't know, what do you think?

[42] Retinal venules are 2 to 4 times larger than retinal arterioles, and they can be distinguished on that basis.

[43] area centralis: In our common domestic mammals, there is no thinning of the inner retinal layers over this area to create a pit or fovea centralis, as is the case in the eye of humans and higher primates.

untreated, will destroy the photoreceptive function of the eyeball.

Iridocorneal Angle: Once in the anterior chamber, the aqueous humor flows peripherally to the angle between the cornea and iris, the iridocorneal angle (Fig. 10-46). The iridocorneal angle is of critical importance because it is predominantly through this angle that aqueous humor exits the anterior chamber for resorption. Within the iridocorneal angle is a meshwork of fine trabeculae forming the **pectinate ligament** (Figs. 10-46 & 10-47). After entering the spaces between these fine trabeculae, the aqueous humor is resorbed into aqueous collector vessels, which join the **scleral venous plexus** (Fig. 10-40). This plexus is drained by the anterior ciliary and vorticose veins.

Because of the delicate balance between production and resorption of aqueous humor, any disruption in the normal outflow path through the iridocorneal angle results in increased intraocular pressure (glaucoma). The iridocorneal angle changes with constriction and dilation of the pupil. **Miosis** (constriction of pupil) increases the iridocorneal angle and facilitates drainage by opening the spaces. **Mydriasis** (dilation of pupil) causes a bunching-up of tissue in the angle and impedes resorption of aqueous humor.

Lens: As previously mentioned, the **lens** of the eye is held in place by the zonular fibers forming the zonula ciliaris. The lens is the soft (initially at least), biconvex, crystalline structure, provided by "Parent Nature," to focus incoming light rays on the pars optica retina. The lens of our common domestic mammals is not generally considered to be the major refracting structure of the eye. Most refraction occurs at the anterior surface of the cornea, but the lens does serve to bring the images into critical focus on the retina.

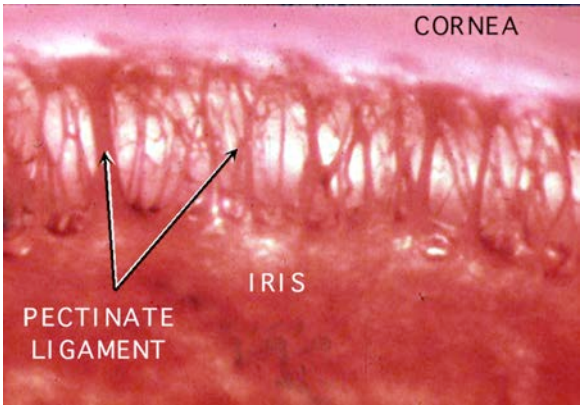


Figure 10-23. Gonioscopic[44] photograph of iridocorneal angle of dog, illustrating meshwork of fine trabeculae that forms the pectinate ligament. Aqueous humor flows between these trabeculae to reach the scleral venous plexus.

Structurally the lens consists of a harder, centrally located **nucleus**, surrounded by a softer, laminated (much like an onion) **cortex** formed by concentric layers of **lens fibers**, and enveloped entirely by a lens capsule (Fig. 10-40). The **anterior surface** of the lens is less convex (flatter) than its **posterior surface**, and the border around the lens, along which the anterior and posterior surfaces meet, is termed the **lens equator** (Fig. 10-40). The geometric centers (highest points) of the lens surfaces are designated the **anterior and posterior poles of the lens**, and a line passing through both poles defines the **lens axis**.

The highly elastic **lens capsule** is the basement membrane secreted by the cells of the lens epithelium. Although a posterior epithelium of the lens is present embryologically, this part degenerates during fetal life, which explains why the anterior capsule is so much thicker than the

[44] Gonioscopy is a specialized diagnostic technique used by ophthalmologists to observe the iridocorneal angle in the living animal.

posterior capsule. Throughout life, lens fibers are continuously formed by proliferation of the definitive (post-developmental) **lens epithelium**, which is located just below the anterior capsule (Fig. 10-46). This continued proliferation of lens fibers would cause the lens to get bigger and heavier throughout life, if it were not accompanied by a progressive condensation and dehydration (shrinkage) of the lens nucleus. This inevitable **nuclear sclerosis** is the primary reason why the lens becomes progressively less elastic in older years.

Nuclear sclerosis is an unavoidable (barring premature cessation of life) process in which the lens nucleus of older animals becomes sort of hazy to partly cloudy. Nuclear sclerosis should not be confused with **cataracts**, which are pathologic opacities within the lens. Nuclear sclerosis can be differentiated from cataracts by the ability to "retro-illuminate" through nuclear sclerosis. In other words, you can shine a bright light through the nuclear sclerosis and it will be reflected from the tapetum, back through the lens to your eye. In contrast, a cataract will block the light so that a shadow is cast on the tapetum.

Just like the cornea, the transparent lens is avascular, and gets what nourishment it needs from direct diffusion from the aqueous humor in-front and the vitreous humor from the back side. For what it's worth, you might notice that the only actively proliferating (most metabolically active) tissue of the lens, the lens epithelium, is immediately subjacent to the anterior capsule-aqueous humor interface.

Careful examination of a removed lens (held up to a view-box light) may reveal the **lens sutures** (radii lentis), which represent the junctions of groups of lens fibers. Three of these sutures radiate from each pole (anterior and posterior) of the lens. The lens sutures on the anterior surface form an upright Y; those on the posterior surface form an inverted Y.

Vitreous Body: The last, but certainly not least important, structure to be discussed is the **vitreous body**, which is that large gelatinous mass that fills the **vitreous chamber** of the eyeball (Fig. 10-40). The vitreous body is a gel-like structure that is almost entirely extracellular, being primarily a liquid (**vitreous humor**) solution of mucopolysaccharides, and about 98% water. The gel-like consistency is reinforced by a delicate connective tissue stroma. Traversing the vitreous body from the optic disc to the center of the posterior lens capsule is the hyaloid canal. Embryologically, the hyaloid artery passed through this canal to nourish the developing lens. Occasionally the vessel persists in the young animal and may produce clinical problems.

Ramp Retina of Horse (Fact or Fiction?): Some authors have given rather convincing descriptions, complete with diagrams, on how the unusual shape of the equine eye allows it to focus near and far images on different parts of the retina.[45] This oblong-eye, static accommodation theory has been called the ramp retina concept. However, it seems that the concept of the ramp retina (originally described in 1930) has little basis in fact. Although horses admittedly have only minimal ability to accommodate actively (poorly developed ciliary muscle), this handicap is certainly not unique to the horse. The results of one study have indicated that, although the equine eye is slightly asymmetric, the difference in lens-retina distance (above and below the optic

[45] Diesem, C. In Sisson and Grossman's *The Anatomy of the Domestic Animals*, Vol. 1, 5th ed., W. B. Saunders, Philadelphia 1975.

axis) is not sufficient to account for any significant degree of static accommodation.[46]

Related to the more lateral position of the equine eyes, the horse has a rather narrow angle of visual overlap between the two eyes (binocular vision). Thus, they have poor depth perception, except in this narrow zone. Whenever horses detect movement of some object in their wide zone of peripheral vision, they attempt to angle their head so as to bring the object into their narrow zone of binocular vision.

Try this little experiment. Place your closed hand around your nose, forming a nice, horse-like muzzle. Now, continue to read this text. It's a little more difficult without tipping your head down, right? Similarly, a horse can't see anything right in front of its elongated face. That area is its blind spot. No wonder a horse does some funny things with its head when trying to see where it is going, especially when approaching an obstacle.

Radiographic Anatomy of Equine Head: In addition to the radiograph of the guttural pouch region, and dental radiographs included above (Figs. 10-17, 10-31, 10-32, 10-33), the occipital region is also an area of interest in the horse (Fig. 10-48).

Palpation Checklist for Head

Horse

1. Buccal branches of facial nerve as they cross masseter muscle
2. Mandibular lymph nodes
3. Take the pulse from the facial artery as it crosses the mandible.
4. Tickle nose and demonstrate levator labii superioris muscle contraction.
5. Temporomandibular joint
6. Facial crest
7. Nasoincisive notch and nasal diverticulum
8. Infraorbital foramen
9. Coronoid process of mandible
10. Define surgical boundaries for trephination of the maxillary sinus.
11. Auriculopalpebral nerve as it crosses zygomatic arch
12. Locate the nasal orifice of the nasolacrimal duct in floor of nasal vestibule.

Ox

1. Take the pulse from the facial artery as it crosses the mandible.
2. Facial tuberosity
3. First upper cheek tooth and infraorbital foramen
4. Temporal line

[46] Sivak, J. G. and Allen, D. B. An evaluation of the ramp retina of the horse eye. Vision Research 15 (1975): 1353-1356.

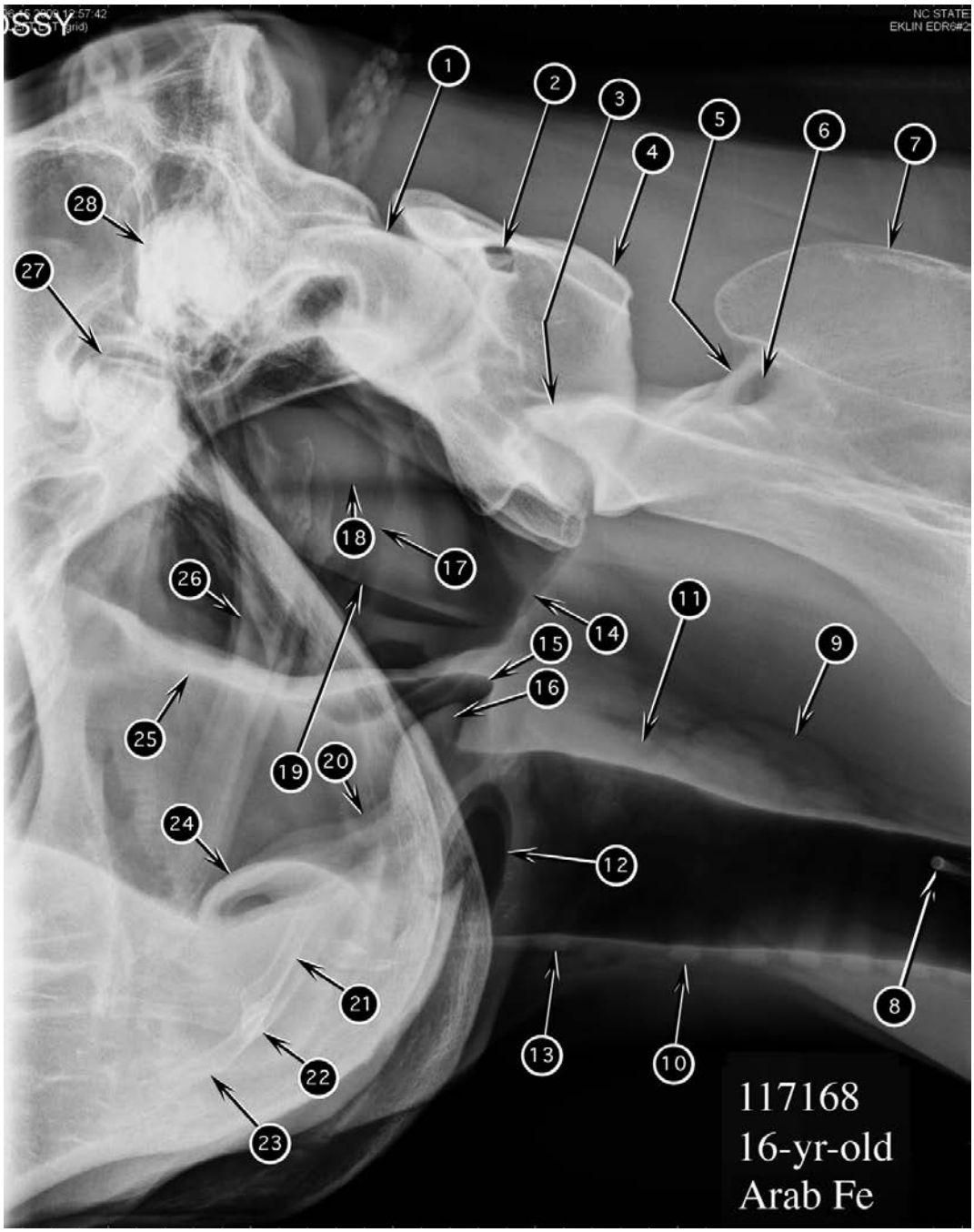


Figure 10-48. Left-Right lateral radiograph of occipital region of equine head: (1) occipital condyles; (2) lateral vertebral foramina of atlas; (3) dens of axis; (4) dorsal arch of atlas; (5) ossified ligaments forming cranial boundary of 6 (not ossified in foals); (6) lateral vertebral foramina of axis; (7) spinous process of axis; (8) catheter in external jugular vein; (9) thyroid gland; (10) tracheal cartilage; (11) lamina of cricoid cartilage; (12) laryngeal ventricles; (13) arch of cricoid cartilage; (14) caudal extent of medial compartments of guttural pouches; (15) laryngopharynx; (16) corniculate processes of arytenoid cartilages; (17) caudal extent of lateral compartments of guttural pouches; (18) rectus capitis ventralis muscle; (19) longus capitis muscles; (20) aryepiglottic folds; (21) thyrohyoid bones; (22) basihyoid bone; (23) lingual process of 22; (24) epiglottic cartilage; (25) dorsal wall of nasopharynx; (26) stylohyoid bones; (27) temporomandibular joints; (28) petrous temporal bones.

Smallwood's Axioms of Learning & Teaching

1. ***Learning is more important than teaching.*** *There is no single best method of teaching.*

2. ***Learning occurs by bridging the gap from the familiar to the less familiar.*** *The most effective teachers are those who are best able to help the learners bridge this gap*

3. ***The most important single element in determining how effectively learners learn is the "teacher."*** *A good teacher serves as a living conduit for the information.*

4. ***The only thing more contagious than enthusiasm is apathy.*** *Effective teachers are hopelessly infected with a contagious enthusiasm for their subject.*

5. ***Ignorance is relative, so don't take yourself too seriously.*** *The most effective teachers are those who take their subject, but not themselves too seriously.*

6. ***The more actively you can get the students involved with the learning process, the better.***

7. ***Ninety percent of what students learn in a given course is directly related to how we test them.*** *Good teachers emphasize the more important points, and their examinations accurately reflect differences in relative importance.*

8. ***Students are people too; they respond to positive and negative reinforcements just like we do.*** *Honesty, fairness, and consistency are absolutely essential to establishing and maintaining the trust of your students.*

9. ***Organization and direction are important, but too detailed directions may actually impede learning.***

10. ***You can tell more about how much a student is learning by the questions they ask than you can by the answers they give.***

11. ***Good teachers emphasize the applied aspects of the subject matter.***

12. ***Being a laboratory instructor is a lot like being a tour guide***

13. ***Forgetting is part of learning.***

14. ***One of the major rewards of teaching is learning.*** *Every teacher is a learner and every learner is a teacher.*

15. ***A good teacher is part benevolent dictator, part coach, part noxious stimulus, and part cheerleader.***