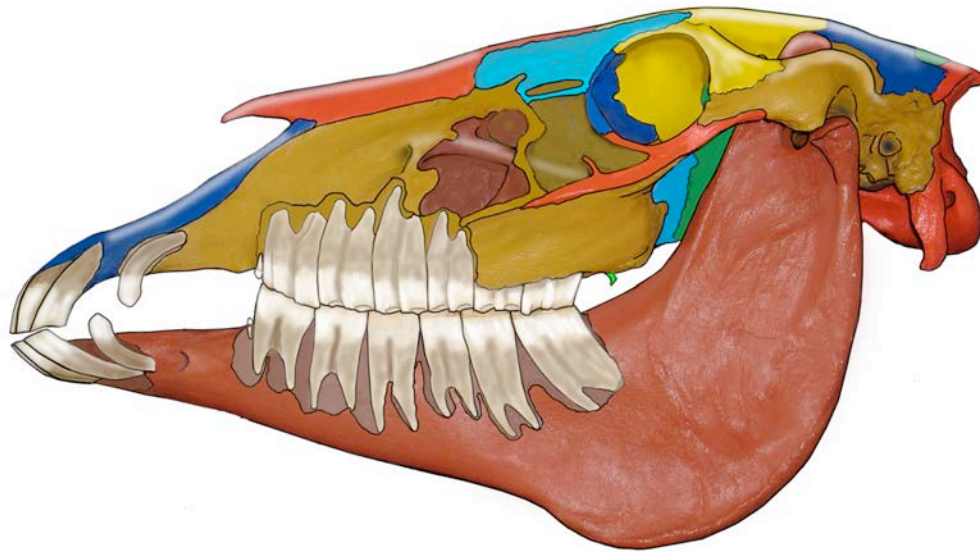
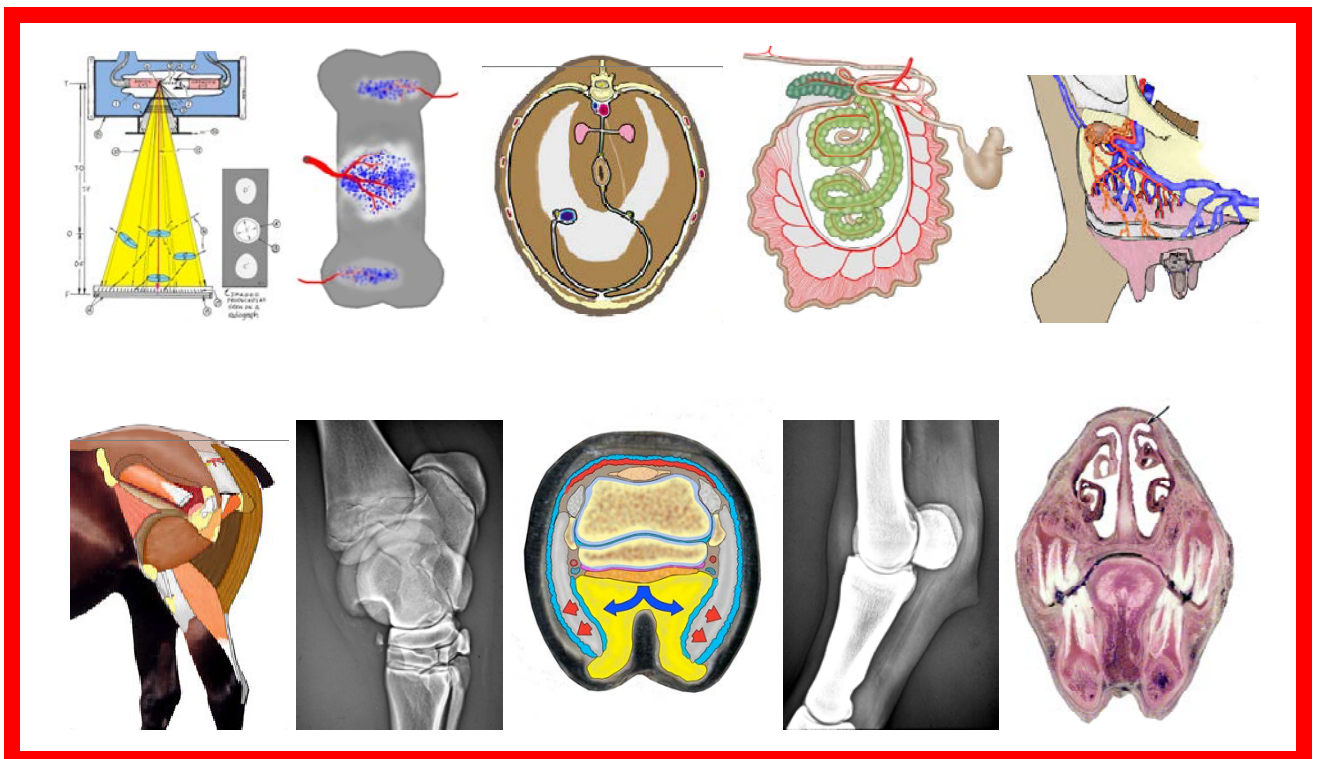


A Guided Tour of Veterinary Anatomy



Twenty-Ten Edition
James Edgar Smallwood



A Guided Tour of Veterinary Anatomy

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In January 2024, Dr. Smallwood decided to make pdf copies of this book available to the veterinary community at no charge. Hopefully it will be found useful to some veterinary student and veterinarians.

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A Guided Tour of Veterinary Anatomy

Dedication & Notes

This book is dedicated to my students, who over the years have endured my lectures, laboratories, stories, and jokes, and who, in spite of that, have gone on to become (for the most part) competent and successful veterinarians. This book was written for my students, but if others find it useful, I am delighted to be of assistance.

About the Author

James Edgar Smallwood was born in Dallas, Texas and grew up on a small farm near Fort Worth. He attended Burleson High School, Sam Houston State University, San Antonio College, and Texas A & M University, from which he received the DVM in 1969. Upon graduation, Dr. Smallwood was offered an instructorship in the Department of Veterinary Anatomy, which *in lieu of* finding a real job, he accepted. Thus he began teaching veterinary students in 1969. While serving as an instructor, he completed his MS degree in veterinary anatomy in 1972, at which time it became obvious he had been educated well beyond his intelligence.

In 1975, Dr. Smallwood left *academia* and tried working for a living as an associate in a small animal practice in San Antonio. The university was gracious enough to extend a one-year leave of absence, during which time the opportunity arose for Dr. Smallwood to return to Texas A & M University in a "split appointment" in veterinary anatomy and radiology. From 1976 to 1981, he spent approximately 50% of his time teaching anatomy and 50% doing a residency in veterinary radiology.



James E. Smallwood, DVM, MS
1945 - ?

In 1981 Dr. Smallwood was offered the unique opportunity to become one of the initial faculty members of a new veterinary college being established at North Carolina State University. He became Professor of Anatomy and began teaching the first class of that college, which graduated in 1985. In 1989 he was named Alumni Distinguished Professor of Anatomy, and continues to harass first-year veterinary students as their "tour guide" in learning veterinary anatomy.

Dr. Smallwood has received numerous teaching awards including the Texas Veterinary Medical Association Faculty Achievement Award for Teaching, Texas A & M University Faculty Distinguished Achievement Award for Teaching, Norden Distinguished Teacher Award, North Carolina State University Outstanding Teacher Award, NCSU Alumni Distinguished Professor Award, UNC

Preface and Introduction

System Board of Governors' Award for Excellence in Teaching, and Second Place Winner of the Student AVMA National Teaching Excellence Awards in Basic Sciences. He has served as President of the American Association of Veterinary Anatomists (1988-89) and the World Association of Veterinary Anatomists (1995-99). In 2002, Dr. Smallwood received the Distinguished Veterinarian Award from the North Carolina Veterinary Medical Association.

About the Book

A Guided Tour of Veterinary Anatomy emerged from the expansion of notes, which had been used for a number of years in teaching comparative anatomy to first-year veterinary students. I call it a "guided tour" because I often compare what I do, in terms of teaching anatomy, with the role of a "tour guide." Consequently, this guided tour is intended to serve as a sort of *gubernaculum** for first-year veterinary students in their dissection and comparative anatomic study of the horse, ox, goat, sheep, and pig. As is the case with the *gubernaculum testis*, it is anticipated that this guide will not deliver all students from the abdominal crypt of anatomic darkness to the full enlightenment of anatomic wisdom.

When people (students) sign up for a *guided tour*, they typically expect that: (1) their guide has been on the tour *at least once* before; (2) their guide will point out the important sites (structures) along the way; (3) their guide will provide them with some interesting facts (even a little trivia) about the sites they will see; (4) their guide will probably provide them with a little more than they really wanted to know about some sites; (5) their guide will probably forget to mention one or two important points; and

(6) *that their guide will not get them totally lost along the way.*

An attempt has been made to emphasize applied anatomy as it relates to physiology, pathology, radiology, medicine, and surgery. In fact, much of the information contained in this guide is related to the application of anatomy to veterinary medicine. It is the opinion of this instructor that the inclusion of such information is not only appropriate, but is critical to acceptable comprehension and full appreciation of the subject by first-year veterinary students.

For one thing, few (if any) students attend veterinary school with the burning desire to become a veterinary anatomist. To the contrary, they typically view successful completion of their gross anatomy courses as just a necessary step toward reaching their objective of becoming a veterinarian. I see absolutely no reason to defer the applied aspects of anatomy to a subsequent course in an already crowded curriculum, in which there is increasing competition for contact hours among the various disciplines. In my experience, first-year veterinary students are perfectly capable of comprehending basic anatomic information and gaining concurrently an appreciation for how that information is going to be important in their other professional courses and in their successful functioning as a veterinarian.

As is already evident from the above, this guide is written in rather plain language, with a liberal interjection of comments that are (at least) slightly humorous. Some of my colleagues will undoubtedly view these notations as out of place, and I accept this criticism constructively. *Thank you.* I really don't see any reason why anatomy can't be fun as well as educational. It has been my experience that instructors are more effective when they don't take themselves too seriously.

* gubernaculum- "helm"; "rudder"; something that guides.

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How This Guide is Used

At North Carolina State University our laboratory tour takes approximately 8 hours per week for 13 weeks for a total of about 104 hours. The tour is supplemented (facilitated) by two hours of lecture per week, but, in my opinion, *anatomy cannot be learned in the lecture theater. Trying to learn anatomy out of a textbook or from powerpoint slides, dvds, computer programs, etc. is much like attempting to understand the principles of aerodynamics by studying a canary that has been run over by a truck.*

When this guide is used, our students have previously dissected the dog and cat during their first semester. Thus they are already experienced dissectors (some with the scars to prove it), and they should have a good understanding of terminology and basic mammalian anatomy. During the dissection periods, students must work together, with different students being the teachers, while others are the learners, at different times.

Purposes of Guided Tour

The purposes of this guided tour are to: (1) emphasize points of major importance that are also covered as lecture topics; (2) provide instructions for dissection of the horse, ox, small ruminants, and pig; (3) point out selected differences among species; (4) *motivate students to enjoy the wonderful and exciting world of anatomy.*

Acknowledgements

The author is greatly appreciative of the dedicated efforts of Mr. Jerry Davis and Ms. Monica Wilson of Millennium Print Group. Without their perseverance and patience, this book would never have been completed.

My lovely and exciting wife, Kay, has helped in many ways with the production of this book. Constructive comments by Dr. Lola Hudson, Dr. Jill Barnes, Dr. Alexander de Lahunta, Mr. William Wise, and hundreds of former students have been most helpful. *Student comments and suggestions relative to the improvement of this guided tour are always welcomed and appreciated.*

Twenty-Ten Edition

This “2010” edition is the third publication of “A Guided Tour of Veterinary Anatomy.” The first edition was published by W. B. Saunders Company in 1992. The second (“Y2K”) edition was published by the author in 1999. Both of these editions were more or less “married” to *The Textbook of Veterinary Anatomy* by Wensing, Dyce, and Sack. I thought this was the best way to serve the students, never intending that this book would be viewed as a comprehensive coverage of the subject matter. Students were directed to various sections, and particularly illustrations, in *The Textbook of Veterinary Anatomy*.

So what’s new in the Twenty-Ten Edition? The “short answer” is many more illustrations and color. There are also new sections on “Bone Development from a Gross Anatomist’s Perspective” (pp. 14-25), and “Comparative Anatomy: How the domestic species we study relate to one another and fit into the larger scheme of mammals on the planet” (pp. 26-33). More emphasis has been placed on the horse. Of the 360 figures in this edition, 159 are new, and many of the remaining 201 have been improved and/or colored. With 360 illustrations, we have respectfully “divorced” (in a friendly sort of way) this guide from other textbooks.



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Chapter 1 • An Introduction to Veterinary Radiology, Bone Development, and Comparative Anatomy

Of Historical Interest

- November 8, 1895 - X-rays discovered by Wilhelm Conrad Roentgen, German Physicist
- January 17, 1896 - First radiograph made of Mrs. Roentgen's hand
- 1901 Roentgen awarded first Nobel prize in physics for his discovery of x-rays

If we are to utilize radiographs in teaching veterinary anatomy, it is necessary for you to have a basic understanding of radiology. Thus, the major objective of these notes is to provide you with the basic information necessary to develop that understanding.

Why bother with radiographs at all? Well, based on my extensive personal experience, I have concluded that it is extremely rare for a *practicing veterinarian* to be called upon to examine a single bone, a complete or partial skeleton, or even an embalmed cadaver (Fig. 1-1).



Figure 1-1. Rare old photograph of young veterinarian being presented with unusual orthopedic case. This type of problem is not often encountered in practice.

Oddly enough then, *one of the primary ways you as a veterinarian will utilize your knowledge of anatomy is in the interpretation of radiographs.* With the possible exception of a canary that has been run over by a truck, most of what you will see in any diagnostic radiograph will represent normal anatomy. *Your problem is to recognize normal and to distinguish it from abnormal. To do this requires not only a good knowledge of normal anatomy, but also an understanding as to how and why specific body parts appear as they do radiographically.*

What are "x-rays" and how do they behave? Diagnostic x-rays represent a form of *electromagnetic radiation* having a wavelength about 1/10,000 that of the visible light spectrum.¹ Although x-rays are actually a succession of electromagnetic waves, they behave as if they consisted of separate little packets of energy called quanta or photons. Thus, their interaction with body tissues (e. g., absorption) is sometimes easier to understand if the x-ray beam is thought of as a shower of little energy packets or photons. *The shorter the wavelength, the greater the energy of the photon.*

As a form of electromagnetic radiation, *x-rays obey basically the same physical laws as visible light* with the most notable exception being that they can penetrate materials that reflect or absorb light. Don't memorize the wavelength of x-rays, but do understand that it is their *short wavelength* that allows them to penetrate the body. It is

¹ The median wavelength of light is about 5.5×10^{-5} cm; that of diagnostic x-rays is about 5.5×10^{-9} cm.

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also their short wavelength that enables them to interact with the atoms of body cells, and in so doing, to *produce potentially harmful biologic changes*, both somatic and genetic. This capability permits high-energy (short wavelength) x-rays and gamma rays (from cobalt and other sources) to be used in radiotherapy, but it also necessitates protective measures (e. g., lead-lined gloves, aprons, etc.) whenever x-rays are used.

Because x-rays are capable of altering atomic structure by ejecting an electron and thus creating two ions, they are a form of *ionizing radiation*.

How are x-rays produced? By an x-ray machine of course, what kind of question is that? OK, but they are actually produced within an x-ray tube (Fig. 1-2).

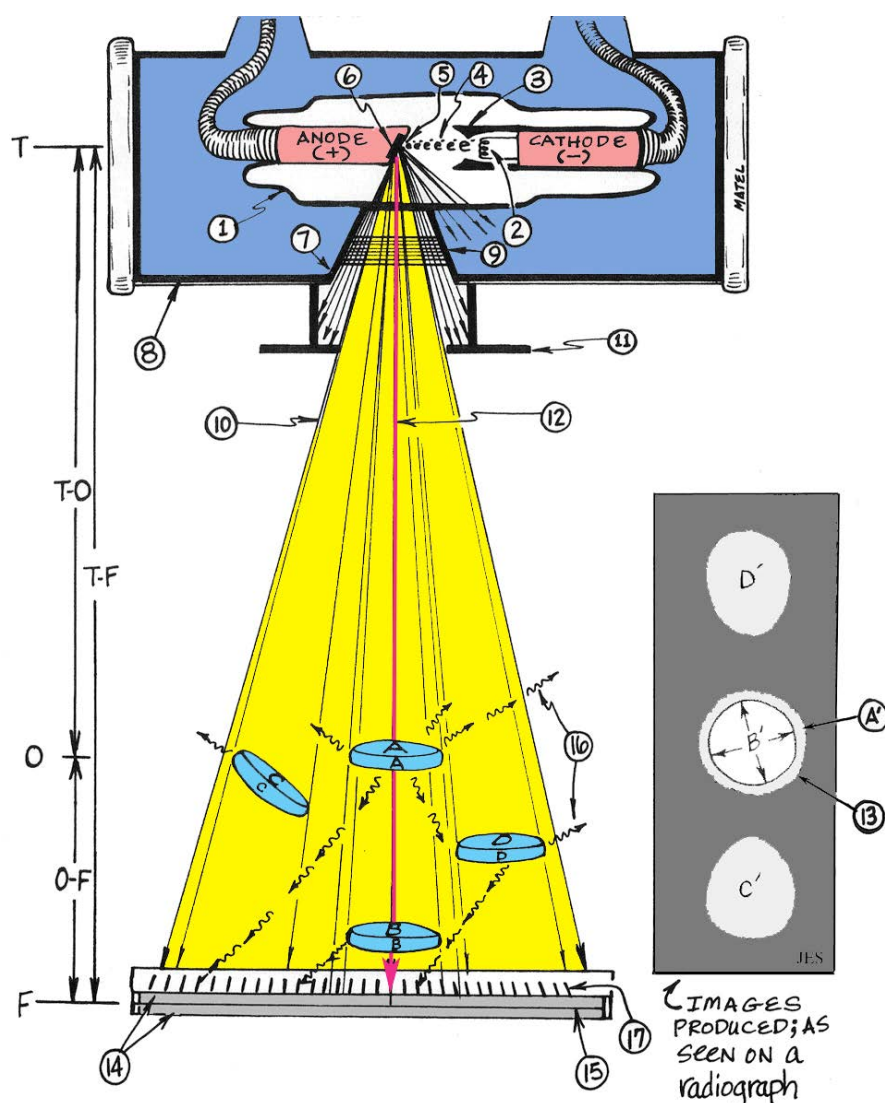


Figure 1-2. Simplified anatomy of x-ray tube, its primary beam, and other related structures and phenomena: T = tube; O = object; F = film; A-D = identical, homogeneous, discoid objects; A'-D' = images of A-D as seen in resulting radiograph; (1) evacuated glass envelope; (2) cathode filament; (3) focusing cup; (4) focused electron beam; (5) focal spot; (6) tungsten target; (7) port; (8) lead shielding; (9) aluminum filter; (10) primary beam; (11) collimator; (12) central ray; (13) penumbra around A'; (14) intensifying screens; (15) radiographic film; (16) scattered radiation; (17) grid.

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X-rays are produced by directing a focused beam of electrons at high velocity against a tungsten target. The cathode filament, which is heated to glow much like that of an incandescent light bulb, serves as the electron source. The higher the milliamperage (mA) set on the machine, the hotter the cathode filament glows, and the more electrons that are available for x-ray production.

When a very high potential (measured in kilovolts) is applied across the components of the evacuated tube, the available electrons are accelerated across from cathode to anode where they impact in the target of the anode with the release of a great deal of energy. Unfortunately, most of the energy is released in the form of heat, but *about 1% is transformed into x-rays*. Tungsten has been routinely used as the target material because it has the necessary high melting point and, due to its high atomic number, is more efficient in producing x-rays.²

*The higher the peak kilovoltage (kVp) set on the machine, the faster the electron beam is accelerated toward the target and the shorter the wavelength of the x-rays produced. Thus, increasing the kVp, decreases the wavelength of the x-rays and increases their penetrating ability. The quantity of x-rays is primarily a function of the number of available electrons (mA) and the length of the exposure. The product of these two measurements, mA x seconds (s) or mAs, primarily determines the quantity of x-rays produced.*³

² A rhenium-tungsten target has replaced the solid tungsten target because of its improved ability to dissipate heat.

³ Increasing the kVp also increases the quantity of x-rays because new, shorter wavelength x-rays are added to those already produced at the lower setting.

What is the focal spot and how does its size affect image quality? The area on the target where the electron beam is focused is the **focal spot** (Fig. 1-2). The length and diameter of the cathode filament and the shape of the focusing cup determine the shape and size of the focal spot. *The smaller the focal spot, the sharper the radiographic image that is produced.* This is because separate images are produced by x-rays originating from opposite sides of the focal spot. The "partial shadow" border created by these multiple images not being exactly superimposed produces a "fuzzy" edge known as the *penumbra*. The smaller the focal spot, the less distance between points on opposite sides of it, and the more closely superimposed are the images produced. This reduces the penumbra and makes the image sharper. However, reducing the focal spot also concentrates the heat so that design modifications such as **rotating anodes** have been developed.

What is a rotating anode, and what is its advantage? Rotating anodes are anodes that rotate during the exposure so that the great amount of heat generated at the focal spot is spread over 360° of spinning target (Fig. 1-3).

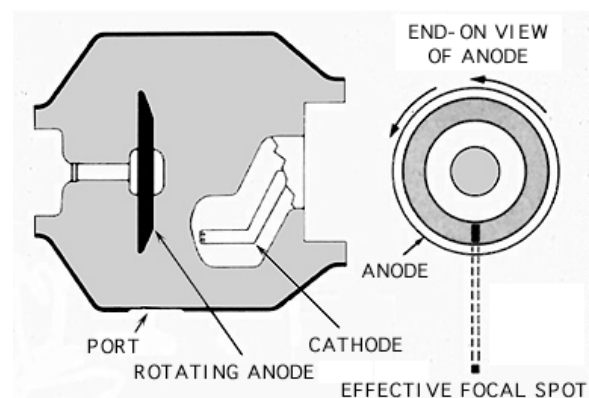


Figure 1-3. Simplified anatomy of a rotating anode showing how the focal spot represents a fraction the total target. (Modified from *The Fundamentals of Radiography*, 11th ed., Eastman Kodak Co., Rochester, NY, 1968, p. 10.)

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Ever wonder what causes that spinning noise inside the x-ray tube? That sound is produced by a motor that spins the anode prior to exposure. The anode has to get up to speed before an exposure can be made. This protects the target from getting blasted with too many electrons over too small a focal area. *In effect, a rotating anode allows for a small focal spot with a large target.*

As the x-rays are produced, they radiate from the focal spot in all directions, but only those directed through the window or *port* (Fig. 1-2) of the tube are allowed to escape. The remainder are absorbed by the lead shielding surrounding the x-ray tube. In fact, some of the longer-wavelength x-rays are not allowed to escape at all. Because these "soft" x-rays are of no diagnostic value and would only add to radiation exposure, they are absorbed by an aluminum filter inserted in the port (Fig. 1-2).

Those x-rays that emerge via the port form the **primary beam**. The size and shape of the primary beam should be modified by a beam-limiting device such as a **collimator**. Like light waves, x-rays travel in straight lines and radiate from the focal spot; they diverge from one another as the distance from the focal spot increases. The line of radiation in the geometric center of the primary beam is termed the **central ray**.

How does the distance from the source affect the intensity of the primary beam?

As one moves down the primary beam, away from the x-ray source, the beam obviously covers a progressively larger area as the x-rays diverge (Fig. 1-4).

This, of course, dilutes or decreases the intensity per unit area of the beam, and it does so in accordance with the **inverse square law**. Thus, as the distance from the

source is doubled, the intensity of the beam is reduced by 2^2 or to $1/4$ that at the original distance; if the distance is tripled, to $1/9$, etc. If you haven't already figured it out, it also means that by moving back from the x-ray tube, say to 6 feet from 2 feet, you can cut your radiation exposure by about 90%. This is something to think about the next time you have to hold an animal for radiography.

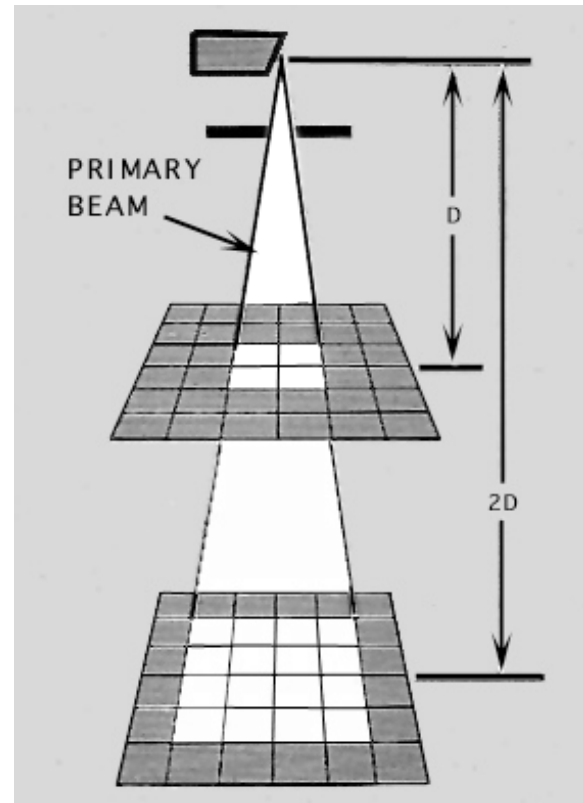


Figure 1-4. Illustration of how inverse square law affects intensity per unit area of primary beam. (Modified from *The Fundamentals of Radiography*, 11th ed., Eastman Kodak Co., Rochester, NY, 1968, p. 37.)

What is a radiographic image and how is it produced?

A radiographic image is a *summation shadowgram*; it is a two-dimensional, somewhat magnified and somewhat distorted representation of a three-dimensional object. A radiographic image is obtained by interposing an object between the x-ray source and a recording

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device such as radiographic film. The *latent image* is produced either directly or indirectly by the x-rays that pass completely through the object and reach the film. The actual visual image results from photographic development. However, not all of the x-rays pass through the object—some are absorbed by it. In fact, *it is the differential absorption of x-rays by different body tissues that forms the basis for using radiography as a diagnostic tool.*

Why is the image magnified? *The image is magnified because the x-rays diverge from the central ray. Thus, by the time they reach the film to produce the image, they cover a larger area than when they passed through the object. As is demonstrated in figure 1-2, the object-film distance affects the degree of magnification. As the object-film (OF) distance decreases, magnification decreases. Although A and B are identical objects, the image of A is larger than that of B. Magnification would also be decreased by increasing the tube-film (TF) distance. If TF were increased, less of the primary beam would be needed to cover A, and the x-rays that would penetrate A would be more parallel to the central ray. Thus, their divergence and the resulting image magnification would be less. However, as TF is increased, the intensity per unit area of the beam decreases according to the inverse square law, and greater exposure would be required to produce the image. For this reason, the TF distance is usually maintained at a "compromised standard" and magnification is reduced by placing the body part of primary interest as close as possible to the film.*

Does placing the body part of interest closer to the film also improve image sharpness? Funny you should ask, as a matter of fact it does. Notice that in figure 1-2 the "artist" has indicated that A' is

"fuzzy" (Fig. 1-2). As was mentioned above, separate images are produced by x-rays originating from opposite sides of the focal spot. Because the separate images will begin to diverge from one another as one moves away from the object, toward the film, the greater this distance, the more divergence of these images. This divergence produces progressively greater "blurring" of the composite image as the individual images are less and less superimposed. Thus, the image produced by A is less sharp than that of B. *As the OF distance is decreased, the sharpness of the image is increased.* As already mentioned, image sharpness is also increased by a smaller focal spot.

Why is the image distorted? The amount of distortion in the image varies a great deal with its spatial orientation with respect to the focal spot and film. Refer once again to figure 1-2. Object C is a circular disc identical to A; however, due to its oblique orientation, its image (C') is distorted to an egg shape. The reason is obvious. That part of C toward the central ray is magnified less than the opposite side. Thus, *distortion is caused by differing degrees of magnification of different parts of the object. Distortion can be decreased by orienting the body part of interest parallel to the film.*

Now consider object D and its lovely image D'. Again, there is distortion of the image. Although the object is parallel to the film, those x-rays passing through the part of D nearer the central ray do not have to travel as far to reach the film as the more peripheral rays. Thus, that part of D nearer the central ray is magnified less than the opposite side. Again, distortion resulted from differences in magnification due to different distances traveled by the x-rays from object to film. Thus, *distortion can be decreased by centering the central ray*

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directly through the body part of interest. Or, in other terms, those body-part images in the radiograph nearer the central ray are distorted less than those toward the periphery of the beam. This means that the images near the edges of the radiograph (assuming that the film was centered on the central ray) are more distorted. *Distortion is also increased when the film is not perpendicular to the central ray.*

What other factors affect sharpness or detail of the radiographic image?

1. Motion of body part during exposure.

Obviously this creates the same problems as with photography and represents a particular problem in veterinary radiography. (OK, dog hold your breath and don't move until I tell you!) Because the quantity of x-rays is primarily a function of mA x time (s), the higher the mA, the shorter the time needed for a given output. Thus, higher-mA machines are required whenever rapid exposures of thick body parts are needed.

2. Speed of film. Just as with photo-graphic film, there are different "speeds" of radiographic film. Generally speaking, the faster (more sensitive) the film, the larger the crystals (more grain) in the emulsion and the less sharp is the image. High-detail films are generally slow films that require more exposure.

3. Speed of intensifying screens. Most of the exposure of the radiographic film is *not* due to x-rays directly. I'm sorry to disappoint you, but most of the exposure of the film is produced by *light*. That light is generated by the interaction of x-rays with phosphorescent crystals contained within one or two intensifying screens. These screens (Fig. 1-2) are located within the radiographic cassette and are held in tight contact with the emulsion on one or both

sides of the film. When the x-rays strike these crystals, they emit light, which in turn exposes the film.

Again, generally speaking, the higher the speed of the screens, the larger the phosphor crystals and the less sharp the image. However, technological advances utilizing so-called "rare-earth" elements have resulted in ultra high-speed screens with little loss in detail. Use of rare-earth screens has enabled veterinarians to produce radiographs of acceptable sharpness with rather low output machines. Rare-earth screens also allow more powerful units to be used at lower settings, thereby reducing both radiation exposure and "tube stress". (When tubes wear out, they're expensive to replace!)

4. Scattered radiation. Figure 1-2 shows a neat little beam of radiation, with all the little x-rays traveling in straight lines directly to the film. As long as we are considering the primary radiation beam traveling through air (even if somewhat polluted), this is a reasonable representation. However, when x-rays "collide" with the atoms of the object, some are completely absorbed, and some are only partly absorbed. In the latter case, secondary x-rays are produced, which radiate out from the object in all directions. Some of this secondary or *scattered radiation* (Fig. 1-2) could reach the film, and because it is traveling in different ("weird") directions, it could alter (mess-up) the image produced by the primary radiation. The effect of scattered radiation on the image can be compared with your visual image of a "human body" located behind a translucent (you know the kind) shower door. Squint as you might, the image remains somewhat "foggy", and something is left to the imagination.

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Scattered radiation can be prevented from "fogging" the image by not allowing it to reach the film. This can be done by using a **grid** (Fig. 1-2). A grid is a device similar to a "venetian blind," which consists of many thin strips of lead embedded in a radiolucent material such as aluminum. The lead strips are carefully aligned with the primary beam so that any oblique rays (scattered radiation) are absorbed by the lead strips, but most of the primary radiation passes between the strips. Thus, grids are used to reduce the effects of scattered radiation on the radiographic image; they are most important when thick (>10 cm) body parts are being radiographed because *the amount of scattered radiation increases with object thickness*. When stationary grids are used, they may produce "grid lines" in the radiograph. To prevent these grid lines, some grids shift position during the exposure so that the lines are blurred in the resulting radiograph. Grids are expensive, and their use increases the amount of radiation required to produce an acceptable image.

So where are we now? We should now understand what x-rays are, something about how they behave, and how they are produced in an x-ray tube. *We should know the difference between an x-ray and a radiograph* (you can see a radiograph, but x-rays are invisible). We should have an understanding of radiographic image formation, know some of the things that are wrong with a radiographic image and how these deficiencies can be minimized.

But there is another problem with a radiographic image that we can't do anything about, but ***we must never forget*** (I don't say that very often). And that is-- ***a radiograph is a two-dimensional representation of a three-dimensional object*** (excluding, of course, the canary that

was run over by the truck). As a demonstration of how limited a two-dimensional representation of a three-dimensional object can be, I respectfully direct your attention to figure 1-5. Here are two rather common, everyday objects or situations as represented by two-dimensional drawings. *What are they?* If you still have lingering doubts about a radiograph being a two-dimensional representation, I kindly direct your attention to figure 1-6.

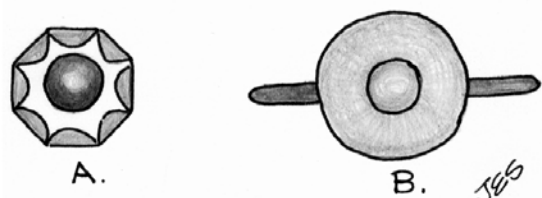


Figure 1-5. Two-dimensional drawings of three-dimensional objects. Identify each object (answers on page 13).



Figure 1-6. Anatomy of radiograph as seen "on-edge." This rare illustration clearly demonstrates the distinct, two-dimensional characteristics of a radiograph.

The reason it is so important to stress this two-dimensional limitation is that ***our brains have been programmed since early childhood to read-in depth whenever we look at a photograph or an image on a TV-screen, etc.*** We quite naturally synthesize the third dimension, even without the aid of 3D glasses. ***When viewing radiographs, you absolutely cannot do this.*** In other words, we have to "deprogram" ourselves *whenever we view radiographs*. Remember, you are looking completely through the body part and all structures penetrated by a given part of the beam are superimposed on one another. *In order to conceive the actual relationship of structures from their radiographic images, at least two*

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radiographic views, made at right angles to one another, are required. We cannot do it from a single view. If you have any doubts about this being true, I politely refer you to figures 1-7 and 1-8.



Figure 1-7. Mediolateral (ML) radiograph of right canine elbow region.



Figure 1-8. Cranial-caudal (Cr-Cd) radiograph of same region as shown in figure 1-7.

Here we have two radiographic views of the right elbow region of a dog. If we had only the mediolateral view, we might have thought everything was just fine. When coupled with the craniocaudal projection; however, lateral luxation of the elbow joint is obvious, *even to the more casual observer.*

What determines how different body parts or tissues appear radiographically in terms of whiteness or blackness? First of all, we must get used to the fact that a standard radiograph is a *negative*; *i.e.*, the background is dark and the structures are represented by varying degrees of "whiteness" (radiopacity). It was stated previously that *the basis of diagnostic radiology was that different body tissues absorb x-rays differently; i.e. differential x-ray absorption accounts for the image.*

Assuming that the x-ray beam is of sufficient intensity and the wavelength of the x-rays are short enough to penetrate most of the tissues, *the radiographic appearance (white vs. black) of different body parts is a function of their ability to absorb x-rays.* Those tissues that absorb the most appear the whitest; those that absorb the least appear the blackest.

The two major factors that determine the amount of absorption are the radiopacity (inherent ability to absorb x-rays) of the tissue and the thickness of that tissue.

RADIOPACITY

The 5 basic radiopacities⁴ in order of increasing "whiteness" on the radiograph are:

⁴ Although these are sometimes referred to as "radiographic densities," this terminology only leads to confusion because "density" has multiple

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1. **AIR**
2. **FAT**
3. **WATER** (soft tissues & fluids)
4. **BONE**
5. **METAL** (contrast media & implants)

You must know these 5 radiopacities and their order to understand why different body structures appear as they do radiographically. (You can learn them now, or regret it later.)

The **radiopacity** of a tissue is a function of the atomic number of the elements composing it and the physical density (g/cm³) of that tissue. Normal bone contains a concentration of high-atomic-number elements (Ca, P, etc.). Thus, the **effective atomic number** (EAN) of bone is high (Table 1-1). These elements absorb more x-rays than the lower-atomic-number elements, which predominate in the water-opaque soft tissues of the body.

The other factor that determines the radiopacity of a substance is the **physical density** of that substance. For any given material, the more tightly packed the molecules of that substance, the greater the x-ray absorption; this is a direct function of probability that an x-ray will strike a molecule. For example, water absorbs more x-rays than ice because water is denser than ice. Even though air has a higher EAN than fat, fat is more radiopaque because it has a higher physical density. Although it doesn't happen even under extreme physiologic circumstances, if air were compressed so

meanings. For example, optical density is a measure of blackness in a radiograph (the exact opposite of "whiteness"), and physical density refers to the weight/volume of a substance. (Some people are occasionally referred to as being "dense," which may or may not have anything to do with their radiopacity.) Describing the radiographic appearance of substances in terms of radiopacity or radiolucency avoids the confusion.

that its physical density equaled that of fat, it would be more radiopaque than fat.

As shown in Table 1-1, the radiopacity or ability of a substance to absorb x-rays *might be expressed* as a function or product of its EAN and physical density. I *propose* that this product be termed a **radiopacity coefficient**.⁵ From these "coefficients" it appears that water and muscle could be differentiated radiographically. However, the slight difference (0.404) of these two substances cannot be distinguished in a *standard radiograph*. Thus, the radiopacity of various body fluids (e.g., blood, urine, bile, cerebrospinal fluid, synovial fluid, etc.) cannot be differentiated from non-mineralized, non-adipose soft tissues such as muscle, ligaments, and the parenchyma of organs. These tissues can be distinguished, however, with a more sensitive radiographic modality, namely *computed tomography*.

THICKNESS

The second major factor that determines the total amount of x-rays absorbed and thus the whiteness on the radiograph is **thickness**. *For any given material, absorption increases with thickness.* This is evident radiographically when the same structure such as a blood vessel (water opacity) is seen from different perspectives. The "end-on" image of the vessel will be "whiter" than the "side-view" image, because a thicker segment of the same structure was penetrated by the x-ray beam in the former case. The effect of thickness can be noted in figure 1-7, where the anconeal process of the ulna is superimposed on the medial epicondyle of

⁵ The proposed term, *radiopacity coefficient*, is not a recognized measurement among radiologists. I said, I *propose* it, which is another way of saying, I just made it up. However, it does make sense to me, and who knows, perhaps it will "catch on."

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the humerus, the superimposed area is whiter (more opaque) than the surrounding areas of bone because a greater thickness of bone had to be penetrated by the x-ray

beam in the superimposed area. A similar summation pattern can be noted in figure 8, where the olecranon of the ulna is superimposed on the humerus.

Table 1-1. Proposed *radiopacity coefficients* of substances as a function (product) of their effective atomic number and their physical density.

Substance	Effective Atomic Number (EAN)		Physical Density (g/cm ³)		Radiopacity Coefficient
Air	7.8	x	0.001	=	0.0078
Fat	6.5	x	0.92	=	5.98
Water	7.5	x	1.00	=	7.5
Muscle	7.6	x	1.04	=	7.904
Bone	12.3	x	1.65	=	20.295

Modified from Thrall, D. E.: *Textbook of Veterinary Diagnostic Radiology*. W. B. Saunders, Co., Philadelphia, 1987, p. 3.

OTHER FACTORS

Another factor that affects how a particular structure (tissue) appears radiographically is the type of material that surrounds the structure. *If a structure is surrounded by material that is more radiopaque, the structure will appear relatively radiolucent and vice versa.* For example, blood vessels passing through the nutrient canal of a bone appear radiolucent; when surrounded by air as in the lung, they appear radiopaque.

If one structure (substance) is in intimate contact with another material of the same radiopacity, the border between the two will be obliterated. An example of the latter is blood (water opacity) surrounded by the heart (water opacity). In routine radiographs, it is not possible to determine the size of the cardiac chambers or the thickness of the heart wall because there is no demarcation between the wall and blood. The lumen of the chambers can be defined,

however, by the injection of a contrast medium (angiocardiology). When two structures of the same radiopacity are in contact, and it is impossible to tell where one starts and the other begins, the phenomenon is known as the *silhouette sign*.

When two structures of the same radiopacity are superimposed on one another, the "overlapping" parts will "summate" and the resulting area of superimposition will have a degree of radiopacity ("whiteness") equal to the sum of the opacities of the two structures (Figs. 1-7; 1-8). In some cases, this summation pattern can create the *illusion* of a separate, non-existent structure having the outline of the superimposed parts of the two real structures. Superimposition of complex structures is one of the problems inherent in diagnostic radiology. Defining selected body structures often necessitates special contrast procedures, special views, or a combination of these two strategies.

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What about radiographic views, how are they named or described? The nomenclature for radiographic views is based on two simple rules:

(1) *Radiographic projections should be named using only proper veterinary anatomic directional terms as listed in the*

Nomina Anatomica Veterinaria (Fig. 1-9) or their standard abbreviations (Table 1-2).

(2) *Radiographic projections should be described by the direction that the central ray of the primary beam penetrates the body part of interest, from point-of-entrance to point-of-exit (Fig. 1-10).*

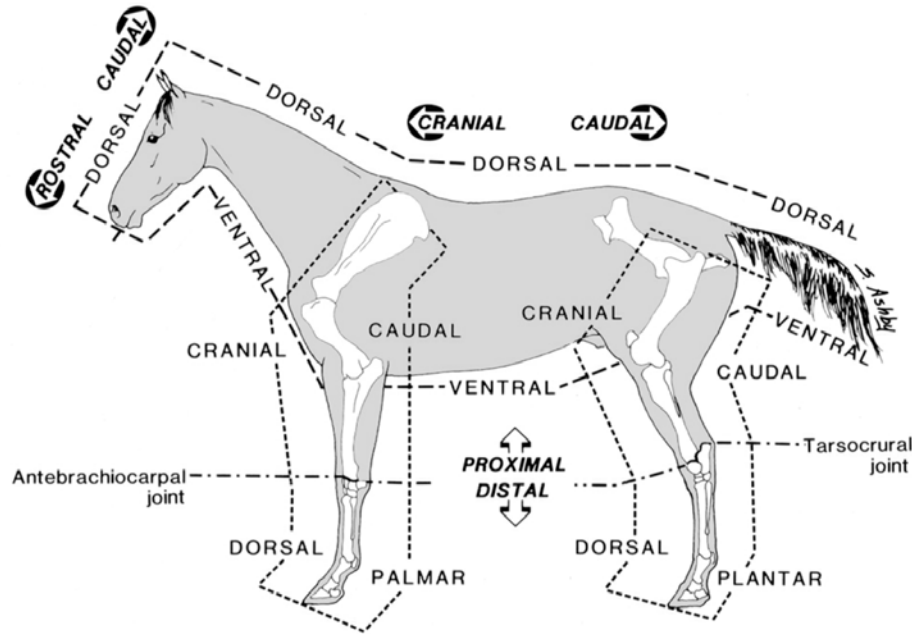


Figure 1-9. Proper anatomic directional terms as they apply to various parts of the body. [With permission from Smallwood, J. E., Shively, M. J., Rendano, V. T., and Habel R. E.: A standardized nomenclature for radiographic projections used in veterinary medicine. *Veterinary Radiology* 26 (1985): 2-9.]

Table 1-2. Directional terms and abbreviations used to describe radiographic views.

Left (Le)	Medial (M)
Right (Rt)	Lateral (L)
Dorsal (D)	Proximal (Pr)
Ventral (V)	Distal (Di)
Cranial (Cr)	Palmar (Pa)
Caudal (Cd)	Plantar (Pl)
Rostral (R)	Oblique (O)

As previously mentioned, the three-dimensional relationship of structures is determined by their appearance in at least

two radiographic views made at right angles to each other. Refer to figure 1-10 and consider the location of the "BB." In the lateromedial (LM) view it is seen just palmar to the middle of the limb, but could be located anywhere along a lateromedial line through that point (gray outlines). In the dorsopalmar (DPa) view, it appears just lateral to the middle of the limb, but could be anywhere along a dorsopalmar line through that point (gray outlines). By combining the information from the two views, the actual location of the "BB" can be determined. It's no more difficult than plotting coordinates on a map to find a specific location. However,

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the example used here was intentionally simplified. Some subtle structures or lesions are more difficult to locate because they don't stand out like a BB. As you can see from figure 1-10, *complex anatomic areas such as the carpus require oblique views and other special projections to be evaluated radiographically.*

Refer again to figure 1-10 and consider the difference in appearance between a dorsopalmar and a palmarodorsal view of this area. *(Pause here to consider.)*

Technically, there are differences because of magnification and sharpness factors related to object-film distance. However, when the entire body part measures only a few cm, such as in this case, these differences are difficult to detect without making careful measurements of specific images in the radiographs. Thus, *for all practical purposes the dorsopalmar and palmarodorsal views would be the same (except for being mirror images) as are any two views made at 180° angles to one another.*

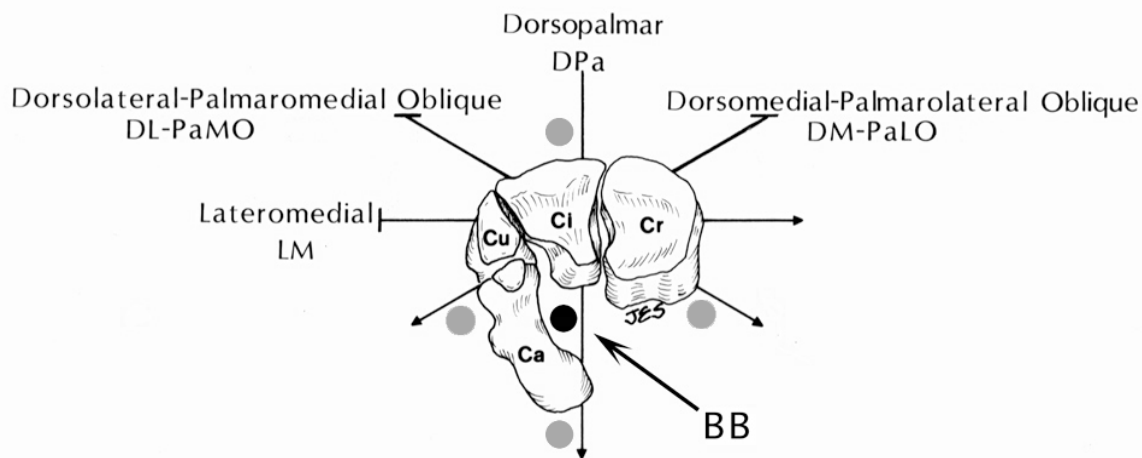


Figure 1-10. Proximal view of equine proximal carpal bones. Radiographic projections are described by the direction of penetration of the central ray of the primary beam, from point-of-entrance to point-of-exit. (Cr) radial carpal bone; (Ci) intermediate carpal bone; (Cu) ulnar carpal bone; (Ca) accessory carpal bone. 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.

Using your knowledge of anatomy rather than "reading-in depth"

When we look at a lateromedial (LM) view of the equine carpus (Fig. 1-11), we see the accessory carpal bone projecting palmarly from the other carpal bones. Now we know that it is lateral, not because it looks further away in the radiograph, but because *we know the anatomy of the area.* We can assume it is lateral in this horse

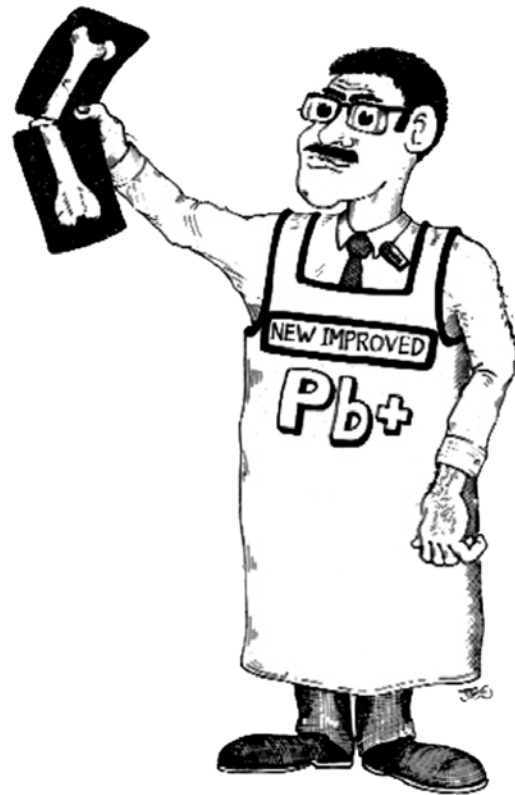
because that is where it is in 99.999% of all horses.

In a mediolateral (ML) view of a canine elbow, we can differentiate medial and lateral epicondyles (Fig. 1-7). Not because one looks brighter so it must be closer, but because, from our *knowledge of anatomy*, we know that the medial epicondyle is larger and its caudal border is squared-off; the lateral one is smaller and rounded-off.

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Figure 1-11. Lateromedial (LM) xeroradiograph of carpus of 5-week-old quarter horse foal: (1) secondary center of ossification for palmar border of accessory carpal bone; (2) radiolucency created by fat in synovial fold of antebrachiocarpal joint capsule.



Bottom Line: *The more we know about anatomy, the more information we can obtain from the radiographic image of the body part.*

Answers to Fig. 1-5: A. end-on view of a pencil; B. aerial view of a person wearing a sombrero riding a bicycle; OK, so it's not something you see *everyday*.

References

Eastman Kodak Company: *The Fundamentals of Radiography*, 11th ed. Eastman Kodak Company, Rochester, NY, 1968.

Morgan, J.P. and Silverman, S.: *Techniques of Veterinary Radiography*. 3rd ed. Veterinary Radiology Associates, Davis, CA, 1982.

Meyer, W.: Radiographic review: Radiographic Density. *J. Am. Vet. Radiol. Soc.* 18 (1977):138-140.

Nomina Anatomica Veterinaria. 4th ed. World Association of Veterinary Anatomists, Ithaca, NY, 1994.

Smallwood, J.E., Shively, M.J., Rendano, V.T., Habel, R.E.: A standardized nomenclature for radiographic projections used in veterinary medicine. *Vet. Radiol.* 26 (1985):2-9.

Thrall, D. E.: *Textbook of Veterinary Diagnostic Radiology*. W. B. Saunders, Philadelphia, 2002.

Bone Development from a Gross Anatomist's Perspective

Contrary to the perception obtained from the study of dried bones in the laboratory, living bones are *dynamic organs* that are susceptible and responsive to various nutritional, hormonal, and physical factors. Even fully mature living bones are continuously changing in response to those factors, by remodeling themselves *via* an ongoing process of **bone production** (osteoblastic activity) and **bone destruction** (osteoclastic activity).

The response of bones to insult of almost any type (*e.g.*, fracture, neoplasm, metabolic or infectious disease) is essentially limited to an *exaggerated* mixture of bone production and destruction, often characterized by a predominance of one process over the other (Fig. 1-12). In order for you as a *veterinarian* to recognize and appreciate how bones respond to various forms of insult, you must first develop a basic understanding of the anatomy (and physiology) of both mature and **developing** bones. The latter is particularly important because many physical (traumatic) and metabolic bone diseases seen in practice involve young animals with immature bones.

In order for you to develop a *comprehensive* understanding of bone development, you will need to merge the gross anatomic information presented here, with detailed microscopic and biochemical information that will be provided in other courses. Our **objective** is to help you establish a *basic* understanding of how bones develop and grow to their mature state. For immediate application, this knowledge is necessary for you to evaluate the radiographs of immature animals that are used in the anatomy laboratory.



Figure 1-12. Mediolateral (ML) radiograph of stifle region of a dog with a lesion in proximal part of tibia: (1) area of bone destruction (lysis); (2) area of bone production. Although this lesion was determined from biopsy to be neoplastic, the response of the bone observed in this radiograph is not pathognomonic⁶ for neoplasia.

Bones develop by the process of **ossification**, which is initiated by the differentiation of cells into **osteoblasts**. Osteoblasts produce the organic bone matrix, which then becomes mineralized to form bone. The site within non-ossified tissue where this process begins is referred to as an **ossification center**. The first such center that appears within a developing bone is the **primary ossification center** of that bone (Fig. 1-13).

⁶ pathognomonic- distinctively characteristic of a specific pathologic condition

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Figure 1-13. Cleared specimen of a fetal pig illustrating many primary ossification centers. Both intramembranous (bones of calvaria, arrow) and endochondral ossification are shown.

In many instances (*e. g.*, most sesamoid and other small bones), the entire bone develops by expansion of this single, primary center. Most large bones, however, particularly those with numerous processes, develop from multiple ossification centers, and *all centers that appear subsequent to the primary center* are referred to as **secondary ossification centers**⁷ (Fig. 1-14).

As mentioned above, the process of ossification is initiated by the differentiation of osteoblasts in a non-ossified tissue. There are two types of connective tissue, where this occurs. Ossification of the bones of the calvaria and face begins within flat sheets or "membranes" of connective tissue (Fig. 1-13). Ossification proceeds peripherally from the primary center by the expansion of trabecular bone, and because the process begins in a "membrane," this type of bone formation is referred to as **intra-membranous ossification**.

During the growth period, the membrane is also expanding so that the calvaria and face are enlarging as the bones are being formed. As the growth of the membrane

slows, the borders of individual bones arising from separate ossification centers begin to approach one another. The gaps of non-ossified tissue that remain between the individual bones during the growth period form the **fibrous joints** or **sutures**, characteristic of the young animal. As a rule, there are no fontanels⁸ present post-natally in the "real" dog.

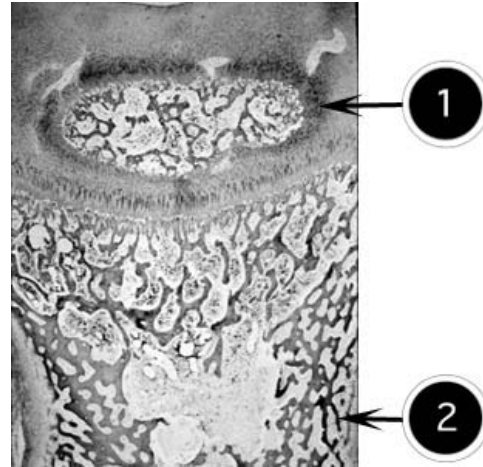


Figure 1-14. Photomicrograph of longitudinal section through a long bone illustrating appearance of a secondary ossification center, which will form the proximal epiphysis of the bone: (1) secondary ossification center; (2) primary ossification center.

In some "toy" breeds (*viz.*, Chihuahua, Pomeranian), areas along the sutures may remain unossified for some time post-natally. This condition is generally "written-off" as being "normal" for the breed. In fact, Chihuahua breeders have a special name for the open fontanel, which they refer to as the "molera." They even consider the presence of a *molera* to be a *desirable characteristic* of the "breed standard." Absence of a molera does not necessarily disqualify a Chihuahua from being shown, but the presence of one pleases the judges. Go figure??

⁷ There's no need to get into tertiary, quaternary, and the like.

⁸ fontanel- a soft spot such as those incompletely ossified areas in a human infant's skull.

Ossification of most bones of the body is initiated within another type of connective tissue, namely **hyaline cartilage**. Because this type of ossification begins within cartilage, it is referred to as **endochondral ossification**. Each bone is preceded by the development of a miniature cartilaginous model of the mature bone. As development continues, these cartilaginous models enlarge and provide substantial support for the body. At a relatively predictable stage of maturity, which varies with the specific bone and species, blood vessels invade the model and bring in the cells that will become osteoblasts (Fig. 1-15).

In addition, the invasion of the blood vessels *changes the local environment* within the cartilaginous model, by increasing the levels of oxygen and nutrients. This enriched environment is *good for osteoblasts*, but not for chondrocytes. As a consequence, the chondrocytes die and the cartilaginous matrix **calcifies**.⁹ Osteoblasts take up residence within this calcified matrix and begin to lay down their organic bone matrix. When this bone matrix begins to receive the deposition of the inorganic mineral complex, we have the initiation of ossification. This process begins locally as multiple minute foci of ossification, which subsequently coalesce to form a definitive center of ossification that can then be appreciated radiographically.

Obviously, spontaneous bone production doesn't just happen by accident. Multiple genetic, nutritional, and hormonal factors are involved in the initiation, control, and ultimate success of the process, and sometimes things go wrong. In contrast to

those of the calvaria, which form intramembranously, the bones that form the base of the cranium and face develop by endochondral ossification. In **brachycephalic breeds** of dogs, there is a genetic defect in programming for the proper growth of the cartilaginous models for the bones of the base of the cranium and face. This is why only the "cartilage bones," not the "membrane bones," are affected.

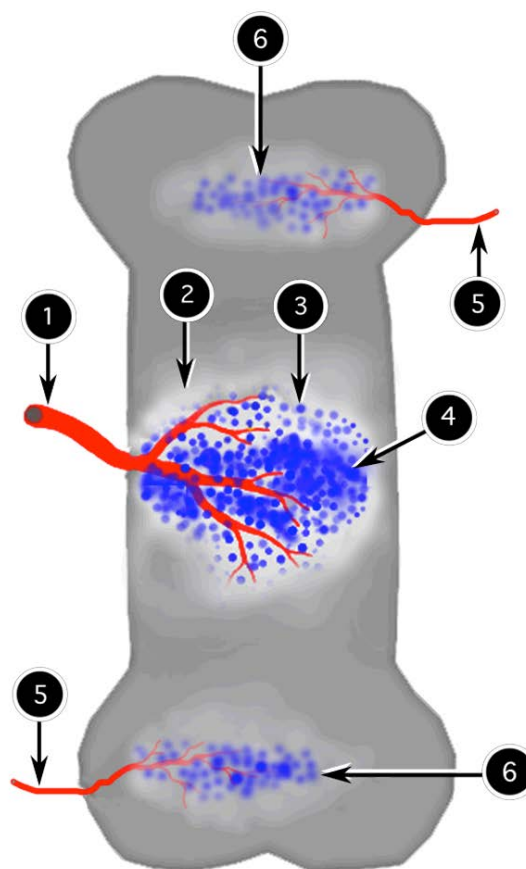


Figure 1-15. Schematic drawing of hyaline cartilage model of typical long bone: (1) primary nutrient artery penetrating cartilaginous model near its middle; (2) chondrocytes dying in presence of increased nutrient & oxygen environment; (3) minute foci of bone production via osteoblastic activity and mineral deposition; (4) coalescence of foci into radiographically detectable primary ossification center for diaphysis of bone; (5) secondary nutrient arteries penetrating cartilage at proximal and distal extremities of model (6) early appearance of secondary centers of ossification (epiphyses).

⁹ Calcification is not the same thing as ossification. Ossification is the specific process of bone formation. Certain tissues of the body can become calcified in the absence of ossification.

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As a consequence of this **chondrodystrophy**,¹⁰ these cartilaginous models do not lengthen properly, and the resulting bones formed from these defective models are too short, which produces the "problematic" brachycephalic skull (Fig. 1-16). In other words, brachycephalic breeds are affected by a form of chondrodystrophy or "dwarfism."



Figure 1-16. Lateral view of brachycephalic dog skull. The cartilage models for the bones forming the base of the cranium and face did not grow properly, resulting in a marked shortening of the skull. Related to their unique embryologic development, the mandibles are unaffected, producing the characteristic prognathism (protruding jaw) of brachycephalic breeds.

Similar genetic defects account for the shortened limbs of the Basset hound, Welsh corgi, dachshund, and numerous other *chondrodystrophic breeds*. To say that such defects are "normal" for the breed is a little misleading. In truth, the words "normal" and English bulldog may not belong in the same sentence. We just accept them for what they are, and then proceed to attend to the inherent problems associated with their dystrophic breed characteristics. Because veterinarians are typically compensated for this attention, it's not all bad from our

perspective; no problems- no need for veterinarians; no need for veterinarians- well you see where I'm going with this.¹¹

Most long bones of the body (*e.g.*, femur, humerus, etc.) develop from multiple ossification centers. The primary center typically appears near the middle of the elongated cartilaginous model, and expands peripherally, then proximally and distally toward the extremities. When it is developed into an elongated unit of bone, it is referred to as the **diaphysis** of that bone, and in the final product will form the **body** or shaft of the mature bone (Fig. 1-17). As the diaphysis expands toward the extremity, replacing cartilage as it goes, the proliferating cartilage cells near the ends of the diaphysis align themselves in distinct, proximodistally oriented *rows* or *columns*. Cells on the end of the columns away from the diaphysis continue to replicate and are added to the rows (Fig. 1-18).

Because most long bones develop from multiple centers, what typically occurs is that a secondary ossification center, initiated by the same process as the primary center, develops within the cartilage of the extremity (Figs. 1-14 & 1-15). This secondary center expands peripherally and replaces most of the cartilage in the extremity, except for that which covers the articular surface of the bone and the zone of proliferating cartilage cells that are forming the columns. The major areas of bone formed by these secondary centers in the extremities are the **epiphyses**. The cartilage that persists over the articular surface becomes the **articular cartilage**, while that which remains between the epiphysis and diaphysis is termed the **epiphyseal cartilage** or **physis** (Fig. 1-18). As a general rule

¹⁰ chondrodystrophy- an abnormal development of cartilage.

¹¹ chondrodystrophic dogs- I didn't say they were "lemons;" they just offer a plethora of repair "opportunities."

then, a long bone develops from three ossification centers, one primary center forms the diaphysis, and two secondary centers form the proximal and distal epiphyses (Fig. 1-17).

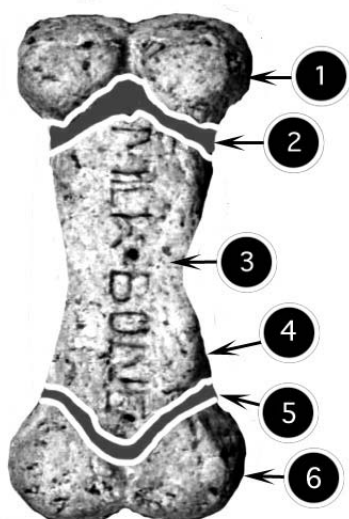


Figure 1-17. Commercially available long bone, which has been modified to demonstrate major developmental regions: (1) proximal epiphysis; (2) proximal physis; (3) diaphysis; (4) distal metaphysis; (5) distal physis; (6) distal epiphysis.

To complicate matters slightly, some long bones have additional secondary centers that appear within the cartilage of specific processes. For example, the medial epicondyle of the humerus develops from a secondary center, which is initially separate from that of the distal epiphysis. What typically occurs is that the additional secondary center fuses to that of the epiphysis prior to the fusion of the latter to the diaphysis.

Another example of a process that develops from a secondary ossification center in some animals is the *anconeal process* of the ulna. During the growth period of an animal, the zone of cartilage between the secondary and primary ossification centers is subject to fracture and separation from the main part of the bone.

When this occurs, the secondary center may fail to unite with the body of the bone. An example of this is un-united (fractured) anconeal process of the ulna in large breeds of dogs (Fig. 1-19). In most dogs in which the anconeal process is recognized to develop from a separate ossification center, fusion should be complete by approximately 20 weeks ($\approx$ 5 months) of age. Failure of this to occur results in a partially detached chunk of bone, which is more or less "free floating" in the elbow joint.

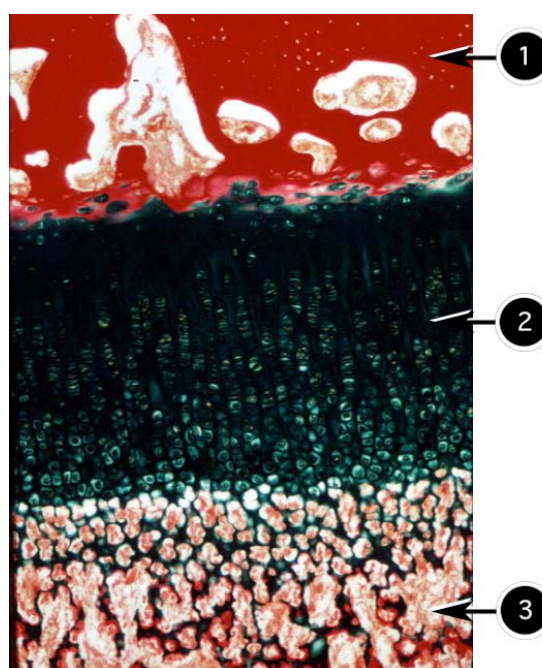


Figure 1-18. Photomicrograph of longitudinal section through proximal physis (epiphyseal cartilage) of a long bone: (1) proximal epiphysis, (2) physis (epiphyseal cartilage); (3) metaphysis.

Obviously, this leads to pain and *degenerative joint disease*. Surgical correction has traditionally involved removal of the detached fragment; however, "re-attaching" the process with a bone screw has also been used by some surgeons. In other cases of epiphyseal fractures, such as a "slipped capital epiphysis" of the femur, blood supply to the epiphyseal bone is compromised by the fracture, and partial resorption is likely to occur.

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Figure 1-19. Mediolateral (ML) radiograph of elbow region of a dog in which the secondary ossification center for the anconeal process of the ulna failed to fuse (unite) with the diaphysis.

If nothing goes wrong, the bone continues to lengthen by growth of the diaphysis toward each extremity. As long as the cartilage cells of the columns proliferate at about the same rate as they are being replaced by bone, the epiphyseal cartilage persists, and growth continues. This state is referred to clinically as an **"open" physis**. As prescribed by genetic programming and influenced by nutritional and hormonal factors, proliferation of the cartilage cells slows and eventually ceases. The epiphyseal cartilage is then completely replaced by bone, uniting the epiphysis and diaphysis into a single unit. Replacement of the epiphyseal cartilage by bone is referred to clinically as **closure of the physis** or **fusion of the epiphysis**. A common mistake is to refer to the epiphyseal cartilage as the **epiphysis**. The epiphysis is *not* the cartilage, but rather the bone that has developed within the extremity of the cartilage model.

Physes close, epiphyses fuse- two ways of saying the same thing.

Different physes, even within the same bone, close at different times, and the approximate ages of closure have been established for most physes of most common domestic species. Although reference tables for the appearance and fusion of selected ossification centers are included at the end of this section, I would caution students that the ages listed therein are only *approximate* times, and should not be interpreted as the "gospel," according to JES. Remember, physal closure is influenced by multiple factors, including genetics, nutrition, and hormonal influences. With so many variables, one should not be too restrictive in their determination of normal vs. abnormal. This is especially true when one considers the great morphologic diversity of *Canis familiaris (lupus?)*.¹²

The principal way that we as veterinarians evaluate bone development and closure of physes is by **radiographic examination**. Because small amounts of cartilage cannot be detected, **radiographic closure** is actually earlier than **anatomic closure** (complete replacement of epiphyseal cartilage). Determination of the latter, however, is not well accepted by the patient because it requires removal of the bone (or part of it) and histologic evaluation. Figures 1-20 through 1-23 have been included here to illustrate skeletal maturation in the feline forelimb from birth through 16 months of age.

¹² *familiaris* vs. *lupus*. DNA testing, has apparently strengthened the belief, long held by some, that the domestic dog is not really a species separate from its only ancestor, the gray wolf.



Figure 1-20. Radiograph of forelimb of a one-day-old kitten. Note the absence of ossification in the areas of the shoulder, elbow, and carpal joints.



Figure 1-22. Radiograph of forelimb of a 224-day-old kitten. Note the well ossified epiphyses of the proximal ulna and distal radius (arrows). Physes are still detected at both sites.



Figure 1-21. Radiograph of forelimb of a 23-day-old kitten. Note that several secondary ossification centers have appeared (arrows).



Figure 1-23. Radiograph of forelimb of a 480-day-old cat. By this age (16 mo.), this cat was considered skeletally mature. Note the absence of radiolucent physes at arrows.

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When you examine an immature long bone in the laboratory, several features should be noted. First of all, the bone is not as sharp and crisp as a mature bone. Some of the mature processes are less distinct or even absent, and the bone has an overall "unfinished" appearance. The epiphyses are not all fused to the diaphysis, and the area of the metaphysis is enlarged with a porous, roughened surface (Fig. 1-24). The epiphysis itself may be relatively larger and shaped differently than the end of the mature bone. The best example of this is the distal epiphysis of the canine ulna, which is an expanded cone-shaped structure, unlike the smoothly tapering lateral styloid process of the mature bone. This is normal for an immature bone, where the distal physis and distal metaphysis are areas of rapid cartilage and bone growth (Fig. 1-24).

Only after the physis closes and linear growth ceases, is the bone remodeled to the sharp, mature configuration. In some cases, Parent Nature plays a few tricks on this area. One example is illustrated in figure 1-24. In this situation, a central core of epiphyseal cartilage has not been properly replaced by bone as the bone has lengthened. In essence, it is being abnormally retained, and is evident radiographically as a radiolucent core within the distal metaphysis of this rapidly growing dog.

Now I should pause here and say that "giant breeds" of dogs have about as many problems as "toy breeds" and there's probably a good explanation. Parent Nature has a plan for dogs that says that there is an optimum adult body size for being the "perfect dog." Those individuals on either end of the "bell curve" are pretty far removed from that optimum. Both are the result of genetic mutations, which have been selected for by "dog's best friend."



Figure 1-24. Craniocaudal (Cr-Cd) radiograph of distal forearm of 4-month-old dog: (1) roughened metaphyseal border (normal for immature bone); (2) distal styloid process of ulna (normal shape for young dog); (3) retained core of cartilage within distal metaphysis. This "retained endochondral core" is not normal.

Particularly with regard to hormonal factors, we have drifted into dangerous territory-- some dogs have way too much growth hormone. Another problem with "giant" breeds is what we do to them next. Let's pour the groceries to them and how about a handful of calcium tablets, just in case. People who want a giant breed are not looking for the "runt of the litter"-- they want the biggest dang dog in the neighborhood. If a little feed will do a little good, a lot of feed will do a lot of good. The resulting over- nutrition, often aggravated by too much mineral supplementation, can bring out the worst in the dog's genetic program.¹³

¹³ Smallwood's First Law of Bone Growth- OPTIMUM growth rate is not the same thing as MAXIMUM growth rate.

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OK, so the dog retains a little cartilage, big deal, what's the problem? Glad you asked; please direct your attention next to figure 1-25. Here is one of several negative effects of improper bone development. Without going into further detail at this time, the radius and ulna must grow in synchrony for the forearm to remain straight. Any insult that causes one bone to grow faster or slower than the other results in a limb deformity due to a *tension effect* on the faster bone by the slower. In this case the ulnar growth was retarded by a metabolic disturbance in cartilage replacement by bone, but in other cases, it could be traumatic in origin. The curving effect of the slower growing ulna on the radius is obvious and will require surgical intervention to correct. Say, there's another one of those repair opportunities. Perhaps you didn't make a poor career choice after all. But you still have to get through vet school.

As indicated back in figure 1-15, the primary nutrient artery for the diaphysis of a long bone penetrates the cartilaginous precursor very near the middle of the cartilaginous unit. As bone develops around these primary nutrient vessels, a **nutrient canal** is established through the outer cortex of the bone around the vessels. *Again, the location of this nutrient canal was originally very near the middle of the cartilaginous precursor of the bone.*

If the bone grows about equally at both ends, the canal remains near the middle of the resulting long bone; however, more often bones grow more at one end than the other. For example, the distal physis of the femur grows more than does the proximal physis. Thus in the final product (Fig. 1-26), there is more bone distal to the nutrient canal than there is proximal to it. The nutrient canal of the femur ends up closer to

the proximal end of the bone than it is to the distal end.



Figure 1-25. Mediolateral (ML) radiograph of distal forearm of 8-month-old dog illustrating marked curvature of the radius and limb deviation resulting from retarded growth at the distal ulnar physis. In this case, retarded ulnar growth was due to improper (delayed) replacement of cartilage by bone in the distal ulnar metaphysis. Synchronous growth rates of the ulna and radius are essential for proper elongation of the forearm.

So what does this mean? Well, when you examine a mature long bone radiographically and can locate the nutrient canal, you can predict the relative amount of bone growth that has occurred at each end of that bone. If the canal is near middle of the body, growth was about same at both ends. If the canal is displaced toward the proximal end (Fig. 1-26), more growth occurred at distal physis, and *vice versa*. *More importantly, you should recognize nutrient canals as normal features of bones, and not confuse the radiolucent line created by these canals for fracture lines.*

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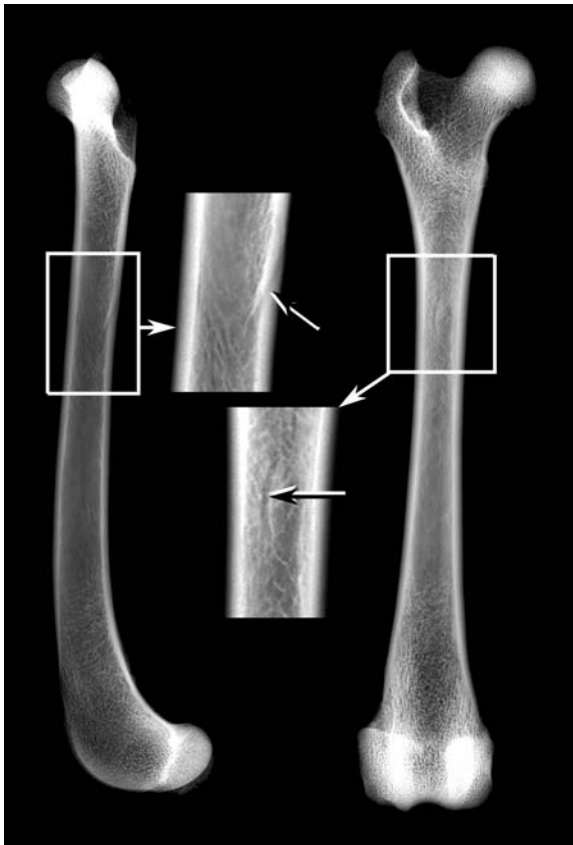


Figure 1-26. Mediollateral and craniocaudal radiographs of an isolated canine femur with enlarged areas indicated by boxes. Note the location of the nutrient canal (arrows) through the proximal part of the caudal cortex of the body. The location of the canal relative to the total length of the femur indicates that about 2/3 of the linear growth occurred at the distal physis. Refer to Table 1-3 and determine whether the proximal or distal epiphysis of the femur bone fuses first.

The secondary ossification center for the tuber calcanei of the horse has been used as one indicator of overall skeletal development. In tracings made from radiographs it can be seen that the tuber calcanei ossifies in a dorsoproximal direction (Fig. 1-27).

As previously noted, a secondary ossification center also develops along the palmar border of the equine accessory carpal bone (Figs. 1-11). As is typical of secondary centers, they begin as multiple foci of bone production (Fig. 1-28), which

then coalesce to form the actual ossification center. This center begins to fuse distally and proceeds proximally.

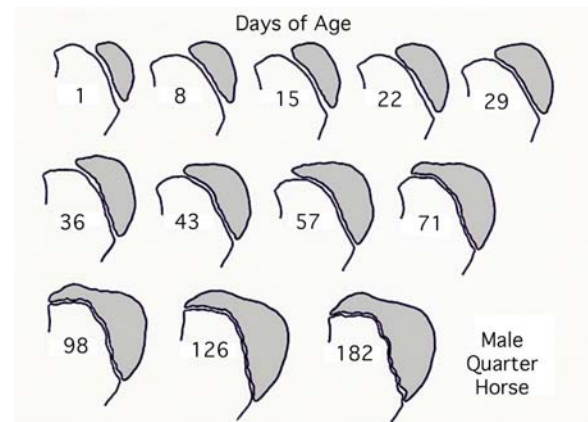


Fig. 1-27. Tracings of progressive ossification of tuber calcanei in male quarter horse. From Smallwood, J.E., Auer, J. A., Martens, R. J. *et al.*, The developing equine tarsus from birth to six months of age. *Equine Pract* 6, 4 (1984): 7-48.

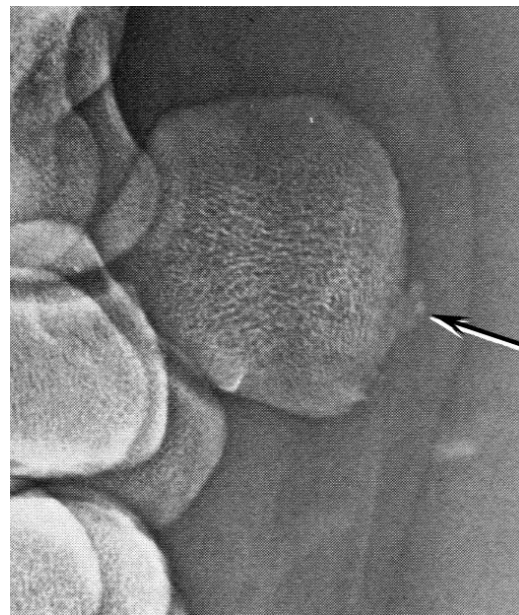


Fig. 1-28. Early appearance of secondary ossification center for palmar border of equine accessory carpal bone (5-week-old quarter horse). Ossification begins as numerous small foci of bone production, which will later coalesce to form the definitive center. From Auer, J. A., Smallwood, J.E., Morris, E. L., *et al.*, The developing equine carpus from birth to six months of age. *Equine Pract* 4, 4 (1982): 35-55.

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Table: 1-3. Appearance of ossification centers and their times of fusion for the canine appendicular skeleton. (Modified after Hare, W.C.D; Smith, R.N., Zeitzschmann, O., and Chapman, W.L.)

Ossification Center	Time of Appearance	Time of Fusion
Scapula		
Body	Birth	
Supraglenoid tubercle	6 - 7 weeks	4.5 - 6 months
Humerus		
Body	Birth	
Proximal Epiphysis	1 - 2 weeks	10 - 15 months
Condyle	2 - 3 weeks	6 - 8 months
Medial Epicondyle	6 - 8 weeks	≈ 8 months
Radius		
Body	Birth	
Proximal epiphysis	3 - 5 weeks	9 - 12 months
Distal epiphysis	2 - 4 weeks	10 - 12 months
Ulna		
Body	Birth	
Proximal epiphysis	8 weeks	8 - 10 months
Anconeal process (large breeds)	12 weeks	14 - 20 weeks
Distal epiphysis	5 weeks	10 - 12 months
Carpal Bones		
Ulnar carpal bone	4 weeks	
First carpal bone	2 weeks	
Second carpal bone	3 weeks	
Third carpal bone	3 weeks	
Fourth carpal bone	3.5 weeks	
Accessory carpal bone –		
Body	2 weeks	
Epiphysis	6 weeks	4 - 6 months
Intermediocarpal bone		
3 centers	3 - 6 weeks	≈ 3 months
Metacarpal Bones		
Body	Birth	
Proximal epiphysis of Mc1	5 - 7 weeks	6 - 8 months
Distal epiphyses (digits 2 - 5)	3 weeks	6 - 8 months
Phalanges		
Proximal phalanges		
Body	Birth	
Proximal epiphysis	4 - 7 weeks	6 - 7 months
Middle phalanges		
Body	Birth	
Proximal epiphyses (digits 2 - 5))	4 - 7 weeks	6 - 7 months
Distal phalanges	Birth	

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Ossification Center	Time of Appearance	Time of Fusion
Sesamoid Bones		
Abductor pollicis longus	4 months	
Dorsal sesamoid bones	4 months	
Palmar sesamoid bones	2 months	
Gastrocnemius	3 months	
Popliteus	4 months	
Os Coxae		
Ilium, Ischium, Pubis	Birth	
Acetabular bone	2 - 3 months	5 - 6 months
Crest of ilium	4 - 5 months	≈ 2.5 years
Tuber ischiadicum	3 months	10 - 12 months
Ischial arch	6 months	≈ 13 months
Os interischadicum	5 months	5 - 6 years
Femur		
Body	Birth	
Head	1 - 2 weeks	8 - 11 months
Greater trochanter	7 - 9 weeks	8 - 11 months
Lesser trochanter	7 - 9 weeks	9 - 12 months
Distal epiphysis	3 - 4 weeks	9 - 12 months
Patella		
	6 - 9 weeks	
Tibia		
Body	Birth	
Proximal epiphysis	2 - 4 weeks	6 - 9 months
Tibial tuberosity	7 weeks	6 - 14 months
Distal epiphysis	2 - 4 weeks	9 - 11 months
Medial malleolus	3 months	4 months
Fibula		
Body	Birth	
Proximal epiphysis	1.5 - 2.5 months	9 - 13 months
Distal epiphysis	4 - 7 weeks	12 - 13 months
Tarsal Bones		
Talus	Birth	
Calcaneus	Birth	
Tuber Calcanei	6 weeks	5.5 months
Central tarsal bone	3 weeks	
First tarsal bone	4 weeks	
Second tarsal bone	4 weeks	
Third tarsal bone	3 weeks	
Fourth tarsal bone	2 weeks	

Ossification times of the metatarsal bones and pelvic phalanges are similar to those of the corresponding bones of the thoracic limb.

Comparative Anatomy: How the domestic species we study relate to one another and fit into the larger scheme of mammals on the planet

Before we get too carried away with focusing our attention on the few domestic ungulates that we will be studying in the following chapters, let's step back a moment and take a broader look at how those species relate to one another and how they fit into the larger scheme of mammals on the planet.

This information is helpful as we try to gain an understanding of why certain species share more common anatomic features with their closer relatives and differ more from their more distant ones. Figure 1-29 shows the present-day orders of mammals.

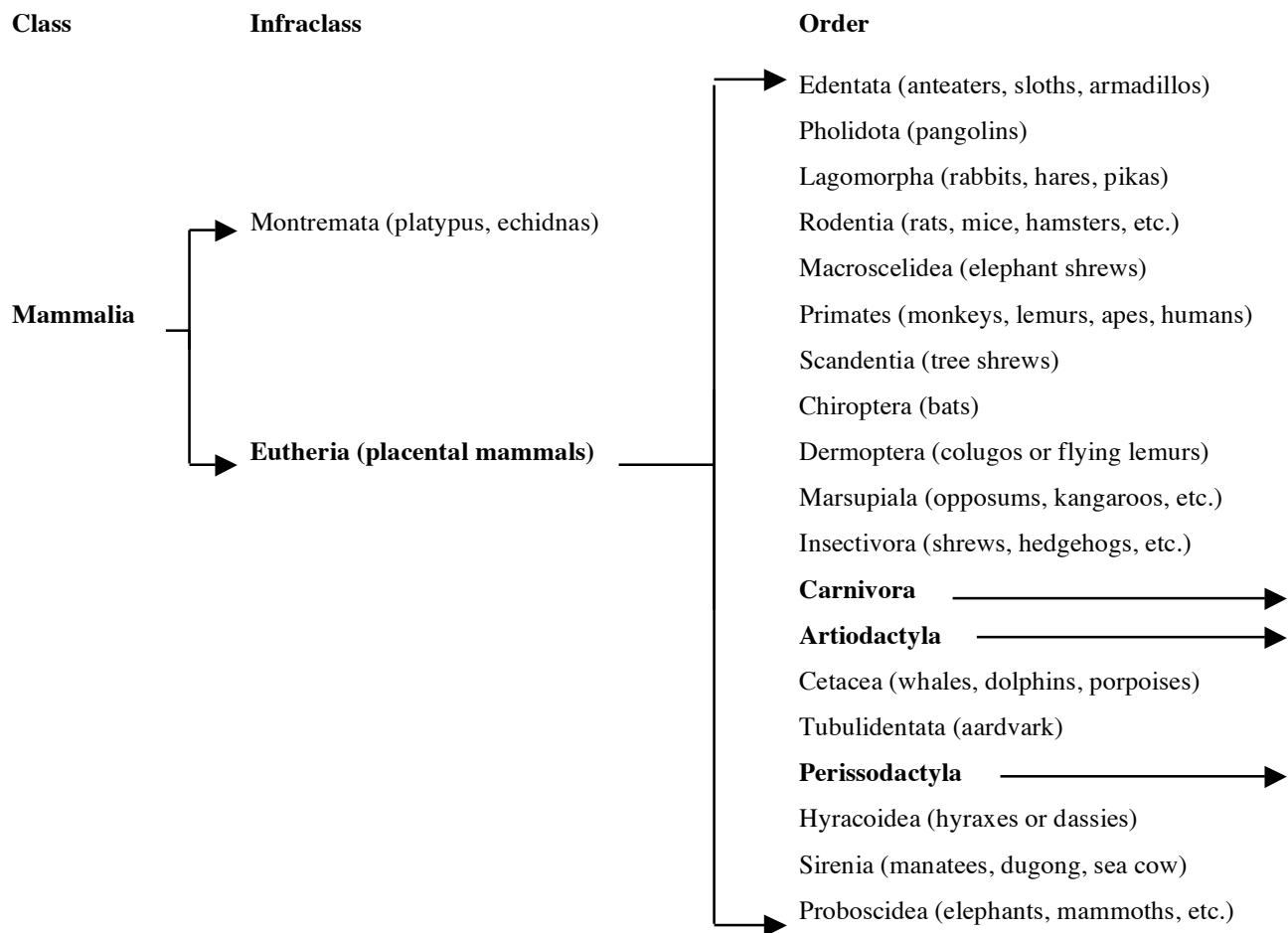


Figure 1-29. Present-day Orders of Mammals. Orders *Carnivora*, *Artiodactyla* (even-toed, hoofed mammals), and *Perissodactyla* (odd-toed, hoofed mammals) are continued in figure 1-30.

* Extinct infraclasses and orders are not included here because it is highly unlikely you will see any of these in veterinary practice. (However, I think I do recall seeing some of these as a small child).

Reference: <http://tolweb.org/tree?group=Mammalia&contgroup=Therapsida>

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As a group, mammals represent a fairly small number of about 5000 recognized species. In comparison, there are at least 10,000 species of birds, and about 24,000 species of fish. Our common domestic species-- dog, cat, ruminants, pig, and horse

fall into one of three orders, which are shown in figure 1-30. Families *Felidae*, *Canidae*, *Bovidae*, *Suidae*, and *Equidae* are continued in the following figures.

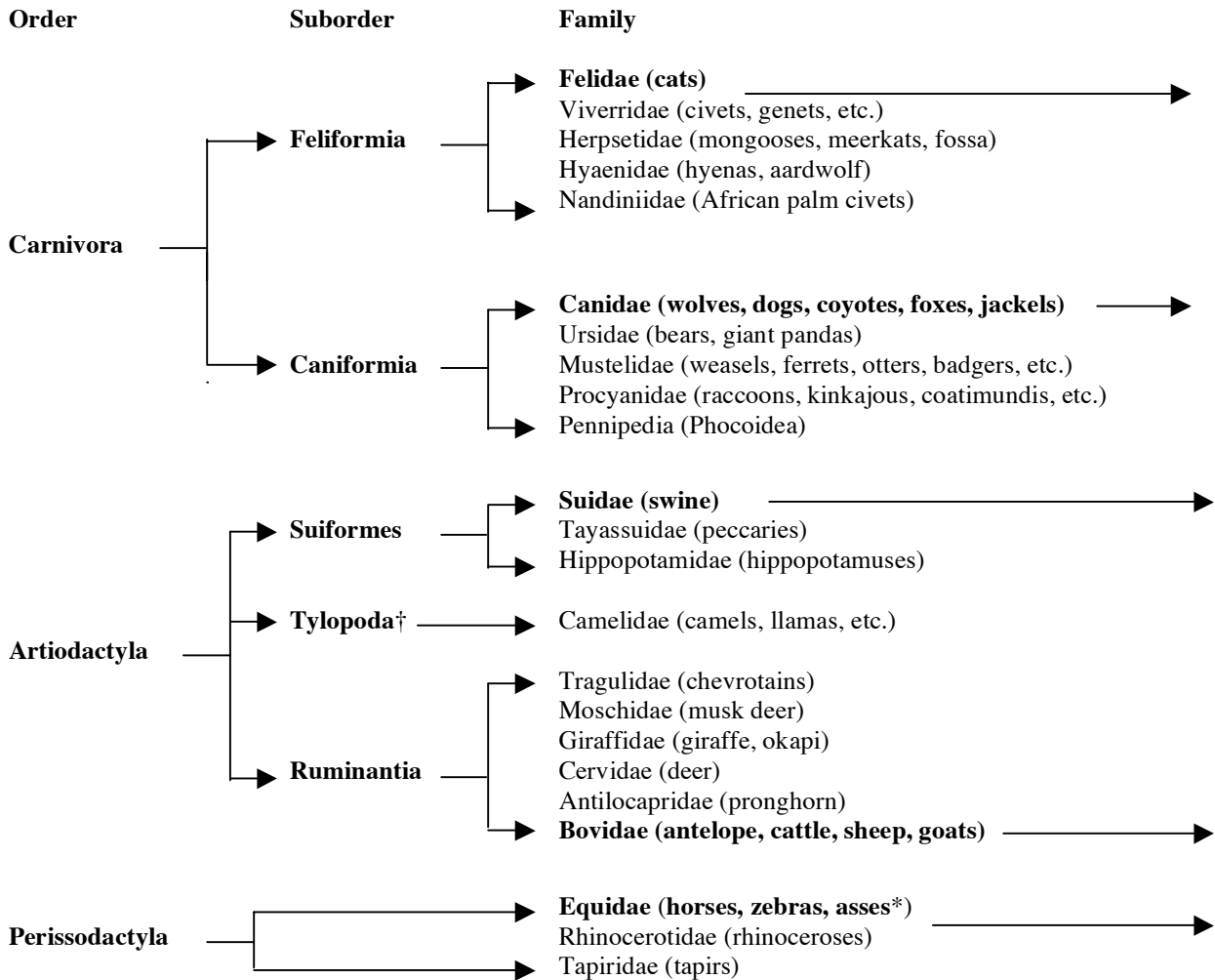


Figure 1-30. Present-day Orders of *Carnivora*, *Artiodactyla*, and *Perissodactyla*. Families *Felidae*, *Canidae*, *Suidae*, *Bovidae* and *Equidae* are continued in the following figures.

* In veterinary practice, it is quite likely that you will encounter certain “asses” that are not members of the family Equidae.

† I also emphasised Tylopoda here because there is some confusion as to whether or not camelids are ruminants—they are *not*, but then they are not *pseudoruminants* either. They are artiodactyls, but are in their own suborder, Tylopoda, which means “padded foot.” Camelids are the only fully digitigrade ungulates.

References: <http://tolweb.org/tree?group=Eutheria&contgroup=Mammalia>
<http://www.ultimateungulate.com/artiodactyla.html>
<http://animaldiversity.ummz.umich.edu>

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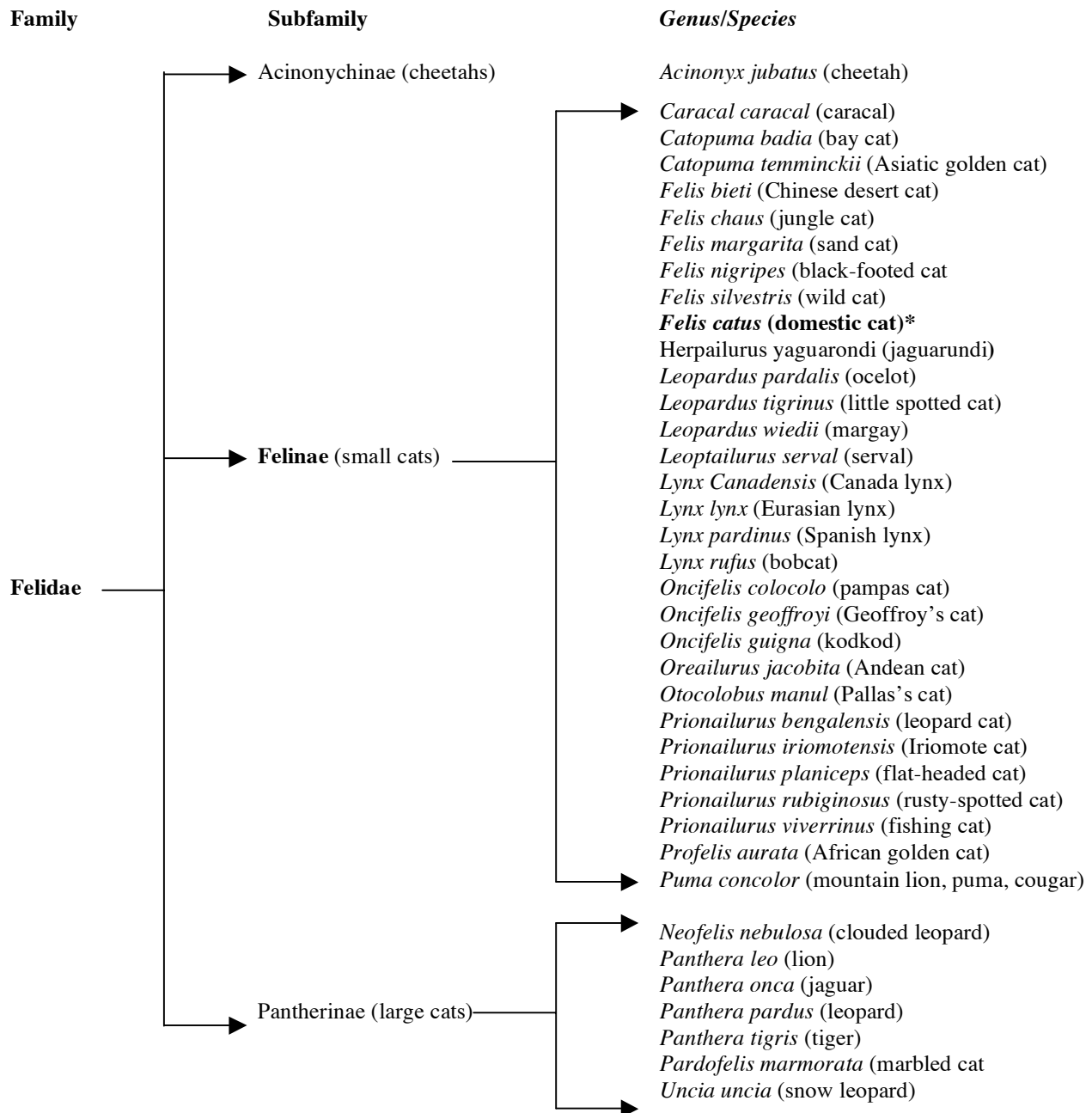


Figure 1-31. Family Felidae, showing some 18 Genera and 38 recognized species.

* *Felis catus*- only species known to have domesticated humans to the level of “indentured servitude”

Reference: <http://animaldiversity.ummz.umich.edu/site/accounts/classification/Felidae.html>

As you consider the **diversity** of mammalian species in each of the families, it should become obvious that certain families have been much more successful than others. Of the 5000 or so known

species of modern mammals, 2000 species (40%) are rodents, and almost 1000 species (≈ 20%) are bats. Of the remaining 40%, artiodactyls (even-toed ungulates) have done very well. In fact, had you invested your

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money in *Bovidae* stock back when it first came on the market, you would be a wealthy person today. Indeed, you would have done very well in the “hoofed-stock” market. On the other hand, had you bet on *Suidae* or

Equidae as an option, you would have pretty much gone “belly-up” in the market. I guess that “eat-now-chew-later” plan has some real advantages after all.

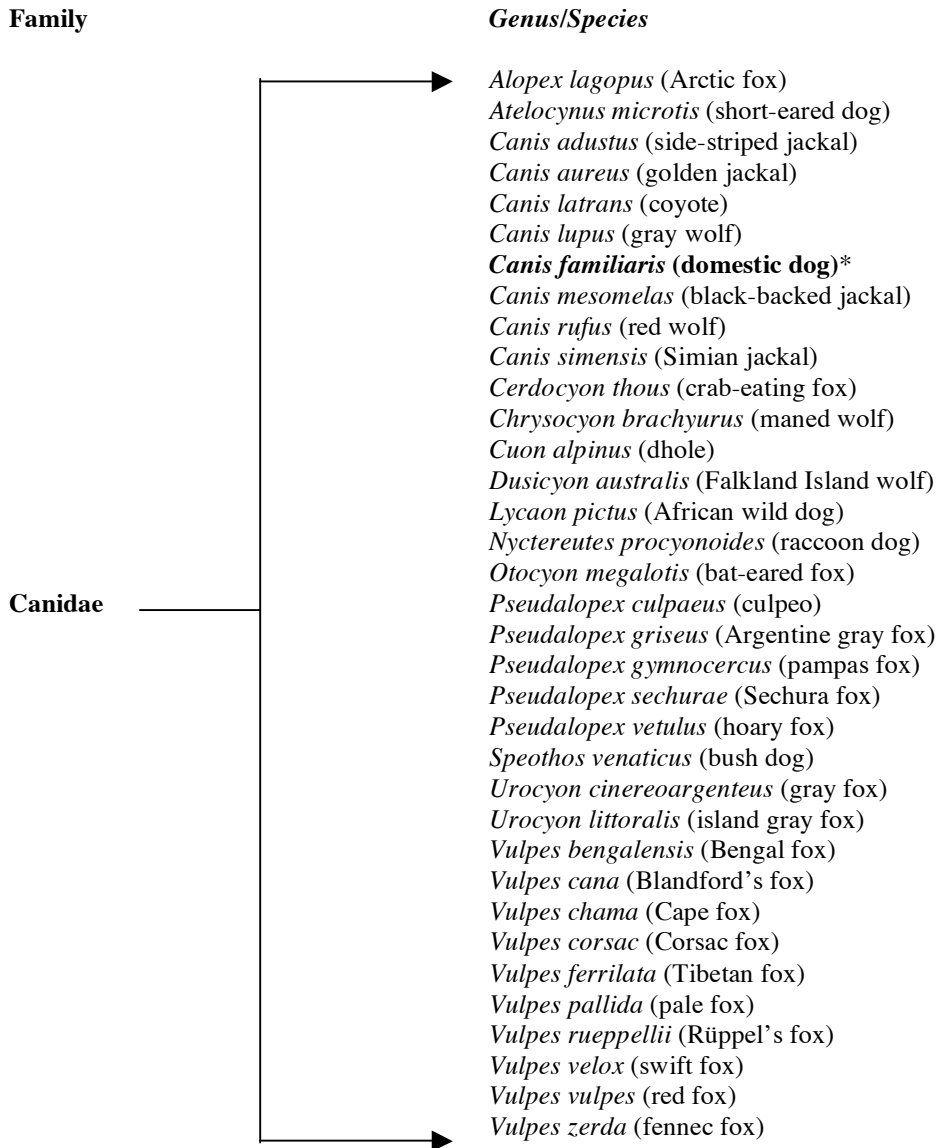


Figure 1-32. Family Canidae, showing some 14 Genera and 35 recognized species.

* Some believe that there is no species distinction between *Canis lupus* and *Canis familiaris* and that domestic dogs are merely *modified gray wolves* (some breeds obviously more modified than others). Likewise, the dingo of Australia and Southeast Asia, is not listed because it is considered to be a subspecies of the gray wolf- *Canis lupus dingo*. Personally, I have my doubts about that being true, but until proven incorrect, I’ll go along with it.

Reference: <http://animaldiversity.ummz.umich.edu/site/accounts/classification/Canidae.html>

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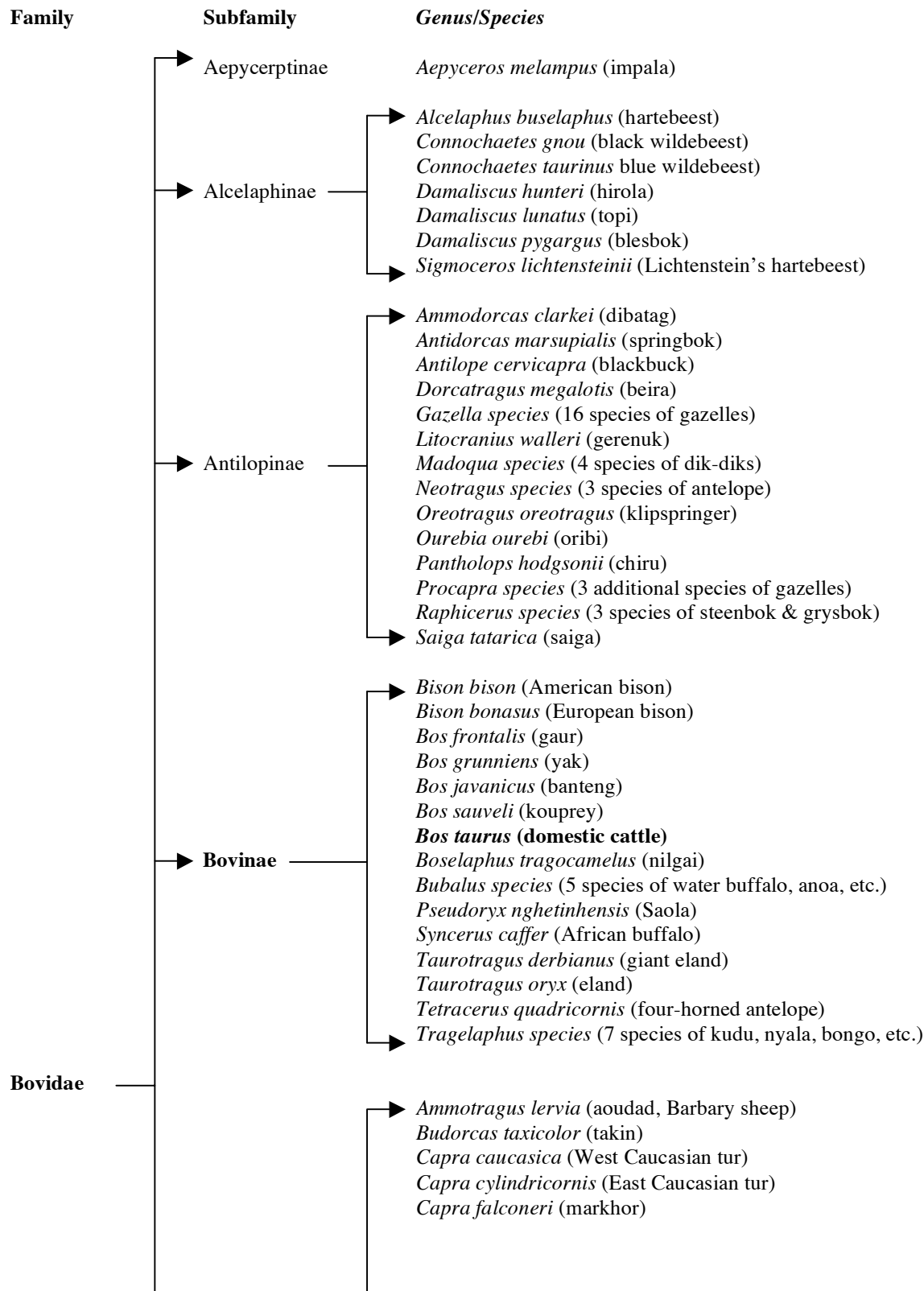


Figure 1-33. Family Bovidae (continued on next page— big family, very successful, good investment)

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Family	Subfamily	Genus/Species
	→ Caprinae	<i>Capra hircus</i> (domestic goat) <i>Capra ibex</i> (ibex) <i>Capra nubiana</i> (Nubian ibex) <i>Capra pyrenaica</i> (Spanish ibex) <i>Capra sibirica</i> (Siberian ibex) <i>Capra walie</i> (Walia ibex) <i>Hemitragus hylocrius</i> (Nilgiri tahr) <i>Hemitragus jayakari</i> (Arabian tahr) <i>Hemitragus jemlahicus</i> (Himalayan tahr) <i>Naemoredus baileyi</i> (red goral) <i>Naemoredus caudatus</i> (Chinese goral) <i>Naemoredus crispus</i> (Japanese serow) <i>Naemoredus goral</i> (goral) <i>Naemoredus sumatraensis</i> (serow) <i>Naemoredus swinhoei</i> (Taiwan serow) <i>Oreamnos americanus</i> (mountain goat) <i>Ovibos moschatus</i> (muskox) <i>Ovis ammon</i> (argali) <i>Ovis aries</i> (mouflon, domestic sheep) <i>Ovis canadensis</i> (bighorn sheep) <i>Ovis dalli</i> (Dall's sheep) <i>Ovis nivicola</i> (snow sheep) <i>Ovis vignei</i> (urial) <i>Pseudois nayaur</i> (bharal) <i>Pseudois schaeferi</i> (dwarf bharal) <i>Rupicapra pyrenaica</i> (Pyrenean chamois) <i>Rupicapra rupicapra</i> (chamois)
	→ Cephalophinae	<i>Cephalophus species</i> (17 species of duikers) <i>Sylvicapra grimmia</i> (bush duiker)
	→ Hippotraginae	<i>Addax nasomaculatus</i> (addax) <i>Hippotragus equinus</i> (roan antelope) <i>Hippotragus leucophaeus</i> (blue buck) <i>Hippotragus niger</i> (mbarapi) <i>Oryx dammah</i> (scimitar-horned oryx) <i>Oryx gazella</i> (gemsbok) <i>Oryx leucoryx</i> (Arabian oryx)
	→ Peleinae	<i>Pelea careolus</i> (common rhebok)
	→ Reduncinae	<i>Kobus ellipsiprymnus</i> (waterbuck) <i>Kobus kob</i> (kob) <i>Kobus leche</i> (lechwe) <i>Kobus megaceros</i> (Nile lechwe) <i>Kobus vardonii</i> (puku) <i>Redunca arundinum</i> (southern reedbuck) <i>Redunca fulvorufula</i> (mountain reedbuck) <i>Redunca redunca</i> (Bohar reedbuck)

Figure 1-33. Family Bovidae, showing some 49 genera and 137 species.

Reference: <http://animaldiversity.ummz.umich.edu/site/accounts/classification/Bovidae.html>

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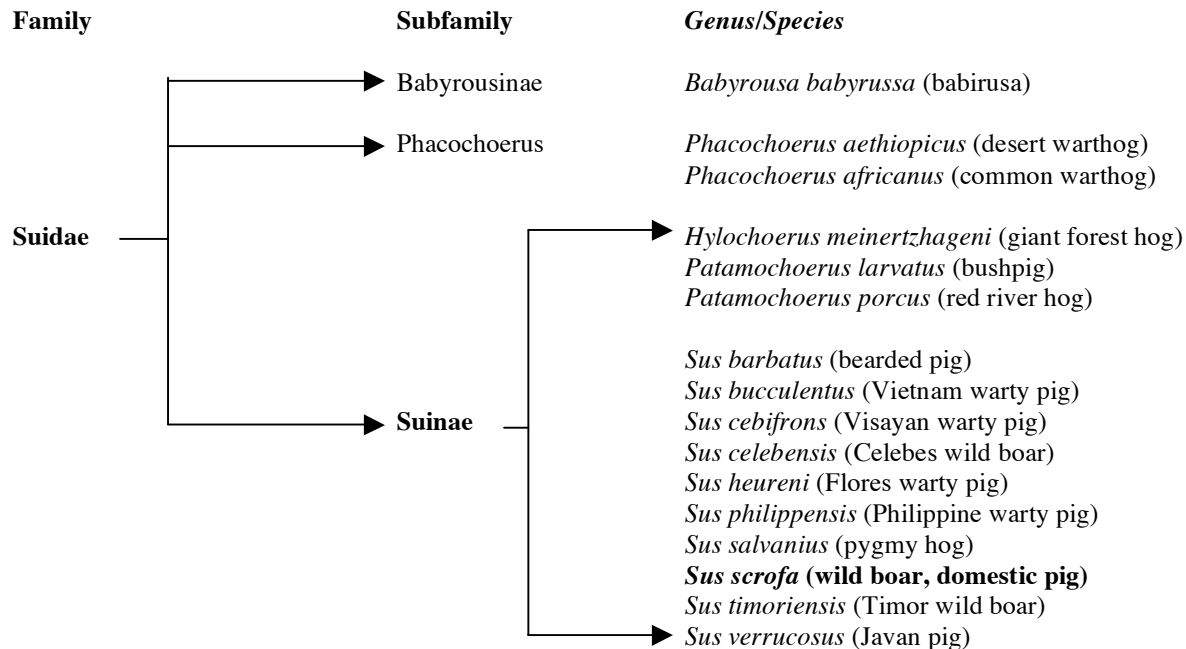


Figure 1-34. Family Suidae, showing 3 Genera and 13 recognized species.

Reference: <http://animaldiversity.ummz.umich.edu/site/accounts/classification/Suidae.html>

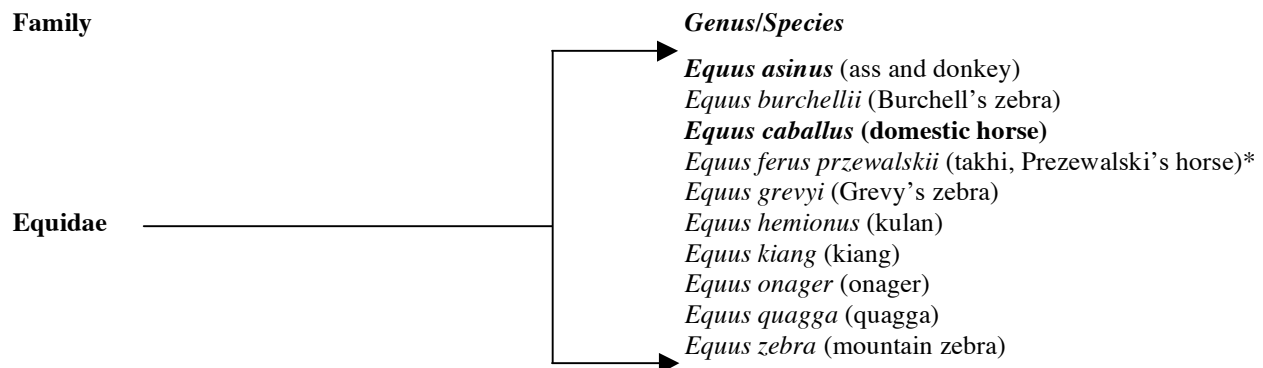


Figure 1-35. Family Equidae, showing 1 Genus and 9 or 10 (?) recognized species.

* There is some debate as to whether Prezewalski's horse is a separate species or a subspecies of *Equus caballus*; however, I think we should give Equidae the benefit of the doubt and consider Prezewalski's horse as a separate species.

Reference: <http://animaldiversity.ummz.umich.edu/site/accounts/classification/Equidae.html>

As you can see from figures 1-34 and 1-35, *Suidae* and *Equidae* have survived to present-day, but have not exactly prospered. As we proceed through the dissections of ruminants, pigs, and horses, you might think

about some of the evolutionary adaptations various species have adopted (or rejected) and consider how certain good or not-so-good choices have affected their ability as a specie to either prosper (expand in number

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of species) or just barely get by (static or reduced number of species). The takhi or Przewalski's horse (Fig. 1-36) is still hanging in there, with only with the help of people.

Equus ferus przewalskii or *Equus caballus przewalskii*?



Figure 1-36: The takhi or Przewalski's horse (Photograph Courtesy of National Zoological Park Photo Gallery, Jessie Cohen, photographer).

The Przewalski's¹⁴ horse, or “takhi” as they are known in Mongolia, was declared extinct in the wild about 1970, and for decades it survived only in captivity. Takhi (meaning “spirit” in Mongolia) were first described scientifically in 1881, when a Polish naturalist Nikolai Przewalski was sent by the Russian czar to investigate stories of “wild horses” drifting across Central Asia. Przewalski's first attempt to find the horses was unsuccessful, but on his second attempt, a Mongolian guard gave the explorer a skull and hide, which scientists at the University of St. Petersburg later determined came from a “wild horse.”

These stocky horses, which average about 13 hands and about 600 lbs., have a Mohawk-type mane with no forelock. They are mostly a “dun” color with a dark stripe down their back. Their limbs are striped

(zebra-style) just behind the carpus and on the hocks. Although the Przewalski's horse possesses 66 chromosomes, two more than *E. caballus*, they can interbreed with the domestic horse, and produce offspring with 65 chromosomes. Now here's the kicker—unlike the horse-donkey hybrids (mules and hinneys),¹⁵ the horse-takhi cross is typically fertile, even with an odd number of chromosomes.

Przewalski's horses are the last surviving species (or subspecies?) of wild horse on our planet. The feral¹⁶ horses of the western US (“mustangs”) and of the outer banks (Shackleford, Corolla, etc.) along the US eastern coast are not truly wild horses, in that they are the descendants of once-domesticated European breeds of *Equus caballus*.

In 1993, reintroduction programs began to return some of the captive takhi to the wild. In cooperation with the Cologne Zoo (Germany) and the Chinese Wild Horse Breeding Centre, the National Zoo (USA) is assisting with a reintroduction project in the Kalameili Reserve in Xinjiang, China. But creating self-sustaining wild populations is not easy. Acclimating to the harsh habitats of Mongolia and northern China, interbreeding with domestic horses, and potential conflicts with people are all challenges that stand between wild horses and the wild.

¹⁵ A mule is the result of a Jack (male donkey) to a mare breeding; a hinney is produced by breeding a stallion to a jenny (female donkey).

¹⁶ feral- a once-domesticated species that has either escaped or been intentionally released, and has returned to a wild or semi-wild status.

¹⁴ Pronounced per-zhih-VHAL-skeez

Chapter 2 • The Neck and Shoulder Region

EXTERNAL FEATURES

The pendulous skin fold along the ventral aspect of the neck in the ox¹ is commonly referred to as the dewlap. It is especially well developed in the Brahman-type (*Bos indicus*) breeds of cattle. In addition, Brahman-type cattle have a characteristic hump at the junction of neck and shoulder. This hump is formed largely by a front-to-back compression and marked thickening of the *rhomboideus cervicis* muscle.

Some goats possess paired skin appendages (*appendices colli*) on the ventral aspect of the throat that are more commonly referred to as tassels. Tassels or waddles may occasionally be seen in the pig (red waddlers) and are rarely present in the sheep. Some people believe that the presence of waddles on pigs represents a throwback to wild hogs and is therefore an undesirable characteristic in a well-bred pig.

The horse has a mane as a special adornment along the dorsum of the poll, neck and withers. Because of its compressed cervical vertebrae, the pig doesn't have much of a neck at all; the head more or less blends directly with the shoulders. Excessive fatty tissue, which may accumulate in the ventral throat region, forms the jowls of the pig.

¹ Veterinary students are typically a little surprised by anatomists' use of the term "ox" to describe what is obviously a cow. Although I certainly don't recommend it for everyday use with clients, when you think about it, there is only one other word in the English language that correctly describes in the singular, a *bona fide* member of the bovine species, without implying gender; the other word is "neat."

REFLECTION OF SKIN

Unless otherwise instructed, both sides of the cadaver are to be dissected. In the ruminant and pig, make a single mid-dorsal incision through the skin of the neck, beginning cranially near the base of the ear and extending caudally to a transverse plane about 20 cm caudal to the olecranon (Fig. 2-1). In the horse, *substitute two dorsal longitudinal incisions, one to either side of the mane. Make a transverse skin incision on each side of the cadaver, beginning at the cranial end of the longitudinal incision(s) and extending ventrally just caudal to the ear and mandible to the ventral midline; the two incisions should join ventrally* (Fig. 2-1).

The third incision begins at the caudal end of the dorsal one(s) and should extend ventrally over the thorax to a point level with but caudal to the elbow joint. Now, incise the skin cranially from the ventral ends of these caudal incisions to the elbow, and cut the skin completely around the limb at this level (Fig. 2-2).

Once these incisions have been made, *the skin should be carefully reflected from the neck and shoulders.* Because the cranial incisions meet ventrally, the skin can be completely reflected from the ventrum of the neck and pectoral region of the specimen, but should remain attached by the hinge-like connection between the ventral ends of the two caudal incisions. The skin should be retained in one large flap so that it can be tied around the animal at the end of the dissection period.

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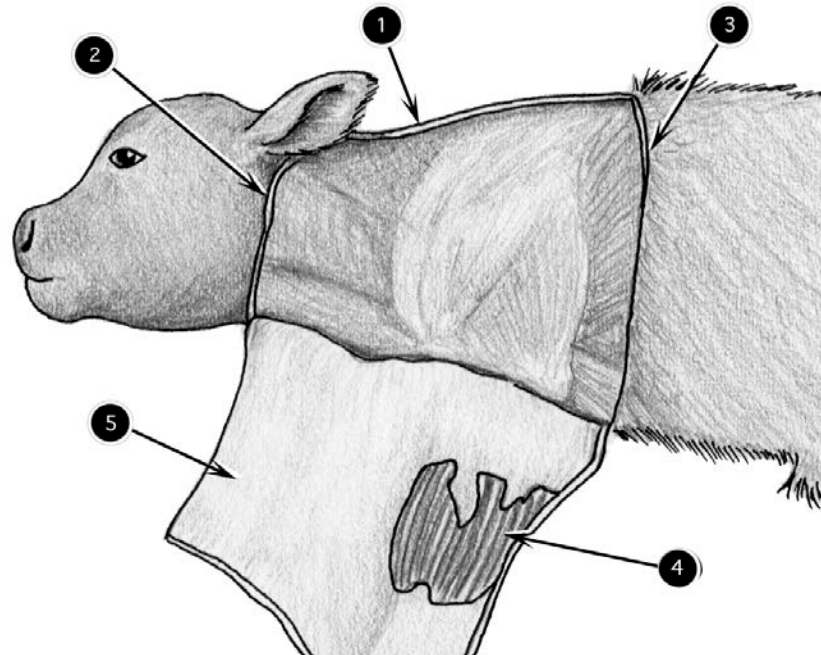


Figure 2-1. Initial skin incisions for exposure of neck and shoulder region of calf: (1) mid-dorsal incision; (2) cranial transverse incision (3) caudal transverse incision; (4) cutaneous omobrachialis muscle; (5) skin flap.

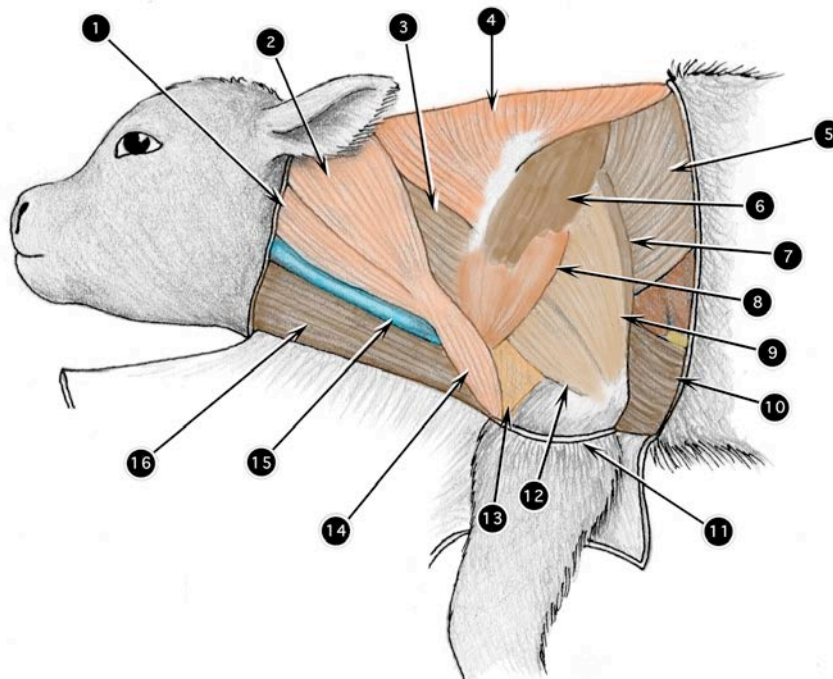


Figure 2-2. Superficial structures of neck and shoulder region of calf: (1) cleidomastoideus (part of brachiocephalicus muscle); (2) cleido-occipitalis (part of brachiocephalicus muscle); (3) omotransversarius muscle; (4) trapezius muscle; (5) latissimus dorsi muscle; (6) infraspinatus muscle; (7) tensor fasciae antebrachii muscle; (8) deltoideus muscle; (9) long head of triceps brachii muscle; (10) ascending (deep) pectoral muscle; (11) skin incision around limb; (12) lateral head of triceps brachii muscle; (13) brachialis muscle; (14) cleidobrachialis (part of brachiocephalicus muscle); (15) external jugular vein; (16) sternomandibularis (part of sternocephalicus muscle).

Chapter 2 • The Neck and Shoulder Region

SUPERFICIAL STRUCTURES

Cutaneus Omobranchialis Muscle: As the name implies, this division of the cutaneous muscle, which is well developed in the ruminant (Fig. 2-1) and horse, lies over the shoulder and arm region and serves to twitch the skin in response to flies or other annoying stimuli. This muscle is particularly active in the horse, in which its irregular dorsal border can sometimes be observed and palpated in the live animal.

Like the cutaneus trunci, the cutaneus omobranchialis is innervated by fibers from the **lateral thoracic nerve**, which reach this region via the **intercostobrachial nerve** (Fig. 3-3). Cutaneous innervation to much of the lateral aspect of the arm and shoulder region is also provided by fibers from the first few intercostal nerves, which contribute to the formation of the intercostobrachial nerve; the latter emerges caudal to the triceps brachii and ventral to the latissimus dorsi muscle.

Cutaneus Colli Muscle: This muscle is essentially nonexistent in ruminants, but is well developed in the horse (Fig. 2-3) and in the pig. The pig possesses a well-developed **platysma muscle**, which completely covers and protects the deeper structures of the neck, including the external jugular vein. After noting the thickness of the porcine platysma, you can appreciate why external jugular venipuncture is not used in the pig.

Note the relationship of the cutaneus colli muscle to the external jugular vein in the horse. You should observe that the muscle covers the caudal part of the external jugular vein and becomes progressively thicker as the vein approaches the thoracic inlet. This is one reason why the preferred site for venipuncture in the horse is in the cranial part of the neck (Fig. 2-3).

Compare the skin thickness over the external jugular vein in the horse and ox. You should observe that *the skin is much thicker in the ox*, which accounts for the difference in technique for external jugular venipuncture in the two species. This difference can best be appreciated by reference to transverse sections. Obviously, much greater force is required to penetrate the thick skin of the ox than the relatively thin equine skin.

Fascia, Nerves, and Lymphatics: The superficial muscles of the neck are closely invested and interconnected by superficial fascia so that on initial reflection of the skin, individual muscle borders are not well defined. Once air has come in contact with this area, however, muscle borders and fiber directions should become more obvious.

You will probably observe some superficial lymphatics that are converging just cranial to the shoulder. These are afferents to the *superficial cervical lymph nodes*, which will be exposed later. In some cattle, there is a discoid lymph node located in the superficial fascia near the junction of the omotransversarius and trapezius muscles. When present, this node, which is a member of the superficial cervical *lymphocenter*,² is palpable in the live animal. It may be present on one side and not the other.

As the skin was reflected, cutaneous branches of the cervical nerves were transected. Ventral branches of nerves C2 to C6 emerge through the brachiocephalicus muscle and can be observed in the superficial fascia. The ventral branch of C2 emerges caudoventral to the palpable wing of the atlas and divides into two named

² Although we often refer to specific lymph nodes in the singular, typically more than one lymph node is present forming a lymphocenter.

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branches, which can be identified in the horse and ruminant. The **transverse nerve of the neck** courses ventrally over the

parotid gland, and the **great auricular nerve** passes craniodorsally toward the base of the ear (Fig. 2-3).

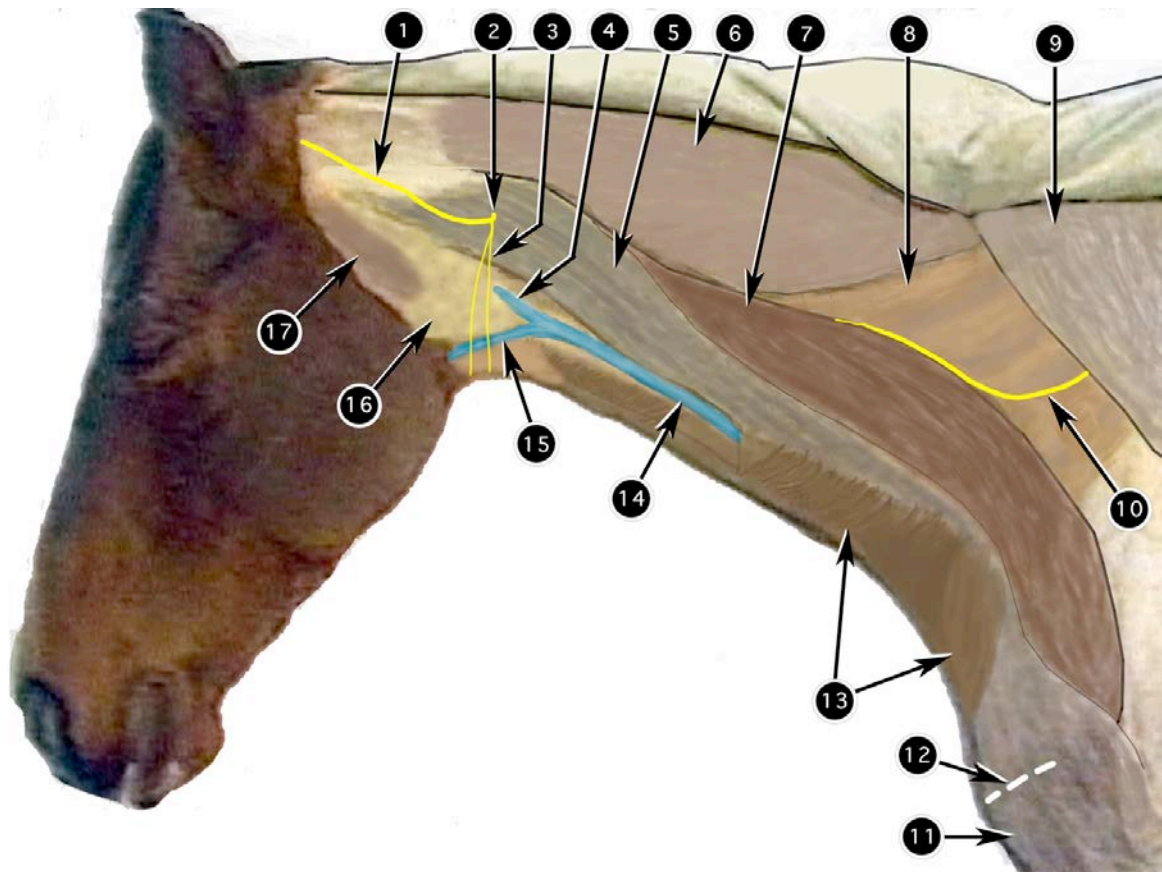


Figure 2-3. Superficial structures of equine neck: (1) great auricular nerve; (2) ventral branch of C2 emerging through brachiocephalicus muscle, caudoventral to wing of atlas (3) transverse nerve of neck; (4) maxillary vein; (5) cleidomastoideus muscle; (6) splenius muscle; (7) omotransversarius muscle; (8) serratus ventralis cervicis muscle; (9) trapezius muscle; (10) dorsal branch of accessory nerve (CN IX); (11) cleidobrachialis muscle; (12) approximate location of clavicular intersection; (13) cutaneus colli muscle; (14) external jugular vein; (15) linguofacial vein; (16) parotid salivary gland; (17) parotidoauricularis muscle.

Referring to figures 2-2 and 2-3, *carefully clean the fascia away, and define the superficial muscles of the neck and shoulder regions. In the pig, dissect the platysma free from its caudal attachment and reflect it cranially to expose the deeper structures.* Much of the ventrolateral aspect of the neck is covered by the large parotid salivary gland of the pig.

Omotransversarius Muscle: The omotransversarius muscle of the horse (Fig.

2-3) appears to be part of the brachiocephalicus muscle to which it is intimately associated ventrally. In fact, prior to the publication of the second edition of the *Nomina Anatomica Veterinaria (NAV)* in 1973,³ this muscle in the horse was referred to as the cleidotransversarius. Today it is considered to be a separate muscle.

³ NAV- This is the little book that veterinary anatomists use to look up the correct names of things (in those rare instances when they don't remember).

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Brachiocephalicus and Sternocephalicus Muscles: The brachiocephalicus and sternocephalicus muscles of the common domestic species show considerable variation (more so than most other muscles). In addition to the cleidomastoideus, which is present in all domestic ungulates, the brachiocephalicus muscle of the ruminant and pig has a dorsal part, the cleido-occipitalis, which passes over the wing of the atlas to the skull (Fig. 2-2). Similarly, the sternocephalicus muscle, which consists of a single division in the horse (Fig. 2-4), is more complicated in some other species. Comparative information on these two muscles is summarized in Table 2-1.

Boundaries of Jugular Groove (Horse and Ruminant): As the name implies, the jugular groove accommodates the external jugular vein, which is commonly used for venipuncture in the horse and ruminants. The **cleidomastoideus** forms the dorsal boundary of the groove in both the horse and ruminant (Figs. 2-2 & 2-3). The part of the sternocephalicus that forms the ventral border of the jugular groove in the horse, ox, and goat is the **sternomandibularis** (Figs. 2-2 & 2-4). The jugular groove is not well defined ventrally *in the sheep because the sternomandibularis is absent*.

Although not yet visible, there is also a medial boundary of the groove in the cranial half of the neck; however, the muscle that primarily forms this boundary is not the same for the horse and ruminant. *To expose this "backstop" to venipuncture, carefully dissect around the cranial third of the external jugular vein and retract the vessel from its groove.*

In the horse, this dissection should expose the **omohyoideus muscle** (Fig. 2-4), which forms the medial boundary of the groove. In the ruminant, the medial wall of

the jugular groove is not primarily formed by the omohyoideus muscle, which is poorly developed in these species. In the ruminant, the medial boundary is formed by the **sternomastoideus**, a part of the sternocephalicus, which is absent in the horse.

The omohyoideus muscle (horse) or sternomastoideus (ruminant) does offer some protection to the structures of the carotid sheath when venipuncture is performed in the cranial half of the neck (Fig. 2-4). *It is possible, however, to puncture the common carotid artery if careless venipuncture technique is used.* Accidental injection of certain drugs such as tranquilizers into the common carotid artery (direct route to brain) rather than the external jugular vein could be fatal to the patient.⁴ The external jugular vein of the pig is not accessible for venipuncture because there is no definable jugular groove and the vein is never in a subcutaneous position. Venipuncture in the pig will be discussed later.

Refer to figure 2-5. Note the *triangular area formed by the caudal border of the mandible, the tendon of the sternocephalicus, and the linguofacial vein*. This area is of surgical importance in the horse, and for lack of a better term is known as **Viborg's triangle**. Some surgeons prefer this approach to the guttural pouch and associated lymph nodes. By virtue of its clinical importance, the boundaries of this triangle have a nasty habit of showing up from time to time on state board exams (and on anatomy tests as well).

⁴ Such accidents in no way foster positive client relations and could well result in an increase in your malpractice insurance premiums.

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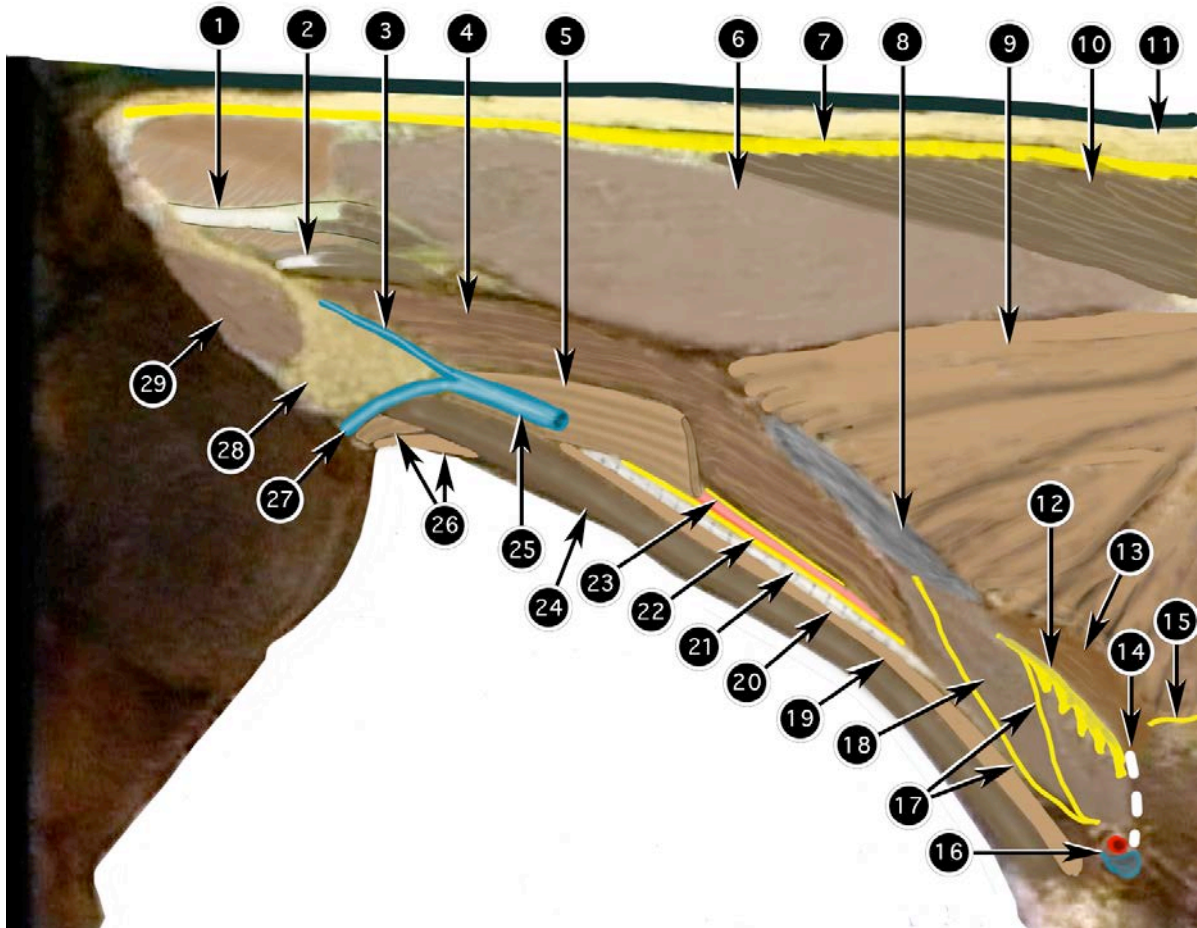


Figure 2-4. Deeper structures of equine neck: (1) tendon of longissimus capitis muscle; (2) tendon of longissimus atlantis muscle; (3) maxillary vein; (4) longus capitis muscle; (5) omohyoideus muscle; (6) splenius muscle; (7) funiculus nuchae; (8) intertransversarius muscle; (9) serratus ventralis cervicis muscle; (10) rhomboideus cervicis muscle; (11) nuchal crest fat; (12) roots of brachial plexus emerging between 13 & 18; (13) middle scalenus muscle; (14) location of first rib; (15) long thoracic nerve; (16) axillary artery & vein; (17) roots of phrenic nerve; (18) ventral scalenus muscle; (19) sternothyrohyoideus muscle; (20) trachea; (21) vagosympathetic trunk; (22) common carotid artery; (23) recurrent laryngeal nerve; (24) sternocephalicus (sternomandibularis) muscle; (25) external jugular vein; (26) combined sternohyoideus & omohyoideus muscles; (27) linguofacial vein; (28) parotid salivary gland; (29) parotidoauricularis muscle.

Even though the term "Viborg's" triangle is an *eponym* and use of this name is in direct violation of Smallwood's Law ("never use eponyms"), we'll let this one slide as there is no correct anatomic name for this specific area. *Demonstrate the boundaries of Viborg's triangle on the live horse. The caudal border of the mandible can be easily palpated. The tendon of the sternocephalicus can be demonstrated by extending the horse's head, and the*

linguofacial vein can be raised by digitally occluding the external jugular vein as you would to perform venipuncture.

*Transect the trapezius cervicalis near its termination on the scapular spine and reflect it dorsally. Locate the dorsal branch of the **accessory nerve (CN XI)** in the horse (Fig. 2-3) and ox (Fig. 2-6). It can be found in the horse along the dorsal border of the omotransversarius muscle, and in the ox, at*

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the point where the omotransversarius, the trapezius, and the cleido-occipitalis meet.

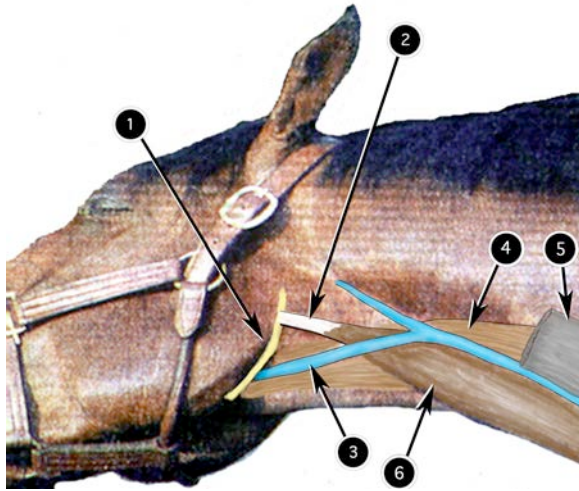


Figure 2-5. Boundaries of Viborg's triangle (1-3) and jugular groove (4-6) in horse: (1) caudal border of mandible; (2) tendon of sternocephalicus muscle; (3) linguofacial vein; (4) omohyoideus muscle; (5) cleidomastoideus muscle (cut); (6) sternocephalicus (sternomandibularis) muscle.

Follow the nerve to the deep surface of the trapezius muscle. Consider the vulnerability of this nerve to careless injections in this area. *Intramuscular injections, when made in the neck, should be made in the heavy muscles of the caudodorsal part of the neck, far enough*

*dorsally to avoid the vertebral column and the dorsal branch of CN XI (Fig. 2-7). With the trapezius cervicalis reflected dorsally, transect the omotransversarius and reflect it cranially to identify the **rhomboideus cervicis**, the **serratus ventralis cervicis**, and the superficial cervical lymph nodes (Fig. 2-6).*

Superficial Cervical Lymph Nodes: These lymph nodes were formerly termed the *prescapular lymph nodes*, and you may hear them referred to as such by some clinicians. As is typical for the lymph nodes of the horse, the superficial cervical nodes consist of a cluster of many small nodes that lies on the cranial border of the subclavius muscle. Unless they are enlarged, these lymph nodes are not typically palpable in the live horse.

In the **ruminant**, there is typically one large primary node that lies on the cranial border of the supraspinatus muscle. In addition, several smaller nodes may be observed in the prescapular fat (Fig. 2-6). The dark-colored nodes are **hemal lymph nodes**. Note the wide area of lymph collection for the superficial cervical nodes.

Table 2-1: Comparison of brachiocephalicus and sternocephalicus muscles among common domestic mammals.

Brachiocephalicus Muscle

cleidobrachialis - all species
cleidomastoideus - all species
cleido-occipitalis - pig, ruminants
cleidocervicalis - dog, cat

Sternocephalicus Muscle

sterno-occipitalis - dog, cat
sternomandibularis - horse, ox, goat
sternomastoideus - ruminants, pig, dog, cat

Modified from deLahunta, A., and Habel, R. E.: *Applied Veterinary Anatomy*. W. B. Saunders, Philadelphia, 1986, p. 67.

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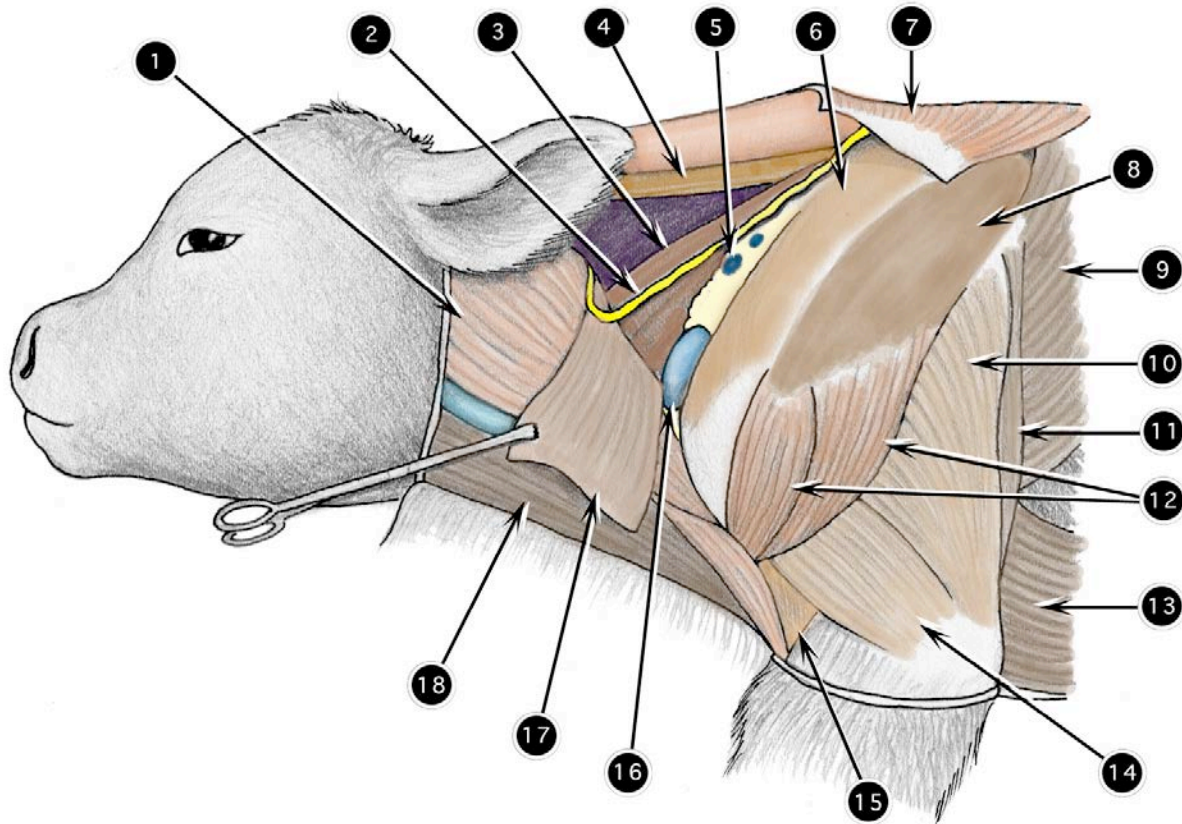


Figure 2-6. Reflection of trapezius and omotransversarius muscles to expose prescapular area of calf: (1) brachiocephalicus muscle; (2) dorsal branch of CN XI; (3) serratus ventralis cervicis muscle; (4) rhomboideus cervicis muscle; (5) hemal lymph nodes; (6) supraspinatus muscle; (7) reflected trapezius muscle; (8) infraspinatus muscle; (9) latissimus dorsi muscle; (10) long head of triceps brachii muscle; (11) tensor fasciae antebrachii muscle; (12) cranial & caudal parts of deltoideus muscle; (13) ascending (deep) pectoral muscle; (14) lateral head of triceps brachii muscle; (15) brachialis muscle; (16) superficial cervical lymph node; (17) reflected omotransversarius muscle; (18) sternomandibularis (part of sternocephalicus muscle).

The blood vessels associated with the superficial cervical lymph nodes in the horse and ruminant are the prescapular branches of the **superficial cervical artery and vein**. The largest superficial cervical lymph node should be palpated in the living ox. *Place your hand on the cow's neck, with the finger tips pressed against the supraspinatus. By drawing your hand cranially, while pressing medially, the node will usually "pop" from under the fingers toward the supraspinatus muscle.*

In the pig, the superficial cervical lymphocenter consists of about ten nodes

spread over a large triangular area, and divided into dorsal, middle, and ventral superficial cervical lymph nodes.

Identify the **rhomboideus cervicis muscle** (Fig. 2-4). The rhomboideus cervicis muscle of Zebu (*Bos indicus*, Brahman) cattle is thickened and shortened to form much of the "hump" characteristic of these animals. Although there is no rhomboideus capitis muscle present in the horse or ruminants, this is a well developed muscle in the pig. *The ventral edge of the rhomboideus cervicis muscle can be defined by palpation in the horse and ruminant.*

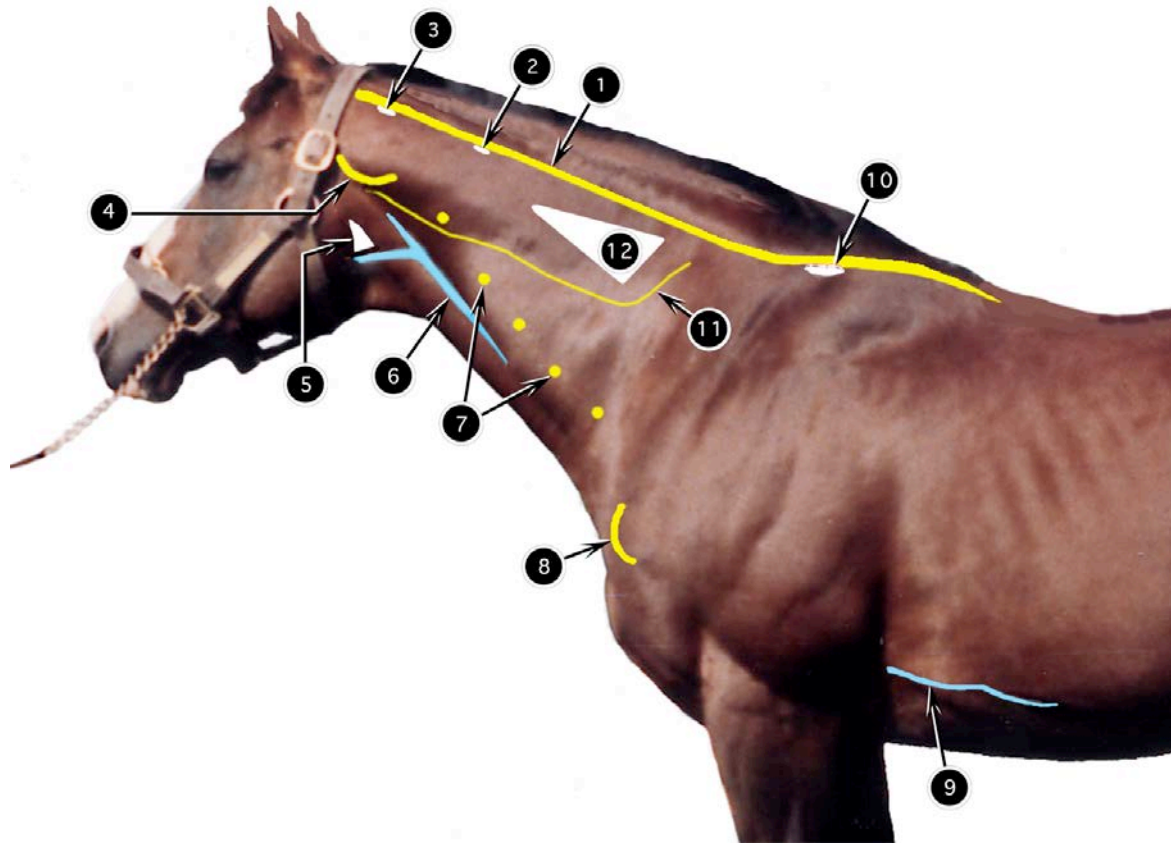


Figure 2-7. Neck and shoulder of a Thoroughbred stallion with selected anatomic features approximated: (1) funiculus nuchae; (2) caudal nuchal bursa over spinous process of axis; (3) cranial nuchal bursa over dorsal arch of atlas; (4) wing of atlas; (5) Viborg's triangle; (6) external jugular vein; (7) transverse processes of cervical vertebrae; (8) point of shoulder; (9) superficial thoracic vein; (10) supraspinous bursa; (11) dorsal branch of CN XI; (12) preferred area in caudodorsal part of neck for intramuscular injections.

Nuchal Ligament: (Figs. 2-4, 2-7 & 2-8). As in the cat, the **nuchal ligament** is absent in the pig. Therefore, for obvious reasons, it will not be examined. The **funiculus nuchae** of the horse is more superficial than that of the ruminant, where it is covered by the trapezius, rhomboideus, and splenius muscles. In the horse, the funiculus nuchae begins as a cranial continuation of the **supraspinous ligament** at T3 to T4.

Transect the trapezius and rhomboideus muscles along the dorsal raphe of the neck (ruminant) or edge of the funiculus nuchae (horse) and reflect them to the limb (the trapezius cervicis may be removed and discarded). Similarly, transect the splenius

muscle and reflect it cranially to the head. Also reflect the cleido-occipitalis of the ruminant to the head. This exposes the funiculus nuchae and the large **semispinalis capitis muscle** (Fig. 2-8), which is not as clearly divided into biventer cervicis and complexus as in the dog.

The funiculus nuchae of the ruminant originates much further caudally (Fig. 2-8), where it partially covers the epaxial muscles. Each part of the funiculus nuchae is wide and lies to the side of the thoracic spines in an almost sagittal plane.

Compare the most cranial attachment of the nuchal ligament in the horse and

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ruminant with that of the dog. In contrast to that of the dog, which ends cranially on the spine of the axis, the funicular part of the equine and ruminant nuchal ligament continues cranially to an attachment on the

skull at the *external occipital protuberance* (refer to skeletons). Thus, in the horse and ruminants, the nuchal ligament provides passive, antigravity support for both the atlantoaxial and atlanto-occipital joints.

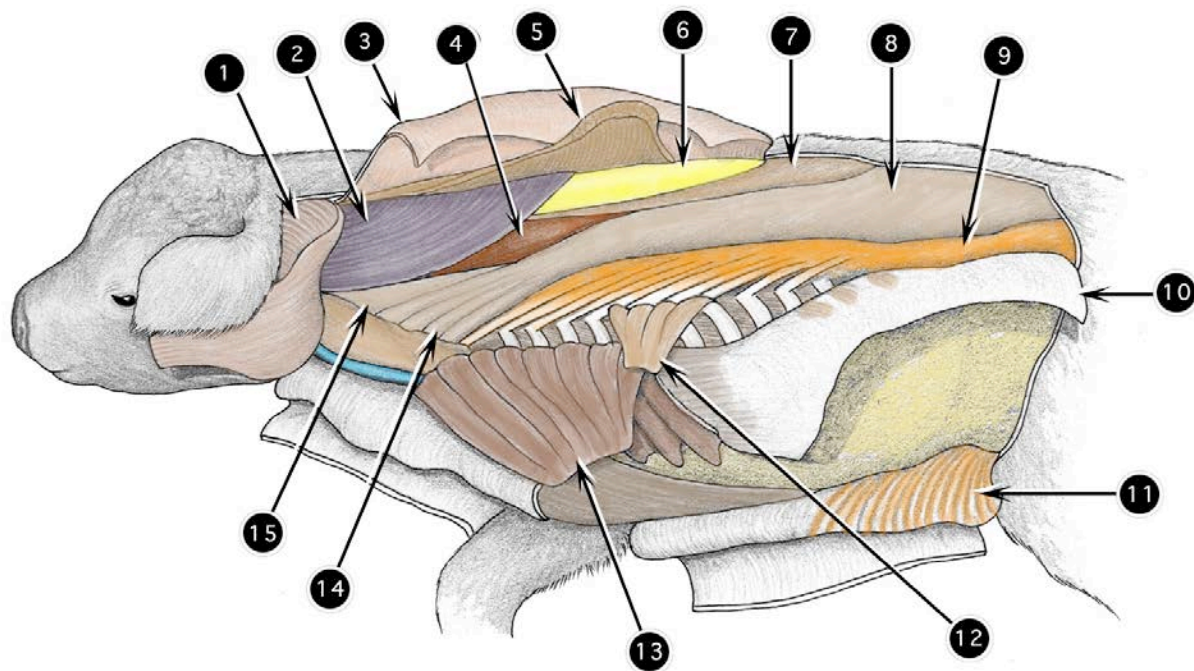


Figure 2-8. Deeper structures of neck and back of calf: (1) reflected brachiocephalicus muscle; (2) splenius muscle; (3) reflected trapezius muscle; (4) semispinalis capitis muscle; (5) reflected rhomboideus muscle; (6) funiculus nuchae; (7) spinalis et semispinalis muscle; (8) longissimus thoracis et lumborum muscle; (9) iliocostalis lumborum muscle; (10) reflected thoracolumbar fascia; (11) cutaneus trunci muscle reflected with skin; (12) reflected serratus dorsalis cranialis muscle; (13) reflected serratus ventralis muscle; (14) longissimus cervicis muscle; (15) longissimus capitis et atlantis muscle.

Transect the semispinalis capitis muscle at the level of the axis and reflect it laterally to expose the lamina nuchae. Like the funiculus nuchae, the **lamina nuchae** of the horse is paired. It originates from the funicular part and from the spinous processes of T2 and T3 and attaches to the spinous processes of C2 to C7. The blood vessels located on the deep surface of the semispinalis capitis are branches of the **deep cervical vessels** (Fig. 2-9).

The lamina nuchae of the ox (Fig. 2-9) is more complex than that of the horse. In addition to the paired cranial part, which in

the ox arises entirely from the paired funicular part, there is a single caudal part that extends from the spinous process of T1 to the spinous processes of C5 to C7. Retract the paired part of the lamina nuchae dorsocranially to expose this caudal, unpaired part in the ruminant (Fig. 2-9).

The nuchal ligament is an important aid in supporting the weight of the head and neck. As an elastic structure, it allows the head to be lowered by the ventral neck muscles, yet aids the dorsal muscles in lifting and extending the head and neck. It

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may also assist in keeping the cervical vertebrae in proper alignment.

Using a large knife, make two transverse cuts, about 5 cm apart through the funiculus nuchae of the horse at the level of T2. Reflect the part of the ligament isolated by

the two cuts and search the underlying area over the spinous processes of T2 and T3 for the **supraspinous bursa** (Fig. 2-7). When the horse lowers its head for grazing, the funiculus nuchae is pulled tightly down over these spinous processes, exerting great pressure over this area.

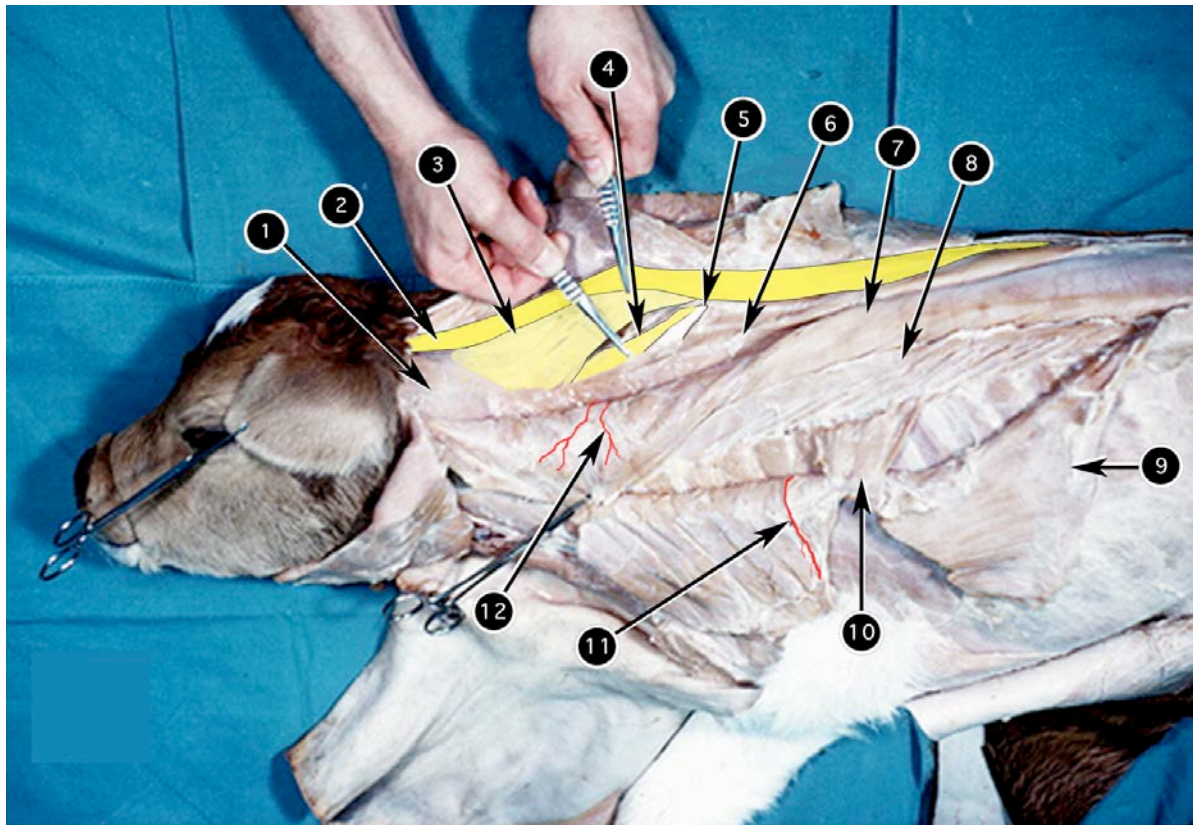


Figure 2-9. Dissection of nuchal ligament and associated structures in calf: (1) oblique capitis caudalis muscle; (2) funiculus nuchae; (3) paired lamina nuchae arising from 2; (4) unpaired caudal part of lamina nuchae arising from first thoracic spine; (5) spinous process of T1; (6) spinalis et semispinalis muscle; (7) longissimus thoracis et lumborum muscle; (8) iliocostalis thoracis muscle; (9) reflected latissimus dorsi muscle; (10) reflected serratus dorsalis cranialis muscle; (11) dorsal scapular vessels on deep surface of reflected serratus ventralis muscle; (12) deep cervical vessels on deep surface of reflected semispinalis capitis muscle.

Although much less common today, cases of *infectious supraspinous bursitis* still occur. Chronically infected bursae become grossly enlarged and multiple sub-compartments may develop as the body attempts to "wall-off" the infection. In some cases, the infection eventually works its way to the surface near the junction of the rhomboideus cervicis and serratus ventralis

cervicis muscles. It then ruptures and drains, producing what is commonly referred to as "fistulous withers." As noted above, the funiculus nuchae of the ruminant is completely divided in the thoracic region, and is not pulled down across the thoracic spinous processes when the head is lowered. Thus, in the ruminant, there is no need for a supraspinous bursa, and none is present.

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VENTRAL STRUCTURES OF NECK

Ventral Branch of Accessory Nerve: The ventral branch of the accessory nerve (CN XI) supplies the sternocephalicus muscle. It can usually be identified as it enters the muscle in the cranial third of the neck. *Transect the sternocephalicus muscle and omohyoideus muscle (horse) in the cranial third of the neck to expose the trachea, esophagus and associated structures.*

Hypertrophy of Neck Muscles of Horse related to “Cribbing” (Crib-biting, Wind-Sucking): Among various vices that bored horses adopt is the habit of hooking their upper (superior) incisor teeth on a fixed object, arching their neck, and contracting their ventral neck muscles to exert extreme pressure on that object. Their choice of cribbing objects is typically a horizontal board or rail, but once perfected, some horses will “crib” on almost any stationary object, horizontal or vertical (Fig. 2-10).

Cribbing is a repetitive behavior that is frequently accompanied by pulling air into the pharynx and upper esophagus, creating a “sucking” sound. Although it is frequently stated that these horses swallow air, which can result in flatulent colic, recent studies indicate that the air is not swallowed, but does enter the proximal (cranial) esophagus.

Because of the repetitive and “addictive” nature of this behavior, several negative consequences occur: (1) hypertrophy of the ventral neck muscles, especially the sternocephalicus, sternothyrohyoideus, and omohyoideus; (2) poor performance and weight loss; (3) abnormal and accelerated wear of the incisor teeth; and (4) possibly colic.



Figure 2-10. Horse cribbing on post: note arching of neck and contracture of neck muscles to exert extreme pressure on the object. (Photograph courtesy of Dr. Brandi Ogle, NCSU-CVM Class of 2005.)

Why horses acquire this behavior has been the focus of many studies, and there are several theories, including the chronic stress, boredom, and anxiety created by solitary confinement of an animal that's natural habitat is an open prairie or pasture.⁵ For many years, treatments for cribbing were directed at the physical effects (undesirable muscle hypertrophy and stall destruction) rather than the underlying behavioral disorder. Quite a variety of

⁵ This brings up the question: What is the number one pathogen (disease-producing organism) of the horse? My answer—*Homo sapiens*. The more you learn about the many clinical conditions of domestic horses (vs. wild equidae), the more you will notice a common theme—*people, and what they do to horses produce more problems than all the bacteria, fungi, and viruses combined.*

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treatments have been tried with variable success, including the use of “cribbing straps,” myectomies of the affected muscles (Forsell’s procedure)⁶, and neurectomy of the ventral branch of the accessory nerve as it enters the sternocephalicus muscle.

Not until animal behaviorists came on the scene, were studies directed more at the underlying behavioral components. The addictive nature of cribbing has been associated with the release of beta-endorphins, and possibly serotonin. Opiate inhibitors have been used to block the “euphoric” reward horses enjoy from the release of endogenous endorphins. As boredom is still considered to play a significant role, providing the confined horse with a companion or “stall mate” in the form of a pony or goat⁷ has been used. Lastly, addictive behaviors in people (*viz.*, alcoholism) have a significant genetic component, and it is quite likely that this may be true in horses.

Thymus: The cervical part of the thymus typically atrophies within the first few months of life in the horse, and therefore, is not usually found except in the young foal. In contrast, the bovine thymus (Fig. 2-11) is identifiable, even in the adult, as a pale, lobulated structure. The right and left cervical lobes are especially well developed in calves, and the thymus is sometimes saved at slaughter as the so-called “**sweetbread**.” The thymus of the pig is also very well developed at the usual slaughter age of about 6 months.

Structures of Carotid Sheath: The **common carotid artery**, **vagosympathetic trunk**, and when present, the **internal jugular vein** course together in a common fascial wrapper along the dorsolateral aspect of the trachea. The internal jugular vein is not typically present in the horse. *Open the carotid sheath and identify these structures* (Figs. 2-11 & 2-12). Note the relatively large internal jugular vein in the pig. Also, more closely associated with the trachea, identify the **recurrent** (caudal) **laryngeal nerve** as it courses cranially to the larynx. This nerve will be studied in more detail later.

Deep Cervical Lymph Nodes (Fig. 2-12): These lymph nodes are closely associated with the trachea and lie along the course of the tracheal lymphatic ducts. In the horse, they are divided into three groups- **cranial** deep cervical (near the larynx), **middle** deep cervical (about the middle of the neck), and **caudal** deep cervical (near the thoracic inlet). The **tracheal trunk** (Fig. 2-12) is the bilateral lymphatic duct that conducts lymph from the head and neck to the thoracic inlet, where the lymph enters venous circulation.

Trachea (Fig. 2-11): In the horse, the trachea becomes relatively superficial cranial to the divergence of the right and left sternocephalicus muscles. Here, the trachea is covered ventrally only by the thin sternohyoideus muscles, which can be divided along the median plane. The tracheal cartilages are easily palpable in this region, and it is at about the level of the 4th or 5th tracheal cartilage that a **tracheotomy** is usually performed. A tracheostomy tube can be inserted through this incision to alleviate respiratory distress resulting from occlusion of the upper respiratory tract, which is relatively common in horses.

⁶ Delacalle, J., et al. Nd:YAG laser-assisted modified Forsell’s procedure for treatment of cribbing (crib-biting) in horses. *Veterinary Surgery* 31 (2002): 111-116.

⁷ Goat as a companion- see movie “Seabiscuit.”

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The sternohyoideus and sternothyroideus muscles are typically combined at their origin from the manubrium of the sternum, and I frequently use the term “sternothyrohyoideus” (Fig. 2-12) to refer to this common segment before the two divisions separate cranially to their terminations, the thyroid cartilage of the larynx and basihyoid bones respectively.

Partial myectomy of the sternothyrohyoideus muscles, which are commonly referred to as the “strap muscles,” is sometimes performed as one of several surgical treatments for dorsal displacement of the soft palate in horses. The idea is that these muscles pull the tongue and larynx caudally during a race, and allow the soft palate to slip up-and-over the epiglottis, thus compromising air-flow through the glottis.

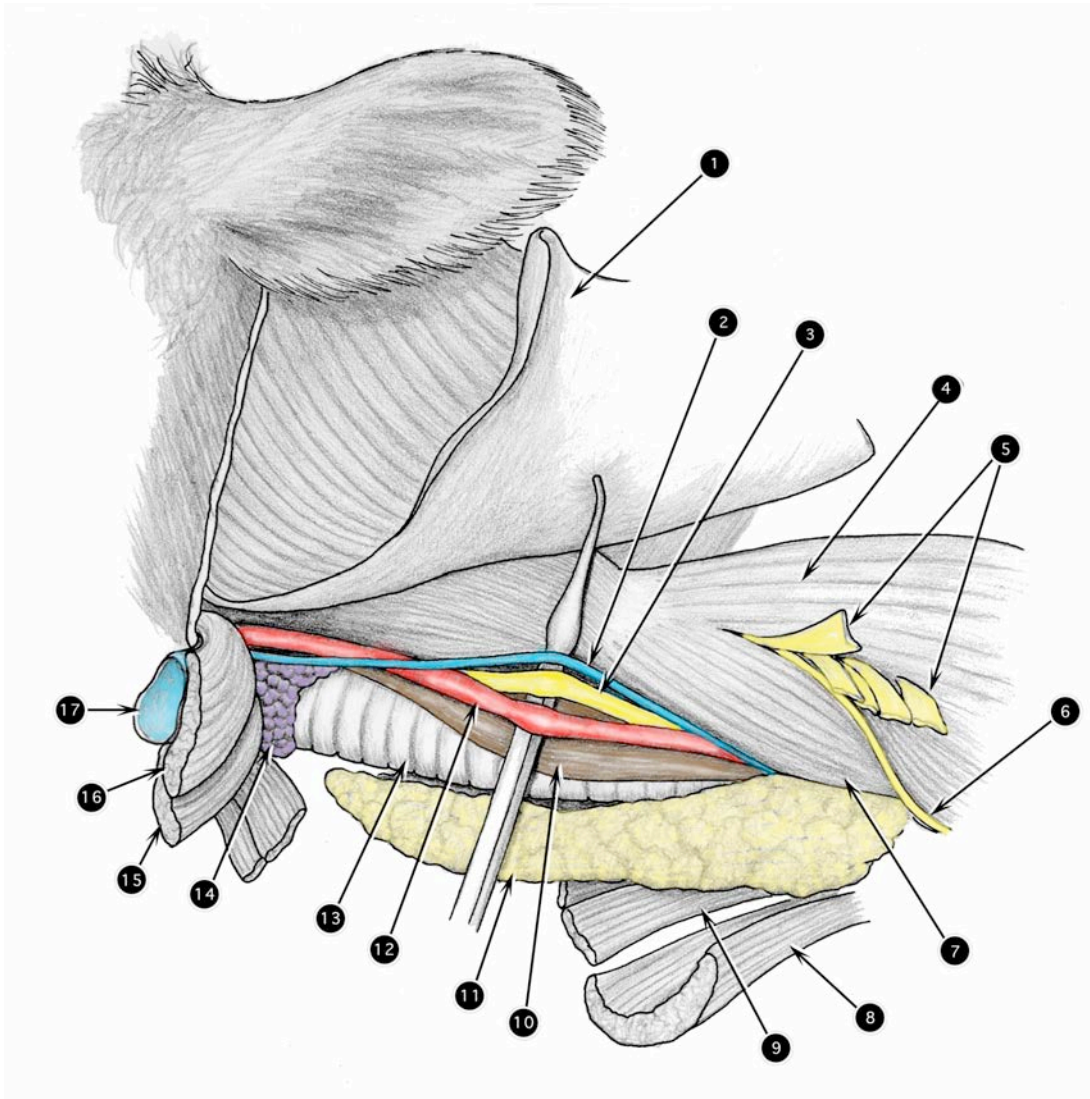


Figure 2-11. Ventral structures of neck of calf: (1) reflected brachiocephalicus muscle; (2) internal jugular vein; (3) vagosympathetic trunk; (4) dorsal scalenus muscle; (5) stumps of brachial plexus nerves; (6) roots of phrenic nerve; (7) ventral scalenus muscle; (8) caudal stump of sternocephalicus muscle; (9) caudal stump of sternothyrohyoideus muscle; (10) esophagus; (11) cervical part of thymus; (12) common carotid artery; (13) trachea; (14) isthmus of thyroid gland; (15) cranial stump of sternomandibularis muscle; (16) cranial stump of sternomastoideus muscle; (17) reflected stump of external jugular vein.

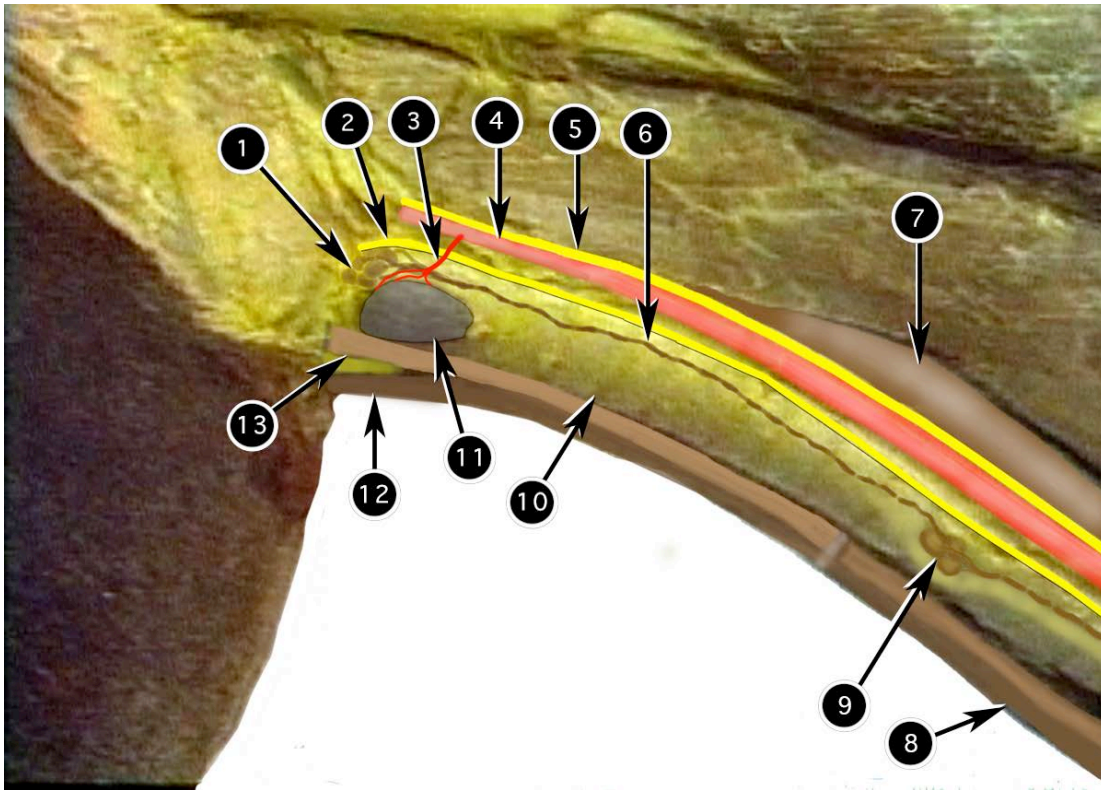


Figure 2-12. Ventral structures of neck of horse: (1) cranial deep cervical lymph nodes; (2) caudal (recurrent) laryngeal nerve; (3) cranial thyroid artery; (4) common carotid artery; (5) vagosympathetic trunk; (6) tracheal lymphatic trunk; (7) esophagus; (8) sternothyrohyoideus muscle; (9) middle deep cervical lymph nodes; (10) trachea; (11) left lobe of thyroid gland; (12) sternohyoideus muscle, attaches cranially on basihyoid bone; (13) sternothyroideus muscle, attaches cranially on thyroid cartilage of larynx.

The **sternohyoideus muscle** of the ruminant is similar to that of the horse, while that of the pig is much larger. As a matter of fact, it would appear that the muscle called the "sternohyoideus" of the pig actually represents an "evolutionary translocation" of the sternomandibularis muscle. The "sternothyroideus" muscle of the pig is divided into two parts, one terminating in the typical (Mary M. Mammal) fashion, and the other attaching more ventromedially on the thyroid cartilage.

What I *speculate* might have happened is that, somewhere along the way, the powerful sternomandibularis has "relocated" medially to the basihyoid, and either concurrently or

subsequently, the original little sternohyoideus has slipped back from the basihyoid to attach to the thyroid cartilage. Thus, the latter is now considered to be part of the sternothyroideus.⁸

Transect the sternohyoideus and sternothyroideus muscles at about the level of the 5th tracheal cartilage, and reflect

⁸ Please note that my idea concerning the sternohyoideus and sternothyroideus muscles of the pig is purely speculative and is not supported by any scientific evidence; *i.e.*, "it just looks that way to me." I might point out that the "sternomandibularis" muscle of the goat terminates on the zygomatic arch, not the mandible. It is my humble opinion that muscles tend to shift around in different species according to the law of "demand and supply" (need precedes supply).

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their stumps to expose the trachea. Make a transverse cut through the trachea and examine its cross section (Fig. 2-13); you may remove a 1-cm section of trachea if you wish. Compare the relative size and configuration of the trachea of the horse with those of the ruminant and pig.

Esophagus (Fig. 2-11 & 2-12): Although the esophagus begins dorsally, it typically slips over to the left side of the trachea in the cervical region. Veterinarians make use of this fact when passing a stomach tube in a horse or ruminant in that the tip of the tube creates a visible bulge in this area as it passes down the esophagus. Thus, by seeing this bulge, one can confirm that the tube is in fact in the esophagus. Occasionally an animal forgets to read the anatomy book, and in these cases, the esophagus passes down the right side of the trachea. Compare the size of the esophagus in the horse with that of the ox. When a ruminant is ruminating, you can observe the boli passing up and down the esophagus in this area.

Thyroid Gland (Figs. 2-11 & 2-12): *There is only one thyroid gland per animal; not right and left thyroids, as is frequently implied. In most mammals, the gland is divided into right and left lobes, connected ventrally by a variably developed isthmus. In the horse (Fig. 2-12), each lobe lies dorsolateral to the first few tracheal cartilages, is distinctly ovoid, resembling half a pecan or plum, and may be palpable in some horses.*

The bovine thyroid gland (Fig. 2-11) is much flatter than that of the horse and is not as firm. In the sheep and goat, the two lobes are elliptical and more closely resemble those of the horse. The thyroid gland of the pig differs considerably from the other species in that the two lobes are fused ventral to the trachea, and it is located nearer

the thoracic inlet. *All students should observe the porcine thyroid gland.*

Parathyroid Glands: There are typically two pairs of parathyroid glands, the external parathyroids (from pharyngeal pouch III) and the internal parathyroids (from pharyngeal pouch IV). These glands are variable in location among the various species and often cannot be located grossly. *Do not spend much time trying to identify them.* (As a matter of interest, internal parathyroids have yet to be located in the pig and are thought to atrophy embryologically.)

The visceral space of the neck, which contains the trachea, esophagus, and associated structures is bounded dorsally by the paired and segmented **longus colli muscles**; lateral to the longus colli muscle in the cranial part of the neck, is the **longus capitis muscle** (Fig. 2-4). The longus colli muscles terminate cranially on the ventral tubercle of the atlas (see skeleton); cranial to this point, the longus capitis muscles converge medially and continue to the base of the skull (to be seen later). In the ruminant particularly, the longus capitis muscle is partially covered laterally by a large component of the cervical **intertransversarii muscles**, which attaches cranially on the wing of the atlas.

Intertransversarii are a group of muscles (Fig. 2-4) that, as the name implies, attach sequential transverse processes of vertebrae. These muscles aid in the evenly distributed lateral “bending” of the vertebral column, and are best developed in those regions of the body with the highest degree of lateral mobility, namely the neck and tail.

Serratus Ventralis Muscle (Figs. 2-3, 2-4, 2-6): This important extrinsic muscle of the forelimb is very extensive in its vertebral attachment, and most students are surprised

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by how far cranially the cervical part extends. Not only does the muscle function more or less passively in "suspending" the trunk between the forelimbs, but it also plays an active role in the coordinated movement between the trunk and scapula during locomotion. This action is most evident in the galloping horse, where the lunging forward of the head and neck acts as a positive force in gaining greater extension and lengthening the stride.

The cranial border of the serratus ventralis cervicis can be defined by palpation in the live horse, where it can be traced to its junction with the rhomboideus muscle. Cut the attachments of the serratus ventralis cervicis to the transverse processes of the cervical vertebrae and reflect the muscle to the limb to expose the longissimus muscles of the neck.

Longissimus Muscles (Fig. 2-4, 2-8, 2-9): As you know, the segmented longissimus muscles constitute the longest muscle system in the body, extending from the ilium to the head. In the ungulates, the most cranial division is divided into two components, the **longissimus capitis**, which extends to the head, and the **longissimus atlantis**, which terminates on the wing of the atlas (Fig. 2-4). The **longissimus cervicis** attaches to the transverse processes of the other cervical vertebrae.

Subclavius Muscle: Although well developed in the horse, this muscle is vestigial in the ox and sheep, where it consists of a narrow band of muscle extending from the first costal cartilage to blend with the deep face of the brachiocephalicus muscle. The subclavius muscle is a little better developed in the goat. Like that of the horse, the muscle is well developed in the pig. Compare the

subclavius muscle in the various species. *The subclavius muscle of the horse can be easily palpated in the live animal.*

Transverse Sections of Neck: Refer to figure 2-13 as you review several transverse sections of the neck. Pay particular attention to the boundaries of the jugular groove, the relationship of the trachea, esophagus, and structures of the carotid sheath. Note also the skin thickness over the external jugular vein in the horse and ox and review the components of the nuchal ligament.

ATLANTO-OCCIPITAL REGION

Dissection of the poll should only be done in the horse. Transect the funiculus nuchae at about the level of C3 and reflect it toward the head with the caudal auricular muscles. Reflect also the splenius and semispinalis capitis muscles to expose the deeper muscles of the atlantoaxial and atlanto-occipital regions.

Nuchal Bursae: As you reflect the funiculus nuchae from the spinous process of the axis, you may (not likely) discover the **caudal nuchal bursa** (Fig. 2-7), which is sometimes present in the horse. More likely, you may identify the **cranial nuchal** (atlantal) **bursa** as the ligament is reflected from the dorsal arch of the atlas. The latter bursa is present in the horse (Fig. 2-7), but is often difficult to identify in a normal animal.

When the horse raises its head, and particularly when the atlanto-occipital joint is flexed in this position, the ligament is pulled tightly across the top of C1 and C2—thus, the need for lubrication, and the presence of these bursae. As mentioned with regard to the supraspinous bursa, these bursae are susceptible to infection.

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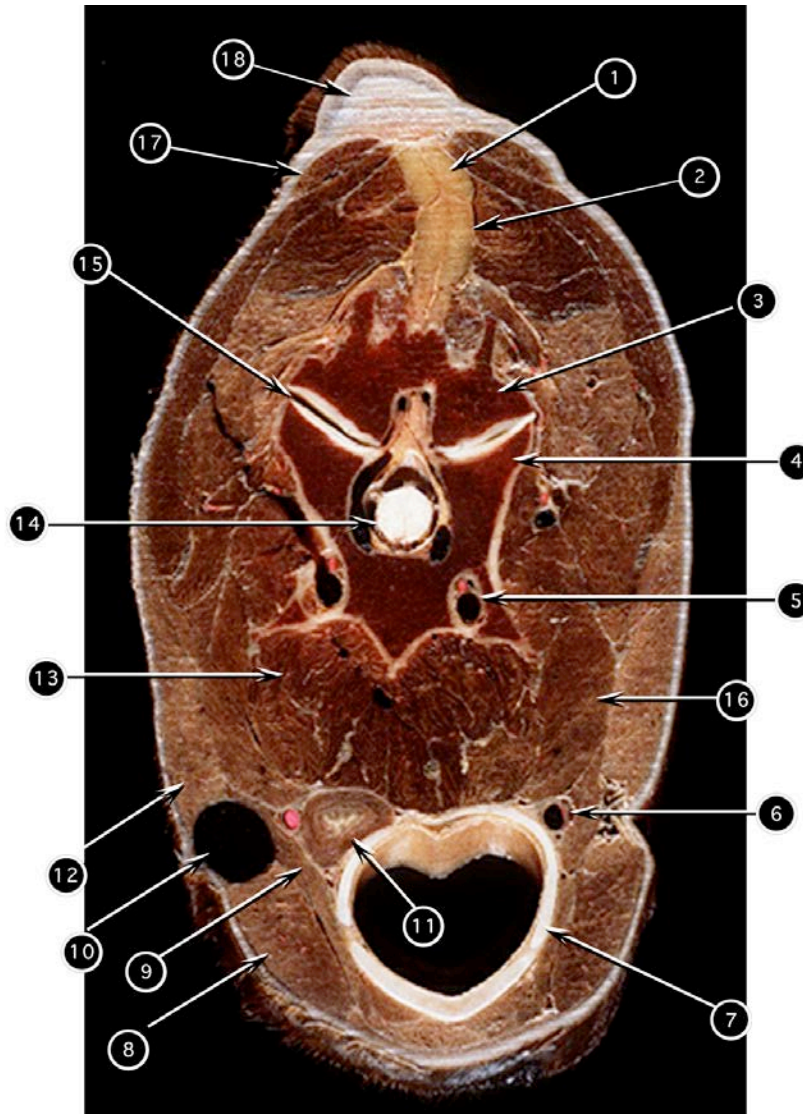


Figure 2-13. Caudal surface of transverse section of equine neck at level of C2-C3 articulation: (1) funiculus nuchae; (2) lamina nuchae; (3) caudal articular process of C2; (4) cranial articular process of C3; (5) vertebral vessels & nerve within transverse canal; (6) common carotid artery & vagosympathetic trunk; (7) tracheal cartilage; (8) sternomandibularis muscle forming ventral boundary of jugular groove; (9) omohyoideus muscle forming medial boundary of jugular groove; (10) external jugular vein; (11) esophagus; (12) cleidomastoideus forming dorsal boundary of jugular groove; (13) longus colli muscle; (14) spinal cord; (15) synovial joint between C2 & C3; (16) longus capitis muscle; (17) rhomboideus cervicis muscle; (18) nuchal crest.

When the cranial nuchal bursa becomes infected, the condition (cranial nuchal bursitis) is commonly referred to by the descriptive term, "poll evil." As was the case with "fistulous withers", the incidence of "poll evil" has been greatly reduced concurrently with the eradication of bovine brucellosis. Because there is no contact between the atlas or axis and the funiculus

nuchae of the ruminant, neither nuchal bursa is present.

Refer to the skeleton and review the atlantoaxial and atlanto-occipital joints. As is evident, these joints are specialized for two different types of movement. The **atlantoaxial joint** is a unique intervertebral joint that allows for rotation around the dens, the so-called "no joint." In contrast,

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the **atlanto-occipital joint** is designed to allow for extension/flexion of the skull on the atlas, the so-called "yes joint."

A number of muscles are specifically associated with rotation of the former and flexion/extension of the latter. The **obliquus capitis caudalis muscle** (Fig. 2-9) originates from the spinous process of the axis and attaches craniolaterally on the wings of the atlas. As is obvious from its orientation, this muscle, which is very well developed in the ox, functions in rotational movement of the atlas-skull unit on the dens of the axis. Although assisted by other muscles and the funiculus nuchae, extension of the atlanto-occipital joint is facilitated by the major and minor **rectus capitis dorsalis muscles**.

*In the horse only, cut the rectus capitis dorsalis major muscle near its origin and reflect it cranially to expose the rectus capitis dorsalis minor. The dorsal branch of nerve C1 and branches of the occipital vessels should be observed in this area. Continue to reflect (remove) the rectus capitis dorsalis muscle to expose the **dorsal atlanto-occipital membrane**, which extends from the occipital bone to the dorsal arch of the atlas and forms the dorsal boundary of the vertebral canal at this level. Carefully cut the membrane away from the atlas and reflect it cranially to expose the **dura mater**.*

Cerebrospinal fluid samples can be obtained by puncture of the atlanto-occipital

membrane, dura mater, and arachnoid to enter the subarachnoid space. The technique will be described in a later course, but this is an excellent time to observe the applied anatomy for the procedure. Cerebrospinal fluid taps are done as a diagnostic procedure. In addition, a radiopaque contrast medium can be injected into the **subarachnoid space** to produce a **myelogram** for diagnostic purposes.

Cervical Vertebrae: Take the time at this point to study the cervical vertebrae of the different species. Review the processes and foramina. Compare those of the horse with the bovine cervical vertebrae; note particularly the difference in length of the vertebral bodies and the shape of C2. The atlas of the ox does not have a transverse foramen (Fig. 2-14). Note the marked difference in the length of the spinous processes of C7 and T1 in the horse and ox. Note the short, compact cervical vertebrae of the pig and the thin spinous process of C2.

Radiographic Anatomy: Review the normal radiographic anatomy of this area (Figs. 2-15 & 2-17). Numerous spinal cord diseases can produce clinical signs of paresis and ataxia in the thoracic and especially in the pelvic limbs of horses. This syndrome has been frequently described by the nonspecific term, "wobbler." One of the causes of these signs is **cervical vertebral stenotic myelopathy**, which produces a focal compressive lesion of the cervical spinal cord.

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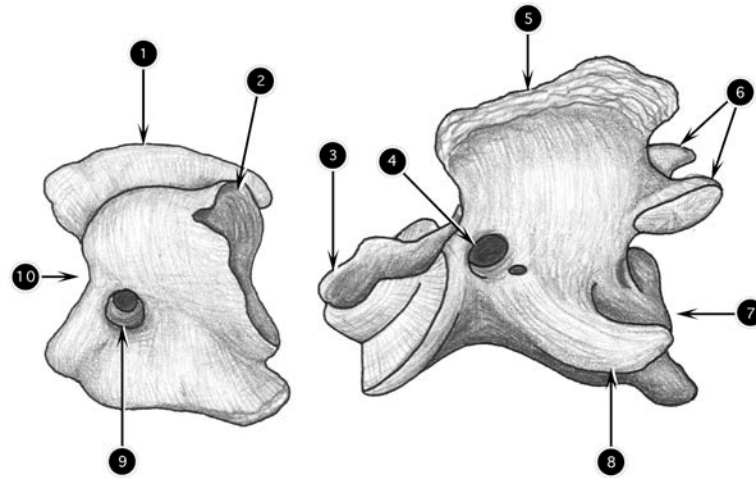


Figure 2-14. Bovine atlas & axis: (1) wing of atlas; (2) caudal articular fovea of atlas; (3) dens of axis; (4) lateral vertebral foramen of axis for passage of cervical spinal nerve 2; (5) spinous process of axis; (6) caudal articular processes of axis; (7) caudal extremity (fossa) of axis; (8) transverse process of axis; (9) lateral vertebral foramen of atlas for passage of cervical spinal nerve 1; (10) cranial articular fovea of atlas.

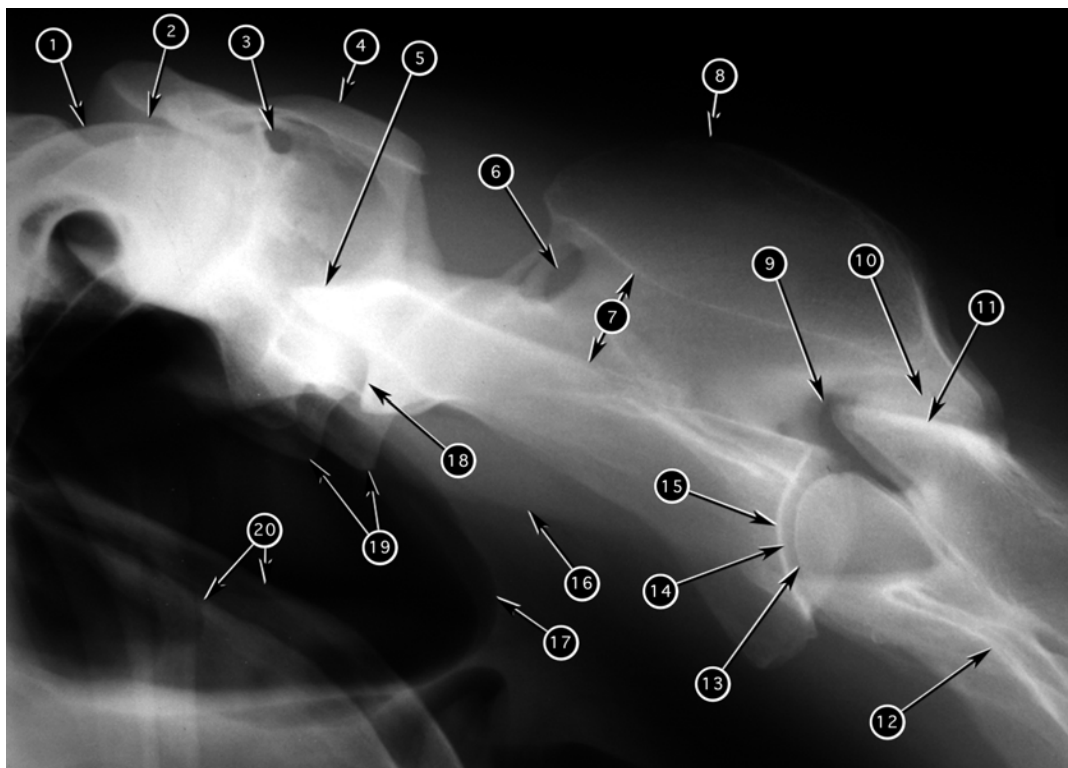


Figure 2-15. Left-Right Lateral radiograph of equine atlas & axis: (1) occipital condyles; (2) cranial articular fovea of atlas; (3) lateral vertebral foramen of atlas for passage of cervical spinal nerve 1; (4) dorsal arch of atlas; (5) dens of axis; (6) lateral vertebral foramina of axis for passage of cervical spinal nerve 2; (7) vertebral canal of axis; (8) spinous process of axis; (9) intervertebral foramina between C2 & C3; (10) caudal articular processes of axis; (11) cranial articular processes of C3; (12) transverse processes of C3; (13) cranial extremity (head) of C3; (14) intervertebral space (disk) between C2 & C3; (15) caudal extremity (fossa) of axis; (16) longus capitis muscles; (17) medial compartments of guttural pouches; (18) cranial articular surfaces of axis; (19) wings of atlas; (20) caudal borders of mandibles.

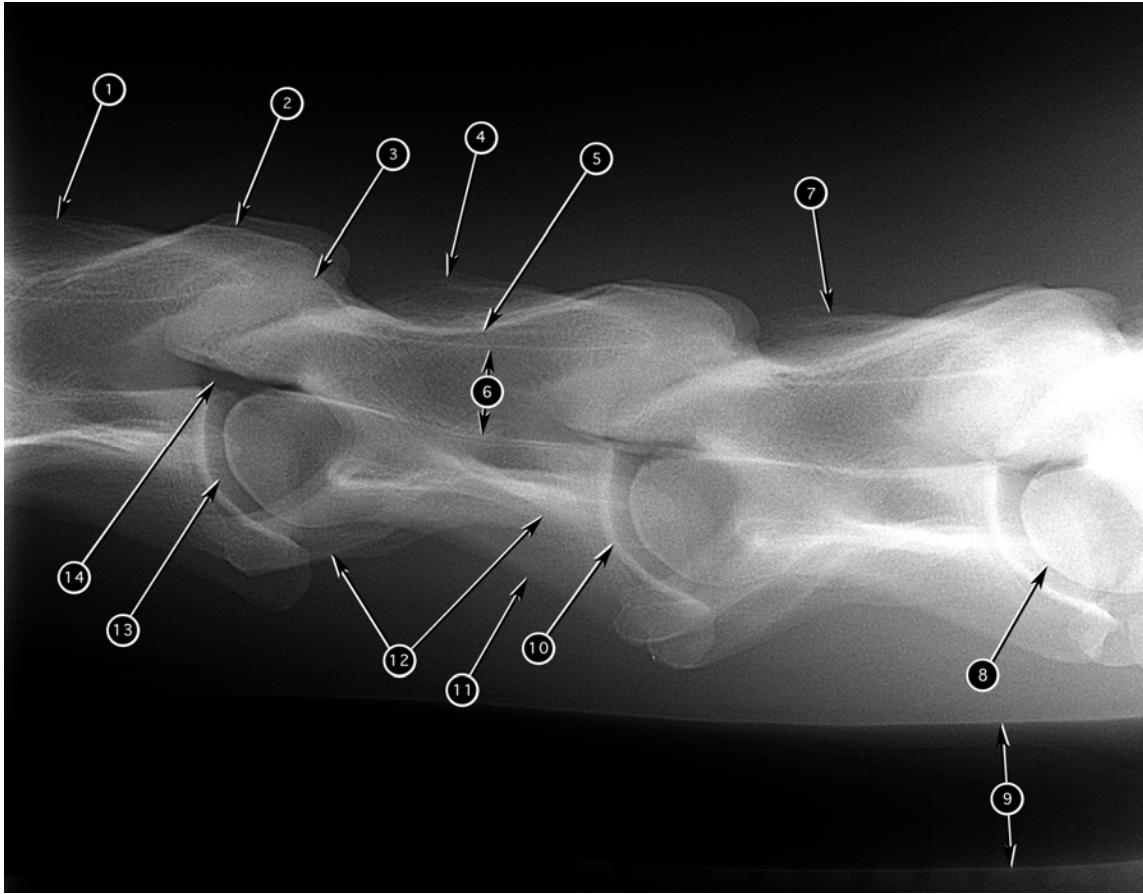


Figure 2-16. Left-Right Lateral radiograph of equine middle cervical vertebrae: (1) spinous process of C3; (2) caudal articular processes of C3; (3) cranial articular processes of C4; (4) spinous process of C4; (5) vertebral arch laminae of C4; (6) vertebral foramen of C4; (7) spinous process of C5; (8) cranial extremity (head) of C6; (9) trachea; (10) caudal extremity (fossa) of C4; (11) body of C4; (12) transverse processes of C4; (13) intervertebral space (disk) between C3 & C4; (14) intervertebral foramina between C3 & C4.

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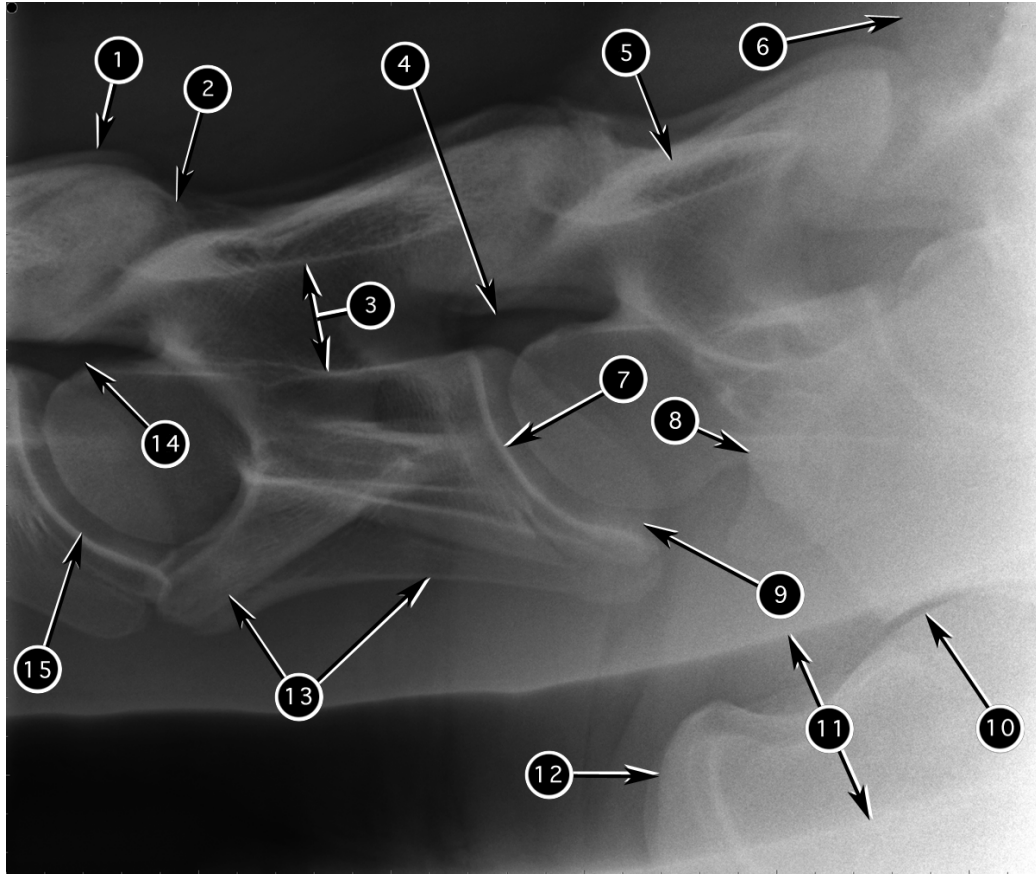


Figure 2-17. Left-Right Lateral radiograph of equine middle cervical vertebrae: (1) caudal articular processes of C5; (2) cranial articular processes of C6; (3) vertebral foramen of C6; (4) intervertebral foramina between C6 & C7; (5) vertebral arch laminae of C7; (6) spinous process of T1; (7) caudal extremity (fossa) of C6; (8) supraglenoid tubercle of scapula; (9) intervertebral space (disk) between C6 & C7; (10) shoulder joint; (11) trachea; (12) intermediate tubercle of humerus; (13) transverse processes of C6; (14) intervertebral foramina between C5 & C6; (15) intervertebral space (disk) between C5 & C6.

Refer to figure 2-18, and note that the caudal part of the cervical vertebral column lies much further ventrally in the neck than one might suspect. This is clinically important because the large caudodorsal muscles of the neck are used as a site for intramuscular injections, particularly in the horse.

Confirm the location of the cervical vertebrae by palpating the transverse processes in the live horse and ox. The palpable wing of the atlas is an important bony landmark that is used as a reference point for several clinical procedures. Determine the proper site for intramuscular injections in the caudodorsal part of the neck in order to avoid the cervical vertebrae and accessory nerve (Fig. 2-18).

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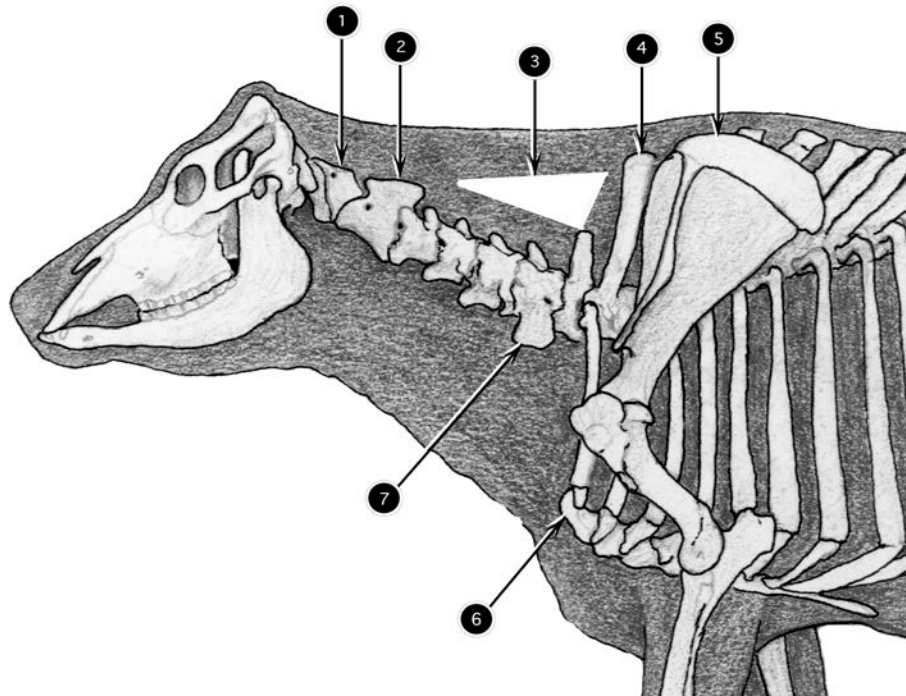


Figure 2-18. Neck and shoulder region of ox: (1) atlas; (2) axis; (3) preferred area in caudodorsal part of neck for intramuscular injections; (4) spinous process of thoracic vertebra 1; (5) scapular cartilage; (6) manubrium of sternum; (7) expanded ventral tubercle of transverse process of cervical vertebra 6.

Palpation Checklist for Neck & Shoulder Region

Horse

1. Boundaries of Viborg's triangle: mandible, linguofacial vein, sternocephalicus tendon
2. Define proper site for intramuscular injections in caudodorsal neck muscles
3. Subclavius muscle: can be moved laterally over supraspinatus muscle
4. Ventral edge of rhomboideus cervicis muscle: define with finger tips
5. Cranial border of the serratus ventralis muscle: rounded border
6. Transverse processes of cervical vertebrae
7. Wing of atlas: important anatomic landmark
8. Tracheal cartilages: ventral, cranial to divergence of R & L sternocephalicus muscles
9. Boundaries of jugular groove; demonstrate external jugular vein by digital occlusion

Ox

1. Superficial cervical lymph node: best about 5-10 cm above point of shoulder
2. Ventral edge of rhomboideus cervicis muscle
3. Transverse processes of cervical vertebrae
4. Wing of atlas: important landmark
5. Tracheal cartilages: ventral, cranial to divergence of R & L sternocephalicus muscles
6. Boundaries of jugular groove: demonstrate external jugular vein by digital occlusion
7. Define proper site for intramuscular injections in caudodorsal neck muscles.
8. Funiculus nuchae- along dorsal midline in cranial fourth of neck

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EXTERNAL FEATURES

Note that much of the lateral wall of the thorax is covered by the forelimb, especially the large triceps brachii muscle. In the squarely standing ox or horse, the **olecranon** is at about the level of the fifth costochondral junction (Figs. 3-1 & 3-2). This can be a useful **clinical landmark**.

Clinical examination of the heart by auscultation requires that the stethoscope head be positioned as much as possible between the limb and trunk. Moving the forelimb as far cranially as possible facilitates this examination. Similarly, the amount of lung accessible for percussion in the ox is surprisingly small (Fig. 3-2). Compare the size of the lung area available for auscultation or percussion in the horse and the ox.

Line of Pleural Reflection: The line of pleural reflection is clinically important because punctures made craniodorsal to this line enter the thoracic cavity, whereas those made caudoventral to the line enter the abdominal cavity. Thus, a veterinarian should be able to approximate the location of this line on the body surface of the live animal.

Note that the line of pleural reflection shown for the horse (Fig. 3-1) is markedly different from that of the ox (Fig. 3-2). Being a natural athlete, the horse has a much larger thoracic cavity than the ox. For one thing, the horse has more ribs (18) than does

the ox (13), and, consequently, the diaphragm is sloped more caudally. Also, the line of pleural reflection in the horse more closely parallels the costal arch, thus following a long, sweeping curve from the eighth costochondral junction to about the middle of the last rib.

Compared with the horse, the ox has a "dumpy" little thorax. In contrast with the long sweeping curve of the horse, the line of pleural reflection in the ox ascends rather abruptly from the eighth costochondral junction, in a slight curve, to the dorsal aspect of the last rib. The line of pleural reflection in the sheep is more caudoventral than that of the ox.

The line of pleural reflection in the pig begins at about the seventh costochondral junction and follows a gentle curve to about the middle of the last rib. Although most pigs have 14 or 15 pairs of ribs, there is considerable variation, ranging from 13 to 17 pairs.

REFLECTION OF SKIN

Continue the dorsal midline skin incision from the level of the previous skin reflection, extending caudally to the level of the tuber coxae. Now make transverse incisions to each side, beginning at the caudal end of the previous incision and extending over the tuber coxae and cranial border of the thigh muscles to the fold of the flank (see Fig. 2-8). Carefully reflect the skin from the entire lateral surface of the thorax and abdomen.

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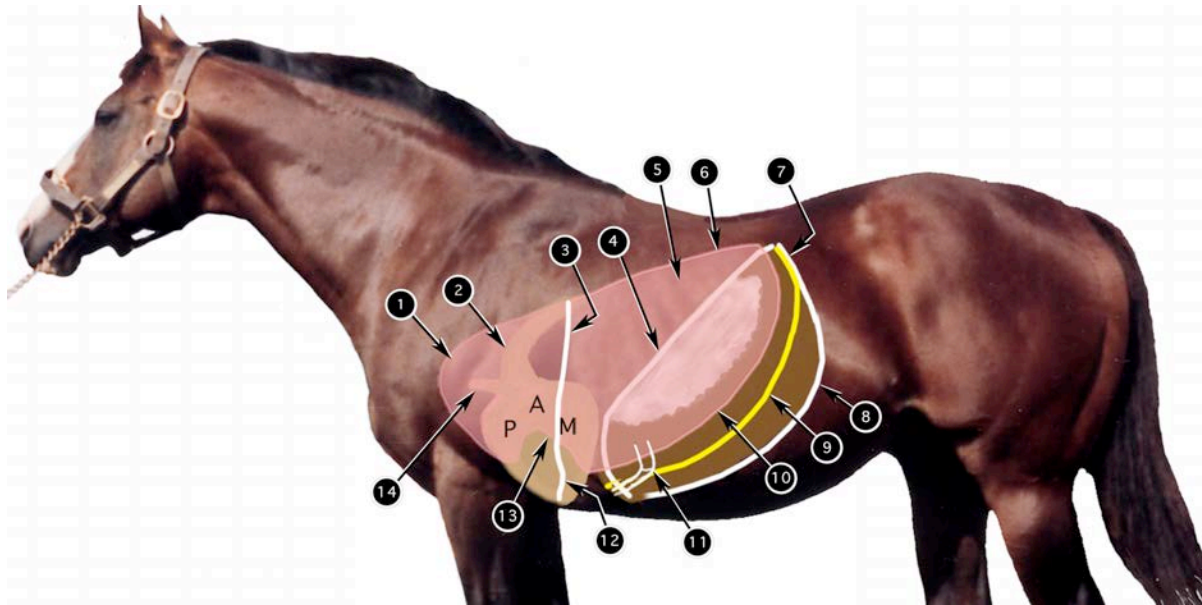


Figure 3-1. Projections of selected thoracic viscera onto body surface of horse: (1) cranial lobe of left lung; (2) aortic arch; (3) caudal border of triceps brachii muscle; (4) cranial surface of diaphragm at midline; (5) caudal lobe of left lung; (6) dorsal border of left lung; (7) rib 18; (8) costal arch; (9) line of pleural reflection; (10) basal border of left lung; (11) eighth costochondral junction; (12) tuber olecranii located at about fifth costochondral junction in squarely standing animal; (13) cardiac notch of lung; (14) brachiocephalic trunk; (P) punctum maxima for pulmonary valve; (A) punctum maxima for aortic valve; (M) punctum maxima for mitral valve.

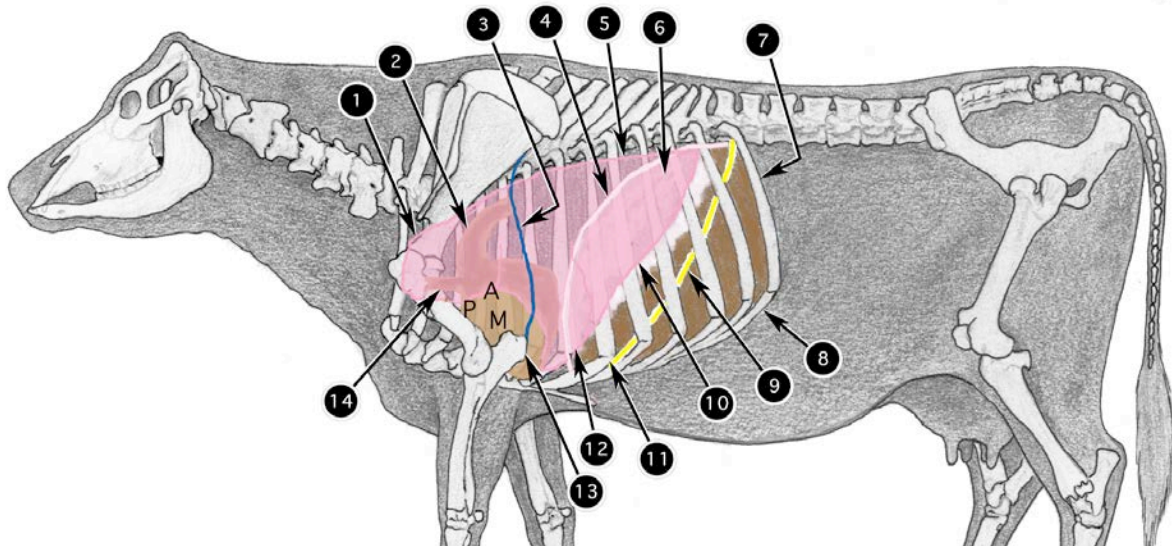


Figure 3-2. Projections of selected thoracic viscera onto body surface of ox: (1) cranial lobe of left lung, cranial part; (2) aortic arch; (3) caudal border of triceps brachii muscle; (4) cranial surface of diaphragm at midline; (5) dorsal border of left lung; (6) caudal lobe of left lung; (7) rib 13; (8) costal arch; (9) line of pleural reflection; (10) basal border of left lung; (11) eighth costochondral junction; (12) cranial lobe of left lung, caudal part; (13) tuber olecranii located at about fifth costochondral junction in squarely standing animal; (14) brachiocephalic trunk; (P) punctum maxima for pulmonary valve; (A) punctum maxima for aortic valve; (M) punctum maxima for mitral valve.

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SUPERFICIAL STRUCTURES

Cutaneus Trunci Muscle: Note that almost the entire lateral surface of the trunk is covered by this extensive muscle (Fig. 3-3), which is intimately associated with the skin and may have been partially reflected with it. The fibers converge cranially, to blend with both the medial and the lateral fascia of the shoulder and arm; caudally, the fibers converge to the **fold of the flank**, which passes to the medial side of the thigh near the stifle. The ventral part of the muscle is thick in both the horse and the ox, which accounts not only for most of the substance

of the flank fold, but also for the ability of these animals to shake or quiver this area vigorously when stimulated.

In a well-muscled, fit horse, an irregular line is produced along the caudodorsal border of the cutaneus trunci muscle that can be observed and palpated in the live animal. Another irregular line may be noted along the dorsal border of the **cutaneus omobrachialis muscle** (Fig. 3-3). Cranioventrally, the cutaneus trunci overlaps and obscures the dorsal border of the ascending pectoral muscle.

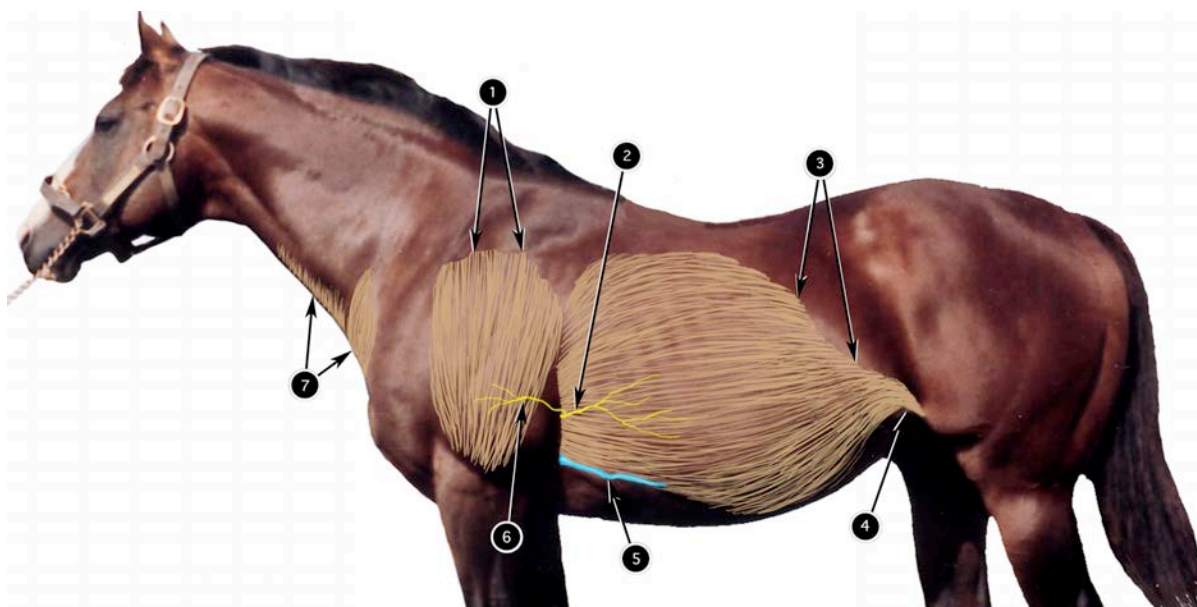


Figure 3-3. Cutaneous muscles of the neck, shoulder and trunk of horse: (1) irregular dorsal border of cutaneus omobrachialis muscle; (2) lateral thoracic nerve to cutaneus trunci muscle; (3) irregular caudodorsal border of cutaneus trunci muscle; (4) convergence of cutaneus trunci fibers within fold of flank; (5) superficial thoracic vein coursing along lateral border of ascending pectoral muscle; (6) intercostobrachial nerve to cutaneus omobrachialis muscle; (7) cutaneus colli muscle.

*Carefully incise the cutaneus trunci, beginning dorsally about 2 cm caudal to the triceps brachii, and reflect it ventrally as you go to expose the latissimus dorsi. As you approach the ascending pectoral muscle in the horse, you should observe a rather large vein that follows the dorsal border of that muscle. This is the **superficial thoracic***

vein (Fig. 3-3), which because of its position is sometimes called the “spur vein.”

This vein can be used as a landmark for separating the cutaneus trunci from the ascending pectoral muscle in the horse as the former is reflected. The ox also has this vein, but it does not course along the dorsal border

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of the ascending pectoral muscle as it does in the horse. Once the cutaneus trunci muscle has been reflected, note that most of the lateral thoracic wall is still covered by the

latissimus dorsi, serratus ventralis, ascending pectoral, and external abdominal oblique muscles (Fig. 3-4).

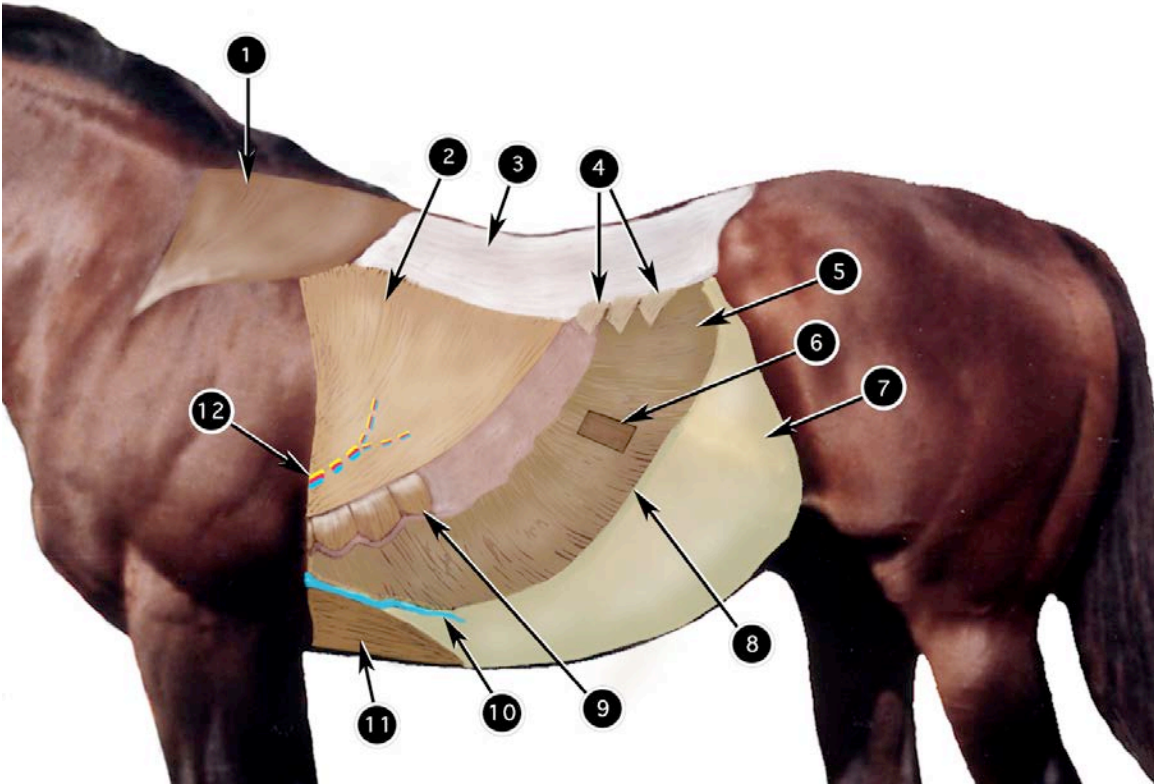


Figure 3-4. Selected muscles and associated structures in horse: (1) trapezius thoracis muscle; (2) latissimus dorsi muscle; (3) thoracolumbar fascia; (4) serratus dorsalis caudalis muscle; (5) external abdominal oblique muscle invested by elastic abdominal tunic; (6) section of elastic abdominal tunic removed to expose fibers of external abdominal oblique muscle; (7) aponeurosis of external abdominal oblique invested by elastic abdominal tunic; (8) musculotendinous line between external abdominal oblique and its aponeurosis; (9) serratus ventralis thoracis; (10) superficial thoracic vein; (11) ascending (deep) pectoral muscle; (12) thoracodorsal nerve & vessels on deep surface of 2.

REMOVAL OF FORELIMB

1. *Transect the latissimus dorsi muscle about 5 cm caudal to the triceps brachii.*

2. *Detach the thoracic part of the trapezius from the trunk.*

3. *While applying steady abduction to the limb, and beginning ventrally, use a large knife to cut through the pectoral muscles,*

axillary vessels, and brachial plexus nerves about midway between the trunk and limb.

4. *Continue abducting the limb and cut the serratus ventralis from its scapular attachment.*

5. *Cut the attachment of the rhomboideus muscle about midway between the trunk and limb.*

6. *Sever any remaining attachments and remove the limb.*

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After removal of the limb, the extensive attachment of the **serratus ventralis muscle** to the trunk can be better appreciated. In the horse and the ruminant, note that the thoracic part of this muscle is invested by a large amount of fibrous connective tissue, which provides for a somewhat passive (effortless) transfer of the body's weight to the limb. Examine the deep surface of the serratus ventralis for branches of the **dorsal scapular artery** (Figs. 2-9 & 3-5).

In the horse only, *carefully scrape the stump of the rhomboideus thoracis muscle off the underlying plate of thoracolumbar fascia from which it originates*. Equidae are unique among our domestic mammals in that the thoracolumbar fascia in the area of the withers (T2-T5) is thickened and gives rise to several laminae that constitute what is termed the **dorsoscapular ligament** (Fig. 3-5).

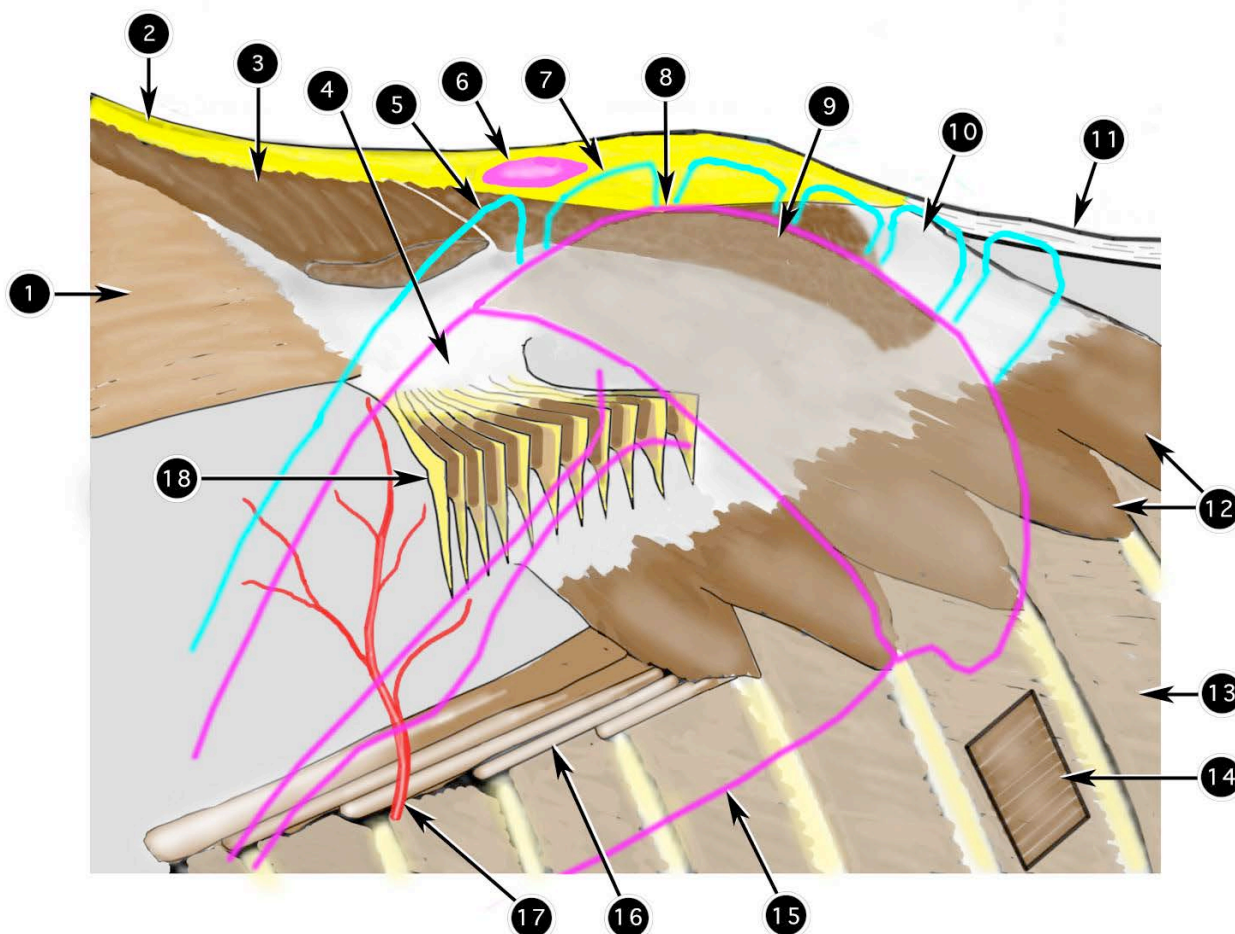


Figure 3-5. Equine dorsoscapular ligament and associated structures: (1) origin of splenius muscle; (2) funiculus nuchae; (3) rhomboideus cervicis muscle; (4) superficial lamina of dorsoscapular ligament giving rise to elastic lamellae; (5) superimposed spinous process of T2; (6) location of supraspinous bursa between funiculus nuchae & spinous processes of T2 & T3; (7) superimposed spinous process of T3; (8) superimposed scapular cartilage; (9) rhomboideus thoracis muscle; (10) dorsoscapular ligament giving rise to serratus dorsalis cranialis muscle; (11) supraspinous ligament; (12) serratus dorsalis cranialis muscle; (13) external intercostals muscle; (14) section of 13 removed to expose fibers of internal intercostal muscle; (15) superimposed outline of scapula; (16) iliocostalis thoracis muscle; (17) dorsal scapular artery emerging from 2nd intercostal space; (18) elastic lamellae of dorsoscapular ligament passing through termination of serratus ventralis muscle to reach medial surface of scapula.

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Various laminae of this ligament provide origin for the rhomboideus thoracis, serratus dorsalis cranialis, splenius, and semispinalis capitis muscles. In addition, the dorsoscapular ligament sends numerous, transversely-oriented, **elastic lamellae** through the termination of the serratus ventralis to the medial surface of the scapula (Fig. 3-5). These lamellae provide an additional elastic attachment of the scapula to the trunk, which may account in part for the smooth blending of the scapula and withers in the horse.¹ Before the forelimb is stored, examine the stump of the serratus ventralis on the scapula for these elastic lamellae. *The limb should be tagged and stored for dissection later.*

Identify the **long thoracic nerve** (Fig. 2-4), which courses caudally across the ventral part of the serratus ventralis thoracis from the brachial plexus and provides motor innervation to this muscle. Note that the **lateral thoracic nerve** (Fig. 3-3), which is derived from spinal cord segments C8 & T1, courses caudally near the dorsal border of the ascending pectoral muscle and innervates the **cutaneus trunci muscle**. This nerve is clinically important because it is the efferent limb of the panniculus, or **cutaneus trunci reflex**, which can be used to localize spinal lesions. *You can best demonstrate this reflex in the large animals by touching the hair along the costal arch.* Unlike the situation in the dog, in which the reflex is variable, the reflex is constant in the normal horse.²

¹ When I was a first-year veterinary student, my anatomy professor made a really big deal out of the equine dorsoscapular ligament; for the past 43 years I have been trying to figure out why. If any of you find out, would you please let me know?

² de Lahunta, A., and Habel, R.E.: Applied Veterinary Anatomy. W.B. Saunders, Philadelphia, 1986.

You may also note several **caudal pectoral nerves** leaving the brachial plexus and entering the **ascending pectoral muscle**, and one or more **cranial pectoral nerves** being distributed to the **superficial pectoral muscles**. You can usually review the pectoral muscles of the ox, particularly the ascending (deep) pectoral in the meat case at your local grocery. It is probably labeled “brisket” or corned beef brisket. The large fascicles, with prominent interfascicular connective tissue (perimysium), make this cut of meat particularly well suited for slow, low-heat cooking.³

*Reflect the latissimus dorsi muscle to its origin from the thoracolumbar fascia. Examine its deep surface for branches of the **thoracodorsal nerve** and **vessels** (Fig. 3-4) You may now remove this muscle and dispose of it.*

In the ox, goat, and pig also identify the **dorsal scalenus muscle** (Fig. 2-11), which sweeps caudally from the more caudal cervical vertebrae over the ventral part of the serratus ventralis muscle. Although this long part of the dorsal scalenus muscle is absent in the sheep and horse, all the domestic ungulates possess the **ventral scalenus muscle** (Figs. 2-4 & 2-11), which extends from the more caudal cervical vertebrae to the ventral part of the first rib.⁴ The brachial plexus passes between the dorsal and ventral (middle in horse) scalenus muscles (Figs. 2-4 & 2-11). Identify the stumps of the brachial plexus nerves that were severed when the limb was removed.

³ Beef brisket cooked slowly over mesquite wood is real Texas Bar-B-Q.

⁴ The scalenus muscles are sort of in the “inter-transversarii family” except that the scalenus muscles have their caudal attachment on a rib(s), rather than on another vertebra.

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Roots of Phrenic Nerve: Identify one or more of these roots as they cross the ventral scalenus muscle to join and pass into the thorax (Figs. 2-4 & 2-11). Phrenic nerve roots typically arise from **spinal nerves C5 to C7** (important), but their relative size and exact course vary. In the horse, the roots from C6 and C7 can usually be identified as they cross the ventral scalenus muscle (Fig. 2-4).

In the ox, the contribution of C6 and C7 usually lies on the surface of the muscle (Fig. 2-11), whereas that from C5 passes through the muscle. In the sheep and goat, the contribution from C7 is small or absent. In the pig, those from C5 and C7 are usually small. These variations are listed here only to help you find them, and to know what you found; *i.e.*, they should not take up limited memory space on your cerebral disk.

Cut the attachments of the serratus ventralis near the ribs; remove the muscle and dispose of it. Reflect the serratus dorsalis cranialis and caudalis muscles, and clean the fascia away from the epaxial muscles of the thoracolumbar region. Discard the serratus dorsalis cranialis. Define the divisions among the transversospinalis, longissimus, and iliocostalis muscle systems (Figs. 2-8 & 2-9).

In the ox, the thoracic parts of these muscles form the ribeye- that is, rib steaks, standing rib roasts, and, at the level of the thirteenth (last) rib, the club steak. The entire **longissimus muscle system**, from ilium to head, can now be examined.

Note that the fiber direction of the **external intercostal muscles** is caudoventral (Fig. 3-5). *Remove a section of one of these muscles*, and note that the **internal intercostal muscles** are oriented in

a cranioventral direction. The external muscles extend ventrally only to about the level of the costochondral junction, whereas the internal muscles fill the spaces between the costal cartilages.

The intercostal muscles of the ox and the pig, along with other adjacent muscles including the diaphragm, are found on such cuts of meat as spare ribs and short ribs. Another muscle that should be identified at this time is the **rectus thoracis muscle**, which is obliquely oriented in a caudoventral direction across the ventral ends of the first few ribs. In the horse, its aponeurosis can usually be traced caudally to the rectus abdominis muscle.

OPENING OF THORACIC CAVITY

Refer to figure 3-6 for the horse and figure 3-7 for the ruminants and the pig. It is important here that we open the **thorax only**, not both the thoracic and the abdominal cavities.

1. In order to gain better access to the dorsal part of the thoracic cavity, *transect the iliocostalis muscle at the level of the last rib, and, beginning caudally, remove the muscle from the ribs and dispose of it.*

2. Leave the first and last ribs intact. In the suspended animals, it is also best to leave the 7th or 8th rib (at least temporarily) for better stability and support of the thoracic viscera (Fig. 3-6). *Using bone cutters (pruning shears in the larger animals), cut the remaining ribs along the lateral edge of the longissimus muscle.*

3. Review the location of the **line of pleural reflection** (Fig. 3-6). We do not want to extend any intercostal incision too near this line so as not to enter the abdominal cavity.

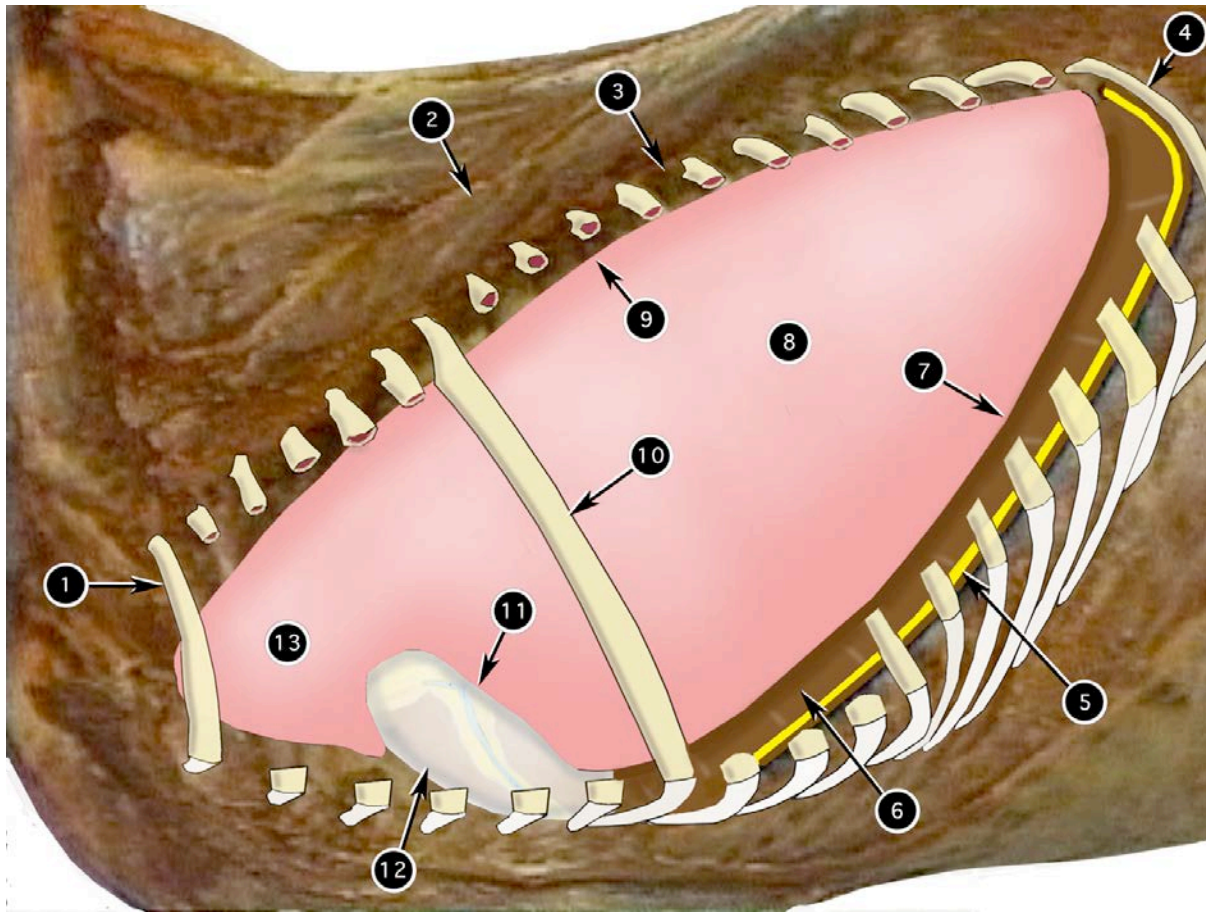


Figure 3-6. Equine thorax, opened from left side: (1) first rib; (2) longissimus thoracis muscle; (3) iliocostalis muscle has been removed; (4) last (18th) rib; (5) line of pleural reflection; (6) costal part of diaphragm; (7) basal border of lung; (8) caudal lobe of left lung; (9) dorsal border of left lung; (10) 7th rib left in place for stability; (11) cardiac notch of left lung; (12) mediastinal pleura covering pericardial sac; (13) cranial lobe of left lung.

4. Carefully incise the intercostal muscles on both ends of the most cranial set of cut ribs. Now, abduct the dorsal part of this isolated unit and simultaneously nick the costal cartilages from the outside until they break over. This allows you to fold down a flap consisting of ribs and intercostal muscles. It should now begin to look something like figure 3-7. Now comes the tricky part.

5. As you isolate the more caudal rib units, pay careful attention so that you do not cut too near the line of pleural reflection. The ventral parts of these ribs have to be cut

with the bone cutters at progressively higher levels to avoid entering the abdominal cavity. It is best to be conservative and cut the ribs well above the line; then, the more ventral part of the flap can be reflected or removed as separate pieces.

Once the thoracic wall flaps have been reflected, the thoracic viscera can be studied *in situ*. Before any further dissection is done, it is important that students move around the lab and examine both sides of several specimens of each species.

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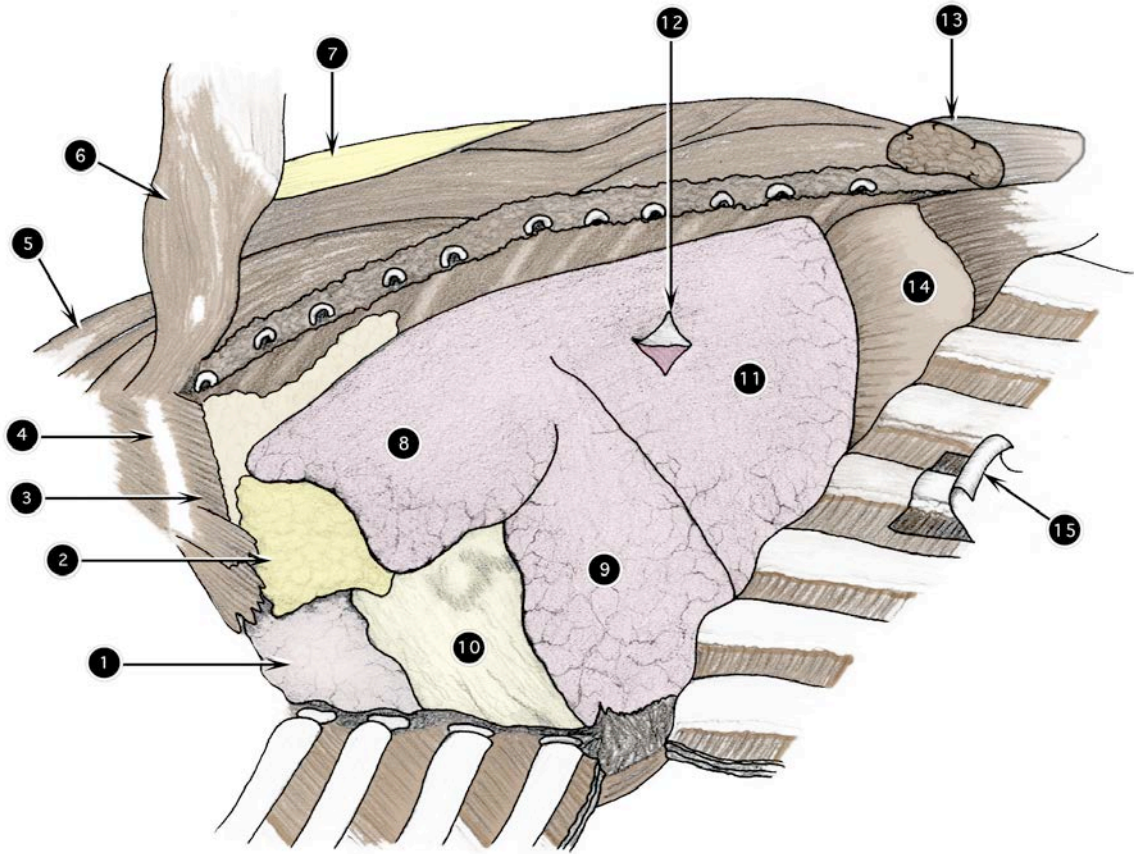


Figure 3-7. Thoracic viscera of calf, left lateral view: (1) cranial lobe of right lung viewed through cranial mediastinum; (2) thoracic part of thymus; (3) external intercostal muscle; (4) first rib; (5) longissimus cervicis muscle; (6) reflected cranial stump of longissimus thoracis et lumborum muscle; (7) funiculus nuchae; (8) cranial part of left cranial lung lobe; (9) caudal part of left cranial lung lobe; (10) mediastinal pleura covering pericardium; (11) left caudal lung lobe; (12) reflected tab of pulmonary (visceral) pleura; (13) caudal stump of longissimus thoracis et lumborum muscle; (14) parietal (diaphragmatic) pleura covering diaphragm; (15) reflected tab of parietal (costal) pleura.

Some anatomy books devote a good deal of attention to the location of the basal border of the lung in each species. However, as should be obvious even to the more casual observer, the **basal border of the lung** is not a fixed line in the living (breathing) animal. During inspiration it moves caudoventrally toward the line of pleural reflection as the lungs expand, and during expiration it moves craniodorsally as the lungs retreat from the **costo-diaphragmatic recess**.

I have never understood why it is important to spend much time trying to learn the location of something that moves with

each breath. Trying to remember too many things only creates confusion and makes it more difficult to remember the important ones. From a clinical standpoint, I think that it is more important for a veterinarian to have a good idea of the location of the **line of pleural reflection** and an appreciation for the normal field of lung auscultation and percussion.

In studying an embalmed cadaver, one must also appreciate the fact that during fixation, the lungs contracted and thus are typically smaller than in the live animal. Furthermore, the area of lung auscultation and percussion is somewhat smaller than the

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actual area occupied by the lungs. This is because a certain minimum thickness of lung tissue is necessary for auscultation and percussion. As one approaches the basal border, where the lung tissue is becoming progressively thinner, the area of lung auscultation and percussion is lost before the basal border is actually reached.

Why is there negative pressure in the pleural cavity? By this time, all good veterinary students should know that there is a negative pressure in the pleural cavity of a living mammal except, of course, in the elephant.⁵ But how many of you really know *why* there is a negative pressure here? I have observed that there is a general misconception among veterinary students, who usually think that the negative pressure is created by the expansion of the thoracic cavity. If that were true, it would be negative only during inspiration and would be positive during expiration.

The truth is that, with rare exception⁶ intrapleural pressures remain negative throughout both phases of respiration. Intrapleural pressure in the neutral resting position is about -5 cm H₂O. The degree of negativity in the pleural cavity varies with the phase of respiration, being most negative during inspiration. It is still negative, however, even during the expiratory phase, when the chest wall and diaphragm are moving toward the lungs.

The simple explanation is that negativity of intrapleural pressure is primarily a

function of the *elastic recoil of the lungs* - that is, the lungs are always trying to collapse, just as they have in your cadaver. Without this negative pressure, the lungs would never follow the expansion of the thorax during inspiration, and no new air would be drawn into the respiratory tree, without the assistance of positive-pressure ventilation (respirator).

The only thing that prevents a living lung from collapsing is the fact that there is nothing *normally* available to fill in the space that would be created between the collapsed lung and chest wall. Whenever air becomes available through an opening in the pleural cavity, whether from puncture of the chest wall, opening the abdomen with a tear in the diaphragm, or the rupture of a bronchus or bronchiole, the lung promptly does what it has been trying to do since day 1- *collapse*.

That is why you hear that little “*p-s-s-s*” sound when you puncture the parietal pleura at surgery. Air is pulled in because the lung collapses; the air doesn’t rush in and collapse the lung, but rather it is drawn in by the collapsing lung.

Free access to air into both pleural cavities is not compatible with life (for very long). Animals can survive, however, with relatively small amounts of air in both pleural cavities (bilateral pneumothorax) as long as the amount of air stabilizes short of being fatal and no new air is allowed to enter. Lungs also collapse or shrink when excess fluid from an effusive process or a tear in, for example, the thoracic duct becomes available to occupy the normally potential space of the pleural cavity.

⁵ After embryologic development, the pleural cavities of the elephant degenerate so that the visceral and parietal pleura form a fibrous adhesion to one another. In essence, this converts the elephant to one large eye-dropper.

⁶ The only exception I know of is a brief period near the end of expiration in the *horse*, when intrapleural pressure becomes slightly positive.

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REVIEW OF PLEURA

The pleura is the serous membrane that lines the walls of the thoracic cavity, envelops the lungs, and forms two closed sacs, the **pleural cavities** (Fig. 3-8). These “potential spaces” typically contain only a small amount of serous fluid-- just enough to lubricate movement of the lungs. Anatomists have decided that we need to classify pleura into categories or regions for descriptive purposes, and I like to classify (outline) pleura as follows:

Visceral (pulmonary) pleura- closely invests the surface of the lungs

Parietal⁷ pleura- lines the walls of the thoracic cavity; divided into three regions:

Costal pleura- lines the inside of the lateral thoracic walls (*e.g.*, ribs)

Diaphragmatic pleura- covers the thoracic surface of the diaphragm

Mediastinal pleura- consists of the medial walls of the right and left pleural sacs; covers those structures of the mediastinum located between the two sacs

Connecting⁸ pleura- double folds of pleura that connect things (*e.g.*, *pulmonary ligaments*, *plica venae cavae*)

Before you have an opportunity to do any more damage to the mediastinal pleura, check it for holes, natural ones, not those

produced by dissectors. In the horse, tiny openings develop postnatally between the two pleural sacs, and the adult horse is considered to have a *fenestrated mediastinum*. Actually, perforations of the mediastinal pleura have been reported to occur in the adult horse, dog, cat, and the occasional old sheep. To me, whether you can demonstrate any tiny holes is academic.

What is more important is the strength of the mediastinal partition and its ability to withstand substantial differences in pressure between the two pleural cavities. Even in the absence of fenestrations, you should note that the mediastinum of the horse is much thinner and more delicate than that of the ox, the goat, and the pig. Thus, the likelihood of air or inflammatory fluid breaking through from one pleural cavity to the other is much greater in the horse- that is, a unilateral *pneumothorax* could become bilateral and possibly fatal.

In clinical experiences, however, dogs and horses have been observed in which inflammatory fluid or air did not spread to the other side. One explanation could be that the tiny openings were closed by the inflammation. Another possibility is that the collapsed lung in unilateral pneumothorax acted as a protective covering over the mediastinum. The fragility of the mediastinum (with or without natural perforations) should be respected as a potentially dangerous predisposition for unilateral pneumothorax to become bilateral and fatal in the dog, the cat, the sheep, and especially the horse.

Carefully pull the left cranial lung lobe laterally. Note that it is being held in place solely by the structures that enter the lung at the hilus. *Carefully try this with either caudal lung lobe.* If you weren't too vigorous, you should have observed that

⁷ parietal- of or pertaining to the wall

⁸ Although connecting pleura is not generally recognized as a separate division, I am not sure why. In my view, these double folds of serous membrane have just as much right to their own classification, as double folds of connecting peritoneum. Sometimes it gets lonely out here on the “leading edge” of anatomic nomenclature.

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something prevented it from moving laterally very far. *Now, place your fingers over the top of the caudal lobe and pull it laterally.* By looking in dorsally, you should note that what is holding the caudal lobe is a pleural attachment that extends

caudally from the hilus. When this attachment is drawn out, by pulling the lung laterally, it has the form of a triangle and is called the **pulmonary ligament** (Fig. 3-8).

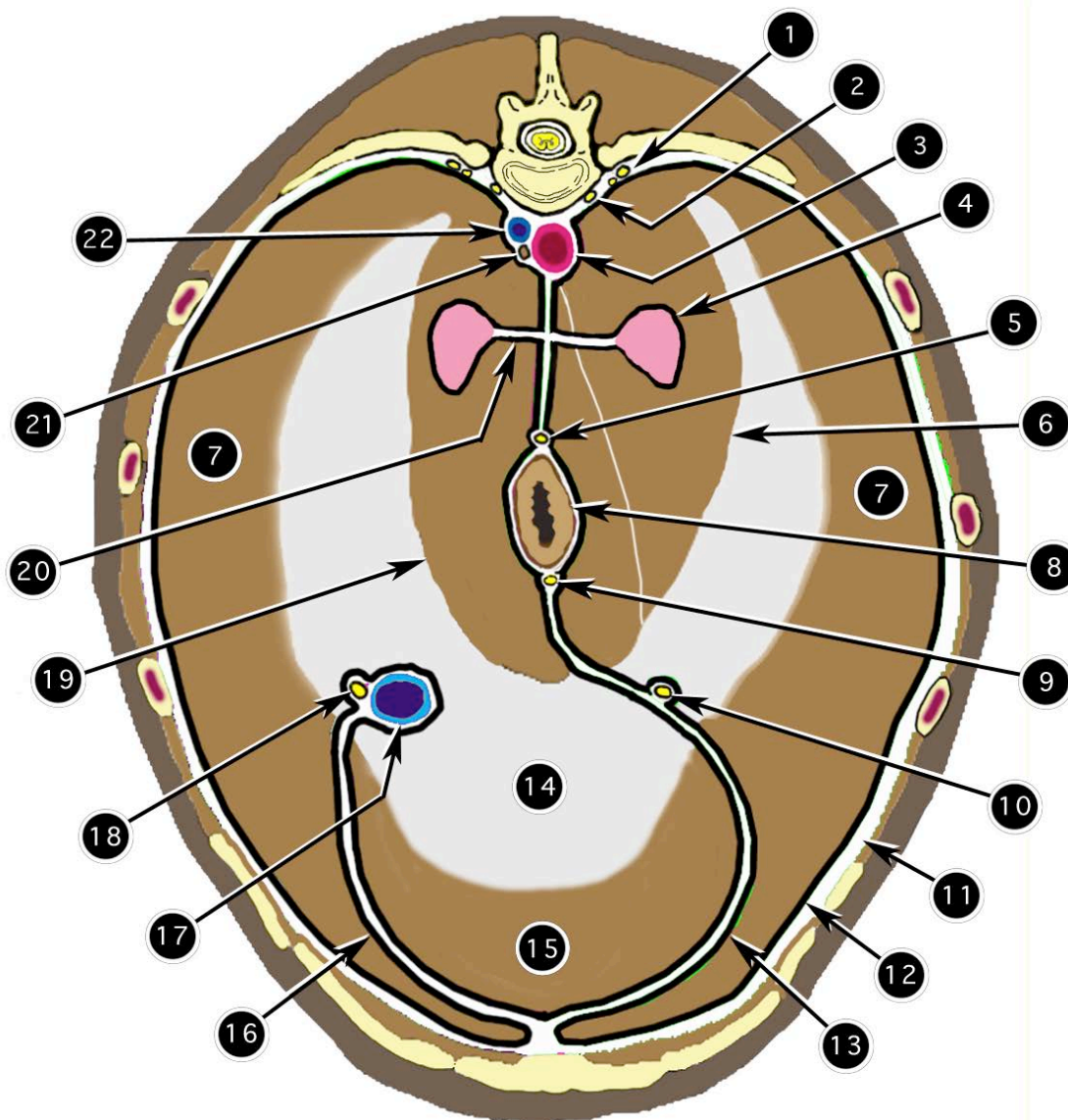


Figure 3-8. Thoracic surface of diaphragm showing pleural relationships: (1) left greater & lesser splanchnic nerves passing over lumbocostal arch of diaphragm; (2) left sympathetic trunk; (3) aorta passing through aortic hiatus between crura of diaphragm; (4) visceral (pulmonary) pleura covering left lung; (5) dorsal vagal trunk; (6) left crus of diaphragm; (7) costal part of diaphragm; (8) esophagus passing through esophageal hiatus penetrating right crus of diaphragm; (9) ventral vagal trunk; (10) left phrenic nerve; (11) endotheracic fascia; (12) costal pleura; (13) caudal mediastinal pleura; (14) central tendon of diaphragm; (15) sternal part of diaphragm; (16) plica venae cavae; (17) caudal vena cava passing through caval foramen penetrating central tendon of diaphragm; (18) right phrenic nerve; (19) right crus of diaphragm; (20) right pulmonary ligament; (21) thoracic duct passing through aortic hiatus; (22) right azygos vein passing through aortic hiatus.

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Lift the right caudal lung lobe and note the **caudal vena cava**. The right phrenic nerve accompanies the vena cava in a special pleural fold. This fold, which extends ventrally from the vein, is another pleural connection, the **plica venae cavae** (Fig. 3-8). Although the fold is sometimes considered as part of the mediastinal pleura, it is separated from the mediastinal pleura by the accessory lobe of the right lung. The caudoventral part of the mediastinal pleura can be seen by raising the caudal lobe of the left lung.

Now try to withdraw the right cranial lung lobe in the ruminant and the pig. Again, you should find that something interferes with its withdrawal. In this case, however, it is an extra bronchus, which leaves the right side of the trachea several centimeters cranial to the main hilus, and supplies this lobe. Oddly enough, it is called the **tracheal bronchus**, and it is present in our domestic artiodactyls.⁹

With the cranial lung lobes withdrawn, take a moment to note that the most cranial extension of the pleural cavity, the **cupula pleurae**, may extend several centimeters cranial to the first rib, especially on the right side. Keep this fact in mind when doing surgery in the caudal part of the neck. As you can see, it is possible to invade the pleural cavity accidentally in this area. That little “*p-s-s-s*” sound could signal the unexpected and immediate need for positive-pressure ventilation.

VENIPUNCTURE IN THE PIG

As previously mentioned, the external jugular vein of the pig is not accessible for venipuncture. To obtain a suitable blood

sample for serologic testing, such as that required for *pseudorabies* examination, the large veins that converge to form the cranial vena cava near the thoracic inlet are used.

The specific techniques will be demonstrated in a later course, but they are summarized in figures 3-9 and 3-10. Entry from the right side is recommended because the phrenic nerve lies near the external jugular vein on the left and is more vulnerable to injury by the needle. All students should become familiar with this clinically important area in the pig.

In the horse and the pig, the **deep cervical** and **dorsal scapular arteries** typically emerge through the dorsal parts of intercostal spaces 1 and 2, respectively (Fig. 3.5). In the ruminant, however, they leave the **costocervical trunk** cranial to the first rib. After the deep cervical artery is given off, the ruminant costocervical trunk is continued as the **vertebral artery**. The most cranial three or four dorsal intercostal arteries (except in the dog) arise from the supreme intercostal artery, which is a branch of the costocervical trunk.

LUNG LOBATION

Lung lobation is actually based on the branching pattern of the bronchial tree (Fig. 3-11), and not on the presence or absence of obvious fissures between regions of the lung. With the exception of the accessory lobe, the lungs of the horse are not divided into distinct lobes by deep fissures (Fig. 3-6), and show little evidence of intralobar lobulation. The **cardiac notches** do, however, partially separate each equine lung into cranial and caudal lobes (Fig. 3-6). Note the location of these notches, which generally corresponds to the area available for cardiac auscultation on each side of the horse (Fig. 3-1 & 3-2).

⁹ artiodactyl- an even-toed, hoofed mammal; see Fig. 1-30.

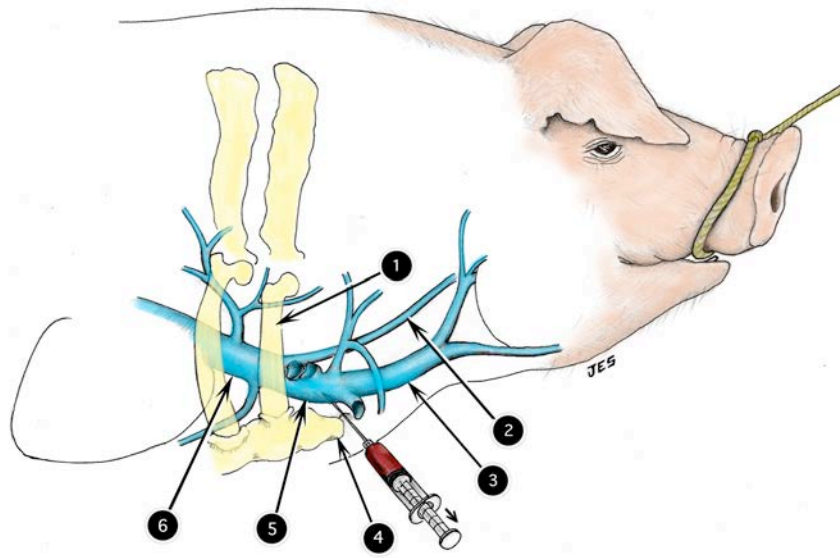


Figure 3-9. Mature pig in standing position, right lateral view. An 18-gauge, 4.5-inch needle, attached to a syringe, is inserted in the right jugular fossa. The needle is directed toward the dorsal border of the left scapula, but the needle tip should remain cranial to the first rib. The needle is advanced slowly with slight negative pressure until blood is obtained: (1) first rib; (2) right internal jugular vein; (3) right external jugular vein; (4) manubrium of sternum; (5) right brachiocephalic vein; (6) cranial vena cava.

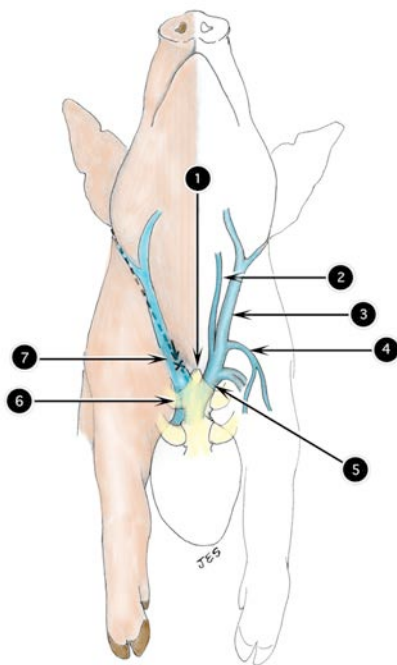


Figure 3-10. Young pig in dorsal recumbency, ventral view: (1) manubrium of sternum; (2) internal jugular vein; (3) external jugular vein; (4) cephalic vein; (5) brachiocephalic vein; (6) cranial vena cava; (7) jugular fossa. The site of needle insertion (x) is the right jugular fossa, on a line from the manubrium of the sternum to the base of the right ear.

In contrast with those of the horse, the lungs of the ruminants and the pig (Fig. 3-11) have distinct lobes. In the ruminants, both cranial lobes are subdivided into cranial and caudal parts, whereas in the pig, only the left cranial lobe is so divided. Otherwise, the artiodactyls have the typical lobation pattern of two lobes on the left and four on the right, with the addition of the tracheal bronchus. Intralobar lobulation of the lung is clearly evident in the ox, less conspicuous in the goat and the pig, and hardly detectable in the sheep.

At slaughter and at autopsy, the heart, lungs, and trachea are typically removed as a single unit, termed the “pluck.” This method has certain advantages to the pathologist in that the major pulmonary vessels remain intact and can be more easily followed and examined. Being anatomists, however, we shall remove the lungs separately to preserve the mediastinal structures *in situ*. During removal of the lungs, take care not to disturb

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or damage the structures within the mediastinum. (You may wish to leave one lung in place for a while, and remove it later when it becomes necessary to do so.)

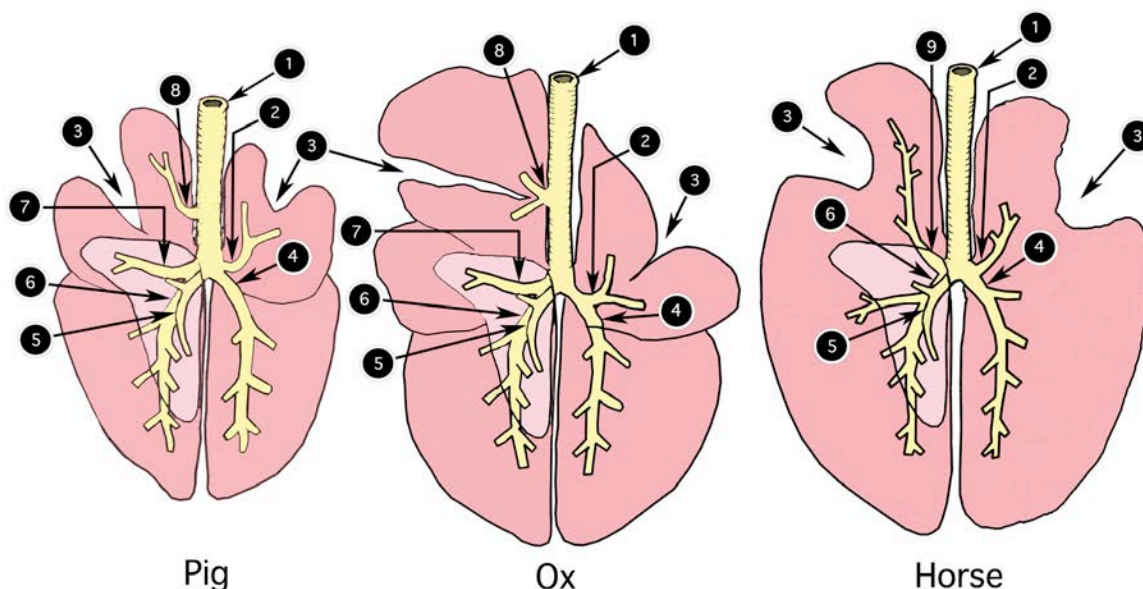


Figure 3-11. Comparative lobation of lungs, ventral view: (1) trachea; (2) left cranial lung lobe; (3) cardiac notch; (4) left caudal lobar bronchus; (5) accessory lobar bronchus; (6) right caudal lobar bronchus; (7) right middle lobar bronchus; (8) tracheal bronchus (artiodactyls); (9) right cranial lobar bronchus.

After all members of the group have had the opportunity to observe the lungs of all species *in situ*, proceed with the following:

1. *Carefully incise the pulmonary ligament, and reflect the caudal lobe to the hilus.*
2. *Withdraw the cranial lobe, and, if present, cut the tracheal bronchus near the trachea.*
3. *On the right side, lift the accessory lobe up and over the caudal vena cava.*
4. *With traction on the lung, carefully incise the hilar structures about midway between the heart and lung.*

Once removed, the visceral surface of the lung can be better examined, and the lungs of different species can be placed on

the table side-by-side and compared relative to their lobation and lobulation (Fig. 3-11).

STRUCTURES OF MEDIASTINUM

Thoracic Duct: Before you have a chance to destroy it, please have one of the instructors confirm the identification of the thoracic duct as it crosses the left side of the esophagus toward its termination in the convergence of large veins near the thoracic inlet (Figs. 3-12 & 3-13). In addition to lymphatic drainage from the caudal part of the body, this important duct transports fat absorbed from the digestive tract to venous circulation. Because of the presence of this absorbed fat, the material within the thoracic duct is known as **chyle**. In cases of trauma or an invasive disease process, the thoracic duct may rupture and allow chyle to leak into the pleural cavity, a condition referred to as **chylothorax**. Chylothorax can be

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differentiated from other forms of pleural effusion by examination of the fluid obtained by way of thoracocentesis.

Thymus: Depending on the age of the animal, the thymus occupies a variable amount of space in the cranial mediastinum (Figs. 3-7 & 3-13). As mentioned earlier, the thymus of the horse involutes early in life, whereas in the ruminant, it remains relatively more obvious in the adult. In young animals, particularly, it may be necessary to dissect away some of the thoracic part of the thymus to observe some of the other mediastinal structures. Do so as necessary.

Mediastinal Lymph Nodes: The numerous lymph nodes within the mediastinal space are generally divided into three groups--cranial, middle, and caudal. In the ruminant, the group of large **caudal mediastinal lymph nodes** is of particular clinical importance; these nodes are located between the esophagus and aorta (Figs. 3-12 & 3-13). When enlarged, these nodes can compress the esophagus and result in bloat. Such enlargement can also damage the vagal trunks and interfere with normal gastric motility. The **tracheobronchial lymph nodes** are located at the bifurcation of the trachea and become enlarged as a consequence of almost any lung infection or other pulmonary disease.

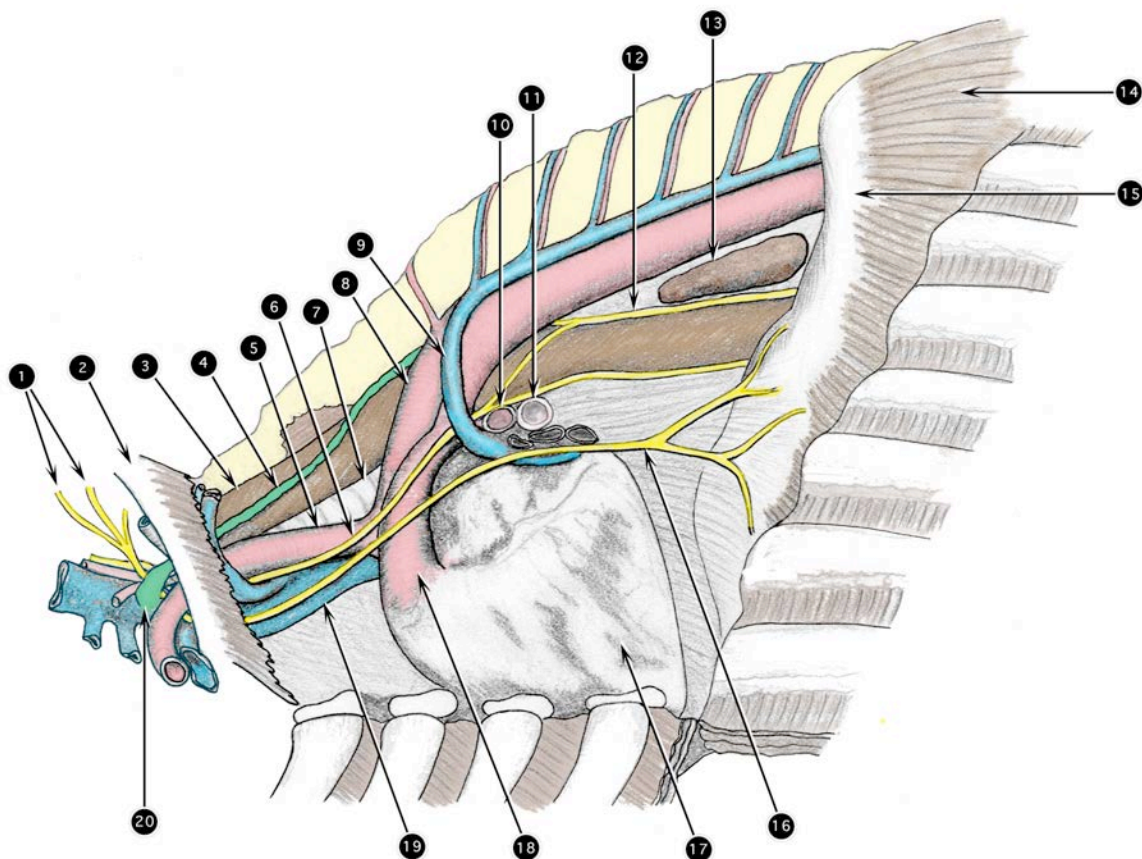


Figure 3-12. Major structures of bovine mediastinum, left lateral view: (1) roots of left phrenic nerve; (2) first rib; (3) esophagus; (4) thoracic duct; (5) brachiocephalic trunk; (6) left vagus nerve; (7) trachea; (8) aortic arch; (9) left azygos vein; (10) left pulmonary artery; (11) left principal bronchus; (12) dorsal vagal trunk; (13) caudal mediastinal lymph node; (14) costal part of diaphragm; (15) central tendon of diaphragm; (16) left phrenic nerve; (17) subpleural fat overlying fibrous pericardium; (18) pulmonary trunk; (19) cranial vena cava; (20) termination of thoracic duct.

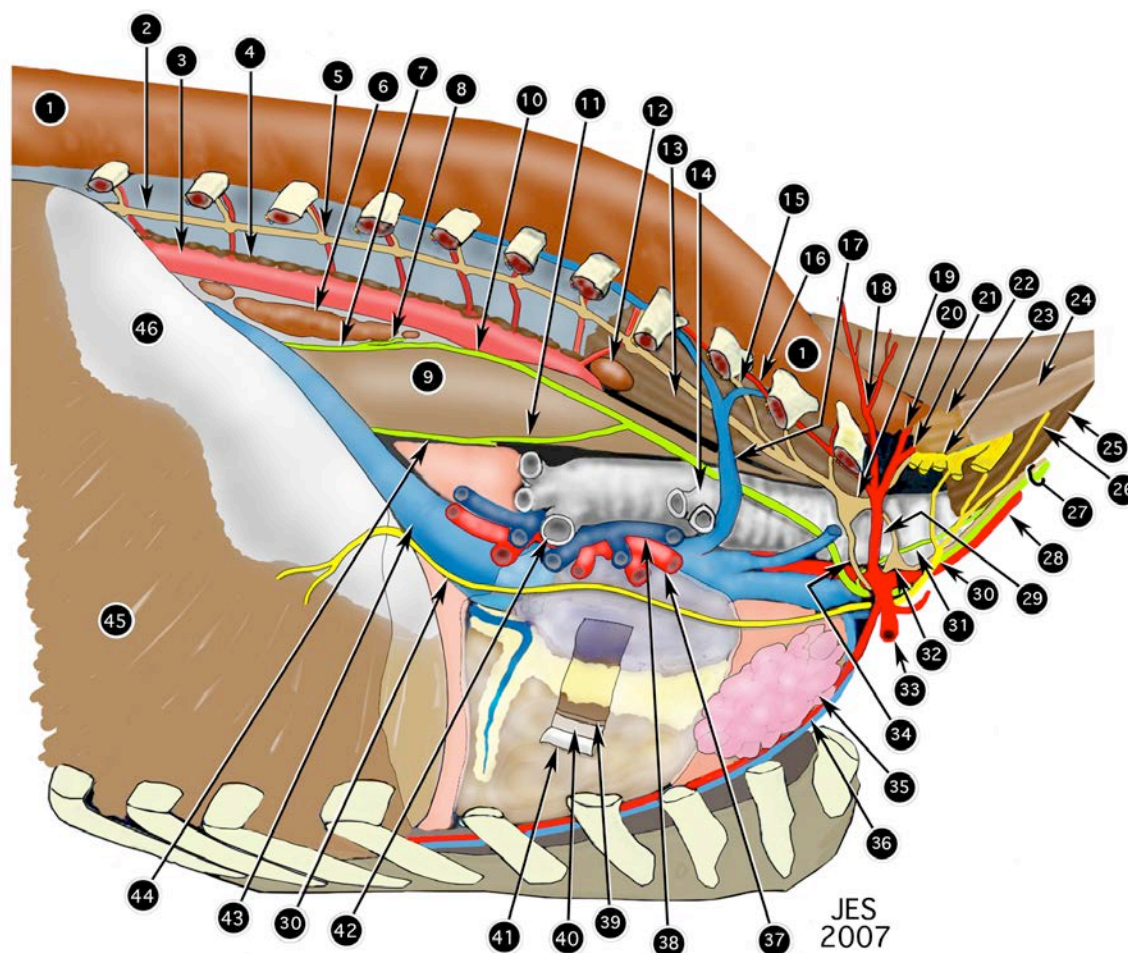


Figure 3-13. Major structures of bovine mediastinum, right lateral view: (1) iliocostalis thoracis muscle; (2) sympathetic trunk; (3) aorta; (4) thoracic duct; (5) sympathetic trunk ganglion; (6) caudal mediastinal lymph node; (7) dorsal vagal trunk; (8) dorsal branch of left vagus nerve; (9) esophagus; (10) dorsal branch of right vagus nerve; (11) ventral branch of right vagus nerve; (12) middle mediastinal lymph node; (13) longus colli muscle; (14) tracheal bronchus to right cranial lung lobe; (15) ramus communicans; (16) supreme intercostal artery; (17) right azygos vein; (18) dorsal scapular artery; (19) cervicothoracic ganglion; (20) deep cervical artery; (21) vertebral artery; (22) middle scalenus muscle; (23) brachial plexus; (24) dorsal scalenus muscle; (25) ventral scalenus muscle; (26) root of right phrenic nerve from C5; (27) vagosympathetic trunk; (28) common carotid artery; (29) costocervical trunk; (30) right phrenic nerve; (31) right recurrent laryngeal nerve; (32) middle cervical ganglion; (33) right axillary artery; (34) ansa subclavia; (35) thymus; (36) internal thoracic vessels; (37) pulmonary veins from right lung; (38) pulmonary arteries to right lung; (39) parietal serous pericardium; (40) fibrous pericardium; (41) mediastinal pleura; (42) principal bronchus to right lung; (43) caudal vena cava; (44) ventral vagal trunk; (45) costal part of diaphragm; (46) central tendon of diaphragm.

Major Veins of Mediastinum: As you know, the major veins from the head, neck, and forelimb converge at the thoracic inlet to form the **cranial vena cava**, and blood from the abdomen, pelvis, and hind limb returns by way of the **caudal vena cava** (Fig. 3-13). Blood from the thoracic wall can return by way of the **internal thoracic**

vein or can be collected dorsally *via* the azygos vein, and here is where some variation exists. From your study of the carnivores, you have become familiar with the **right azygos vein**, which joins the cranial vena cava near the right atrium (Fig. 3-13). This is also the situation in the horse.

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Embryologically, both right and left azygos veins develop as the *caudal cardinal veins*, but typically one or the other atrophies. In the carnivores and the horse, the right azygos persists, whereas in the artiodactyls the **left azygos vein** predominates.¹⁰ The left azygos vein passes cranial to the hilus of the left lung and then curves caudally to enter the right atrium at the coronary sinus (Fig. 3-12). Occasionally, a complete right azygos vein is also present in the ox, but in most cases this vein represents only the cranial part of an azygos vein (Fig. 3-13).

The presence of a complete right azygos vein (in addition to the left) is more common in the sheep and the goat. Structures such as the **costocervical trunk** or **vertebral artery** are accompanied by veins of the same name. *As the dissection proceeds, feel free to resect these veins as necessary to see the underlying structures.*

Major Branches of Aortic Arch: As you recall from your study of the carnivores, the two major branches of the aortic arch (after the coronary arteries) are the brachiocephalic trunk and left subclavian artery. Among the domestic ungulates, the **left subclavian artery** is a direct branch of the aorta only in the pig. In other species, it typically arises as a branch of the brachiocephalic trunk (Fig. 3-14). Not only is there species variation in how the major subclavian branches arise, but the horse usually does it differently on the left and right sides (Fig. 3-14).

On the right side of the horse, the **deep cervical artery** typically arises from the costocervical trunk, along with the **dorsal scapular**, whereas on the left side, the deep cervical artery arises separately. Ruminants

have the simplest arrangement in that dorsal scapular, deep cervical, and vertebral arteries all arise from the costocervical trunk. Regardless of how the arteries arise, *they are named according to their destination*, not their origin. Although I have provided you with comparative drawings, the details of origin are not as important as being able to identify the vessel according to its area of supply. Just recognize that all the variations do exist, and you don't have a prayer to ever keep all these differences straight. *It's OK; you can still be a good veterinarian.*

Autonomic Nervous System: *Cut the first rib at the costochondral junction. Rock it back and forth, carefully disarticulate the head, and remove the first rib.* Locate the **vagosympathetic trunk** in the caudal cervical region, and trace it caudally. Near the thoracic inlet it divides into its constituent components. Most of the fibers of the cervical **sympathetic trunk** separate dorsally and pass directly to the **cervicothoracic ganglion** (Fig. 3-15). Some sympathetic fibers, however, remain closely associated with the **vagus nerve** as it continues ventrally around the subclavian artery. Shortly thereafter, these fibers also leave the vagus and go to the cervicothoracic ganglion, thus forming a loop around the artery, the **ansa subclavia**.

Actually, the sympathetic fibers are not going to the ganglion, but rather are coming from it on their way to the head (we were just following them caudally). At the point where the sympathetic fibers get back together cranially, near the vagus, you may note a small, somewhat poorly defined lump. This enlargement contains some sympathetic neuron cell bodies and is termed the **middle cervical ganglion** (Fig. 3-15). Some sympathetic fibers typically leave the ansa subclavia and are distributed

¹⁰ An old name for the left azygos vein is the hemiazygos- a sort of "half-azygos" term.

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to the heart as **cardiac nerves**. Similarly, form one or more cardiac nerves. parasympathetic fibers leave the vagus and

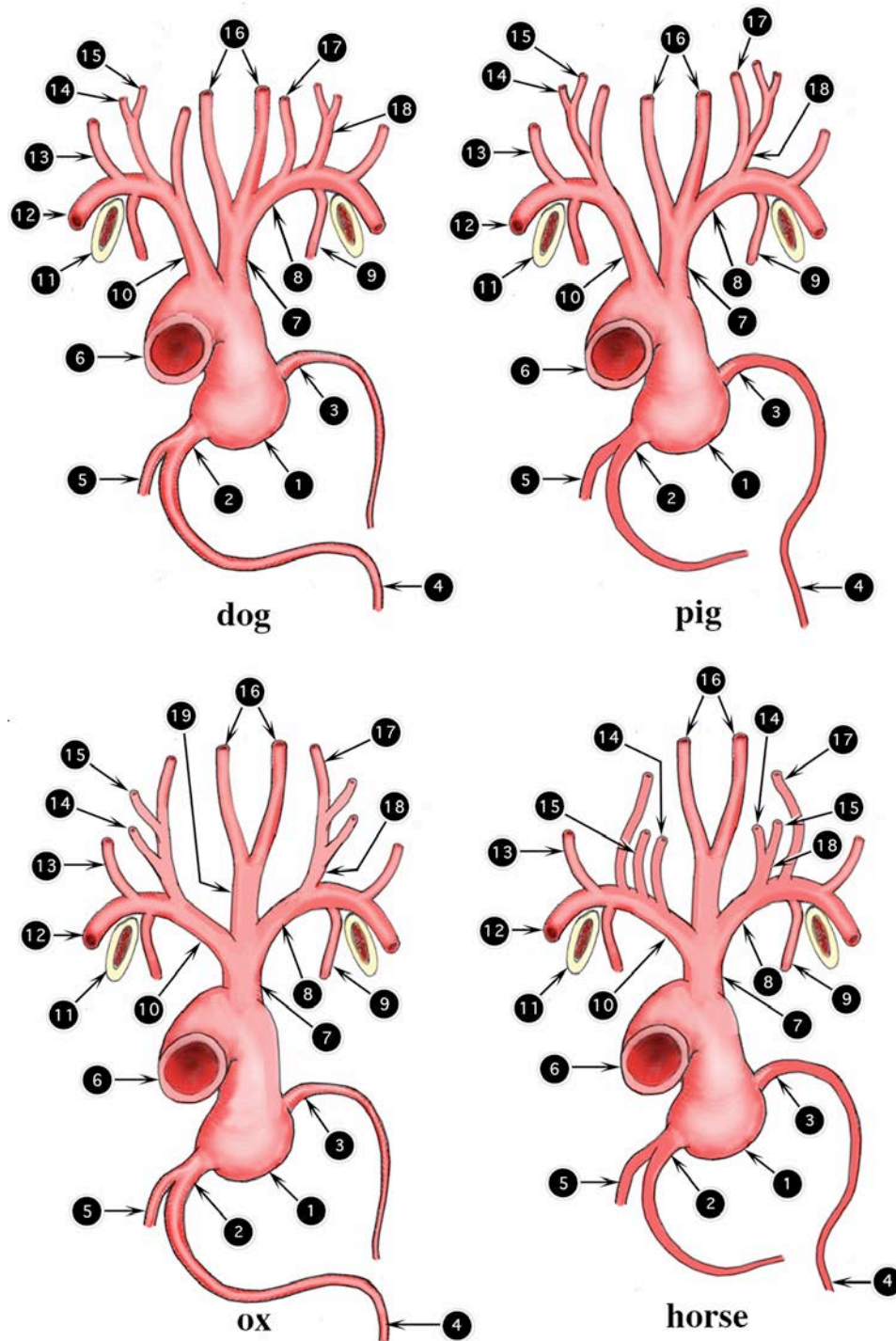


Figure 3-14. Typical patterns for branches of aortic arch, caudodorsal view: (1) aortic bulb (sinus); (2) left coronary artery; (3) right coronary artery; (4) subinuosal interventricular branch; (5) paraconal interventricular branch; (6) descending aorta; (7) brachiocephalic trunk; (8) right subclavian artery; (9) internal thoracic artery; (10) left subclavian artery; (11) rib 1; (12) axillary artery; (13) superficial cervical artery; (14) dorsal scapular artery; (15) deep cervical artery; (16) common carotid arteries; (17) vertebral artery; (18) costocervical trunk; (19) bicarotid trunk.

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You might wonder why we have a cranial cervical ganglion near the tympano-occipital fissure and a middle cervical ganglion, but no “caudal” cervical ganglion. The answer is that those neuron cell bodies

forming the caudal cervical ganglion are incorporated with the first several thoracic vertebral ganglia to form the large cervicothoracic ganglion. The name of the ganglion denotes this fusion.

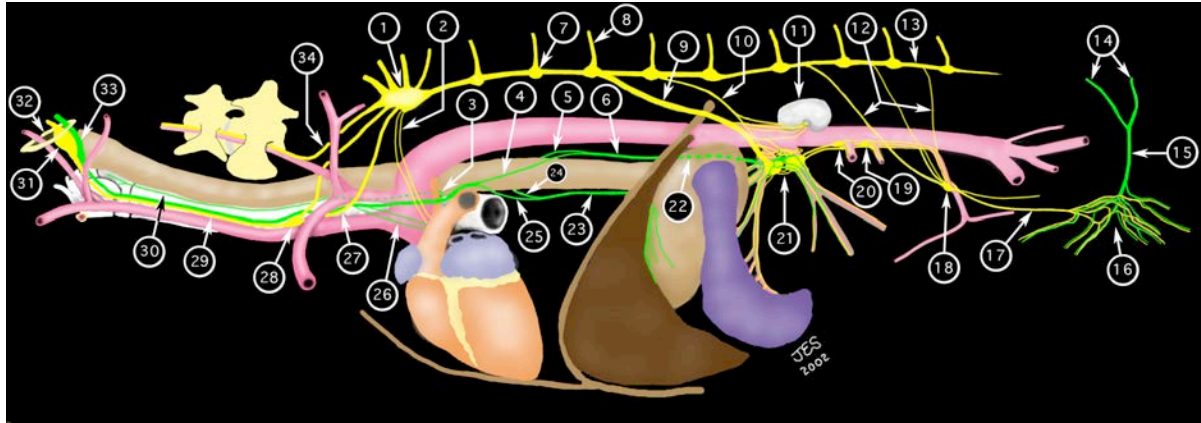


Figure 3-15. Schematic illustration of selected parts of Autonomic Nervous System: (1) left cervicothoracic (stellate) ganglion- results from fusion of caudal cervical ganglion with one or more thoracic ganglia; (2) sympathetic cardiac nerves; (3) left recurrent laryngeal nerve looping around ligamentum arteriosum to follow trachea back to larynx; (4) dorsal branch of left vagus nerve; (5) dorsal branch of right vagus nerve; (6) dorsal vagal trunk formed by union of 4 & 5; (7) sympathetic trunk ganglion; (8) communicating branches (*rami communicans*) between sympathetic trunk and spinal nerves; (9) major (greater) splanchnic nerve; (10) minor (lesser) splanchnic nerve; (11) left adrenal gland; (12) lumbar splanchnic nerves; (13) sympathetic trunk; (14) roots of pelvic nerve from S2-S3; (15) left pelvic nerve (*n. erigentes*); (16) left pelvic plexus- associated with peritoneum of rectogenital pouch; (17) left hypogastric nerve; (18) caudal mesenteric ganglion; (19) ovarian or testicular plexus; (20) renal plexus; (21) celiacomesenteric (solar) ganglia & plexus; (22) celiac branch of dorsal vagal trunk; (23) ventral vagal trunk; (24) ventral branch of right vagus nerve; (25) ventral branch of left vagus nerve; (26) cardiac branches of left vagus nerve; (27) left ansa subclavia; (28) left middle cervical ganglion; (29) left vagosympathetic trunk; (30) left caudal laryngeal nerve (terminal part of 3); (31) left cranial cervical ganglion; (32) left tympano-occipital fissure; (33) distal ganglion of left vagus nerve; (34) left vertebral nerve- provides sympathetic innervation to neck.

As you continue to trace the vagus nerve caudally, note that another branch, the **recurrent laryngeal nerve**, leaves the vagus and turns cranially around a major artery. On the left side, the recurrent nerve loops caudally around the **ligamentum arteriosum** (embryonic aortic arch 6), which connects the pulmonary trunk and aorta (Fig. 3-15). Here the nerve comes to lie adjacent to the trachea, which it follows cranially to the larynx. On the right side, the recurrent nerve leaves the vagus, loops around the **right subclavian artery** (embryonic aortic arch 4), passes medial to

the costocervical trunk, and joins the trachea for a free ride to the larynx.

Continue to follow the **vagus nerve** caudally, and note its division into **dorsal** and **ventral branches** (Fig. 3-15). Caudal to the tracheal bifurcation, the ventral branches from the right and left nerves unite to form the **ventral vagal trunk**. Further caudally, the two dorsal branches similarly join to form the **dorsal vagal trunk**. The dorsal and ventral vagal trunks supply branches to the esophagus and accompany it through the esophageal hiatus of the diaphragm. As previously noted,

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enlargement of the caudal mediastinal lymph nodes in the ruminant can involve the dorsal vagal trunk, resulting in abnormal gastric motility and bloat.

Phrenic Nerves: The roots of the phrenic nerves from the ventral branches of C5 to C7 have been previously identified. These roots unite near the thoracic inlet to form the phrenic nerve proper (Figs. 3-12 & 3-13). Note that the phrenic nerve crosses the pericardium and continues to the diaphragm, to which it provides motor innervation. Unlike the vagus nerve, which passes dorsal to the root of the lung, *the phrenic nerve passes ventral to the hilus of the lung*. This fact can be used for easy differentiation between the two nerves at surgery. On the left, the phrenic nerve remains within the mediastinum; however, on the right, it accompanies the caudal vena cava in its special fold of connecting pleura, the plica vena cavae (Fig. 3-13).¹¹

There is also a connection between the phrenic nerves and sympathetic fibers from the celiac plexus. It is apparently these autonomic fibers that are involved with the phenomenon of “getting the wind knocked out of you” or getting hit in the “solar plexus;” i. e., the celiac plexus. A blow near the xiphoid region apparently results in a

con`tre`coup¹² type trauma to the “solar plexus,” resulting in a temporary, spasmodic contraction of the diaphragm, during which breathing is very difficult.

Because of the supporting function of the other respiratory muscles (e.g., intercostals), an animal can survive in a basal resting state with transection of both phrenic nerves. However, origin of the phrenic nerve from spinal segments C5 to C7 represents the most cranial extent of the respiratory motor apparatus. Thus, if a spinal or epidural anesthetic migrates cranially to include C5 to C7, as well as the thoracic segments, all respiratory muscles are paralyzed, and the animal is unable to sustain itself without positive-pressure ventilation. Another point to keep in mind is that the diaphragm muscle is skeletal, and contraction is *voluntary, not autonomic*. Otherwise, you wouldn't be able to hold your breath. The fact that it works *automatically* (below the level of consciousness) should not be misunderstood to imply *autonomic* function.

Esophagus: *Transect the esophagus about 6 cm cranial to the esophageal hiatus of the diaphragm.* Compare the thickness of the muscular coat at this level in the various species. In the dog and the ruminant, the *tunica muscularis* consists of skeletal muscle throughout, whereas in the horse, the pig, and the cat, there is a transition to smooth muscle caudal to the heart. The tunica muscularis is especially thick in the caudal part of the equine esophagus¹³, which may be partly responsible for the fact that

¹¹ Although it is generally believed that the phrenic nerves are the sole nerve supply to the diaphragm, I have a lingering doubt that the crura may actually receive a separate nerve supply from one or more lumbar spinal nerves. It would be quite the exceptional event for somatic musculature of the lumbar body wall to form the crura, then have nerves from the cervical region grow back to innervate it. There are apparently some unanswered questions as to how exactly the diaphragmatic musculature develops.

¹² con`tre`coup - a concussion or shock produced by a blow in a part or region opposite to where the blow was received.

¹³ In very old horses (> 20 years) the caudal esophageal musculature may be 2 to 3 times the thickness of a young horse.

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the horse can neither regurgitate food nor eructate (belch) gas from its stomach. Ruminants, on the other hand, do this all the time.

Pericardium: In the horse and ruminants, *strip some of the mediastinal pleura away from the underlying pericardial sac.* As this is done, you should note the presence of some subpleural fat, which comes away with the pleura (Fig. 3-12).

Cut a window in the parietal pericardium, and remove the section (Fig. 3-13). Now check its toughness by trying to tear it with your hands. Tough, isn't it? The increased strength and opacity of the parietal lamina versus the thin, transparent structure of the visceral lamina is a result of the adherent **fibrous pericardium**, which is inseparable from the parietal lamina and is continuous with the fibrous tissue of the mediastinum. Ventrally, this fibrous tissue is thickened to form the **sternopericardiac ligament**, which maintains the apex of the pericardial sac in a relatively fixed position near the sternum. Although the heart does shift with changes in body position, anchorage of the pericardium prevents the heart from flopping all around when the animal rolls over.

Consider the consequences of excessive fluid accumulation within the pericardial sac. This fluid may be a transudate, blood (cardiac tamponade), or, in the ox particularly, an infectious exudate (pericarditis). After attempting to tear the parietal lamina with your hands, you can appreciate the effect of pericardial effusion on the heart. Basically, it compresses and strangles the heart, preventing dilatation and filling of the chambers, which of course greatly compromises cardiac function and increases central venous pressures because of the impedance of blood flow into the

atria. It is like putting a tourniquet around the heart, resulting in poor venous return and distention of peripheral veins (e.g., the external jugular veins).

Note the area of contact between the pericardium and diaphragm in the ox. The importance of this is discussed later during dissection of the abdomen, but this is the area where sharp foreign bodies that collect in the reticulum can migrate through the diaphragm to puncture the pericardium and heart (traumatic pericarditis).

REMOVAL OF HEART ¹⁴

1. *Transect the brachiocephalic trunk (and left subclavian artery in the pig) about 1 cm from the aorta; then transect the aorta about 10 cm distal to the origin of the brachiocephalic trunk.*
2. *Transect the cranial vena cava at the same level as the brachiocephalic trunk, and transect the azygos vein about 2 cm proximal to its termination.*
3. *Transect the caudal vena cava about midway between the diaphragm and heart.*
4. *Free any remaining attachments, including the sternopericardiac ligament, and remove the heart and pericardium.*

Enlarge the window that you previously cut in the parietal pericardium until the heart can be pushed out through the opening. Pull the parietal pericardium up over the base of the heart (like pulling off a T shirt). This demonstrates the **line of pericardial reflection**, where the **parietal**

¹⁴ We will select those animals in the laboratory that have been particularly well dissected to illustrate the structures of the mediastinum. We have these groups leave the heart and great vessels in place for review and use during the *dreaded* practical examination.

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lamina becomes continuous with the **visceral lamina** of the serous pericardium (epicardium) around the heart base and the origins of the great vessels. *Remove the combined fibrous pericardium and parietal*

lamina of the serous pericardium, leaving only a small flap of the latter to mark the line of pericardial reflection (Fig. 3-16). Review the external anatomy of the heart and major vessels at its base.

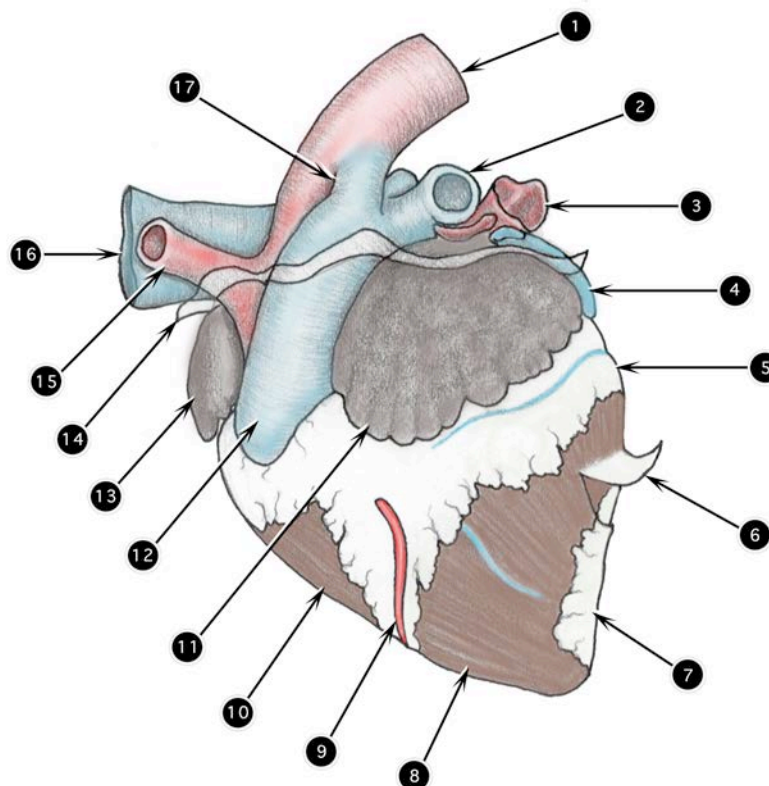


Figure 3-16. Heart of a newborn calf, left lateral view: (1) aorta; (2) left pulmonary artery; (3) left pulmonary vein; (4) left azygos vein curving around to join great cardiac vein; (5) coronary groove; (6) reflected tab of visceral lamina of serous pericardium (epicardium); (7) subepicardial fat; (8) left ventricle; (9) paraconal interventricular branch of left coronary artery; (10) right ventricle; (11) left auricle; (12) pulmonary trunk; (13) right auricle; (14) reflected cut edge of parietal lamina of serous pericardium; (15) brachiocephalic trunk; (16) cranial vena cava; (17) ligamentum arteriosum.

Ligamentum Arteriosum: All students should observe this structure in the newborn calf (Fig. 3-16). *Remove sections from the walls of the pulmonary trunk and aorta of the calf to observe the internal orifices of the ligamentum arteriosum.* During fetal life, the **ductus arteriosus** allowed most of the blood in the pulmonary trunk to bypass the nonfunctional fetal lungs and enter the aorta. Note that it enters the aorta distal to the origin of the brachiocephalic trunk so that the more highly oxygenated blood from the left ventricle flows to the brain, before it can

be mixed with the less oxygenated blood from the pulmonary trunk.

Immediately after birth, blood flow through the ductus is reversed because of the increase in left-side and concurrent decrease in right-side pressures. The ductus arteriosus has a muscular wall, which is stimulated to constrict after birth. However, closure and sealing may not be complete for several days. In fact, it is not uncommon for the ductus arteriosus of a foal to remain patent for up to a week.

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In the newborn calf, you should be able to pass a probe through the ligamentum arteriosum. Being able to pass a probe through the ligamentum arteriosum of a neonatal animal is not evidence in itself of any abnormality. A clinically significant patent ductus arteriosus is accompanied by other pathologic changes.

Note the relative size of the **right** and **left coronary arteries** of the different species. The right coronary artery gives rise to the subsinuosal interventricular branch in the horse and the pig, whereas in the

ruminant and the dog, it arises from the circumflex branch of the left coronary artery (Fig. 3-14).

Turn the heart so that it is viewed from the right side. Locate the stumps of the cranial and caudal vena cavae. *Pass a probe through the opening of the caudal vena cava so that it comes out through the cranial vena cava. Now, incise the lateral walls of both vessels along the probe. From the center of this incision, cut ventrally, and then out to the tip of the right auricle to open the right atrium* (Fig. 3-17).

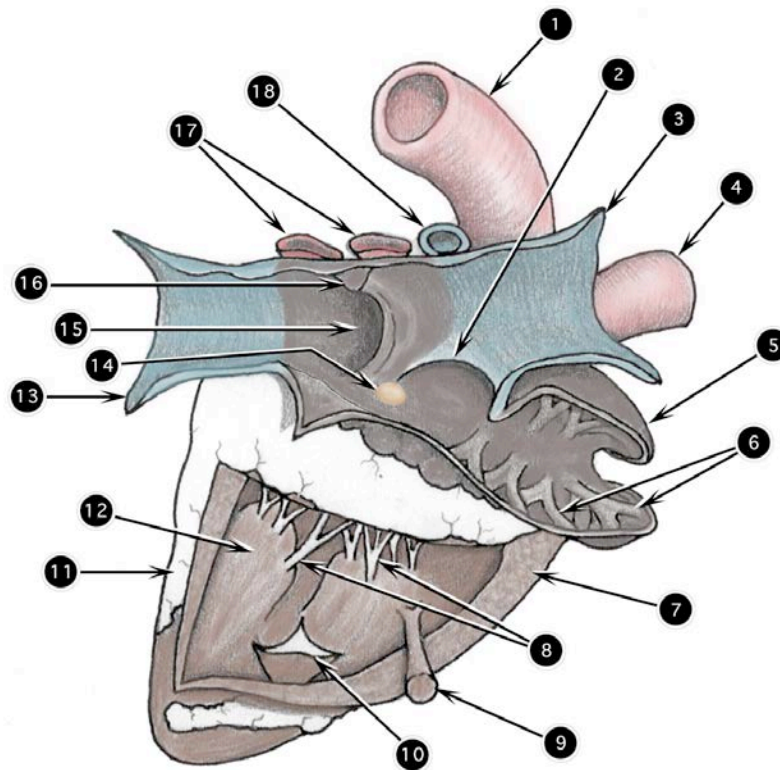


Figure 3-17. Heart of a newborn calf, right lateral view with right atrium and ventricle opened: (1) aorta; (2) terminal crest; (3) opened cranial vena cava; (4) brachiocephalic trunk; (5) opened right auricle; (6) pectinate muscles; (7) incised wall of right ventricle; (8) chordae tendineae; (9) trabecula septomarginalis; (10) reflected tab of endocardium; (11) subepicardial fat within subsinuosal interventricular groove; (12) papillary muscle; (13) opened caudal vena cava; (14) approximate location of SA node; (15) fossa ovalis; (16) intervenous tubercle; (17) right pulmonary veins; (18) right pulmonary artery.

Right Atrium: The **intervenous tubercle** forms a crest that diverts the blood from the cranial and caudal vena cavae toward the right atrioventricular ostium (Fig. 3-17).

The opening of the **coronary sinus** is located ventral to that of the caudal vena cava. Blood from the **great cardiac vein**, including that from the left azygos of

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artiodactyls, enters the right atrium through this opening. The **terminal crest** separates the cranial vena cava and the **right auricle**. The **sinoatrial node** (not grossly visible) is located just below the junction of the terminal crest with the interatrial septum (Fig. 3-17). The **atrioventricular node** (not grossly visible) is located just cranial to the opening of the coronary sinus (Fig. 3-18). The **pectinate muscles** are essentially limited to the auricular appendage and are not found in the larger, smooth-walled part of the atrium, which is known as the **sinus venarum**.

Fossa Ovalis: Observe the fossa ovalis in the newborn calf; you should be able to pass the handle of a probe through to the left atrium. During fetal life most of the highly oxygenated blood from the caudal vena cava is diverted through the **foramen ovale** into the left atrium (Fig. 3-19). You should note that the opening through the interatrial septum of the fetus is an oblique passage, designed to receive the more freshly oxygenated blood from the caudal vena cava, not the “second-hand” blood returning from the head and forelimbs *via* the cranial vena cava.

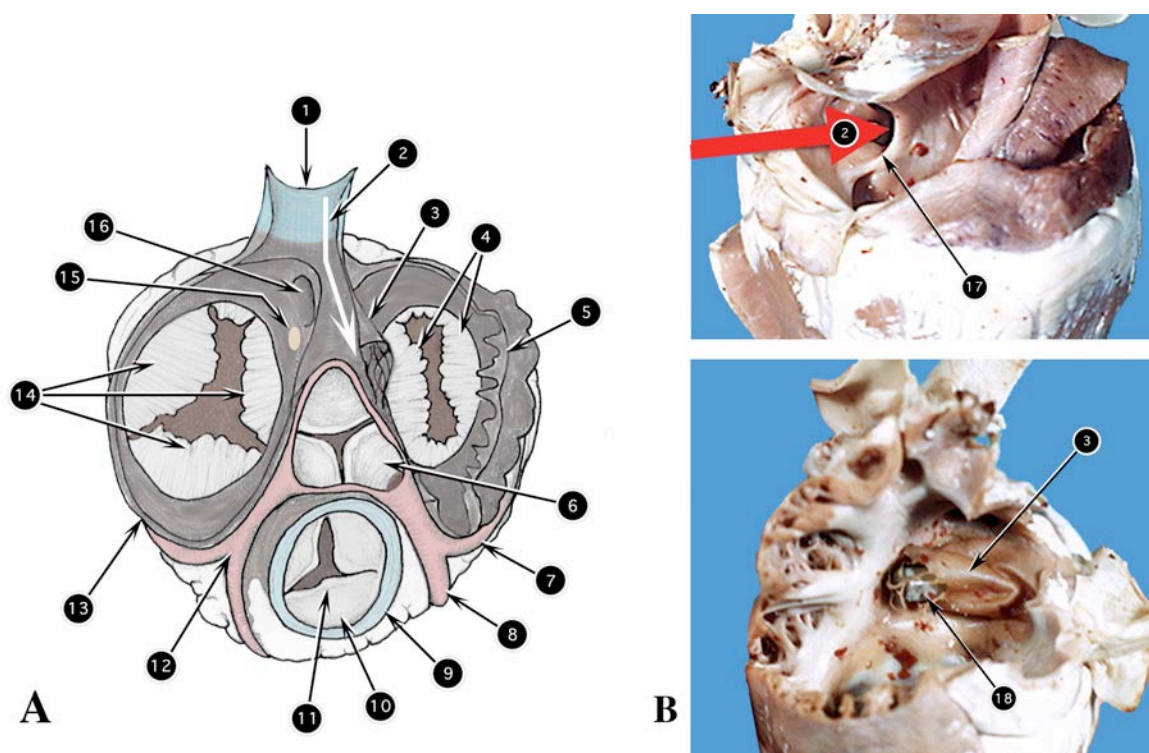


Figure 3-18. **A.** Heart of a newborn calf, dorsal view with aorta, pulmonary trunk, and parts of both atria removed; **B.** Photograph of interatrial septum of newborn calf heart as viewed from right atrium (top) and left atrium (bottom): (1) opened caudal vena cava; (2) arrows indicate flow of most caudal vena caval blood through foramen ovale during fetal life; (3) thin-walled flap that closes foramen ovale and represents remnant of *septum primum* of embryonic heart; (4) two major cusps of left atrioventricular (mitral) valve; (5) incised wall of left atrium; (6) semilunar cusp of aortic valve; (7) circumflex branch of left coronary artery; (8) paraconal interventricular branch of left coronary artery; (9) incised wall of pulmonary trunk; (10) cusp of pulmonary valve; (11) nodular thickening at midpoint of each semilunar cusp; (12) right coronary artery; (13) incised wall of right atrium; (14) three major cusps of right atrioventricular (tricuspid) valve; (15) approximate location of AV node; (16) opening of coronary sinus- receives blood from great cardiac and left azygos veins; (17) rim or limbus of fossa ovalis (foramen ovale); (18) fenestrated end of thin-walled septum representing remnant of embryonic *foramen secundum*.

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Developmentally, separation of the two atria, *without restricting blood flow*, is a tricky construction project. An initial thin septum (*septum interatriale primum*) develops only to a certain point, leaving a hole (*foramen interatriale primum*) for blood to flow from right to left. As growth of the *endocardial cushions* begins to occlude this primary foramen, small perforations appear at a new location in the primary septum.

These holes coalesce to form a new, secondary opening (*foramen interatriale secundum*), which allows for continued interatrial blood flow. A thicker, secondary septum (*septum interatriale secundum*) now grows down along the right side of the newly formed (secondary) foramen, leaving a large opening, the *foramen ovale*, at about the level of the original *foramen primum*.

The oblique passage you now see through the interatrial septum of the newborn calf is the result of this unique developmental process. The *foramen ovale* is protected on the left side by the thin remnant of the septum primum, and the fenestrated end of the septum is the remains of the *foramen secundum* (Fig. 3-18). The final product forms sort of a one-way, tubular valve that allows approximately 60% of the blood from the caudal vena cava to be diverted *via* the *foramen ovale* directly into the left atrium.

The **right atrioventricular valve** consists of three cusps, which accounts for its commonly used clinical name of **tricuspid valve**. The right ventricle should now be opened by reflecting a flap of muscle as shown in Fig. 3-17.

Beginning near the **subsinoasal interventricular groove**, *incise the wall of the right ventricle just below and parallel to*

the coronary groove. As the incision approaches the pulmonary trunk, make a turn and incise to near the paraconal interventricular groove (Fig. 3-20). Now, *make another turn and incise parallel to the latter groove. Continue to near the subsinoasal groove, and turn and continue to the starting point.* This should form a flap that is still attached to the interventricular septum by the **trabecula septomarginalis**.

Right Ventricle: Compare the size of the trabecula septomarginalis in the bovine and equine hearts. These trabeculae contain some of the specialized conduction (Purkinje) fibers that distribute the electrical stimuli responsible for initiating ventricular contraction.

Each cusp of the right atrioventricular (AV) valve receives **chordae tendineae** from two different **papillary muscles**. Also, note that the right ventricle curves around the left ventricle so that the right ventricular outflow narrows to form the **conus arteriosus**, which joins the pulmonary trunk to the left of the aorta.

Open a window in the pulmonary trunk and examine the pulmonary valve from the arterial side. Note the semilunar, three-cusp construction of the **pulmonary valve** (Fig. 3-18). Careful inspection of the valve cusps should reveal a small nodular thickening at the midpoint of the free border of each. When the valve is closed, these three nodules (“little balls”) converge to form a blood-tight closure¹⁵, and thus prevent leakage during ventricular diastole.

¹⁵ Blood-tight is not the same as water-tight because, as you know, “blood is thicker than water.” In cases of severe anemia, blood may actually become so thin that the valves can no longer prevent regurgitation, producing what may be called an “anemic” murmur.

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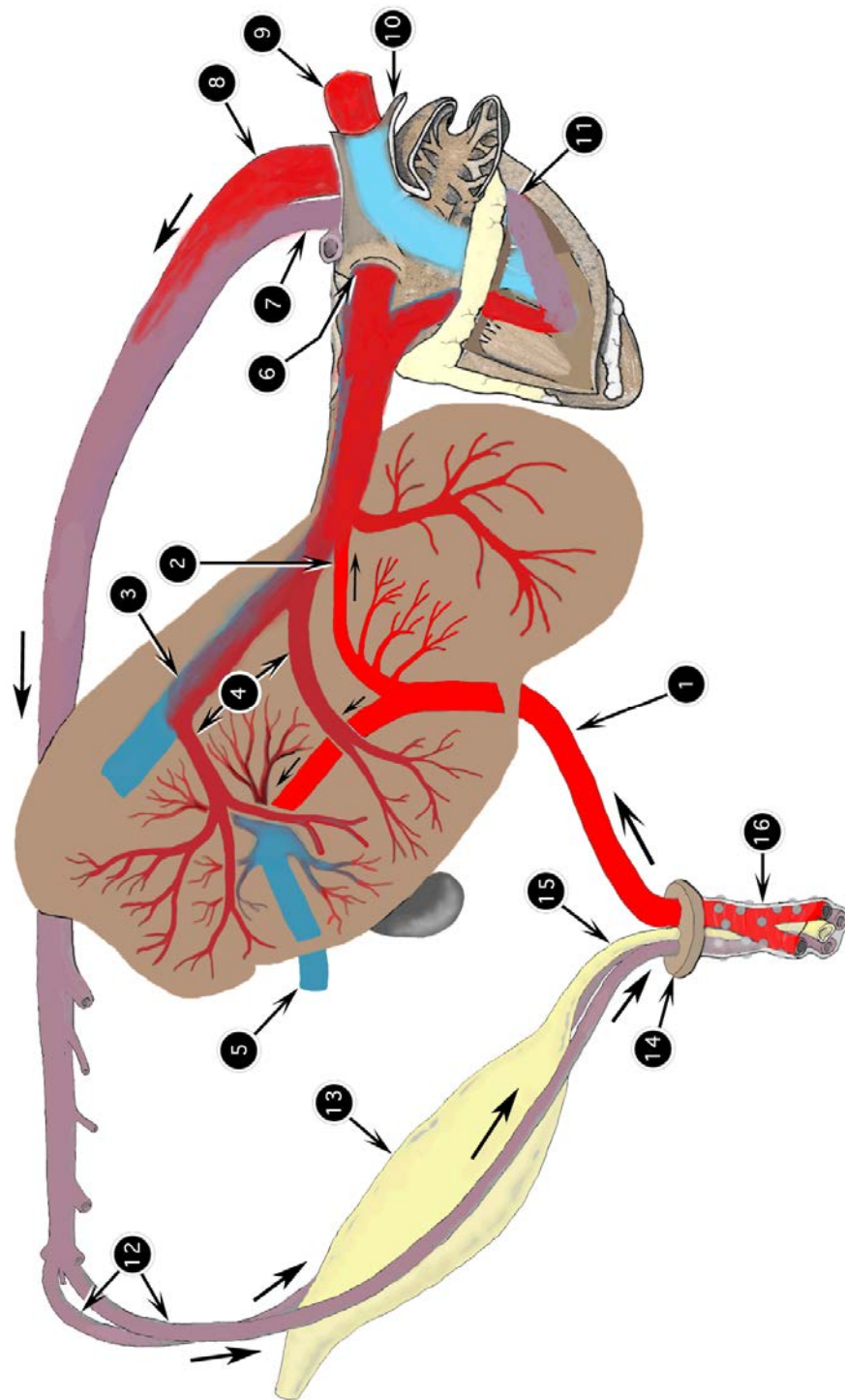


Figure 3-19. Schematic representation of fetal circulation in calf, right lateral view. Arrows indicate direction of blood flow: (1) umbilical vein; (2) ductus venosus; (3) caudal vena cava; (4) hepatic veins; (5) portal vein; (6) foramen ovale; (7) ductus arteriosus; (8) aorta; (9) brachiocephalic trunk; (10) cranial vena cava; (11) conus arteriosus leading to pulmonary trunk & ductus arteriosus; (12) umbilical arteries; (13) urinary bladder; (14) umbilicus; (15) urachus; (16) amnion surrounding umbilical cord. (Modified from *Applied Veterinary Anatomy*, de Lahunta and Habel, w. B. Saunders, Co, 1986, p. 196.)

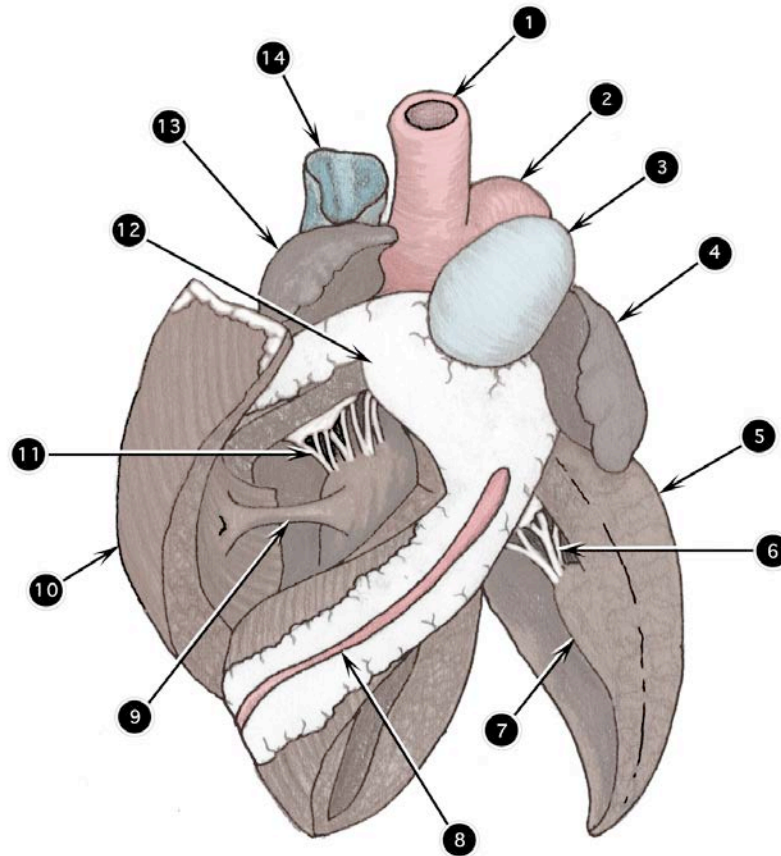


Figure 3-20. Heart of a newborn calf, cranioventral view with ventricular walls reflected: (1) brachiocephalic trunk; (2) aorta; (3) pulmonary trunk; (4) left auricle; (5) reflected left ventricular wall; (6) chordae tendineae of left AV (mitral) valve; (7) papillary muscle; (8) paraconal interventricular branch of left coronary artery; (9) trabecula septomarginalis; (10) reflected right ventricular wall; (11) chordae tendineae of right AV (tricuspid) valve; (12) conus arteriosus of right ventricle; (13) right auricle; (14) cranial vena cava.

Left Atrium: Locate a number of the openings of the **pulmonary veins** that return blood from the lungs to the left atrium (Figs. 3-16 & 3-17). *Open the left atrium by incising its lateral wall.*

In the newborn calf, note the presence of the thin-walled septum (*septum primum*) that normally closes to seal the foramen ovale and physically separate the two atria (Fig. 3-18). This tubular valve is functionally closed by increased blood flow from the pulmonary veins into the left atrium at birth, but it may take several weeks for physical closure (“healing shut”) of the fenestrated opening (*foramen*

secundum). Again, being able to push a probe through this opening in a neonatal animal is not evidence of any abnormality. Examine the left side of the interatrial septum in some of the older animals to see the scar that results from this fusion.

The **left atrioventricular valve** has two major cusps and is occasionally referred to as the “bicuspid valve” (Fig. 3-18). Early anatomists must have thought that the two-cusp structure of this valve resembled the hat of a bishop, which is known as a miter-hence, the more clinically popular name of **mitral valve**.

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Left Ventricle: *Open the left ventricle as shown in figure 3-20.* Note that the myocardium of the left ventricular wall is considerably thicker than that of the right ventricle¹⁶. In cross section, the actual relationship of the two ventricles can be better appreciated. In essence, the left ventricle forms the main part of the ventricular mass and extends to the apex, whereas the right ventricle looks like it was added on to the side. Observe the papillary muscles and chordae tendineae in the left ventricle. The left ventricular outflow is near the center of the heart base (Fig. 3-18).

Reflect a flap of the aortic wall large enough to allow examination of the aortic valve from the arterial side. If your animal was injected with red latex, you should have a nice cast of the aortic arch. Remove this cast and note the impressions made by the aortic valve. Try to identify the coronary and other arterial branches on the cast. Note that the valve is similar in structure to the pulmonary valve, and that the most proximal part of the aorta is “bulb-like,” forming the **aortic sinus**, from which the right and left coronary arteries originate (Fig. 3-18). Probe the openings of the coronary arteries from the aortic sinus and *remove some of the fat around the aorta* to expose the proximal parts of these arteries.

Fibrous Skeleton of Heart: The myocardium of the atria is separated and insulated from that of the ventricles of the

heart by a fibrous plate perforated by five ostia, which accommodate the four heart valves and the AV bundle of modified cardiac (*Purkinje*) fibers. In addition to serving as an *electrical insulator*, this fibrous plate, which often contains fibrocartilage, provides firm support for anchorage of the valve attachments.

Palpate the aortic valve attachments in the heart. In the ox, the fibrous annulus surrounding the aortic valve becomes partially calcified and forms two bones, the **ossa cordis**. Similar calcification of the fibrocartilage may occur in other species, but not as consistently as in the ox. The AV bundle penetrates the fibrous plate to conduct the electrical stimulus from the AV node to the ventricular muscle. The time delay, before the AV node releases the electrical stimulus through the fibrous plate allows for proper filling of the ventricles by contraction of the atrial musculature. This delay is represented in the ECG by the P-Q segment.

Auscultation of Heart Valves: It should be remembered that the thoracic limb largely covers the projection of the heart onto the thoracic wall. In the ox, this projection is from the second intercostal space (ICS) to the sixth rib, and the olecranon lies at about the level of the fifth costochondral junction (Fig. 3-21). Therefore, to listen to the heart sounds, it is necessary to move the thoracic limb cranially and to place the stethoscope between the thoracic limb and thoracic wall.

The valves are auscultated in the area about midway between horizontal lines through the shoulder joint and tuber olecrani. The site on the thoracic wall where each valve is best auscultated is referred to as the **punctum maximum** of that valve. *The points of maximum sound intensity do not necessarily correspond to*

¹⁶ In the newborn, this difference is much less than in more mature animals, which is related to the increased resistance offered by the pulmonary circulation prior to birth. In the fetus, right-side pressure is higher than left-side pressure, which is why flow through the ductus arteriosus is from pulmonary trunk to aorta. Once the lungs inflate and pulmonary resistance is drastically reduced, right-side pressure drops below that of the left side, and flow through the ductus reverses so that, prior to closure, flow is from aorta to pulmonary trunk.

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the exact anatomic position of the valves, but rather represent those points where the

sounds of valvular closure are best radiated to the chest wall (Fig. 3-21).

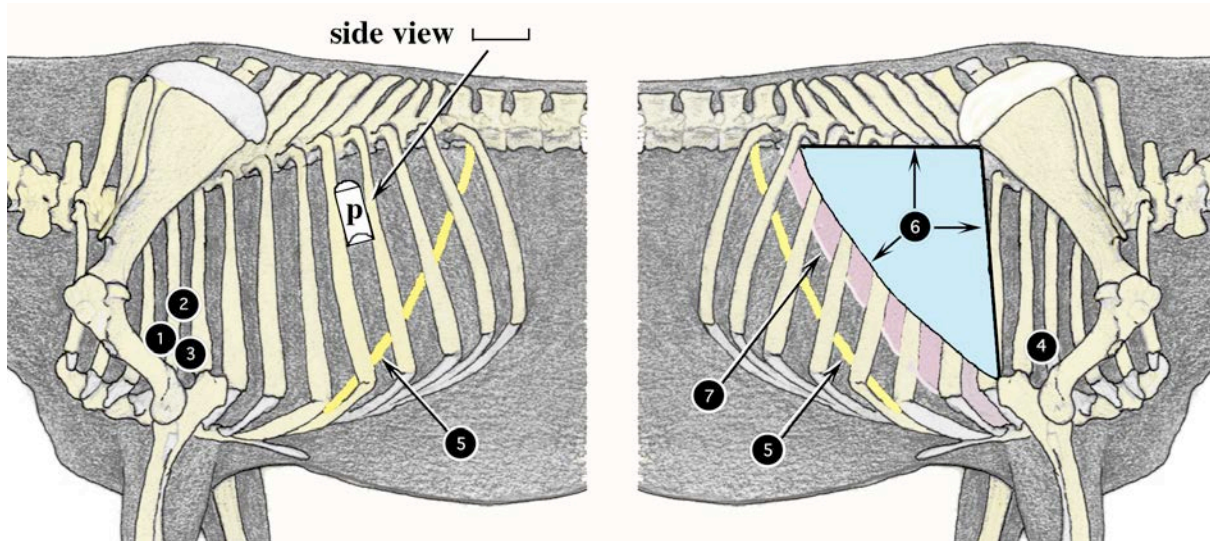


Figure 3-21. Thorax of ox indicating puncta maxima for auscultation of heart valves and area of lung percussion and *puncta maxima* for heart valves: (1) pulmonary valve; (2) aortic valve; (3) left AV valve; and (4) right AV valve; (5) line of pleural reflection; (6) approximate lung field as defined by percussion; (7) approximation of basal border of lung; (p) pleximeter correctly positioned in intercostal space.

On the left side, the pulmonary valve is best auscultated low in the third ICS, the aortic valve higher in the fourth ICS, and the left AV valve low in the fifth ICS in the horse (4th ICS in the ox). On the right side, the punctum maximum of the right AV valve is low in the third or fourth ICS (Fig. 3-21).

Introduction to Percussion:¹⁷ In today's medicine, we are surrounded by all types of high-tech diagnostic tools; viz., CT, ultrasound, nuclear imaging, and MRI. These are great tools, but they all require specialized equipment and are relatively expensive. One negative consequence of having so many "toys" is that students are less apt to develop some older, more low-tech diagnostic skills such as keen observation, palpation, and percussion. Of

these "old fashioned" skills, percussion may well be the most under utilized diagnostic modality. It is my objective in this section to provide a *brief introduction* of first-year veterinary students to the art of percussion.

Because radiography is not typically available "in the field," one method of clinical evaluation of the thorax in large animals is by way of percussion. Percussion is performed by tapping the body wall and listening to the sound produced. Any of you who have ever tapped on a wall trying to locate a stud to hang a heavy picture or mirror have already used percussion to evaluate what lies behind the wall. The hollow (resonant) sound you hear when you tap between the studs hopefully contrasts with the solid sound when you tap directly over a stud.

¹⁷ Percussion, like palpation, is an art; to become proficient requires practice.

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Sounds easy enough, but as you have probably noticed, the two sounds are not always that distinct. As you tapped along horizontally, approaching a stud, the sound got progressively duller (less hollow) until it reached a maximum dullness directly over a stud, and from there it would gradually become more resonant as you continued beyond the stud. So it is with “clinical percussion.” There are gradations in the quality of sounds produced by percussion of the body wall, which are largely dependent on the solid vs. hollow nature of the underlying organ or substance.

In other words, there are areas that are clearly resonant, other areas that are absolutely dull, and just about everything in between. These “in-betweens” can be thought of as areas of relative dullness. Because lungs of living animals typically contain air, it should come as no surprise that percussion over areas backed up by substantial normal lung produces a resonant (hollow) sound. Parts of gut (*viz.*, stomach, cecum), which may be distended with gas, produce a highly resonant or *tympanic* sound.

Likewise, when you percuss over areas backed-up by more solid organs (*viz.*, liver, spleen, or fluid-filled viscus), you should hear a dull (solid) sound. Using your knowledge of topographic anatomy, combined with your soon-to-be-gained experience with percussion of normal animals, you should be able to distinguish gross, if not subtle, differences between normal and abnormal with this technique.

The key to making percussion work for you is producing a good vibration in the body wall. In dogs, cats, and people, this can typically be accomplished by merely placing a finger firmly against the body and tapping it just proximal to the nail with the

middle finger of the other hand. *Problem-* Although more discriminating, the body wall of adult horses and cattle, is difficult to vibrate using “finger-tapping.” You may bloody your finger before you get the body wall to vibrate sufficiently. *Solution-* use a *hammer*; a rubber hammer such as that used to test patellar reflexes.

Another *problem-* if you hit your finger with this hammer hard enough to move the chest wall of a horse or cow, it will hurt.¹⁸ *Solution-* use something besides your finger. You need what is called a *pleximeter*,¹⁹ which in this case, is a solid flat object (about the size of a credit card cut-in-half lengthwise) that can be held firmly against the body wall and tapped with the rubber hammer. Although pleximeters may be available from a commercial source (?), you can make your own out of wood, plastic or metal. What ever you choose, *the important part is that you do not want to hear the sound of the hammer striking the pleximeter*; you are only interested in the sound produced by the *mediation of the vibration* through the body wall.

The idea is to set the pleximeter firmly against the body wall in the shallow troughs created by the intercostal spaces as indicated in figure 3-21. You do not want to place the pleximeter over a rib because that would produce vibration all along the bone

¹⁸ personal experience

¹⁹ pleximeter- a plate to be struck to mediate percussion. Some people claim that using the “finger method” is better in large animals. I wouldn’t argue that it is more discriminating, but weighing the overall negative impact it has on one’s finger, I think I’ll stick with the pleximeter method, or at least use a student’s finger. The pleximeter I have used for years is home-made and consists of a short metal strip with its ends turned up so that it can be grasped comfortably between the thumb and index finger (Fig. 3-21).

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and not localize the sound to the region of interest. Likewise, you do not want a pleximeter too wide to fit within the intercostal space.

With experience, you should be able to pretty well define the extent of the lung field using percussion. The degree of resonance produced by air-filled lung tissue is dependant, to a large degree, on the amount of lung tissue under the site of percussion. As you percuss over your expected area of lung field, you should note that the degree of resonance is greatest over the more dorsal lung field, and decreases as you move caudoventrally toward the basal border of the lung. In fact, you will typically lose the lung resonance before you reach the actual basal border of the lung, which as you recall, is *a moving target*. This is because the lung tapers toward its basal border, and it takes a certain minimum thickness of lung tissue to produce the resonant sound. Thus, the lung field, as defined by percussion is smaller than the actual lung field (Fig. 3-21).

Because the stomach (hollow organ) lies caudal to the diaphragm on the left side, the best place to learn percussion is on the right side, where the liver (solid organ) is in contact with the diaphragm and body wall. Dorsally, the area of lung percussion is limited by a line extending from the caudal angle of the scapula to the tuber coxae, which roughly corresponds with the lateral edge of the major epaxial muscles (Fig. 3-21). The caudal border of the brachial musculature (triceps brachii) forms the cranial boundary of this *percussion triangle*. The basal boundary curves slightly as it ascends from the tuber olecrani to the top of the next to last intercostal space.²⁰ As explained above, this line does *not*

correspond with the actual basal border of the lung (Fig. 3-21).

Live-animal Percussion (Horse or Ox): *Starting in the center of the percussion triangle as shown in figure 3-21, work your way caudoventrally until you define the basal border and mark it on the animal's side with a piece of chalk. Now move caudally and cranially, repeating this process in each intercostal space until you have marked the basal border of the lung as defined by percussion. Note the distinct difference between the resonant sound of the lung vs. the solid sound over the liver. Now, stand back and look at the area of lung percussion in the ox as related to the whole side of the animal. Pretty small huh? Congratulations, you have now been introduced to percussion; keep practicing.*

Auscultation of Lungs: Like percussion, auscultation is an art or skill that can only be developed through practice. It's another one of those "*use it or lose it*" talents. Lung sounds, as we can detect with a stethoscope, are thought to be produced by various degrees of turbulence as air moves through the larger components of the bronchial tree. Because there is little turbulence in a normal, relaxed animal, lungs sounds may well be difficult to hear, even with a good stethoscope. In contrast, the labored breathing of patients in severe respiratory distress can be heard quite well with your stethoscope still in your pocket.

Normal lung sounds are most audible near the tracheal bifurcation and become diminished as you move your stethoscope toward the peripheral lung areas. The sound should mimic that of a gentle breeze rustling the leaves of a tree; they tend to be louder during inspiration and softer during expiration.²⁰ In the relaxed horse, normal inspiratory lung sounds are heard only in the

²⁰ de Lahunta, A., and Habel, R.E.: *Applied Veterinary Anatomy*. W.B. Saunders, Philadelphia, 1986.

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area of the tracheal bifurcation. After exercise, the sounds are accentuated and can be detected over a larger area of the lung. In the ox, lung sounds are louder and harsher than in the horse.²⁰ *Using your stethoscope, try to auscultate the normal lung sounds in the area dorsal to the heart, just caudal to the triceps brachii. Compare the normal lung sounds of the horse and ox.*

DIAPHRAGM & THORACIC WALL

With the heart and lungs removed, we can gain a good appreciation for the structure of the diaphragm. Commensurate with the increased number of ribs in the horse, the diaphragm has a long, sloping angle when viewed from the side. Step back and take a look at how far it extends cranially. Most students are surprised that it almost reaches the fifth intercostal space, where the olecranon is located in the squarely standing animal (Fig. 3-1). This is also true in the ruminant and the pig, although the diaphragmatic angle is much steeper in the ox (Fig. 3-2).

Now turn your attention to the cranial surface of the diaphragm and the location of the mediastinal reflection from its surface. Although the dorsal part of the mediastinum is near the median plane, it deviates far to the left ventrally (Fig. 3-8). The plica vena cava extends ventrally and to the right from the **caval foramen** and then inclines back toward the sternum. The area between the plica vena cava and mediastinum is the **mediastinal recess**, which accommodates the accessory lobe of the right lung.

The **lumbar part** of the diaphragm originates from the lumbar vertebrae and is composed of the **right** and **left crura** (Fig. 3-8). The **aortic hiatus** is located between the two crura and accommodates, in addition to the aorta, the thoracic duct and azygos

vein. *From the left side of your cadaver, place the tip of a probe into the aortic hiatus and pull ventrally to define the division between the two crura.* You should observe that the right crus is considerably larger than the left and extends well across the median plane to the left side (Fig. 3-8). The **esophageal hiatus**, through which the esophagus and vagal trunks pass, is not located between the crura, but rather penetrates the larger right crus.

The third natural opening in the diaphragm is the **caval foramen**, which penetrates the central tendon and transmits the caudal vena cava (Fig. 3-8). Unlike the aortic and esophageal hiatuses, which can slide somewhat over the transmitted structures during excursion of the diaphragm, the adventitia of the caudal vena cava is fused with the central tendon. Especially prominent in the horse are the large **phrenic veins**, which converge to join the caudal vena cava at the caval foramen.

The muscular peripheral part of the diaphragm can be divided into **costal** and **sternal parts**, according to the area of attachment (Fig. 3-8). Follow the **costo-diaphragmatic recess** dorsally to identify the dorsal border of the diaphragm, which extends from the crura to the costal attachment. It is over this border, which is termed the **lumbocostal arch**, that the **greater** and **lesser splanchnic nerves** enter the abdominal cavity (Fig. 3-8). Follow the sympathetic trunks caudally and identify the splanchnic nerves as they leave the trunk and pass over the diaphragm.

Now turn your attention to the ventral surface of the thoracic cavity. The **internal thoracic vessels** pass under the **transverse thoracis muscle** (Fig. 3-13). *On one side, incise this muscle and trace the internal thoracic vessels caudally to the diaphragm.*

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Here the internal thoracic artery gives rise to the **musculophrenic artery**, which ascends along the costal attachment of the diaphragm. The parent artery is then continued under the diaphragm as the **cranial epigastric artery**. In the adult cow, the internal thoracic vein becomes markedly enlarged as it serves as part of a major route of venous return from the udder. It serves a similar purpose in the lactating sow.

Radiographic Anatomy of Equine Withers: The equine withers are occasionally radiographed (Fig. 3-22). Note that the spinous process of T1 is short in the horse, and is typically not imaged. These spinous processes are capped by cartilage in the young horse. Gradual ossification occurs with age, giving these tuberosities the appearance of being pathologic; however, this irregular appearance is normal.

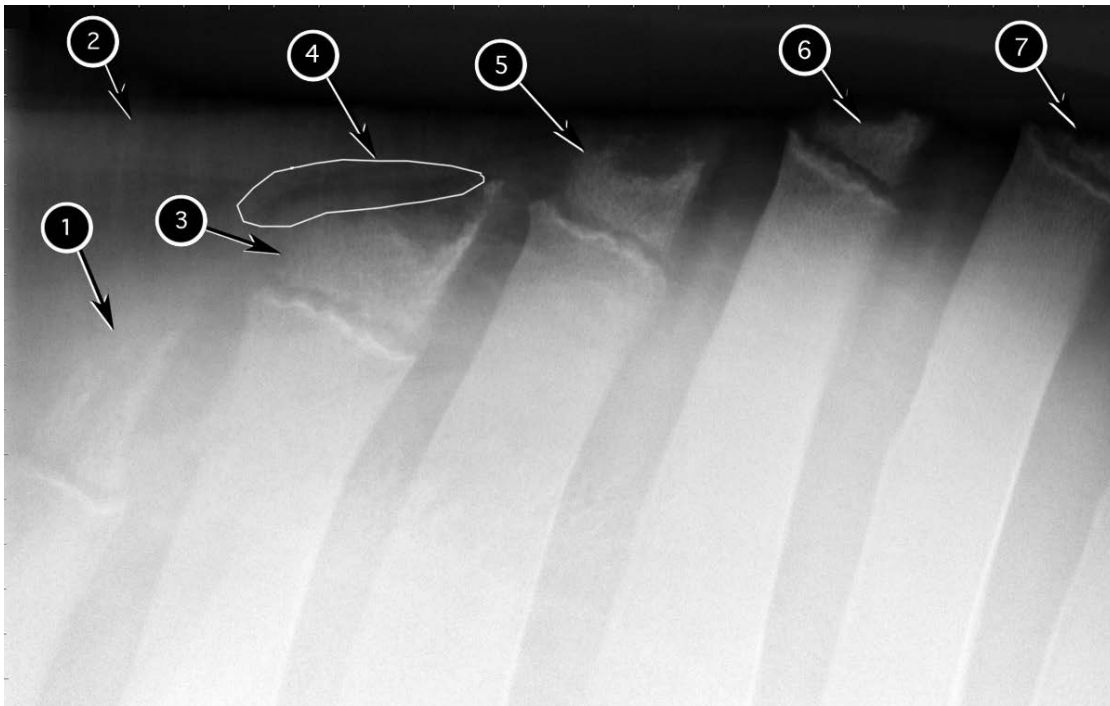


Figure 3-22. Left-Right Lateral radiograph of equine withers: (1) spinous tuberosity of T2; (2) funiculus nuchae; (3) spinous tuberosity of T3; (4) approximate location of supraspinous bursa; (5) spinous tuberosity of T4; (6) spinous tuberosity of T5; (7) spinous tuberosity of T6.

Radiographic Anatomy of Equine Thorax: Due to the size and thickness of the thorax of an adult horse, radiography of this region requires specialized, high-output x-ray equipment and the use of a grid to absorb the scattered radiation. Also, it is not possible to image the entire thorax in a single image. Typically 4 lateral projections, with the horse standing, are made using overlapping 14- x 17-inch cassettes.

Figures 3-23 and 3-24 illustrate the four radiographs required to image the thorax of an adult horse. The thorax of the young foal can be imaged, much like that of a large dog, with the foal in lateral recumbency on an x-ray table (Fig. 3-25).

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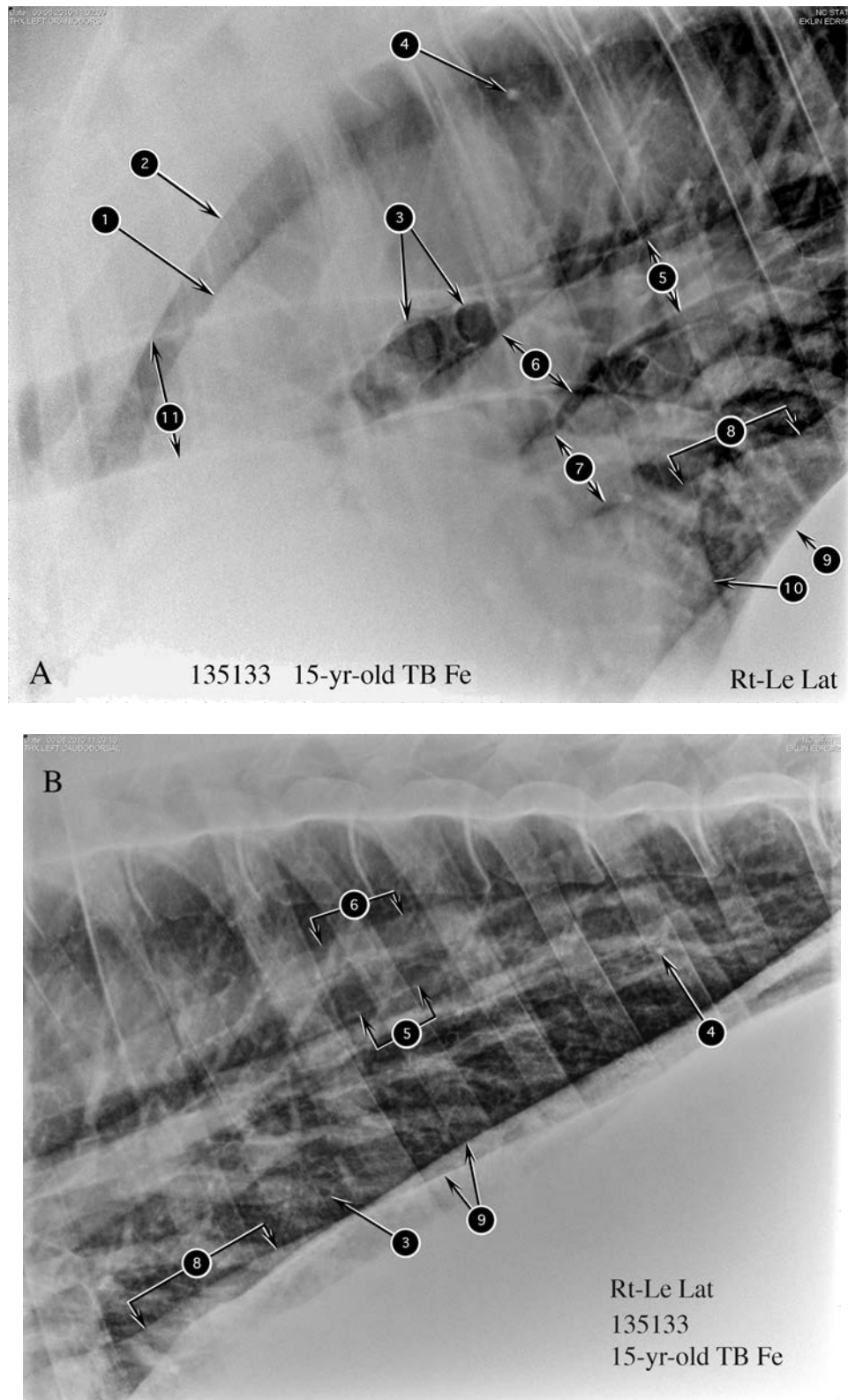


Figure 3-23. Right-Left Lateral views of (A) craniodorsal and (B) caudodorsal equine thorax: (1) aortic arch; (2) caudal border of scapula; (3) end-on views of bronchi; (4) end-on view of vessel in lung; (5) caudal lobar bronchus; (6) caudal lobar pulmonary artery; (7) caudal lobar pulmonary vein near left atrium; (8) caudal vena cava; (9) diaphragm; (10) caudal border of cardiac silhouette; (11) trachea.

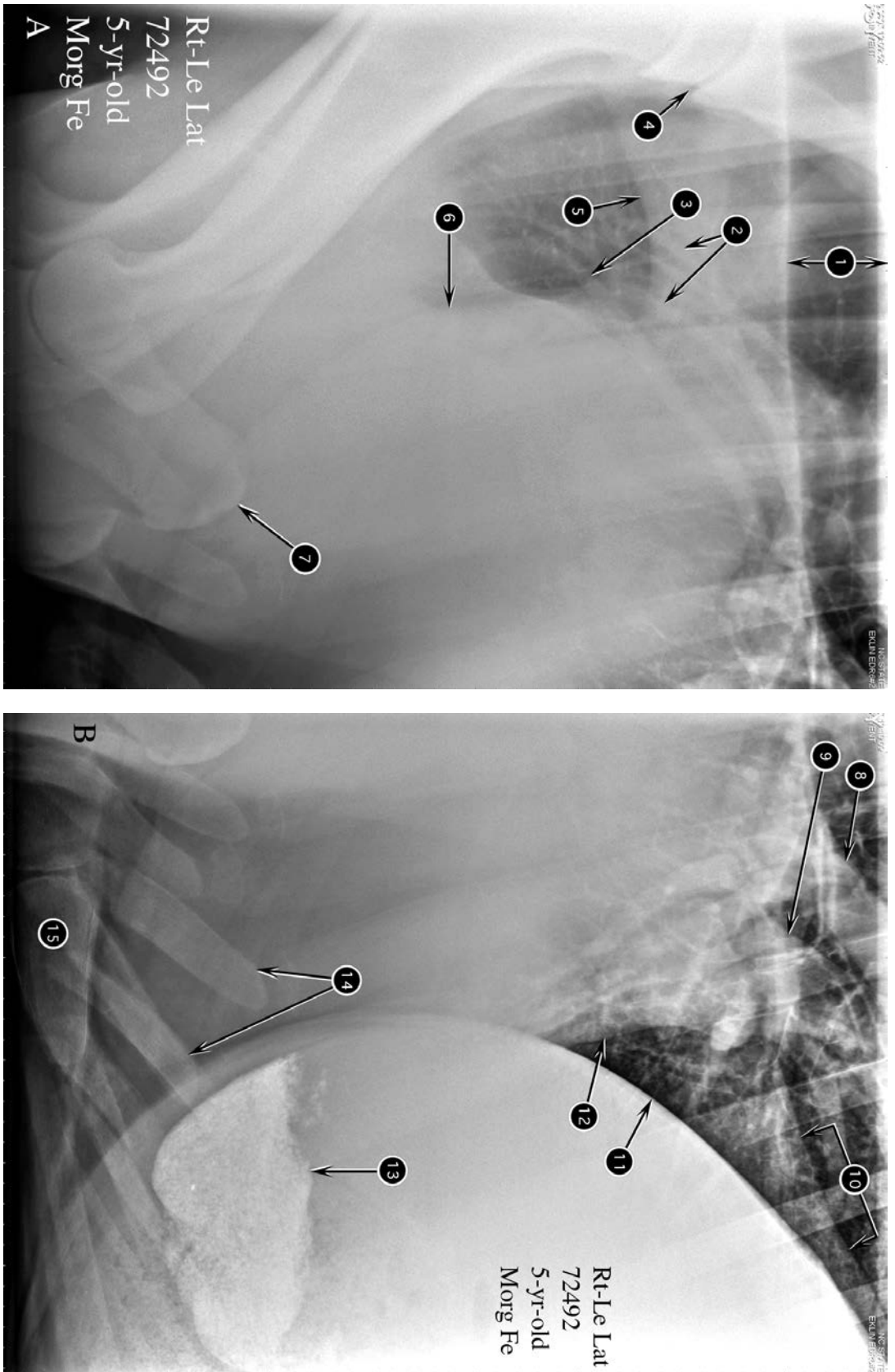


Figure 3-24. Right-Left Lateral views of (A) cranioventral and (B) caudoventral equine thorax: (1) trachea; (2) cranial lobar pulmonary arteries; (3) cranial lobar pulmonary vein; (4) shoulder joint; (5) cranial mediastinal structures; (6) cranial border of cardiac silhouette (area of right ventricle); (7) tuber olecrani; (8) caudal lobar pulmonary artery; (9) caudal lobar pulmonary vein near left atrium; (10) caudal vena cava; (11) diaphragm; (12) caudal border of cardiac silhouette (area of left ventricle); (13) sand in diaphragmatic flexure of colon; (14) costal cartilages showing some age-related

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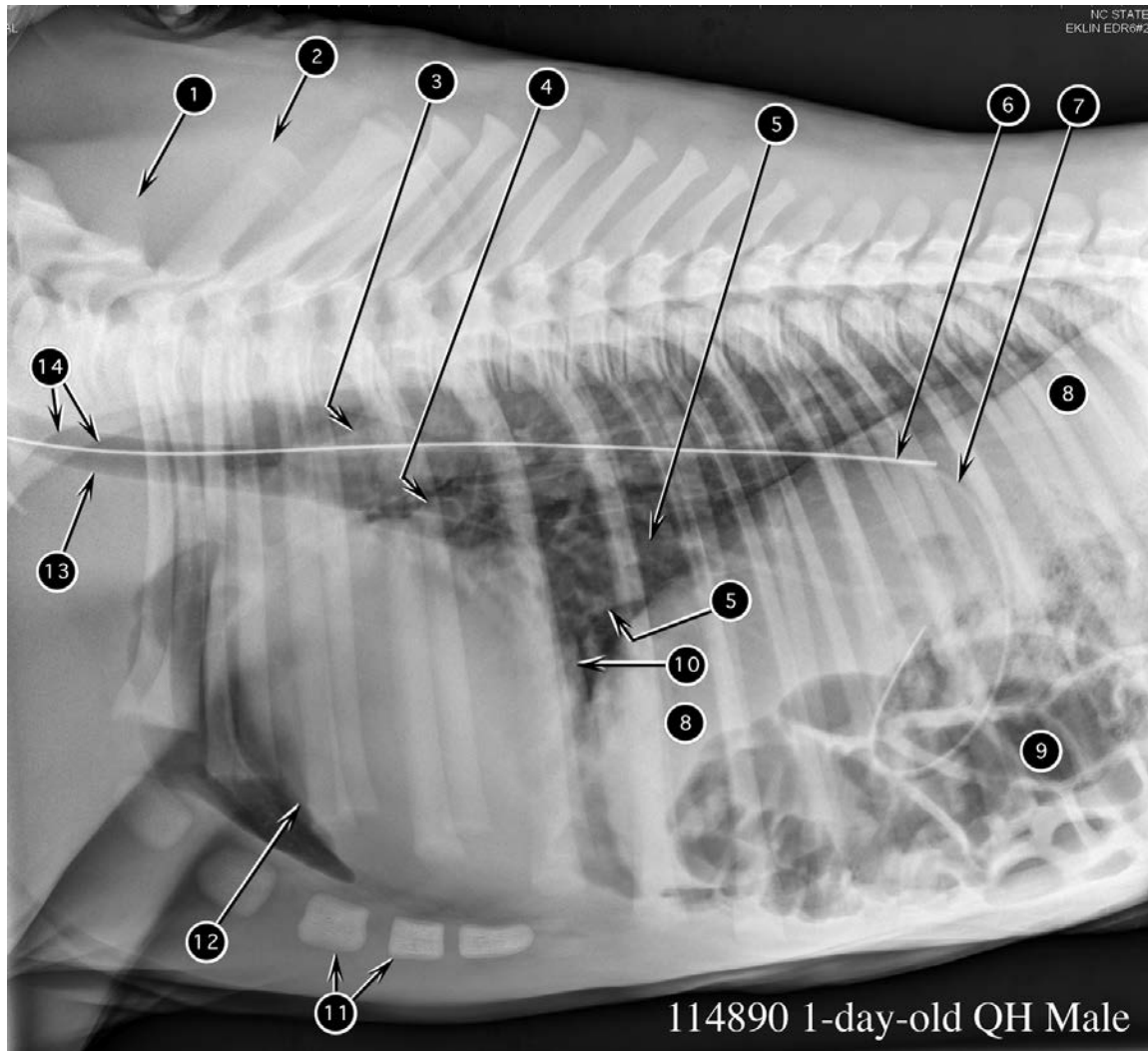


Figure 3-25. Right-Left Lateral radiograph of a 1-day-old foal: (1) spinous process of T1; (2) spinous process of T2; (3) aortic arch; (4) pulmonary artery; (5) caudal vena cava; (6) radiopaque marker in nasogastric tube located within esophagus; (7) continuation of tube within stomach; (8) liver; (9) intestinal gas; (10) caudal margin of cardiac silhouette in area of left ventricle; (11) sternbrae; (12) cranial margin of cardiac silhouette in area of right ventricle; (13) trachea; (14) caudal borders of scapulae.

Palpation and Auscultation Checklist for Thorax

Horse

1. Approximate the line of pleural reflection on the body surface (Figs. 3-1, 3-6).
2. Define the area of lung percussion in the live animal (Fig. 3-6).
3. Auscultate the heart and define the *puncta maxima* for the heart valves.
4. Auscultate the lungs.

Ox

1. Approximate the line of pleural reflection on the body surface (Figs. 3-2, 3-21).
2. Define the area of lung percussion in the live animal (Fig. 3-21).
3. Auscultate the heart and define the *puncta maxima* for the heart valves (Fig. 3-21).
4. Auscultate the lungs.

Chapter 4 • The Abdomen

EXTERNAL FEATURES

Unlike the carnivores, which occupy a higher position in the food chain, the domestic ungulates are either herbivores or omnivores and have evolved a more sophisticated digestive apparatus. Therefore, by necessity, they have a proportionately greater percentage of their trunk devoted to housing the larger organs required for fermentative digestion. Note how much of the abdominal cavity lies cranial to the costal arch and is thus protected by the thoracic cage (Figs. 3-1, 3-2). This portion of the abdominal cavity is sometimes referred to as the “intrathoracic” part. The lateral part of the abdominal wall that is not protected by the rib cage, pelvis, or thigh is called the **flank**. In the horse, the last rib is very close to the tuber coxae, leaving only about one hand's-width space in the upper flank. Surgical intervention in this area is therefore limited in the horse (Fig. 3-1).

Paralumber Fossa: This triangular depression in the upper part of the flank is especially prominent in the standing domestic ruminant, in which it is an important surgical area (Fig. 4-1). It is bounded dorsally by the transverse processes of lumbar vertebrae L2 to L5, cranially by the last rib, and caudoventrally by a tension ridge created by the weight of the abdominal viscera on the ventral part of the internal abdominal oblique (IAO) muscle. In the living horse and pig, the paralumber fossa is small and is not routinely appreciated.

There are typically six **lumbar vertebrae** in the horse, ox, sheep, and pig. Some sheep and pigs have seven, whereas some horses have only five. Goats usually have seven lumbar vertebrae. The tips of

transverse processes are important palpable landmarks for paravertebral anesthesia in the ox. Refer to the skeleton and note that the tip of L1 is protected by the last rib. Similarly, the tuber coxae prevents the tip of L6 from being palpable (Fig. 4-2). Thus, in the live cow, the tips of L2 to L5 are typically palpable, with L1 being palpable in some cases.

The **fold of the flank** is a skin fold that extends from the caudoventral abdominal wall to the craniomedial aspect of the thigh near the stifle. The **cutaneous trunci muscle** is contained within this fold, which accounts for the active twitching of the fold, especially in the horse (Fig. 3-3). The fold can also be used as a handhold in the restraint of calves and small ruminants—hence, the term “flanking a calf down.”

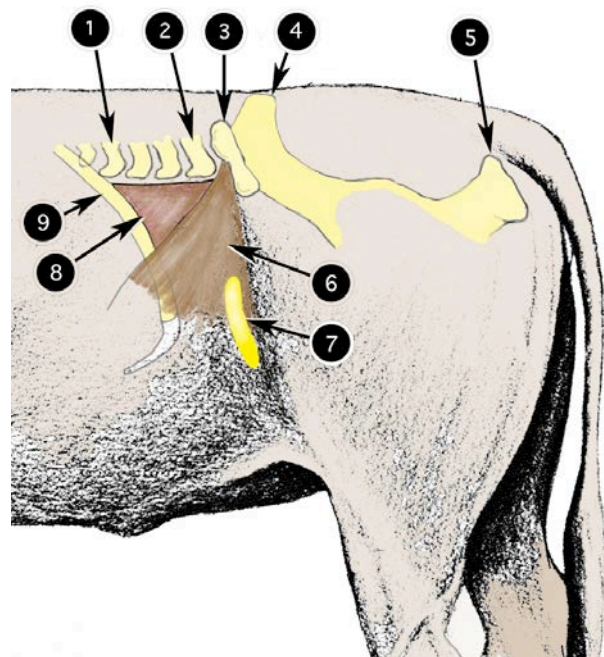


Figure 4-1. Paralumber fossa of ox: (1) transverse process of L2; (2) transverse process of L5; (3) tuber coxae; (4) tuber sacrale; (5) tuber ischiadicum; (6) caudoventral part of IAO muscle forming boundary of paralumber fossa; (7) subiliac lymph node; (8) dorsal part of IAO muscle; (9) last rib.

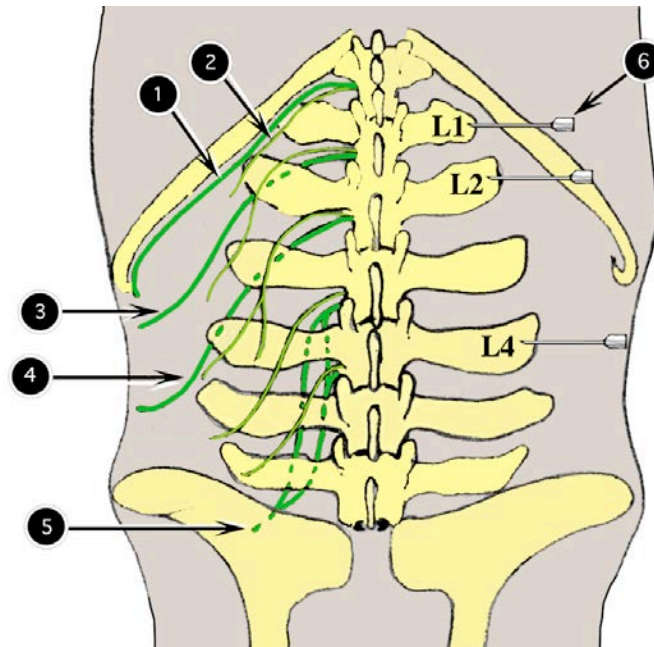


Figure 4-2. Lumbar nerves of ox, dorsal view: (1) ventral branch of spinal nerve T13; (2) dorsal branch of spinal nerve T13; (3) ventral branch of spinal nerve L1; (4) ventral branch of spinal nerve L2; (5) genitofemoral nerve formed by ventral branches of spinal nerves L3 & L4; (6) approximate needle placement for paravertebral anesthesia of spinal nerves T13 – L2 above & below transverse process of L1, L2, & L4. (Modified from *Applied Veterinary Anatomy*, de Lahunta and Habel, W. B Saunders, Co., 1986, p. 212.)

SUPERFICIAL STRUCTURES AND ABDOMINAL WALL

The **cutaneus trunci muscle** may have already been reflected. In well-muscled, fit horses, the caudal border of the cutaneus trunci, which extends from the flank fold craniodorsally over the abdominal wall, can be seen as a ridge in the live animal (Fig. 3-3). If the muscle has not been reflected, *reflect it now*.

Subiliac Lymph Nodes: Locate these lymph nodes in the fascia along the cranial aspect of the thigh, proximal to the stifle (*i.e.*, below the tuber coxae of the ilium). Compare those of the horse, the ruminant (Fig. 4-1), and the pig. These lymph nodes are not present in the dog and the cat. In addition to the skin over the thigh and stifle, these nodes drain the area of the flank.

These lymph nodes can be palpated in the ox in much the same way as the superficial cervical lymph nodes. *Place your fingertips against the body wall about midway between the tuber coxae and fold of the flank with the palm of the hand facing cranially. Press against the body wall and pull cranially until the lymph node rolls under your fingertips, returning to its original position. Do not give up too soon, as the cranial border of the tensor fasciae latae muscle may be felt prior to the lymph node. The lymph node is much larger than the muscle border.*

The lateral abdominal wall is formed by two oblique and one transverse abdominal muscle to provide a three-ply arrangement, with fibers in each successive layer oriented in a different direction. This, of course, provides for much greater strength than if it

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were a cheaper, single-ply model. More ventrally, the aponeuroses of the three lateral muscles form a sheath for the longitudinally oriented rectus abdominis muscle. Fusion of their aponeuroses along the ventral midline forms the **linea alba**.

Supporting several hundred pounds of viscera is a big job in the horse and the ox. After all, there is no rigid (skeletal) support between the xiphoid process cranially and the pubis caudally (Fig. 3-2). Thus, the abdominal muscles are under substantial tension in the standing animal, and “Parent Nature” has provided these large herbivores with a passive support in the form of the **elastic abdominal tunic** (*tunica flava abdominis*), which is a modification of the deep fascia that closely invests the **external abdominal oblique muscle** (Fig. 3-4).

Remove a section of the elastic tunic to reveal the underlying external oblique fibers. Test it for stretch and elasticity—good quality, yes? The elastic tunic takes some of the stress off the abdominal muscles and acts as sort of a “living girdle.”

*Preserving the underlying internal oblique muscle, cut the attachments of the external abdominal oblique muscle from the ribs and tuber coxae and reflect it ventrally. On the deep surface of the external abdominal oblique, note the **musculotendinous junction** (the curved line along which muscle meets aponeurosis). Fold the muscle back up to its original position, and note the location of the muscle-aponeurosis junction (Fig. 3-3).*

In the resting animal, expiration is typically a passive process, accomplished largely by the normal elastic recoil of the lungs and thoracic walls. In animals with chronic pulmonary disease, much of this important elastic recoil is lost, forcing them

to recruit their abdominal muscles to assist with active expiration. Over time, the abdominal muscles, by necessity, become stronger and hypertrophied (thickened); however, the aponeurosis does not change in response to this added work.

Thus, the muscle-aponeurosis junction becomes accentuated in the live animal as a curved ridge, indicating that the abdominal muscles are more active in expiration than is normal. Obviously, this is not a desirable characteristic for an athletic or endurance animal, and the correlation of this so-called “heave line” with the presence of emphysema (“heaves”) in the horse puts the veterinarian on the alert to the condition. Such an animal is often referred to as being “wind broke” (*i.e.*, respiratorily challenged).

The **internal abdominal oblique muscle** of the ox covers the entire paralumbar fossa and is divided into two parts (Fig. 4-1). The dorsal part terminates on the last rib, whereas the aponeurosis of the ventral part passes lateral to the costal arch and continues to the linea alba. Because the ventral part of the muscle is under tension by the weight of the abdominal viscera in the standing ox, a ridge is formed along its upper border. It is this tense ridge that forms the caudoventral border of the paralumbar fossa.

Paravertebral Anesthesia in Ox: Regional anesthesia of the flank is important in ruminants to perform surgical procedures such as rumenotomy and cesarean section. Of principal concern in anesthesia of the flank are the **dorsal and ventral branches of spinal nerves T13, L1, and L2**. All students should understand the distribution of these nerves in the ruminant (Figs. 4-2 & 4-3).

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Several methods of paravertebral anesthesia can be used. One method involves blocking the nerves near their exit from the vertebral canal. This technique also blocks the motor innervation to the epaxial muscles, which some consider to be an undesirable side effect. The loss of epaxial muscle tone on the anesthetized side causes the vertebral column to deviate or bow, with the convexity toward the anesthetized side.

Another method has been devised in which the nerves are blocked as they cross the tips of the transverse processes of **L1**, **L2**, and **L4** (Fig. 4-2). The dorsal and ventral branches are blocked above and below the tips of these processes. *Because of some variation in the course of these nerves, anesthesia at the tip of the*

transverse process of L3 might be a good idea. Why not, you're already in the neighborhood, so why take chances?

*Carefully cut the attachment of the internal abdominal oblique muscle along the last rib and then cut it vertically ventral to the tuber coxae; reflect it ventrally. This should reveal the large **ventral branches of the spinal nerves** crossing the surface of the **transverse abdominis muscle** (Fig. 4-3).*

In the ox note that in the area of the paralumbar fossa, the transverse abdominis muscle is aponeurotic, not muscular. Thus, surgical incisions limited to the paralumbar fossa of the ox do not involve cutting the transverse muscle proper, only its aponeurosis.

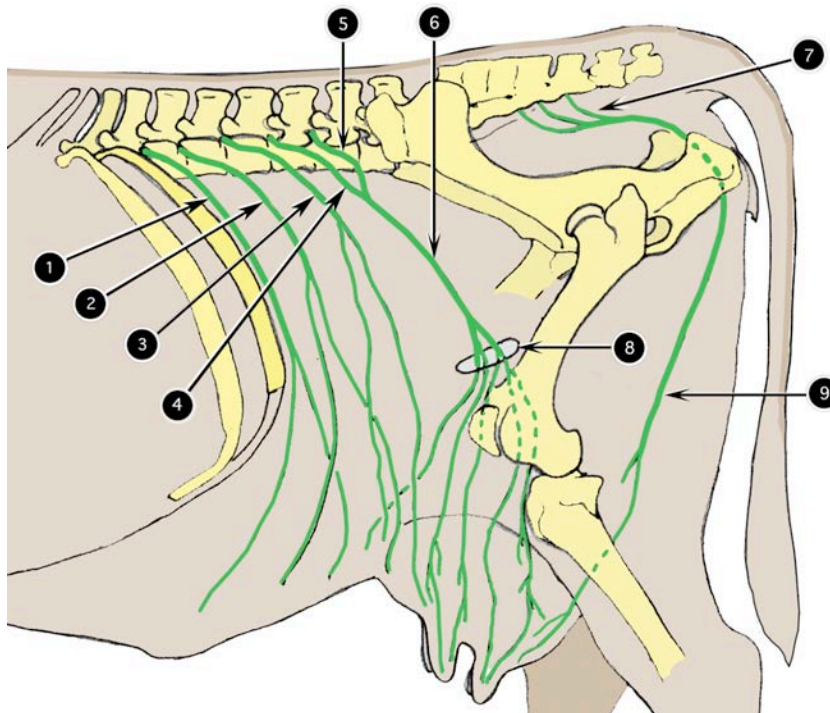


Figure 4-3. Lumbar and superficial perineal nerves of ox: (1) ventral branch of spinal nerve T13; (2) ventral branch of spinal nerve L1; (3) ventral branch of spinal nerve L2; (4) ventral branch of spinal nerve L3; (5) ventral branch of spinal nerve L4; (6) genitofemoral nerve; (7) ventral branches of spinal nerves S2 – S4; (8) superficial inguinal ring; (9) superficial perineal nerve. (Modified from Getty: *Atlas for Applied Veterinary Anatomy*, Iowa University Press, 1964.)

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In contrast, note that the transverse abdominis of the horse is fleshy in this region. Also, in the horse, you should note several rather prominent vessels in the upper flank, emanating from near the tuber coxae. These vessels, which are **cranial branches of the deep circumflex iliac artery and vein**, have to be dealt with in surgeries involving dorsal flank incisions in the horse.

As the internal abdominal oblique muscle is reflected further, note that its aponeurosis fuses with that of the external oblique to form the **external lamina** of the sheath for the **rectus abdominis muscle**. Also, the transverse abdominis passes deep to the rectus muscle, thereby forming the **internal lamina** of the sheath. Note that the rectus abdominis muscle of these herbivores, with their more rotund abdomen, is considerably wider than that of carnivores.

*Carefully cut the attachment of the transverse abdominis muscle along the lumbar transverse processes, along the caudal border of the last rib, and vertically ventral to the tuber coxae. Reflect the abdominal-wall flap ventrally. This should expose the underlying, **parietal peritoneum**. Carefully incise the parietal peritoneum around the boundaries of the flank and reflect it ventrally to expose the abdominal viscera. Don't move anything around until everyone has had the opportunity to study the *in situ* positions; i.e., don't mess anything up, yet. With the last rib and costal arch left in place for reference, carefully incise the diaphragm from the ribs only, and reflect it craniodorsally to expose more of the abdominal viscera. Do not cut any attachments of the diaphragm to the abdominal organs.*

ABDOMINAL TOPOGRAPHY

Because of major species differences at this point, it is imperative that each student observe *both* sides of *all species* before the position of the abdominal organs has been altered.

In the suspended animals, it must be recognized that there is an artifactual "sag effect" of the abdominal viscera, which gives the false impression that the abdominal organs do not contact the sublumbar musculature. Actually the abdominal walls stretch as necessary to accommodate the contents of the abdominal cavity- no more, no less. The normal peritoneal cavity is *a potential space*, containing only a thin layer of peritoneal fluid, spread out around the organs. (How much? *Just enough*.)

Left Side of Horse: Most of the dorsal flank area is occupied by a mixture of jejunum (smooth) and descending colon (haustrated) resting on the ascending colon. The pelvic flexure of the colon may be noted near the pelvic inlet in the left flank (Fig. 4-4). Part of the spleen may be seen projecting from under the last rib. With the diaphragm reflected, you should be able to see the spleen, the greater curvature of the stomach, and part of the left lobe of the liver.

Right Side of Horse: The upper right flank area is occupied by the base of the cecum, which more ventrally is continuous with the body of the cecum (Fig. 4-5). Part of the right ventral colon may also be noted in the concavity of the cecum, which inclines medially. With the diaphragm reflected, you should be able to see the descending duodenum, the right kidney, the right lobe of the liver, and more of the ascending colon.

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Left Side of Ruminant: In the adult, almost the entire left side of the abdominal cavity (and more) is occupied by the rumen, with the dorsal sac located in the paralumbar fossa. The ventral sac is covered by the superficial wall of the greater omentum. With the diaphragm reflected, you should be able to see the spleen, the cranial sac of the rumen, and the reticulum (Fig. 4-6).

In the newborn calf, the rumen is small and deflated. Most of the left flank is occupied by small intestine that may be partly covered by the greater omentum, which attaches ventrally to the abomasum (Fig. 4-7). Depending on the amount of sublumbar, retroperitoneal fat, you may also be able to identify the left kidney. With the diaphragm reflected, you should be able to see the spleen and the ruminoreticulum (Fig. 4-7).

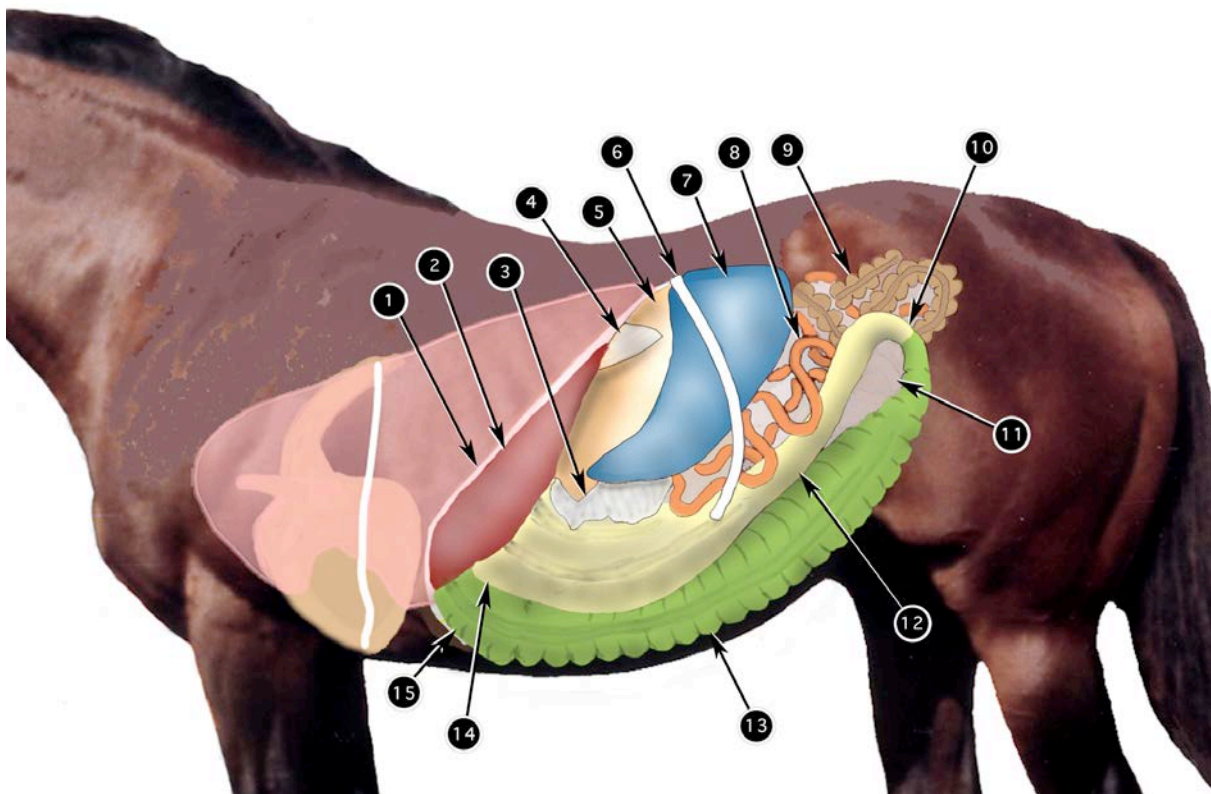


Figure 4-4. Abdominal organs of horse *in situ*, left side: (1) diaphragm at midline; (2) left lobe of liver; (3) greater omentum; (4) left triangular ligament of liver; (5) fundus (saccus cecus) of stomach; (6) last rib; (7) spleen; (8) jejunum; (9) descending colon; (10) pelvic flexure of ascending colon; (11) mesocolon; (12) left dorsal part of ascending colon; (13) left ventral part of ascending colon; (14) diaphragmatic flexure of ascending colon; (15) sternal flexure of ascending colon.

Right Side of Ruminant: Typically, the only organ identifiable on initial reflection of the parietal peritoneum is the descending duodenum (Fig. 4-8). Dorsal to the duodenum is the mesoduodenum, which

contains fat and the right lobe of the pancreas; ventral to the duodenum is the superficial wall of the greater omentum, which typically contains a great deal of fat. The caudal free fold of the greater omentum

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may also be identified (Fig. 4-8). With the diaphragm reflected, you should be able to see the liver and gallbladder, part of the abomasum, and the omasum, which is covered by the lesser omentum.

In the newborn calf, most of the right flank area is occupied by the intestines, but the large liver of the newborn projects caudal to the last rib. Ventral to the costal arch, you can see the abomasum, which is crossed by the large, flat round ligament of the liver (fetal umbilical vein) (Fig. 4-9).

Left Side of Pig: Unlike that of other adult domestic ungulates, the **cecum** of the pig is typically located near the dorsal part of the left flank and closely associated with the cecum is the spiral part of the ascending colon. More ventrally, you can see many loops of the jejunum (smooth) and more haustrated coils of the spiral colon. With the diaphragm reflected, you should be able to see the left kidney, the spleen, the stomach, and the liver.

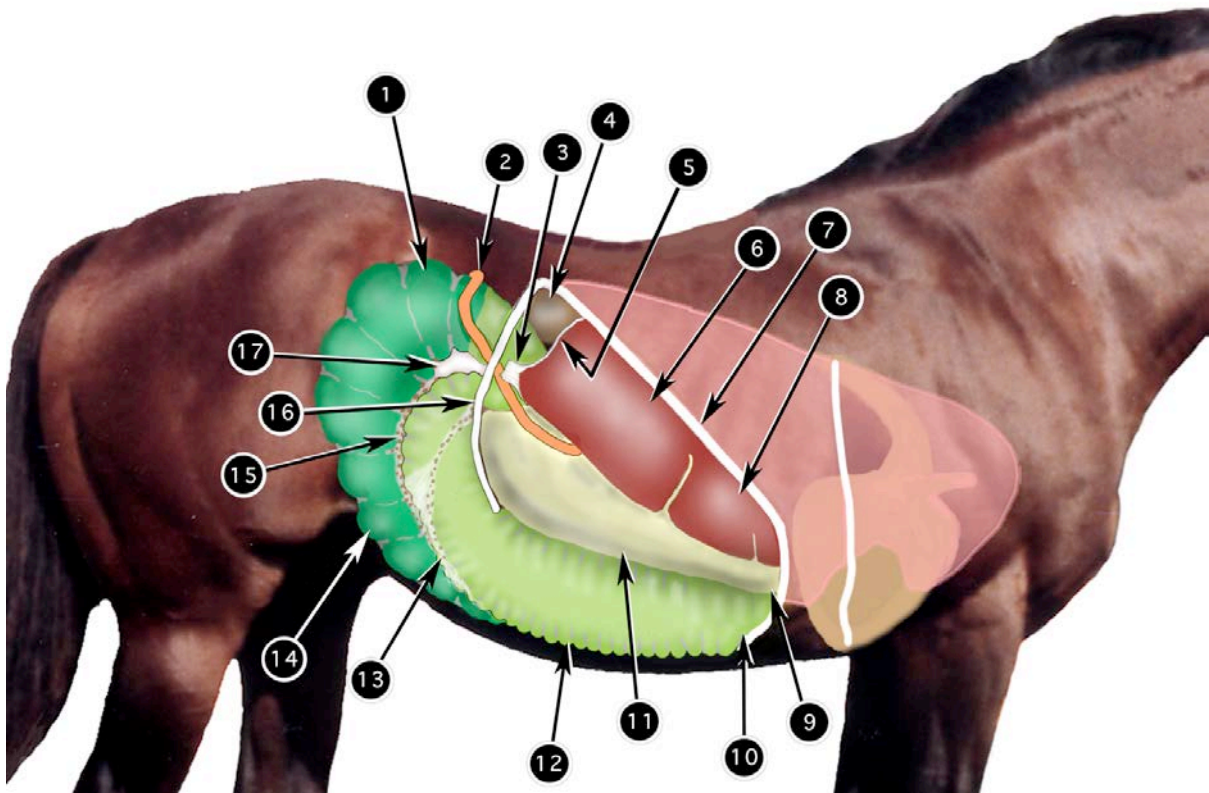


Figure 4-5. Abdominal organs of horse *in situ*, right side: (1) base of cecum; (2) caudal flexure of duodenum; (3) right triangular ligament of liver; (4) right kidney; (5) coronary ligament of liver; (6) right lobe of liver; (7) diaphragm; (8) quadrate lobe of liver; (9) diaphragmatic flexure of ascending colon; (10) sternal flexure of ascending colon; (11) right dorsal part of ascending colon; (12) right ventral part of ascending colon; (13) band of ascending colon with colic lymph nodes and attachment of cecocolic fold; (14) body of cecum; (15) band of cecum with cecal lymph nodes and attachment of cecocolic fold; (16) last rib; (17) proximal part of cecocolic fold.

Right Side of Pig: In the non-pregnant animal, most of the caudal part of the

abdominal cavity is filled with intestines, primarily jejunum. Part of the liver and the

Chapter 4 • The Abdomen

gallbladder project beyond the costal arch. With the diaphragm reflected, you should be able to see the right kidney and more liver.

EMBRYOLOGY- The Key to Understanding the Abdomen

As you can now appreciate from the diversity of abdominal relationships among domestic ungulates, there is a lot to learn here. Attempting to *memorize* all the names and relationships of the various abdominal organs and attachments is not only difficult, but the information is soon forgotten. *The key to understanding the final relationships of the abdominal viscera and their peritoneal attachments is to understand*

their embryologic development. If you help build a house, you don't have to memorize where all the electrical outlets are- you know there is one behind the couch because you put it there.

Similarly, if you understand how the simple digestive tube of the embryo was originally attached to the body wall, and how it lengthened, expanded, and rotated to form specific parts of the bowel, then everything makes sense and the complex becomes relatively easy to comprehend, even when multiple species are considered. Therefore, as we proceed, we shall make many references to the embryologic development of the abdominal viscera.

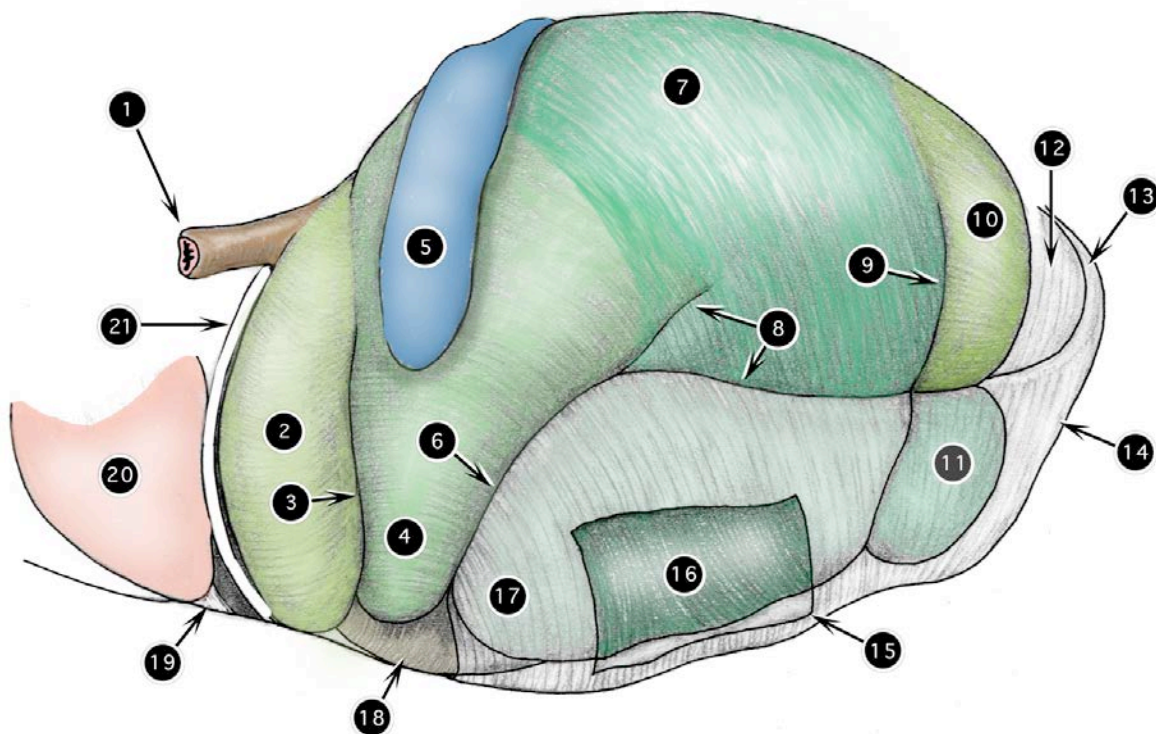


Figure 4-6. Adult ox stomach and spleen, left lateral view: (1) esophagus; (2) reticulum; (3) ruminoreticular groove; (4) cranial sac of rumen; (5) spleen; (6) cranial groove of rumen; (7) dorsal sac of rumen; (8) left longitudinal groove of rumen; (9) left dorsal coronary groove of rumen; (10) caudodorsal blind sac of rumen; (11) caudoventral blind sac of rumen; (12) deep wall of greater omentum; (13) caudal free fold of greater omentum; (14) superficial wall of greater omentum; (15) window cut in superficial wall of greater omentum; (16) ventral sac of rumen; (17) recess of rumen; (18) body of abomasum; (19) sternopericardiac ligaments; (20) pericardium; (21) diaphragm.

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REVIEW OF PERITONEUM

Before we go any further, let's talk peritoneum. The peritoneum is the serous membrane that lines the walls of the abdominal cavity, extends partially into the pelvic cavity, envelops the descended testes of the male, completely or partially covers all organs in the abdominal cavity, and forms multiple connections among structures. Note that the word is *singular*- it is one continuous membrane that does all the above. Anatomists apply regional names to specific parts of this membrane. Here is the way I like to "outline" the peritoneum:

Parietal Peritoneum- lines the walls of the abdominal cavity; extends into the pelvic cavity, and outside the cavity in the male (and bitch) through the inguinal canals (from somatic mesoderm)

Visceral Peritoneum- closely invests an organ's surface; adherent to that surface (from splanchnic mesoderm)

Connecting Peritoneum- double folds of peritoneum that connect things

Mesentery- connects the bowel to the body wall (*e.g.*, mesoduodenum, mesocolon); in the broader usage, connects some other organ to the body wall (*e.g.*, mesorchium, mesovarium)

Omentum- attaches the stomach to something; the greater omentum connects the stomach to the body wall (embryologically it was the dorsal mesogastrium), and the lesser omentum attaches the stomach to the liver (embryologically was part of ventral mesogastrium)

Fold- connects different parts of the bowel or other organ to one another (*e.g.*, ileocecal fold, genital fold)

Ligament- connects organs other than the bowel to the body wall or to the bowel (*e.g.*, broad ligament, falciform ligament, gastrosplenic ligament)

Before things get pulled too much out of shape, let's have some fun and take a little tour of some of these peritoneal attachments.

Attachments of Liver to Diaphragm: As was demonstrated when you tried to reflect the diaphragm away from the liver, there are numerous attachments between these two structures. In fact, the liver is attached to the diaphragm by a short ligament that encircles the caval foramen and esophageal hiatus- thus, the term **coronary ligament** (Fig. 4-5).¹ You can demonstrate the line of attachment of this short ligament by pushing your fingers between the liver and the diaphragm until they are stopped by the coronary ligament. Now feel around the coronary ligament. At each end (right and left) of the coronary ligament, the attachment is continued by a peritoneal fold, which, when pulled out, forms a triangle between the liver and the diaphragm-- hence, the terms **right** and **left triangular ligaments** (Figs. 4-4 & 4-5). Locate and identify the triangular ligaments.

Round and Falciform Ligaments of Liver: All students should observe these structures in the newborn calf (Fig. 4-9). In fetal life, the **umbilical vein** served to transport the highly oxygenated blood from the placenta to the liver (Fig. 3-19).

¹ coronary- to encircle like a crown. It does not mean *pertaining to the heart*, as is frequently assumed.

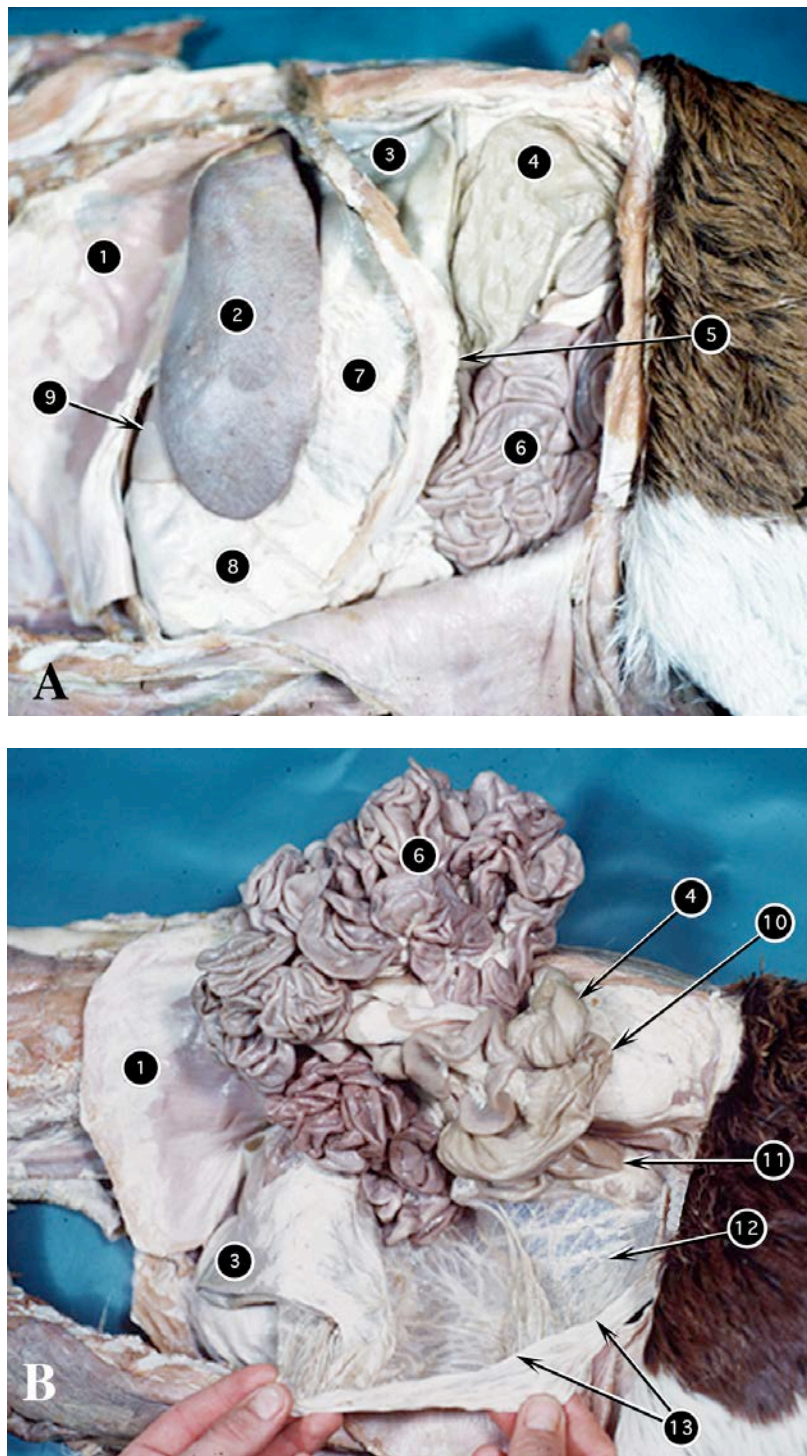


Figure 4-7. Opened abdomen of newborn calf, left side: (A) *in situ*; (B) with spleen removed and intestines reflected dorsally: (1) diaphragm; (2) spleen; (3) rumen; (4) cecum; (5) last rib; (6) jejunum; (7) greater omentum; (8) abomasum; (9) reticulum; (10) proximal loop of ascending colon; (11) caudal flexure of duodenum; (12) deep wall of greater omentum forming wall of supraomental recess; (13) caudal free fold of greater omentum. (Please Note: Some of the pictures in this section were made before gloves were invented.)

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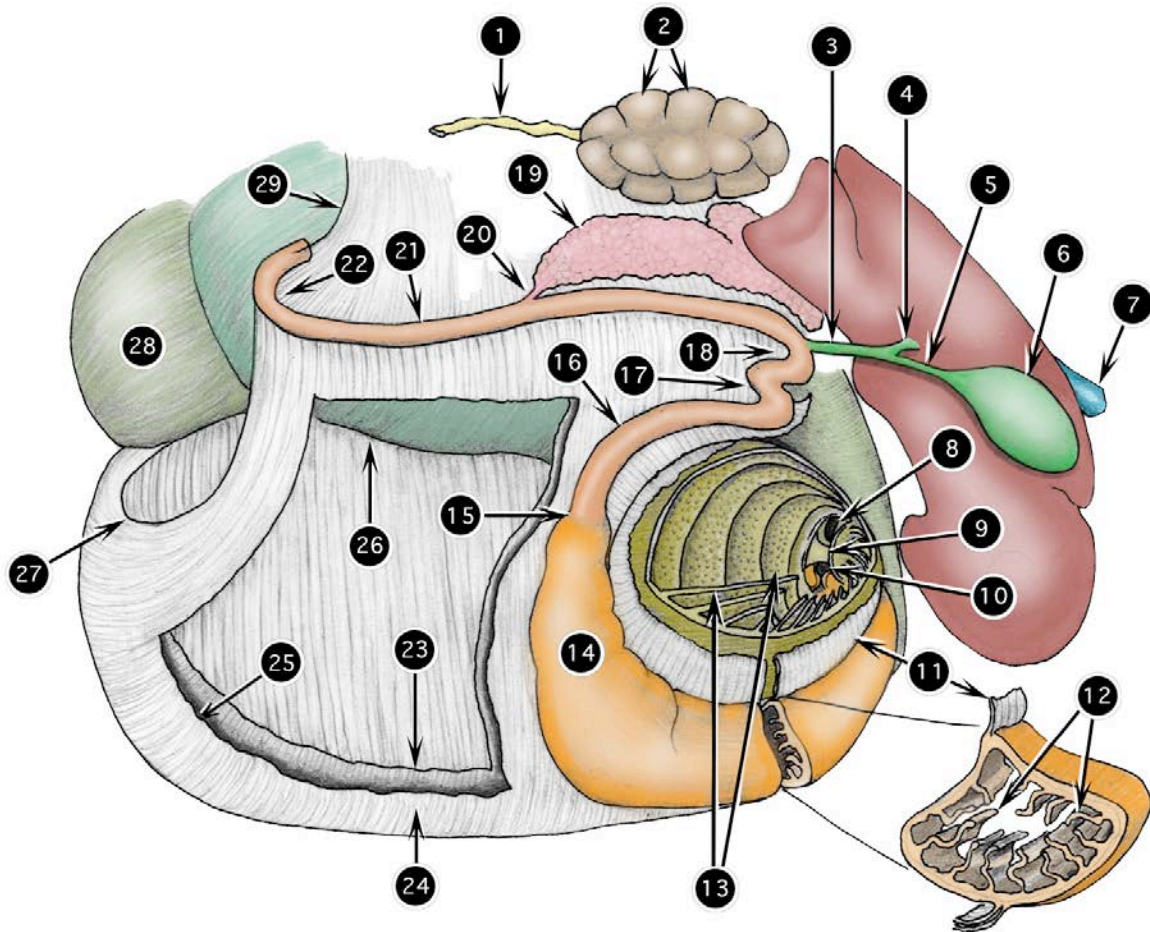


Figure 4-8. Adult ox abdominal viscera, right lateral view: (1) right ureter; (2) lobes of right kidney; (3) bile duct; (4) common hepatic duct; (5) cystic duct; (6) gallbladder; (7) caudal vena cava; (8) reticulo-omasal opening; (9) omasal pillar; (10) omasoabomasal opening; (11) lesser omentum; (12) spiral folds of abomasum; (13) omasal laminae; (14) pyloric part of abomasum; (15) pylorus; (16) cranial part of duodenum; (17) sigmoid flexure of duodenum; (18) cranial flexure of duodenum; (19) right lobe of pancreas; (20) accessory pancreatic duct; (21) descending duodenum; (22) caudal flexure of duodenum; (23) deep wall of greater omentum; (24) superficial wall of greater omentum; (25) omental bursa; (26) right longitudinal groove of rumen; (27) caudal free fold of greater omentum; (28) caudodorsal blind sac of rumen; (29) mesoduodenum.

In the ruminants and carnivores, an internal shunt, the **ductus venosus**, persists until birth. About 10% of the umbilical blood by passes the liver through the ductus venosus and flows directly to the caudal vena cava. *Do not attempt to dissect the ductus venosus.* After birth, the umbilical vein atrophies to form the **round ligament of the liver** (Fig. 4-9).

Another peritoneal fold, which embryologically represented that part of the

ventral mesogastrium between the liver and the body wall, is associated with the liver and umbilical vein (round ligament of liver). By carefully passing your finger behind the round ligament of the liver from caudal to cranial, you should note that it is enclosed in a thin peritoneal fold, the **falciform ligament** (Fig. 4-9).

With the diaphragm reflected, you should be able to see that the falciform ligament is attached to the parietal surface of

the liver, along a line from the notch where the umbilical vein entered the liver to the area of the caval foramen (Fig. 4-9). Unlike the falciform ligament of the dog, that of the ox does not serve to enclose a major fat

depot. The notch for the entry of the round ligament (umbilical vein) into the liver marks the division between the quadrate and left lobes.

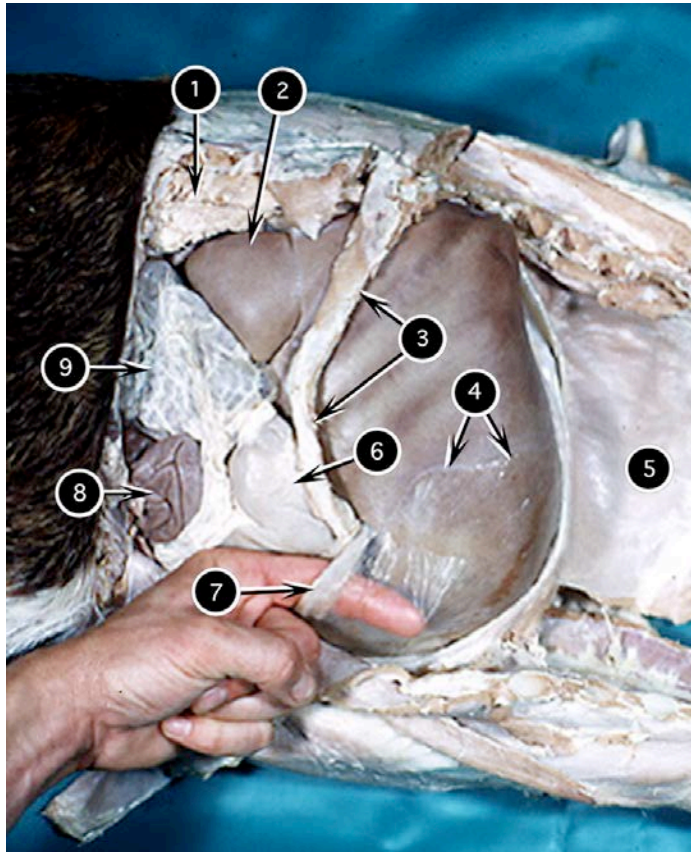


Figure 4-9. Opened abdomen of newborn calf, right side: (1) sublumbar fat surrounding right kidney; (2) caudate process of liver; (3) last rib; (4) line of attachment of falciform ligament; (5) reflected diaphragm; (6) pyloric part of abomasum; (7) fetal umbilical vein, now forming round ligament of liver in free edge of falciform ligament; (8) jejunum; (9) superficial wall of greater omentum.

Attachments of Stomach and Duodenum to Body Wall: Embryologically, the stomach primordium and proximal duodenum are attached to the dorsal and ventral body walls by the dorsal and ventral mesogastria (Fig. 4-10). The liver primordium grows ventrally from the duodenum and develops between the layers of the **ventral mesogastrium**. As previously noted, that part of the ventral mesogastrium between the liver and the

body wall becomes the falciform ligament, and that part between the stomach and liver becomes the **lesser omentum**.

The dorsal part of the stomach primordium grows faster than the ventral part, thus creating **greater** (dorsal) and **lesser** (ventral) **curvatures**. As the greater curvature (dorsal part) rapidly expands, it becomes “top-heavy” and “flops over” to the left side, carrying with it the dorsal

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mesogastrium, which becomes the **greater omentum**. After it flops over, the greater curvature, which now faces to the left, continues to grow faster so that the stomach now rotates around a dorsoventral axis, carrying the pylorus to the right and cranially (Fig. 4-11).

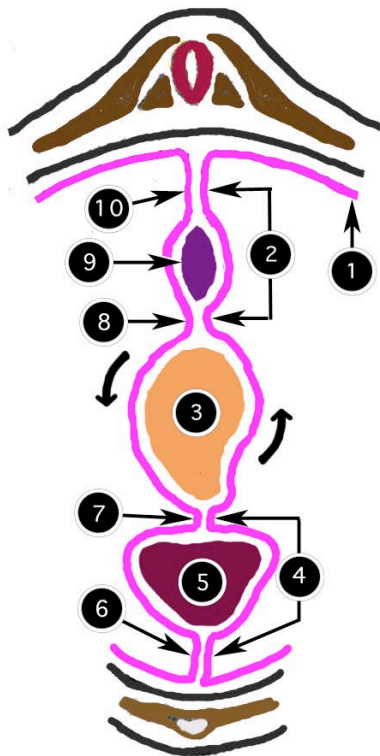


Figure 4-10. Schematic representation of embryonic attachments of developing stomach, transverse section, caudal view: (1) parietal peritoneum; (2) dorsal mesogastrium; (3) stomach primordium; (4) ventral mesogastrium; (5) liver developing within 4; (6) becomes falciform ligament; (7) becomes lesser omentum; (8) becomes gastrosplenic ligament; (9) spleen developing within 2; (10) becomes greater omentum. Arrows indicate the direction of *initial gastric rotation* around a longitudinal axis so that the dorsal part (greater curvature) of the stomach moves over to the left side. (Modified from, *The Viscera of the Domestic Mammals*, Schummer, et al., Springer-Verlag, 1979, p. 12.)

In the ruminant, continued expansion and modification along the proximal part of the greater curvature, now facing the left,

results in the formation of the rumen and reticulum. Similarly, an outgrowth and modification near the lesser curvature results in formation of the **omasum** (Fig. 4-12). Knowing this, it makes sense that, in the adult animal, the greater omentum is closely associated with the ruminoreticulum and greater curvature of the abomasum, whereas the lesser omentum is related to the omasum and lesser curvature of the abomasum (Fig. 4-12). Conversely, the attachments of the greater and lesser omenta in the adult animal mark the embryonic greater and lesser curvatures of the stomach. Contrary to a popular misconception, *no part of the ruminant stomach develops from the embryonic esophagus*.

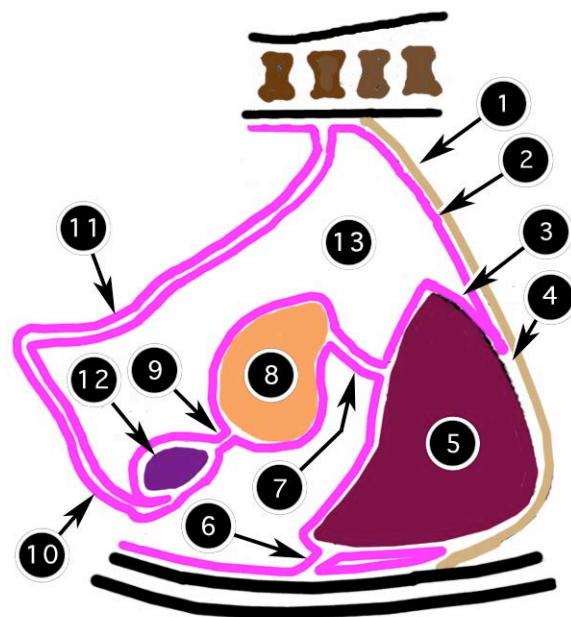


Figure 4-11. Schematic representation of peritoneal attachments following embryonic rotation of stomach around a dorsoventral axis, sagittal section, right lateral view: (1) diaphragm; (2) parietal peritoneum; (3) visceral peritoneum; (4) attachment of liver to diaphragm *via* coronary ligament; (5) liver; (6) falciform ligament; (7) lesser omentum; (8) stomach; (9) gastrosplenic ligament; (10) superficial wall of greater omentum; (11) deep wall of greater omentum; (12) spleen; (13) omental bursa. (Modified from, *The Viscera of the Domestic Mammals*, Schummer, et al., Springer-Verlag, 1979, p. 12.)

The **spleen** develops in the dorsal mesogastrium of the embryo (Fig. 4-11). Thus, it makes sense that the spleen is associated with the greater curvature (omentum) of the stomach in the adult. That part of the greater omentum between the stomach and the spleen is referred to as the **gastrosplenic ligament**. Similarly, the more proximal part of the dorsal mesogastrium that attached the stomach directly to the diaphragm becomes the **gastrophrenic ligament** of the adult. Identify these ligaments in the pig and the horse.

In the ruminant, the gastrosplenic and gastrophrenic ligaments have been replaced by an area of direct attachment to the body wall. Beginning caudally, run your hand along the dorsal wall of the rumen until this area of attachment is located. Note that, in the adult ruminant, much of the cranial and dorsal sacs of the rumen firmly adhere to the crura of the diaphragm and sublumbar muscles.

Because it developed in the dorsal mesogastrium, the dorsal extremity of the spleen was included in this area of direct attachment so that it is not completely covered by peritoneum. What actually occurred is that, as the ruminoreticulum expanded, it came into such intimate contact with the craniodorsal abdominal wall that the peritoneum receded back out of the area, leaving a direct adhesion instead of a mesenteric attachment. This area of direct attachment enlarges as the ruminoreticulum reaches its full development after birth. (A newborn calf is only a *potential* ruminant, you know.) Also, as a result of the expansion of the ruminoreticulum, the spleen of the ruminants was moved away from its embryonic association with the greater omentum.

Omenta: As previously noted, the greater and lesser omenta develop from the dorsal and ventral mesogastria of the embryo, respectively. In those ungulates with a simple stomach (horse and pig), the omenta remain relatively simple, whereas in the ruminant, the stomach and the greater omentum are more complex. In the horse and the pig, the greater omentum, like that of the dog, consists of a simple peritoneal fold that extends from the greater curvature of the stomach to the dorsal body wall (Fig. 4-11). The **superficial wall** of the greater omentum extends caudally a variable distance from the greater curvature before turning back on itself as the **deep wall**, which continues cranially, then dorsally, to the body wall. Between the superficial and deep walls is an enclosed part of the peritoneal cavity known as the **omental bursa**. Commensurate with its small stomach, the greater omentum of the horse is *not really so great* (poorly developed) and does not typically extend back to cover the intestinal mass (Fig. 4-4).

It is interesting to note that, among our common domestic mammals, the horse has the most poorly developed greater omentum and is most susceptible to peritonitis. One recognized function of the greater omentum is that it quickly (within minutes) adheres around any area of peritoneal *insult* and seals it off. Its vessels then serve as an *avenue of attack* for inflammatory cells to combat any invasion of the peritoneal cavity by foreign material (e.g., bacteria, intestinal leakage).

Although I should stop short of drawing an absolute cause-effect relationship, *the relative susceptibility of our domestic mammals to peritonitis is inversely related to the development of the greater omentum.*

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The ruminant is most resistant; the horse is most susceptible. Before the advent of relatively aseptic surgery rooms and modern antimicrobial drugs, surgery of the equine abdomen was more or less an “antemortem

necropsy”- that is, most of the patients would die. As one of my senior colleagues once noted, “*a chance to cut was a chance to start the tractor.*”

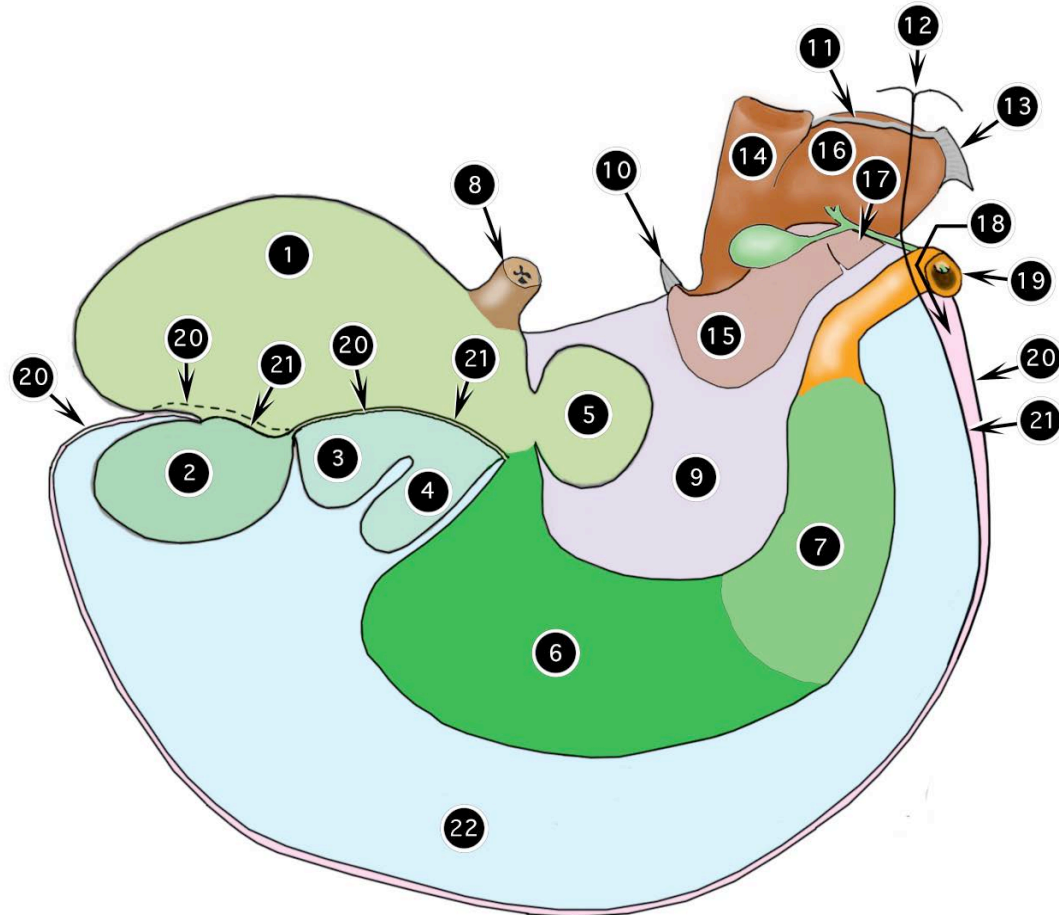


Figure 4-12. Schematic representation of peritoneal attachments of ruminant stomach and liver: (1) dorsal sac of rumen; (2) ventral sac of rumen, enveloped by omental bursa; (3) cranial sac of rumen; (4) reticulum; (5) omasum; (6) body of abomasum; (7) pyloric part of abomasum; (8) esophagus; (9) lesser omentum attaching stomach to liver; (10) left triangular ligament of liver; (11) coronary ligament of liver; (12) attachment of deep layer of greater omentum to dorsal body wall; (13) right triangular ligament of liver; (14) caudate lobe of liver; (15) left lobe of liver; (16) right lobe of liver; (17) quadrate lobe of liver; (18) epiploic foramen, forming entrance to omental bursa; (19) cranial part of duodenum; (20) superficial wall of greater omentum; (21) deep wall of greater omentum; (22) supraomental recess.

GREATER OMENTUM

Newborn Calf: The attachments of the greater omentum of the ruminant can best be understood by first studying that of the newborn calf. First, identify the **caudal fold** of the greater omentum on the left side (Fig. 4-7B). This free fold represents the line of

reflection of the superficial wall back on itself to form the deep wall. Follow the free fold to the rumen, and note that it attaches along the caudal groove. Here the two walls separate; the **superficial wall** continues in the left longitudinal groove, whereas the **deep wall** continues in the right longitudinal groove (Fig. 4-12).

Thus, the ventral sac of the rumen is *enveloped* by the omental bursa, but *it is not within the bursa*, because the bursa is a *potential* space. The ventral sac is covered by visceral peritoneum, which is continuous with the greater omentum along its line of attachment. *The relationship of the ventral sac of the rumen to the omental bursa is analogous to the relationship of the heart to the pericardial sac.* The deep and superficial walls come back together in the cranial groove of the rumen, and both walls continue along the greater curvature of the abomasum (Fig. 4-12).

Return now to the caudal border, and reflect the intestinal mass dorsally out through the left flank (Fig. 4-7B). Follow the free border to the right side, and note that it attaches here to the duodenum at about the point of the caudal flexure (where the descending duodenum turns sharply cranially to become the ascending duodenum). Both the superficial and the deep walls attach along the antimesenteric border of the descending duodenum. More proximally, the deep wall detaches from the cranial part of the duodenum, and continues dorsally to the body wall (Fig. 4-12). It is at this level, near the bile duct, where it is possible to pass through the **epiploic foramen** into the omental bursa, which is special “subdivision” of the peritoneal cavity.

Thus, the greater omentum forms a double-walled “basket” around the intestinal mass, which is known as the **supraomental recess** (Fig. 4-7B). *The supraomental recess is not the same thing as the omental bursa*, which is located between the superficial and deep walls.

Adult Ruminant: Now that you have reviewed the attachments of the greater

omentum in the newborn calf, you are ready to study them in the adult ruminant. On the right side, identify the **superficial wall** of the greater omentum, which attaches to the descending duodenum (Fig. 4-8). Slide your hand caudodorsally along the superficial wall until you locate the **caudal fold** of the greater omentum, which extends from the caudal flexure of the duodenum on the right to the caudal groove of the rumen on the left.

Notice how nicely your hand fits around the caudal fold of the omentum; your fingertips are now in the supraomental recess and are resting on the deep wall of the omentum. Smart surgeons learn how to manipulate this fold to allow the organ of interest (*e.g.*, uterine horn) to slip out of the supraomental recess, and then release it to “sack up” and contain those pesky loops of bowel.

On the right side, cut a window in the superficial wall about 5 cm ventral to the descending duodenum to expose the deep wall (Fig. 4-8). You have just opened the omental bursa. If you exposed the intestines, you went too deep and invaded the supraomental recess; back up one wall.²

Now move around to the left side, and note the attachment of the superficial wall along the left longitudinal groove of the rumen (Fig. 4-6). Again, locate the caudal fold and trace it back toward the right side of the animal. A better understanding of the omental attachments can be gained by reference to a transverse schematic drawing (Fig. 4-13).

² You might notice at this point that the greater omentum of the adult is used for fat storage, between the peritoneal layers of each wall. A common (packing house) name for the greater omentum is the “caul.”

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All Species: From the right side, lift the liver craniodorsally, and locate the **lesser omentum** extending between the lesser curvature of the stomach (abomasum) and the **visceral surface** of the liver. While holding the liver up, place your hand on the lesser omentum, and slide it dorsally toward the caudate process. You should locate a slit-like, natural opening at the dorsal border of the lesser omentum, large enough to accommodate one or more fingers. Congratulations, you have just found the **epiploic foramen**, and you now have your finger in the omental bursa (Fig. 4-12/18). As you can see, the peritoneal cavity proper communicates with the omental bursa through this opening. The epiploic foramen is principally bounded by the caudate process and caudal vena cava dorsally and by the portal vein and pancreas ventrally. (Another older name for the omentum is the *epiploon*.)

The major clinical significance of the epiploic foramen is in the horse, where occasionally a loop of jejunum finds its way through the opening and becomes strangulated. Fortunately, this doesn't happen very often, because it is very difficult to make an accurate diagnosis without an exploratory laparotomy. Even then, this area is difficult to expose at surgery.

Livers *In Situ*: Take one last look at the thoracic surface of the diaphragm. *Leaving the area circumscribed by the coronary, triangular, and falciform ligaments, trim away as much of the central tendon and peripheral muscular part as necessary to expose the parietal surface of the liver.*

The Latin name for liver is *hepar*- thus, the adjective form *hepatic*. One of the problems with studying the dog and the cat first is that, *unless otherwise informed*,

students often get the mistaken impression that "Mary M. Mammalian liver" has six lobes. Therefore, the first thing we need to get straight is that your basic "off-the-shelf" liver consists of four lobes, some of which may be subdivided. As previously noted, the duct system of the liver develops as an outgrowth of the embryonic gut (duodenum) into the ventral mesogastrium. Here, the duct system invades mesoderm and becomes associated with some embryonic veins to complete the formation of the parenchymal tissue of the organ. One of the first things you should have observed is that the livers of the various species are not oriented the same way in the body.

Liver of Pig: Although slightly shifted, the liver of the pig is oriented most like that of the dog (Fig. 4-14) and the cat- that is, with the rounded border facing almost dorsally, and with the right lobe on the right side and the left lobe on the left side of the animal. Ventrally, the liver extends beyond the costal arch.

Liver of Horse: The liver of the horse is obliquely oriented at about a 45° angle so that the rounded border faces dorsally and to the left. The right lobe is now more dorsal, and the left lobe more ventral (Figs. 4-4 & 4.5). Except in the young foal, where it may project beyond the costal arch, the liver lies entirely within the *intrathoracic* part of the abdominal cavity.

Liver of Ruminant: The liver of the ruminant has essentially vacated the left half of the abdomen to allow for expansion of the ruminoreticulum by rotating about 90° so that its rounded (dorsal) border now faces to the left (Figs. 4-8 & 4-9). The ruminant liver is vertically oriented so that the right lobe is now dorsal and the left lobe is ventral. The liver of the adult ox is related to the diaphragm and right abdominal wall

from the level of about the sixth intercostal space (ICS) cranioventrally to about the thirteenth rib caudodorsally. In a younger animal the right lobe and caudate process

may extend caudal to the last rib (Fig. 4-9). The **gallbladder** of the ox is related to the abdominal wall at about the ninth or tenth ICS.

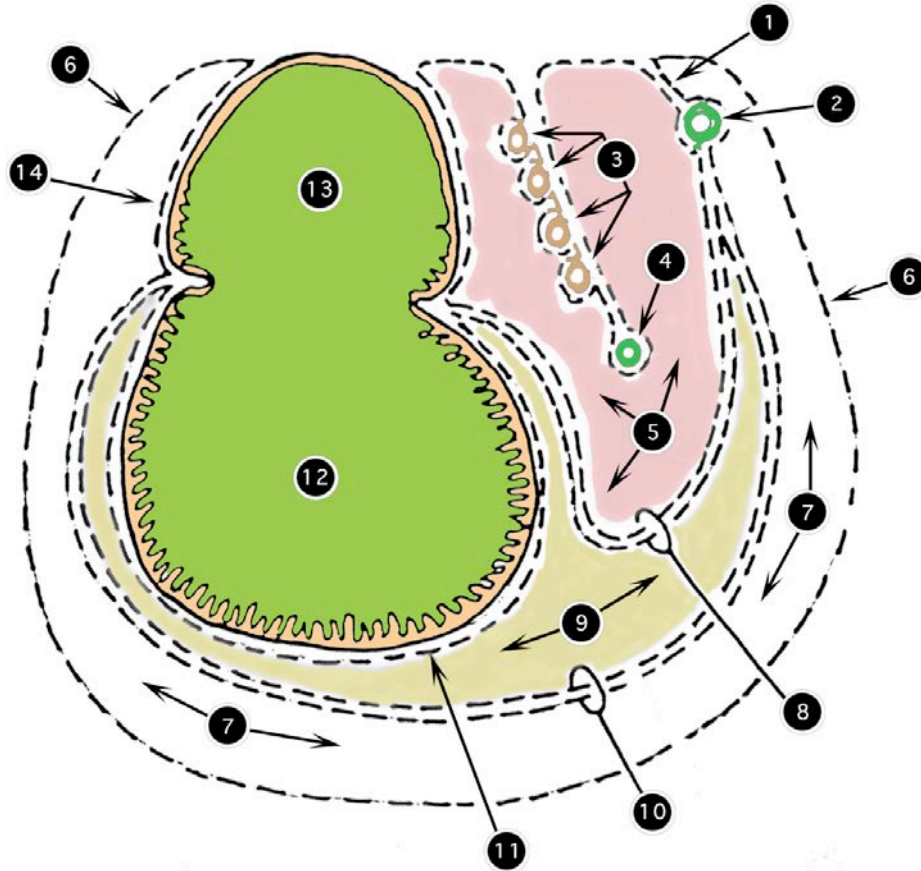


Figure 4-13. Schematic representation of transverse section through bovine abdomen, caudal view: (1) mesoduodenum; (2) descending duodenum; (3) spiral colon adherent to left side of mesojejunum; (4) jejunum; (5) supraomental recess; (6) parietal peritoneum; (7) peritoneal cavity; (8) deep wall of greater omentum; (9) omental bursa; (10) superficial wall of greater omentum; (11) visceral peritoneum covering ventral sac of rumen; (12) ventral sac of rumen; (13) dorsal sac of rumen; (14) visceral peritoneum covering dorsal sac of rumen.

Note the relatively large size of the liver in the newborn calf, where it consistently projects beyond the costal arch and last rib (Fig. 4-9). Having an additional prenatal function in *hematopoiesis*, the liver of newborn and juvenile animals of all domestic species is relatively larger than in adults.

Because diagnostic radiography of the abdomen in large animals requires powerful, high-milliamperage equipment, it is not readily available to practitioners in the field. Therefore, the art of percussion of abdominal viscera is relatively important. The area of lung percussion, which has already been defined (Fig. 3-21), is contiguous on the right side with the area of liver percussion. In sharp contrast with the

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resonant, drum-like sound over the lung, the liver yields a dull, solid sound on percussion. An experienced clinician can detect hepatic enlargement by the increased area of liver percussion in an affected animal. Even a first-year veterinary student should be able to distinguish between lung and liver sounds on percussion. *Define the area of liver percussion on the live cow.*

Livers Epi Table:³ Now that we have had the opportunity to study the livers *in situ*, let's take them out for comparative study. *Beginning in the epiploic foramen, transect the caudal vena cava dorsally, and the combined portal vein, hepatic artery, and bile duct ventrally. Be sure to leave a stump of the bile duct on the duodenum. Carefully sever the liver-to-diaphragm ligaments and any remaining attachments, as necessary, to remove the liver and embedded part of the caudal vena cava together.*

Before we put our livers on the table, let's pause a moment to note those abdominal viscera that are related to the **visceral surface** of the organ. These usually make recognizable impressions on the very firm, *embalmed* liver. Except in the pig, you should observe that the **caudate process** is excavated (renal impression) to “caress” the cranial extremity of the right kidney. The liver of the pig, unlike that of other domestic mammals, does not contact the right kidney, so there is no renal impression. The stomach (omasum) makes a variable impression on the liver, and, in the horse, the imprint of the colon and cranial part of the duodenum can usually be identified.

Now put all the livers on the table in a neat row and compare them. Turn them, visceral side up, with the rounded border facing away from you (Fig. 4-15). Locate

the following livermarks:⁴ (1) esophageal notch; (2) notch for the round ligament; (3) point where the caudal vena cava crosses the rounded border of the liver; (4) gallbladder (in the horse, the distinct notch where the gallbladder would have been); and (5) the **hepatic porta**⁵ (where the portal vein and hepatic artery enter the liver).

The lobe projecting caudally toward you, that is dorsal to the porta, is the **caudate lobe**, which in the ruminant has two parts, a **caudate process** and a **papillary process**. The caudate process is especially large in the ox, and the papillary process is more prominent in the sheep. The horse and the pig do not have a papillary process.

Now, let's play connect the *livermarks*. First, connect (1) and (2); now connect (3) and (4). *Congratulations-* you have just divided the remainder of the liver into the other three lobes. To the left of line 1-2, you have the **left lobe**, which in the pig and the horse is divided into medial and lateral parts. To the right of line 3-4, you have the **right lobe**, which is divided into medial and lateral parts in the pig. Between lines 1-2 and 3-4, you have the **quadrate lobe**, which is relatively small in the pig (Fig. 4-15).

On the visceral surface, note the line of attachment of the lesser omentum and the **hepatic lymph nodes** in the vicinity of the porta. In addition to the stump of the **portal vein**, identify those of the **hepatic artery** and the **bile duct**. As you recall, the portal vein receives blood from the stomach, spleen, pancreas, and intestines that is laden with absorbed nutrients (except triglycerides), and may also contain infectious organisms and/or toxic material.

³ Livers on the table

⁴ A livermark is a lot like a landmark- one is hepatic, the other terrestrial.

⁵ hepatic porta = hilus of liver

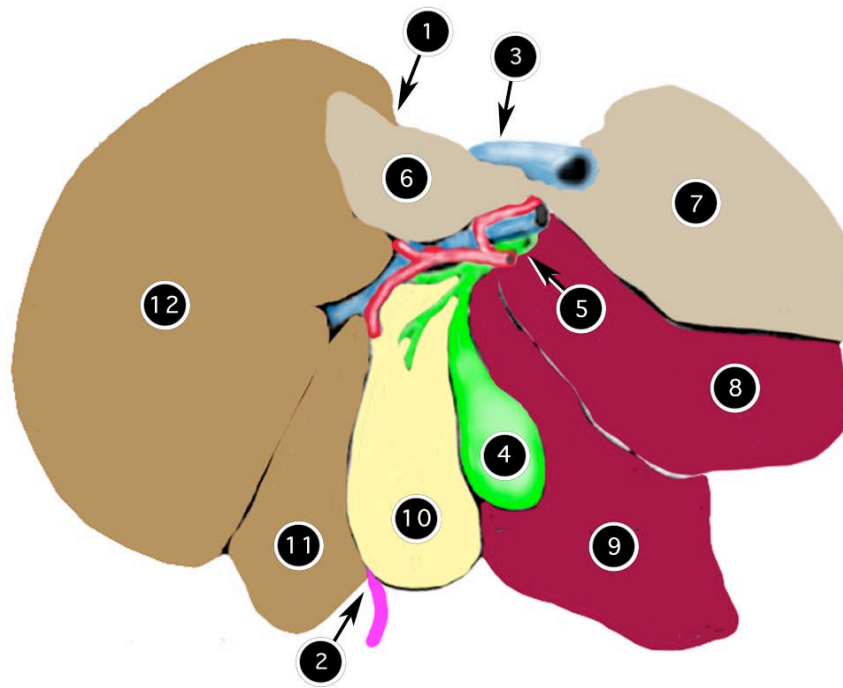


Figure 4-14. Visceral surface of canine liver: (1) esophageal notch; (2) notch for the round ligament; (3) point where the caudal vena cava crosses rounded border of the liver; (4) gallbladder; and (5) the hepatic porta with stumps of hepatic artery, portal vein, and bile duct; (6) papillary process of caudate lobe; (7) caudate process of caudate lobe; (8) lateral part of right lobe; (9) medial part of right lobe; (10) quadrate lobe; (11) medial part of left lobe; (12) lateral part of left lobe. (Modified from, *The Viscera of the Domestic Mammals*, Schummer, *et al.*, Springer-Verlag, 1979, p. 117.)

Portal blood represents the **functional blood supply**. Being strategically interposed between the gut and general circulation, the liver has the first shot at the absorbed nutrients. With the complex enzyme systems of the *hepatocytes*, these nutrients can be metabolically converted, stored, and released over time in the appropriate form to the general circulation. Similarly, the liver, functioning as a *filter*, can capture infectious organisms and help detoxify certain toxins. As a result, the liver is affected directly by many toxins, and abscesses of the liver are not uncommon, especially in feedlot cattle.

The liver is too dynamic an organ to depend solely on second-hand blood for its

own nourishment, so the hepatic artery delivers its **nutritional blood supply**.

Now turn the liver over and examine its **parietal surface**. Note the lines of attachment of the coronary, triangular, and falciform ligaments (Fig. 4-9). *Using scissors, open the caudal vena cava longitudinally, beginning at the caval foramen.* Numerous large **hepatic veins** should be observed entering the embedded wall of the vena cava. Blood that enters the liver through the portal vein and hepatic artery returns to the general circulation through the hepatic veins to the caudal vena cava. The liver, therefore, acts as a *filter* of

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portal blood (it gets first shot at the good, the bad, and the ugly).

The parenchyma of the pig liver is supported by a pronounced *fibrous stroma*, which is evidenced on the surface by the

more obvious lobulated appearance of the pig liver. Depending on the lifestyle and husbandry of the animal, the livers of domestic ungulates frequently bear the scars of parasitic larval migrations.

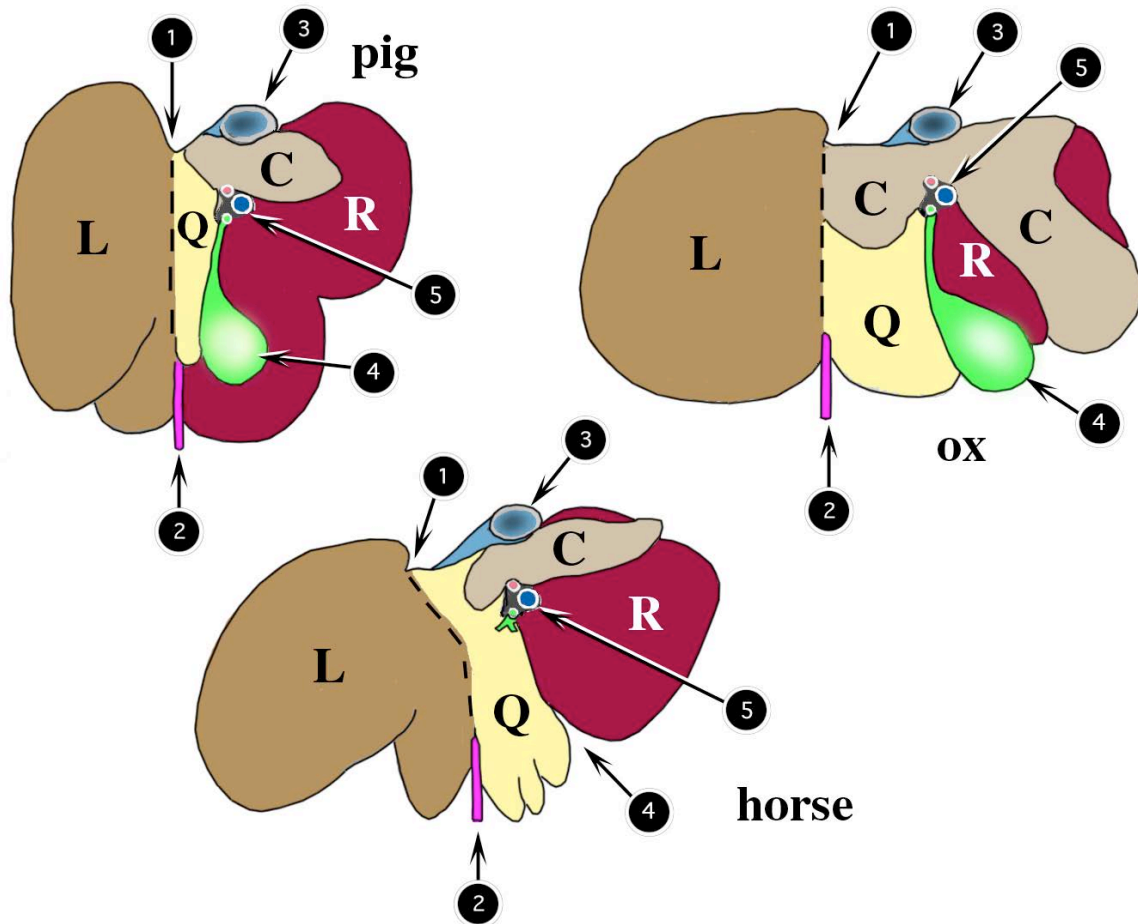


Figure 4-15. Schematic representation of livers of pig, ox, & horse, visceral surfaces: (1) esophageal notch; (2) round ligament of liver; (3) caudal vena cava; (4) gallbladder or notch for same in horse; (5) hepatic porta; (L) left lobe of liver, divided into medial and lateral parts in pig & horse; (R) right lobe of liver, divided into medial and lateral parts in pig; (Q) quadrate lobe of liver; (C) caudate lobe of liver. (Modified from Nickel, Schummer, Sieferle, and Sack, *The Viscera of the Domestic Mammals*, 2nd ed., Springer-Verlag, New York, 1979, p. 116.)

Pancreas: Now put your livers away, return to the cadaver, and locate the pancreas near the stump of the portal vein (Figs. 4-8 & 4-16). Like the liver, the exocrine part of the pancreas develops as an outgrowth of the embryonic gut (duodenum); however, in the case of the pancreas, there are two primordial buds, dorsal and ventral. The dorsal bud grows into the mesoduodenum,

while the ventral bud is closely associated with the developing liver in the ventral mesogastrium. By *definition*, the ventral bud forms the **pancreatic duct**, and the dorsal bud forms the **accessory pancreatic duct**. The two buds grow together near the cranial flexure of the duodenum to form the body of the pancreas, and their individual duct systems anastomose with one another.

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Now, comes the tacky part. Because only one excretory duct is really needed, some animals choose to do away with the other one. The problem is they don't all do it the same way. Thus, some species (ox, pig) retain only an accessory duct, some (sheep, goat) retain only the pancreatic duct, and some (horse, dog) keep both (just in case). Even within the same species, there is some variation (*viz.* the cat may or may not retain an accessory pancreatic duct). Remember that the two ducts *are named by definition*. It has nothing to do with relative size of the ducts; the one that opens with the bile duct is the pancreatic duct (even if absent).

Pancreas of Ruminant: Expose the right lobe of the pancreas in the descending mesoduodenum, and in the ox, isolate the accessory pancreatic duct near the caudal part of this lobe (Figs. 4-8/20 & Fig. 4-16). *Open the duodenum* and identify the **minor duodenal papilla**. (*Hint: Palpating the gut wall distal to the duct may help you find the papilla.* This is the only duct that typically persists in the ox, but rarely a pancreatic duct may be found. In the small ruminants, only the pancreatic duct, which opens with the bile duct on the major duodenal papilla, persists postnatally. Locate the bile duct and pancreatic ducts in the goat and the sheep; open the duodenum and identify the **major duodenal papilla**.

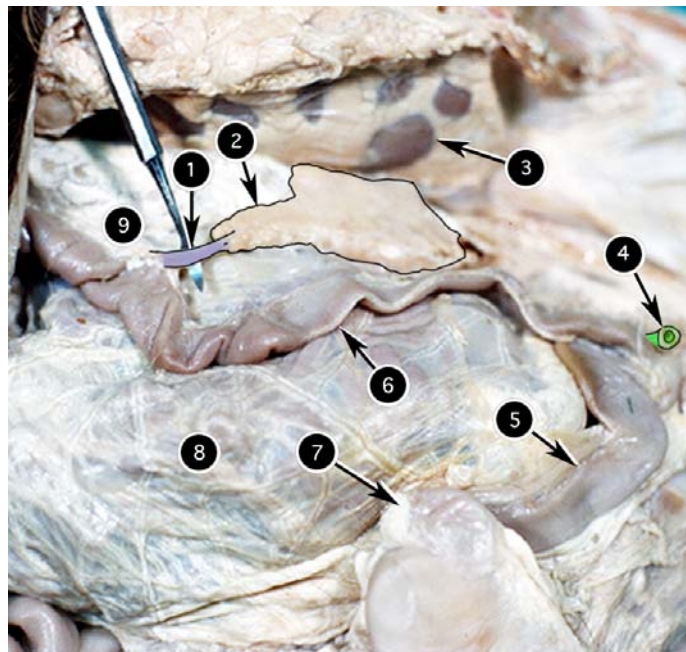


Figure 4-16. Opened abdomen of newborn calf, right side: (1) accessory pancreatic duct; (2) right lobe of pancreas; (3) right kidney; (4) bile duct; (5) cranial part of duodenum; (6) descending duodenum; (7) pylorus of abomasum; (8) superficial wall of greater omentum; (9) mesoduodenum. Note: Some structures have been graphically enhanced (artistic license).

Pancreas of Horse: The pancreas of the horse completely surrounds the portal vein, forming the *annulus pancreatis*. Locate the pancreatic and bile ducts. *Open the duodenum* and identify the **major duodenal papilla** (Fig. 4-17). The papilla is

surrounded by a neat little “moat,” contained by a mucosal ridge- sort of like a vallate papilla of the tongue. The short terminal duct formed by the bile duct and the pancreatic duct is termed the hepatopancreatic ampulla. Now look right

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across the gut and locate the **minor duodenal papilla**. While you're in the neighborhood, note that the most proximal part of the equine duodenum is expanded, forming the **ampulla duodeni** (Fig. 4-17). The reason I point this out now is that

students tend to confuse the ampulla duodeni and ampulla hepatopancreatica. They are two different things, which just happen to be close together.

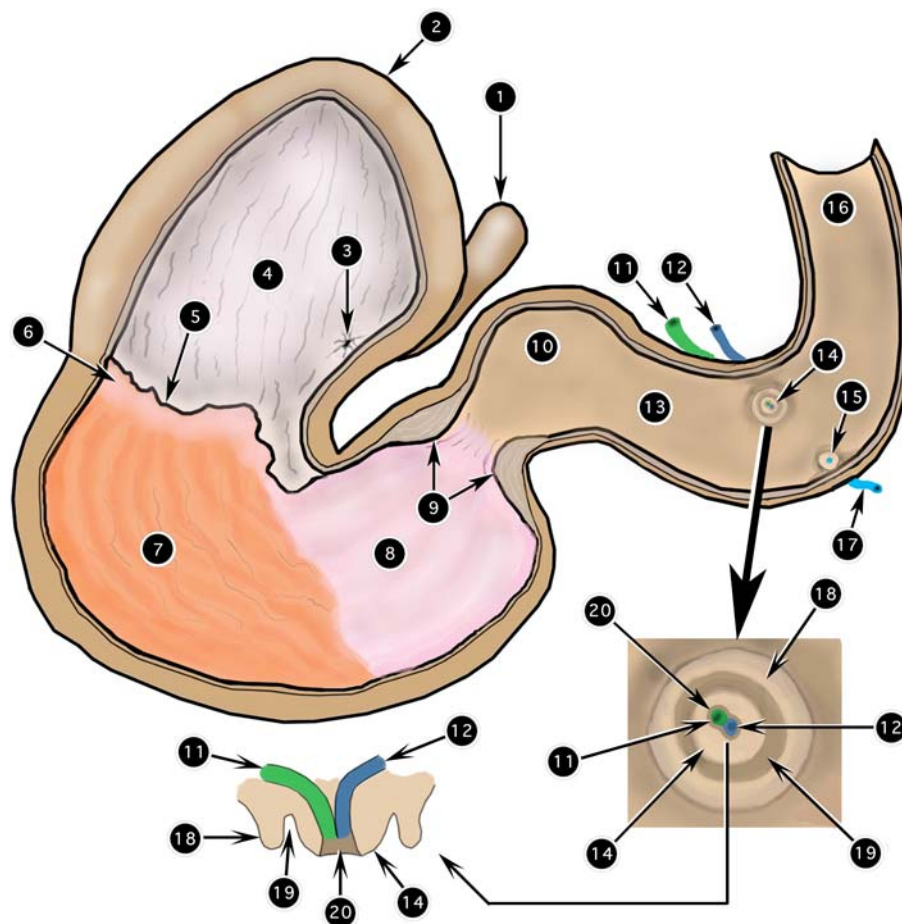


Figure 4-17. Opened stomach and proximal duodenum of horse, caudal view: (1) esophagus; (2) fundus (saccus cecus of stomach); (3) tightly closed cardia; (4) nonglandular (stratified squamous) part of stomach; (5) margo plicatus separating glandular and nonglandular parts; (6) narrow zone of mixed cardiac and pyloric glands; (7) region of proper gastric glands; (8) pyloric gland region; (9) pylorus; (10) ampulla duodeni; (11) bile duct; (12) pancreatic duct; (13) cranial part of duodenum forming sigmoid loop; (14) major duodenal papilla; (15) minor duodenal papilla; (16) descending duodenum; (17) accessory pancreatic duct; (18) mucosal ridge surrounding 14; (19) "moat" or recess surrounding 14; (20) hepatopancreatic ampulla, short common duct for 11 & 12.

Pancreas of Pig: Like that of the horse, the pancreas of the pig completely surrounds the portal vein. Locate the **accessory pancreatic duct**, which enters the descending duodenum. Open the duodenum and identify the **major** and **minor duodenal papillae**.

Spleen: The Latin name for spleen is *lien*; however, the Greek *splen* has predominated. Although its shape differs considerably in our domestic mammals, its position is similar- against the left abdominal wall and usually covered by ribs (Figs. 4-4, 4-6, & 4-7). Because of relaxation of its muscular

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capsule, the spleen is usually enlarged in specimens that were anesthetized with barbiturates or tranquilized. Having developed in the dorsal mesogastrium, the spleen is closely associated with the greater curvature of the stomach, and, in the pig particularly, its craniocaudal position varies with the fullness of the stomach.

Spleen of Horse: In the horse, the size of the spleen (Fig. 4-4/7) varies considerably with breed type. *Hot-blooded* horses, bred for speed and endurance, have spleens that are about twice as large as *cold-blooded* breeds, such as draft horses. More red blood cells can be dumped into general circulation on demand in hot-blooded horses so there is more oxygen-carrying capacity of their blood. The **hilus** of the equine spleen, like that of the pig, is linear, and many **splenic lymph nodes** are located along the hilus.

Spleen of Ruminant: The spleen of the ox is tongue-shaped (Fig. 4-6/5), whereas that of the sheep and the goat is more oval or triangular. As mentioned above, the spleen is compressed against the dorsal abdominal wall by expansion of the ruminoreticulum and is thus involved in the area of direct attachment of the stomach to the body wall. Consequently, it does not retain a complete covering of visceral peritoneum, and this *area nuda* includes the nonlinear **hilus**. *Make a cross-sectional incision through the spleen.* Note the thick, fibrous **capsule** and the numerous **trabeculae** that extend into the parenchyma; together with the capsule, the trabeculae form the framework (fibrous skeleton) of the organ. On the cut surface of the ruminant and pig spleens, the nodular accumulations of *lymphoreticular* tissue that form the splenic corpuscles are visible grossly as the *white pulp*, in contrast to the background of *red pulp* that consists of reticular connective tissue and venous sinuses. A common name for the bovine

spleen is the *melt*. *There are no splenic lymph nodes in ruminants.*

Spleen of Pig: In the fresh (non-embalmed) state, the elongated spleen of the pig is bright red. *Make a cross-sectional incision through the spleen.* Its cut surface is mottled by the presence of the white pulp of the splenic corpuscles.

GASTROINTESTINAL TRACT

Ungulates, especially herbivores, have a *food problem*. Being fairly low on the protein totem pole, they must devise a digestive apparatus capable of handling relatively large amounts of almost indestructible, high-fiber plant material. How do they solve this problem? They have to resort to fermentation, and to do so *they need a little help from their friends; i.e., fermentative organisms.*

Fermentative digestion (*versus hydrolytic digestion*) has several requirements:

1. **Volume-** the digestive system must be enlarged to hold more material.
2. **Time-** as any good wine maker knows, fermentation takes time, so a relatively *slow passage* (several days) of ingesta through the *fermentation vat* is necessary.
3. **Fluid environment-** the fermentative organisms (*e.g.*, bacteria) need a happy home, *buffered close to neutral in terms of pH*.
4. **Continuous removal of fermentation products** (*e.g.*, volatile fatty acids)-otherwise they build up and *stop the process*.

These are the *general requirements of the solution*. Basically, there are two

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segments of the gastrointestinal tract in which food slows down enough to allow for fermentative digestion, the *stomach* and the *large bowel*. For purposes of description, we shall designate these as *plan A* and *plan B*, respectively. Because there are substantial differences in how different ungulates choose between *plan A* and *plan B*, we shall consider each species separately and gain an understanding of one before we tackle the next.

Gastrointestinal Modifications of Ungulates: We shall begin by first reviewing the relatively simple GI tract of the dog, and then we shall consider which parts are modified in each of the ungulates. Return with us now to last semester (Fig. 4-18). The dog has a simple little stomach, which as we have already learned, rotates embryologically so that the greater curvature faces to the left and ventrally, and the pylorus is on the right.

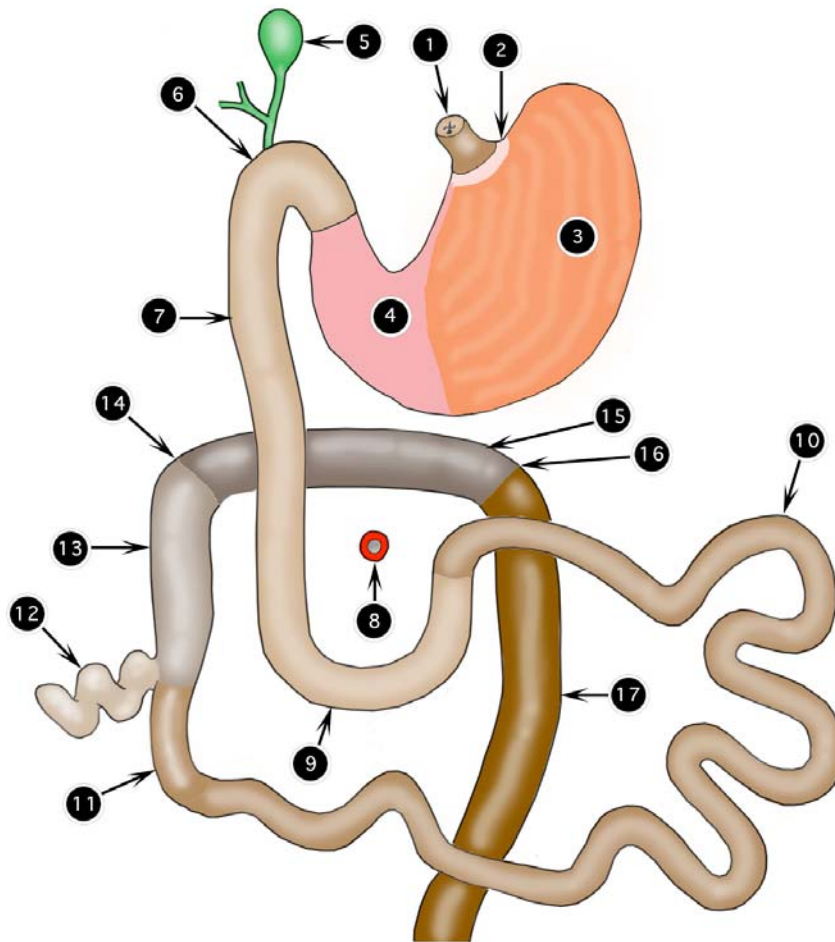


Figure 4-18. Schematic representation of gastrointestinal tract of dog, ventral view: (1) esophagus; (2) cardiac gland region of stomach; (3) region of proper gastric glands; (4) pyloric gland region; (5) gallbladder; (6) cranial flexure of duodenum; (7) descending duodenum; (8) cranial mesenteric artery; (9) caudal flexure of duodenum; (10) jejunum; (11) ileum; (12) cecum; (13) ascending colon; (14) right colic flexure; (15) transverse colon; (16) left colic flexure; (17) descending colon.

The embryonic intestine continues to elongate so that it soon runs out of room in

the abdominal cavity and forms a loop out through the umbilical opening. Next, the

loop rotates about 270° in a counter-clockwise direction (*when viewed from below*) around the **cranial mesenteric artery**. A diverticulum develops at the proximal end of the large intestine to form the cecum. The result of the intestinal rotation is that the *transverse colon comes to lie cranial to the cranial mesenteric artery*, and the *caudal flexure of the duodenum lies caudal to it* (Fig. 4-18). Similar rotation occurs in the ungulates, and *the same relationships with the cranial mesenteric artery are produced*. We shall now *customize* this simple canine gut to produce the more sophisticated gastrointestinal tracts of the ungulates.

Gastrointestinal Modifications of Horse:

Modifications of the horse basically involve four segments: *stomach*, *cecum*, *ascending colon*, and *descending colon* (Fig. 4-19). The horse makes a feeble attempt at enlarging its stomach, but apparently gives up on *plan A* as a lost cause and switches to *plan B*. The horse does manage to enlarge the fundus of the stomach enough to form a dome-like **saccus cecus** (blind sac). Frankly, though, the stomach of the horse is too small for the job, and it is primarily remarkable only because it is so small for such a large animal. The horse does better with *plan B*.

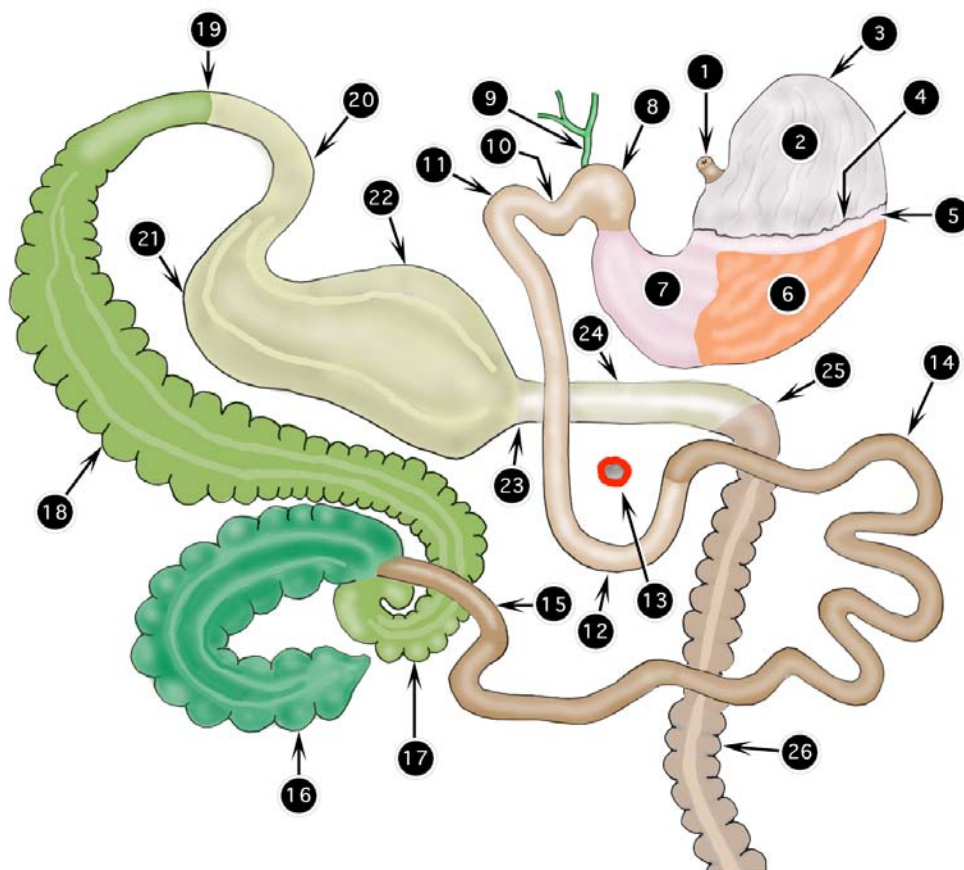


Figure 4-19. Schematic representation of gastrointestinal tract of horse, ventral view: (1) esophagus; (2) nonglandular region of stomach; (3) saccus cecus; (4) margo plicatus; (5) mixed pyloric & cardiac glands; (6) region of proper gastric glands; (7) pyloric gland region; (8) ampulla duodeni; (9) bile duct; (10) sigmoid flexure of duodenum; (11) cranial flexure of duodenum; (12) caudal flexure of duodenum; (13) cranial mesenteric artery; (14) jejunum; (15) ileum; (16) cecum; (17) right ventral colon; (18) area of sternal flexure; (19) pelvic flexure; (20) left dorsal colon; (21) area of diaphragmatic flexure; (22) right dorsal colon; (23) right colic flexure; (24) transverse colon; (25) left colic flexure; (26) descending colon.

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The **cecum** is enlarged to the point that it occupies most of the right flank and extends cranioventrally to near the xiphoid cartilage (Fig. 4-5). Another modification of the cecum that allows for better mixing and kneading of the ingesta with the fermentative organisms is the development of sacculations, or **haustra**. This is accompanied by a concentration of the outer longitudinal layer of the tunica muscularis into distinct bands, or **tenia**.

The **ascending colon** elongates into a large loop, with dorsal and ventral limbs, that grows cranially to the diaphragm, where it is deflected to the left under the stomach, and then continues along the left side of the abdomen all the way to the pelvic inlet (Figs. 4-5, 4-6 & 4-19). The ventral limb of

the loop also enlarges and becomes haustrated, and the last segment of the loop becomes greatly dilated. Thus, the great colon of the horse is formed from a modified loop of ascending colon. The descending colon of the horse also elongates and becomes distinctly haustrated.

Gastrointestinal Modifications of Pig: Modifications of the pig basically involve three segments: *stomach*, *cecum*, and *ascending colon* (Fig. 4-20). Like the horse, it appears that the pig momentarily considered the possibility of *plan A*, but then elected *plan B*. As a result, the **stomach** is only slightly modified in the development of a peculiar out-pocket at the fundus, the **gastric diverticulum** (Fig. 4-20).

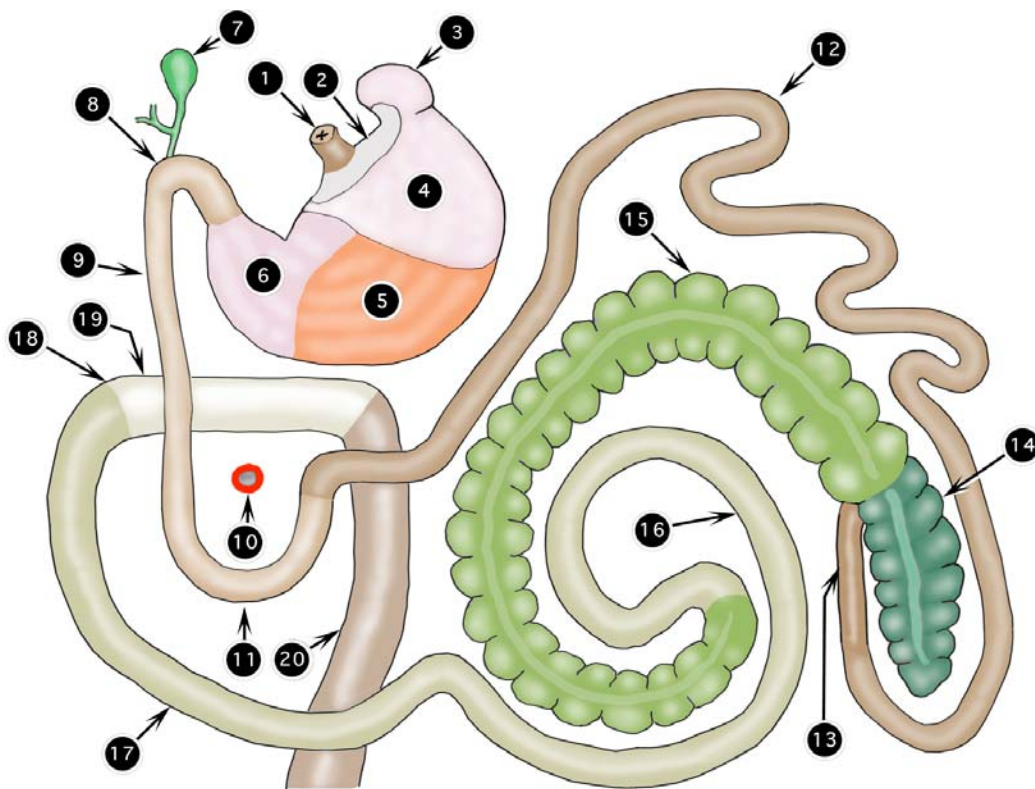


Figure 4-20. Schematic representation of gastrointestinal tract of pig, ventral view: (1) esophagus; (2) nonglandular region of stomach; (3) gastric diverticulum; (4) large cardiac gland region; (5) region of proper gastric glands; (6) pyloric gland region; (7) gallbladder; (8) cranial flexure of duodenum; (9) descending duodenum; (10) cranial mesenteric artery; (11) caudal flexure of duodenum; (12) jejunum; (13) ileum; (14) cecum; (15) centripetal coil of spiral loop of ascending colon; (16) centrifugal coil of spiral loop of ascending colon; (17) distal loop of ascending colon; (18) right colic flexure; (19) transverse colon; (20) descending colon.

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The **cecum** enlarges somewhat, although not nearly as much as that of the horse, and the **ascending colon** elongates to form a **spiral loop**. One unique feature of the pig is that the cecum shifts to the left side, unlike that of other domestic mammals, so that the ascending colon immediately enters the spiral loop on the left side of the mesojejunum. Both the cecum and the initial part (**centripetal coils**) of the ascending colon become haustrated with tenia (Fig. 4-20). The **centrifugal coils**, however, are smooth, and a distal loop is necessary for the ascending colon to return

to the right side for union with the transverse colon.

Gastrointestinal Modifications of Ruminant: Modifications of the ruminant basically involve three segments: *stomach*, *cecum*, and *ascending colon* (Fig. 4-21). Here, we finally find an animal that follows through with *plan A*, but also uses *plan B*. The more proximal part of the embryonic stomach primordium becomes greatly enlarged and subdivides into three compartments, all lined with a nonglandular, stratified squamous epithelium (Fig. 4-21).

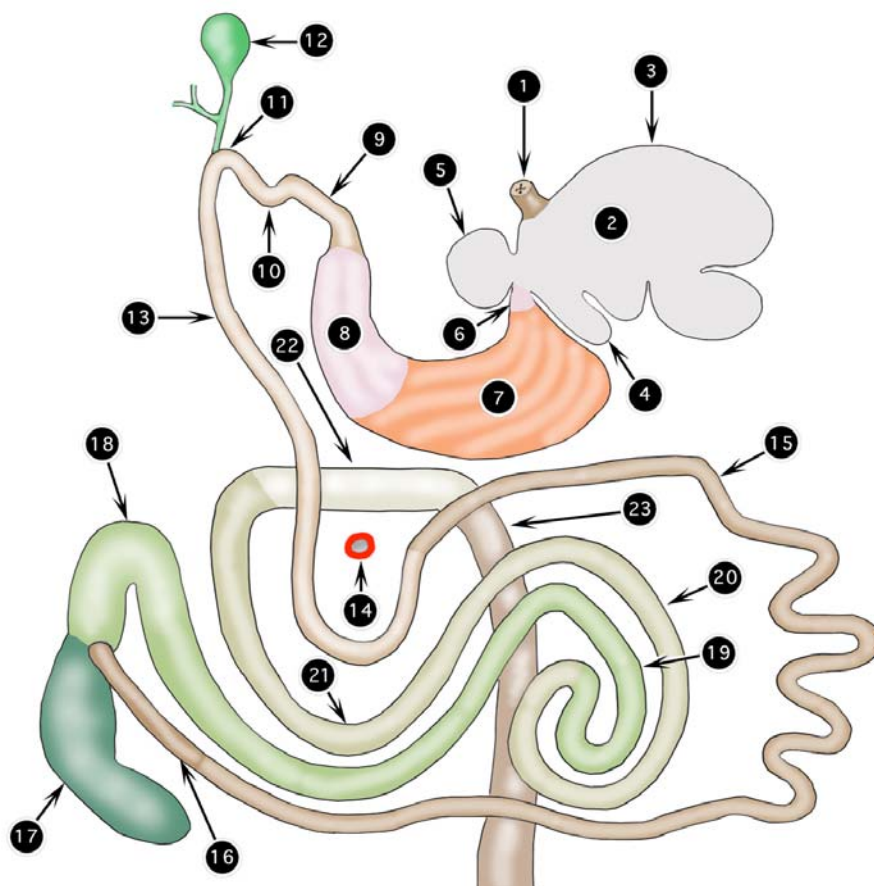


Figure 4-21. Schematic representation of gastrointestinal tract of ox, ventral view: (1) esophagus; (2) nonglandular region of stomach; (3) rumen; (4) reticulum; (5) omasum; (6) small cardiac gland region; (7) region of proper gastric glands; (8) pyloric gland region; (9) cranial part of duodenum; (10) sigmoid flexure of duodenum; (11) cranial flexure of duodenum; (12) gallbladder; (13) descending duodenum; (14) cranial mesenteric artery; (15) jejunum; (16) ileum; (17) cecum; (18) proximal loop of ascending colon; (19) centripetal coil of spiral loop of ascending colon; (20) centrifugal coil of spiral loop of ascending colon; (21) distal loop of ascending colon; (22) transverse colon; (23) descending colon.

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You should note that I made no mention of any part of the forestomach developing like a crop from the distal part of the esophagus; also, I neglected to point out that ruminants have *four* stomachs. The reason of course is that neither of these statements is true; sometimes you just have to *unlearn* things.

Now for *plan B*. The **cecum** enlarges somewhat, but without haustrations or tenia, and the **ascending colon**, like that of the pig, forms a long **spiral loop**. Unlike the pig, however, the ruminant cecum is on the right side, so a **proximal loop** is necessary to get the colon over on the left side of the mesojejunum (Fig. 4-21). A **distal loop** is also needed to bring it back to the right so the ascending colon can join the transverse colon at the right colic flexure.

Ungulates, therefore, especially herbivores, *need digestive assistance*. Beginning with the simple GI tract of the dog, one can *build to suit* a specialized digestive apparatus capable of using *fermentative digestion* (in addition to hydrolytic digestion) to solve the problem of breaking down the complex plant structures that constitute the natural foodstuffs of the domestic ungulates. *Plans A and B* are available. Although initially the results appear different, *they all have a common basic plan*, as represented by the digestive tract of the dog (Fig. 4-18). The modifications at first appear complex, but they become less complex when approached from a comparative point of view (Fig. 4-22).

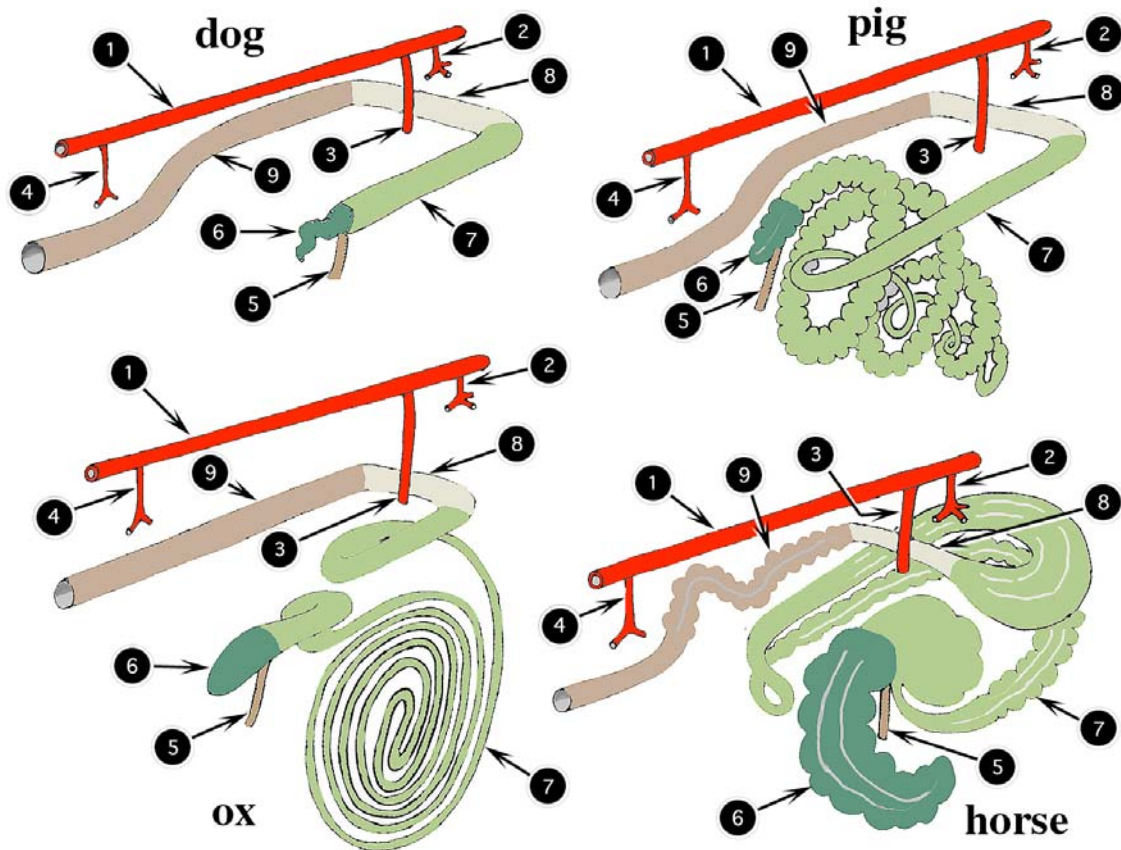


Figure 4-22. Comparative schematic of modifications of large intestine, right caudolateral view: (1) abdominal aorta; (2) celiac artery; (3) cranial mesenteric artery; (4) caudal mesenteric artery; (5) ileum; (6) cecum; (7) ascending colon; (8) transverse colon; (9) descending colon. (Modified after Preuss.)

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Tracing Course of GI Tract: Now that we have a basic (schematic) understanding of how the GI tracts of the domestic ungulates are modified, we should be able to identify the parts in the cadavers. For the time being, we will not consider the stomach in detail, but will turn our attention to the intestinal arrangement. Pretend that you have just been ingested by your cadaver and *trace your course through the intestinal tract of the horse, the pig, and the ruminant*

GI Tract of Horse: As noted above, the horse selected *plan B* as its solution to the digestion of high-fiber plant material. It could be argued that this was not a particularly good choice in that the modifications to its colon imposed by this plan have left the horse especially vulnerable to digestive problems. In other words, *the intestinal tract of the horse has become a little too complicated for its own good, and the horse is more or less a "colic" looking for a place to happen.* Although the word **colic** means (literally) *pertaining to the colon*, usage of this term has, among horsepersons, mistakenly come to connote some particular disorder of the equine bowel. In truth, *colic is not a specific disease* at all, but rather a *clinical syndrome, characterized by acute abdominal pain.*

Now horses may not be the world's best communicators, but they invariably let us humans know when they have "pain in the belly." They become restless and may begin pawing; they typically start to sweat (horses tend to sweat anytime they hurt bad), they may want to lie down and roll, and they often bite or kick at their belly. Although most, but not all, "colics" do involve problems with the GI tract, there are numerous anatomic-physiologic changes that may be responsible for their abdominal pain. Some of these include: gas accumulation, twisting or displacement of

one or more segments of bowel, and/or obstruction (impaction) of the gut. As we proceed to "tour" the GI tract of the horse, we shall attempt to point out some of the more common "problematic areas" along the way.

From the ampulla duodeni, the **duodenum**⁷ turns cranially at the **sigmoid flexure** and then immediately caudally at the **cranial flexure** to become the descending duodenum (Fig. 4-19).

Here, it passes over the base of the cecum where the **caudal flexure**, continues as the ascending duodenum (Fig. 4-23). Move around to the left side and pull out a loop of **jejunum**⁸, which can easily be distinguished from the descending colon by its smooth, nonhaustrated appearance.

Note the long **mesojejunum** that gives the bowel a great deal of mobility and allows the jejunum to get into every little nook and cranny that becomes available, including the *epiploic foramen*. Such a long mesentery also predisposes the jejunum to becoming twisted on its mesentery, like a swing on its chains. This, of course, is not good. Twisting of the mesentery, and vessels contained therein, can greatly compromise venous and lymphatic return, and the arterial supply to the affected bowel segment. This type of twist is termed a *volvulus*, and is one form of potentially fatal colic in the horse. If you pull out on the jejunum, you can see that it is attached at the **root of the mesentery**, which surrounds the

⁷ duodenum- literally means *twelve*; early anatomists (working I suppose without a ruler) noted that this most proximal, relatively "fixed" part of the human small bowel was about 12 finger-breadths long.

⁸ jejunum- literally means *empty* or *hungry*. It looks flat and empty in the living animal except for gas pockets.

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cranial mesenteric artery. In contrast to the colic and cecal lymph nodes (Fig. 4-5), the **jejunal lymph nodes** are not spread along

the jejunum but are congregated in the root of the mesentery.

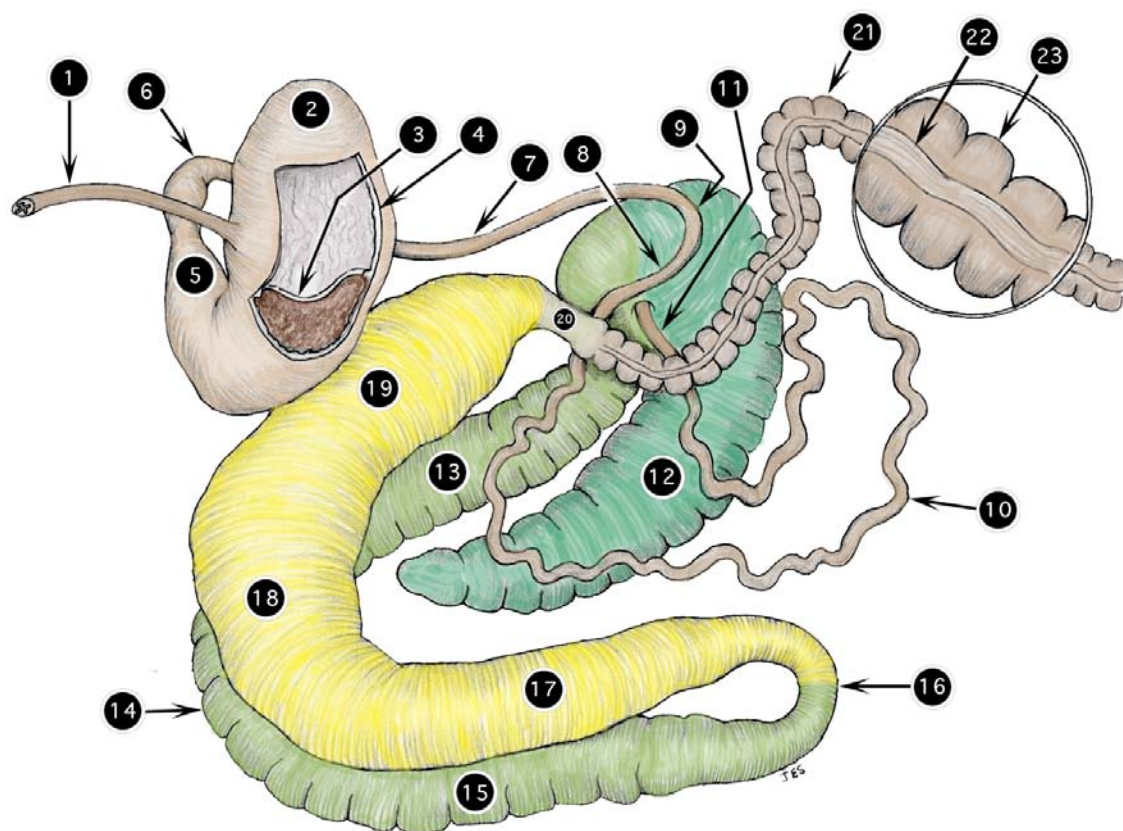


Figure 4-23. Semi-schematic drawing of equine gastrointestinal tract, left lateral view: (1) esophagus; (2) saccus cecus of stomach; (3) margo plicatus; (4) window in wall of stomach; (5) pyloric part of stomach; (6) cranial flexure of duodenum; (7) descending duodenum; (8) ascending duodenum; (9) caudal flexure of duodenum; (10) jejunum; (11) ileum; (12) cecum; (13) right ventral colon; (14) sternal flexure; (15) left ventral colon; (16) pelvic flexure; (17) left dorsal colon; (18) diaphragmatic flexure; (19) right dorsal colon; (20) transverse colon; (21) descending colon; (22) tenia; (23) haustrum.

Examine the vascular pattern in a segment of mesojejunum (Fig. 4-24). Neighboring **jejunal arteries** are joined by *arcuate branches*, which in turn give rise to a secondary set of smaller, branching arteries that supply the gut wall (Fig. 4-24). Thus, there is a substantial safety net of arterial anastomoses that protects the gut from infarction⁹ in case of arterial blockage.

The larvae of *Strongylus vulgaris* penetrate the gut wall and migrate proximally along the jejunal arteries to reach the cranial mesenteric artery. These parasites can cause a remarkable amount of damage (*verminous arteritis*) to the cranial mesenteric artery and its major branches without producing major gut wall infarction and death of the horse. I suppose that's one reason we still have horses, and some horses still have *strongyles*, or “bloodworms.” Prior to the widespread use of ivermectin, almost all laboratory ponies had some degree of

⁹ infarct- an area of tissue necrosis resulting from local ischemia caused by obstruction of circulation to the area.

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cranial mesenteric arteritis (e.g., wall thickening, fibrosis). I feel confident that those worms are out there somewhere, working night and day, trying to figure out a

way around ivermectin. Given enough “R&D” time, they’re bound to find the answer one of these days.

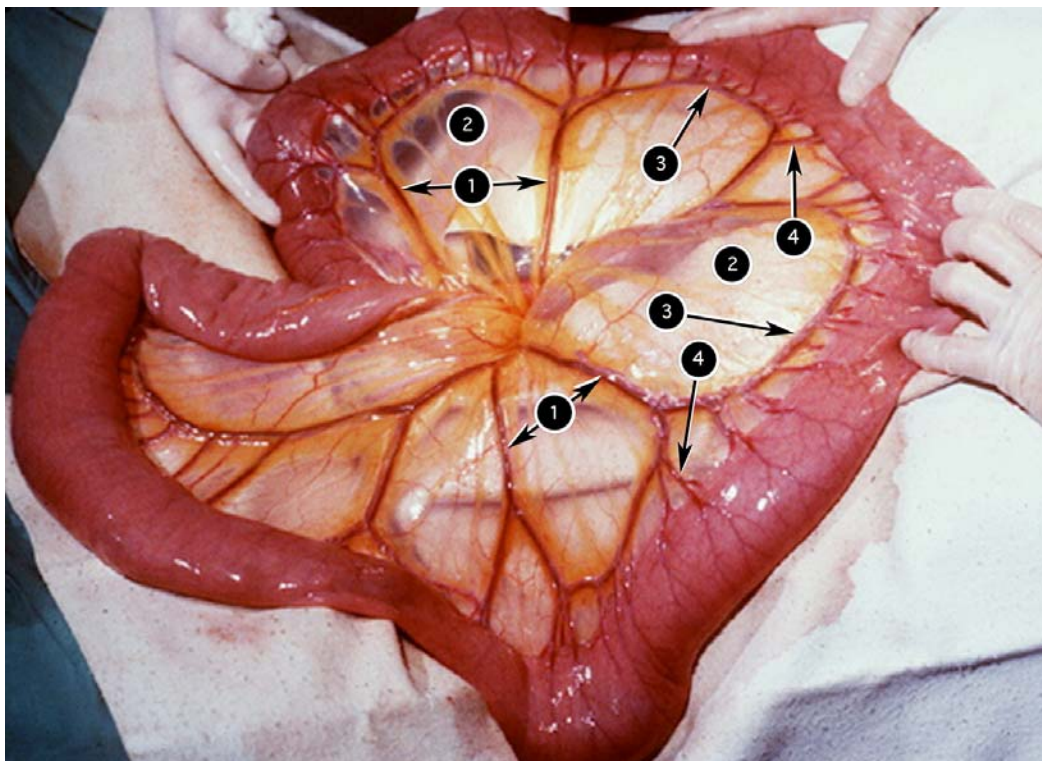


Figure 4-24. Surgical exposure of equine jejunum: (1) jejunal arteries & veins; (2) mesojejunum, containing jejunal lymphatics; (3) arcuate branches connecting adjacent jejunal arteries; (4) secondary set of smaller, branching arteries that supply gut wall. (Photograph courtesy of Dr. Don Smith, Cornell University.)

*Trace the jejunum proximally, up under the left kidney, where it begins at the **duodenojejunal flexure** (Fig. 4-23). As you know, the jejunum is continued distally by the ileum, which will be seen later. For now, move back to the right side and locate the **base** of the **cecum** (Fig. 4-5). The **body** of the cecum continues in a comma-shaped curve to the **apex**, which is located near the xiphoid cartilage. Note the haustra and tenia of the cecum (Fig. 4-23). The cecum has four tenia, but because I usually have trouble finding all of them, even in the dissection room, I personally don't find this bit of information very useful in identification of*

the cecum; its size, large haustra, and blind end are dead giveaways, however.

*Reach around the caudal part of the cecal base and draw it out of the flank so that its medial surface can be examined. You should now be able to locate the **ileum**, which is attached to the cecum by the **ileocecal fold**. Although there is no “dotted line” to indicate the transition from jejunum to ileum, the junction of these two parts of the small bowel is defined by the proximal edge of the ileocecal fold. *There is typically no antimesenteric ileal artery in the horse**

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Grasp the ileum and palpate its thick-walled structure, as compared with that of the jejunum. The ileum becomes more muscular as it approaches the large bowel, and *ileal impaction* has been reported to be the most frequent cause of non-strangulating obstruction in the small intestine of the adult horse.¹⁰ Although the cause of ileal impaction is unclear, it occurs much more commonly in the southeastern United States, where horses are often fed coastal Bermuda grass hay. The high fiber content of this hay, coupled with heat and other stress factors, is suspected as a contributing factor to the development of ileal impaction.

Open the base of the cecum as shown in figure 4-25 and remove enough of the cecal contents to locate the ileal papilla and cecocolic ostium. The **ileal papilla** is the short projection of the ileum into the large intestine at the anatomic junction of the cecum and colon. The ileum serves as a *sphincter* to control passage of ingesta into the large bowel and as a *pump* to move that material into the large intestine at the appropriate time. The **ileal ostium** is surrounded by the ileal sphincter. Thus, the ileum is sort of the “gate-keeper” of the large bowel. All of this is, of course, regulated by the autonomic nervous system, particularly vagal innervation.

What appears to be the most cranioventral part of the cecal base is actually the initial part of the ascending colon that is sharply curved like a hook (Figs. 4-22 & 4-25). That being said, *there is a bit of disconnect in fact and reality here*. In the *real world* of equine medicine, that initial part of the ascending colon is considered to be part of the cecum. This makes sense physiologically in that the

narrow opening through which ingesta must exit the cecum is down stream from the true origin of the ventral colon. The **cecocolic ostium** (Fig. 4-25/3) is protected by the **cecocolic valve**, formed by two mucosal folds.

Although uncommon, both cecocolic and cecocolic intussusceptions do occur in horses. Among the suspected causes of these intussusceptions are alterations in cecal or colonic motility related to the administration of organophosphates, arterial damage produced by *Strongylus vulgaris*, various intestinal infections, and particularly to inflammation caused by the horse tapeworm, *Anoplocephala perfoliata*.¹¹

Another clinical problem related to the cecum is *sand impaction*, resulting from the incidental ingestion of sand, especially when horses are forced to graze too closely in areas with sandy soil. Although the sand can apparently be moved along by the small bowel, once it enters the cecum, it is pretty much there to stay. In extreme case, the cecum can become essentially filled with sand over time.

From the cecum, the **right ventral colon** (more tightly haustrated than cecum) continues cranially to the **sternal flexure** near the xiphoid and is continued along the left side as the **left ventral colon** (Fig. 4-23).¹² The entire ventral colon is haustrated, with four tenia. The diameter of the colon becomes reduced as it approaches the **pelvic flexure**, and the haustrations play out (Fig. 4-23). Here, the left ventral colon turns back on itself to become the **left dorsal colon**.

¹⁰ Emerson RM, Colahan PT, Brown MP, *et al.* Ileal impaction in the horse. JAVMA 186 (1985): 570-572.

¹¹ Martin BB, Freeman DE, Ross MW, *et al.*, Cecocolic and cecocolic intussusception in horses: 30 cases (1976-1996). JAVMA 214 (1999): 80-84.

¹² Inflated demonstration specimens of the equine colon are very useful here.

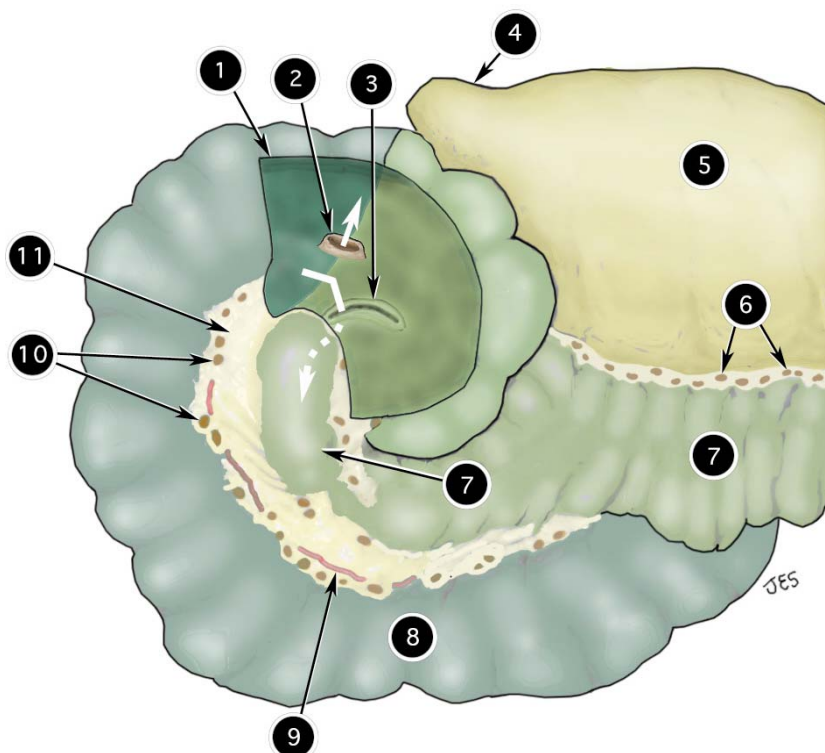


Figure 4-25. Opened base of equine cecum, right lateral view: (1) window made in cecal base; (2) ileal papilla projecting into large intestine at junction of cecum and colon; (3) cecocolic ostium; (4) right colic flexure; (5) ampulla coli of right dorsal colon; (6) colic lymph nodes in mesocolon; (7) right ventral colon; (8) body of cecum; (9) lateral cecal artery; (10) cecal lymph nodes; (11) cecocolic fold. Large white arrows indicate flow of ingesta from ileum to cecum to colon.

*Draw the pelvic flexure out of the abdomen, and note that it has no visible tenia; however, confirm that it does have a single palpable tenia in its mesenteric border. The pelvic flexure (and proximal part of the left dorsal colon) can be identified on rectal palpation by this **single palpable band**.*

Trace the left dorsal colon cranially to the diaphragmatic flexure (Fig. 4-23). Here, the colon turns caudodorsally as the **right dorsal colon**, which has the greatest diameter of any part of the colon, forming a sac-like expansion known as the **ampulla coli** (Fig. 4-25). Locate the right colic flexure, which is the junction of the right dorsal and transverse colon. Here the diameter is reduced so drastically that the area resembles an *inverted funnel*. You don't need a PhD in physics to understand

how this area would be subject to getting plugged (impaction). The ingesta must move up and out through a small opening to enter the transverse colon, and the more liquid component of the fermentative mass doesn't want to go that way. *Thus, the right colic flexure (junction of the right dorsal and transverse colon) is a frequent site of impaction colic in the horse.*

In contrast with the haustrated ventral colon, the entire dorsal colon is smooth; however, tenia are present. Beginning with the single one, present in the mesocolon of the left dorsal part, two more appear over the diaphragmatic flexure and continue onto the right dorsal colon. (Again, the number of tenia isn't very important, at least to me, but the fact that the ventral colon is haustrated and the dorsal colon is smooth is basic to differentiating them visually.)

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From an old anatomist's perspective, the large intestine of the horse actually represents *three, consecutive "fermentation chambers,"* separated from one another by either a sphincter or by a narrow (transport) section. Here's my interpretation: Ingesta is held back by the ileal sphincter until *chamber one*, the **cecum**, has passed on most its contents to the ventral colon. Then the ileal valve opens, and the muscular ileum pumps the cecum full of undigested grass or hay, moved down rapidly from the stomach through the small bowel, and is ready for *stage-one* fermentation.

The partially digested material moving through the cecocolic ostium is ready for *stage-two* fermentation, which occurs in the **ventral colon**. The material is held here for sufficient time by the increased resistance created by the much narrower pelvic flexure and left dorsal colon. These latter two segments then serve to then transport the stage-two material to *chamber 3*, composed of the **diaphragmatic flexure and right dorsal colon (ampulla coli)**. Here is where *stage-three* fermentative digestion occurs. After sufficient digestion and nutrient absorption (volatile fatty acids, etc.) has taken place, the drier portion of the stage-three ingesta is moved through the short, narrow transverse colon to the descending colon. In the descending colon, which is much longer than it need be to reach the "great outdoors," much of the remaining water is absorbed, leaving only the "meadow muffins to fill the rectum, and eventually return to the soil."¹³

Note the **mesocolon** between the left dorsal and ventral parts of the colon. The pelvic flexure is the apex of that long, free loop of ascending colon that grew around into the left caudal abdomen (Fig. 4-4). Thus, the large colon is free to twist around on its mesentery, producing a *volvulus* of the large colon.¹⁴ If that weren't enough, there is a reduction in bowel diameter in the pelvic flexure-left dorsal colon segment, so this area is also a natural place for bowel impaction.

Not only is the large colon subject to *volvulus* and *impaction*, but because it represents a free loop of bowel, it is also subject to *displacement*. Volvulus may involve the area of the sternal and diaphragmatic flexures, or the right colon may become twisted around the base of the cecum. The pelvic flexure may be displaced cranially as if it were going back around to the right side, or the entire left colon may be displaced dorsally around the spleen, so that it becomes hooked over the renosplenic (nephrosplenic) ligament between the spleen and the left kidney. Thus, this displacement is clinically referred to "nephrosplenic entrapment."

The transverse colon is continued by the **descending (small) colon**, which is easily distinguished visually and rectally by its two distinct tenia- one mesenteric and one antimesenteric (Fig. 4-23). The descending colon usually lies mixed with loops of jejunum in the left dorsal part of the abdominal cavity.

¹³ It is often stated that horses need to engage in coprophagy (poop-eating) to obtain nutrients from their "hind-gut" digestion. Rabbits do this selectively, but I just can't buy that idea for horses. It goes against all common sense that a nomadic creature like the horse (here today-gone tomorrow) would go to all that effort to digest such complex

plant material, only to have to re-ingest it to gain much of any nutrient value.

¹⁴ Hackett RP, Nonstrangulated colonic displacement in horses. JAVMA 182 (1983): 235-240.

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Although I have mentioned the number of tenia on the various parts of the equine colon, it should be obvious that it isn't really necessary to memorize this information.¹⁵ When you can see the bowel of the horse (at surgery or on the necropsy floor), I expect that any of you could differentiate dorsal (smooth) from ventral (haustrated) parts of the colon. The ventral colon is more tightly haustrated than the cecum. Information on the number of bands is important when you are forced to use the *Braille technique*, such as in the rectal examination of a colicky horse.

Even with the most zealous palpator, certain physical limitations (namely, the combined length of the human arm, hand, and fingers) prohibit you from palpating the diaphragmatic and sternal flexures. Therefore, it appears that you are primarily concerned with distinguishing the *jejunum*, *pelvic flexure area*, and *descending colon* by touch. *The jejunum has no bands (tenia), the pelvic flexure area has one, and the descending colon has two.* Commit these to memory and, if interested, look-up the others.

To demonstrate that you do not need to memorize the number of tenia on every part of the equine bowel to identify them at surgery, I refer you to figure 4-26. Here we have three parts of the equine intestines isolated at surgery. Identify each bowel part based on your knowledge of anatomy.

GI Tract of Ruminant: The intestinal tract of the ruminant is most easily followed in

the *newborn calf* so it's a good idea to follow it first in those specimens. Beginning at the pylorus, the **duodenum** courses cranially as the **cranial part**, during which it makes a **sigmoid flexure** near the liver, then turns caudally at the **cranial flexure** to become the **descending duodenum** (Figs. 4-8, 4-16, & 4-21). At the caudal flexure, the duodenum turns cranially as the ascending duodenum to the **duodenojejunal flexure**.

Here, the peritoneal attachment lengthens to support the very long **jejunum**, which is arranged in many tight, crowded loops in the free edge of the mesentery (Fig. 4-27). Adjacent to the jejunal loops, a series of prominent **jejunal lymph nodes** should be noted. During inspection of the intestinal mass (*offal*¹⁶) at the slaughterhouse (*abattoir*), the mesentery can be fanned through the fingertips, and these lymph nodes palpated for evidence of disease, which could lead to condemnation of the offal or, if more widespread involvement is detected, the entire carcass.

The junction of jejunum and **ileum** is defined by the proximal edge of the **ileocecal fold** (Fig. 4-27), and the ileum can be traced to the **ileocecocolic junction**. The **cecum** is directed caudally, and the **proximal loop** of the ascending colon, which is typically about the same diameter as the cecum, courses cranially, then bends back on itself and turns around the caudal edge of the mesentery to become continuous with the **spiral loop**. The spiral loop of the ascending colon in the ruminant is actually more *coiled* than *spiraled* and becomes adhered embryologically to the left side of the mesojejunum (Fig. 4-13).

¹⁵ FYI ONLY (which, of course, means, you'll remember it forever): the cecum & ventral colon have 4 bands; the pelvic flexure has 1 band; the dorsal colon starts with one and ends with 3 bands; and the transverse & descending colon has 2 bands. OK, so I let it slip out- (that's 4-4-1-3-2 for those of you who just have to know.)

¹⁶ *offal*- the viscera and trimmings of a butchered animal that are removed at slaughter.

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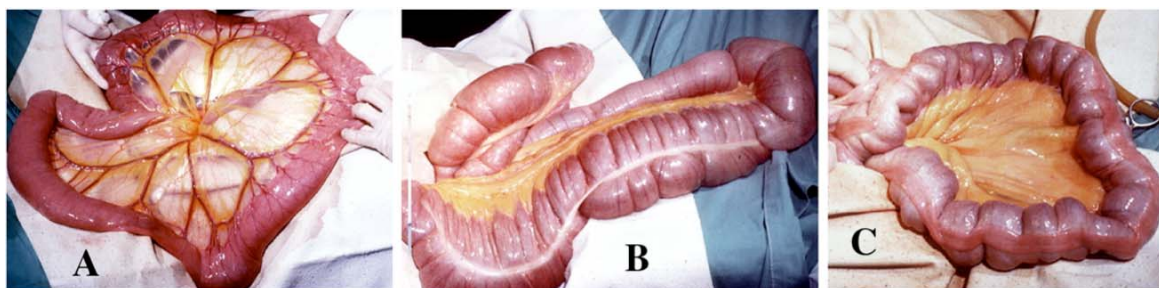


Figure 4-26. Photographs of three segments of equine bowel isolated at surgery. Please identify each segment based on your knowledge of anatomy about their visual characteristics (answers at end of chapter). (Photographs courtesy of Dr. Donald F. Smith, Cornell University.)

The proximal half of the spiral loop is coiling toward the center of the loop and those turns are designated **centripetal coils**. At the **central flexure** (homologous to pelvic flexure of horse), the bowel continues spiraling from the center, and the more distal turns are designated **centrifugal coils**. (You keen observers have undoubtedly already picked up on the underlined letters of correlation in the previous two sentences—can't get anything past you.)

Note that the *last centrifugal coil* in the *sheep* and *goat* leaves the other coils and courses very close to the jejunum. This longer loop allows more time for *water resorption*, and the material contained in this coil is typically beginning to be formed into the pellet-type feces, characteristic of the small ruminants. Sheep and goats are better water conservers than cattle, and are thus better adapted for arid conditions.

Note also that the mesenteric nerves, lymphatics, and blood vessels pass across the right side of the spiral loop, which explains why the loop is more difficult to see from the right. Because of the accumulation of mesenteric fat, the spiral colon of the adult ruminant is difficult to follow without removal and dissection; thus, it can best be observed (and understood) in the newborn calf. The **cranial mesenteric**

artery courses within the mesentery between the spiral colon and jejunum, and primary jejunal arteries anastomose and give rise to secondary branches, which supply the jejunum (Fig. 4-28).

In the ox, but not in small ruminants, a large **collateral branch** leaves the cranial mesenteric artery, crosses the right side of the spiral colon, and rejoins the main artery distally. This “bypass” diverts blood directly to the more distal jejunum and ileum without having to take the more circuitous route by way of the cranial mesenteric artery; this arrangement apparently provides for more uniform perfusion pressures along the jejunum and ileum.

The **distal loop** of the ascending colon passes caudally around the mesenteric root and returns the colon to the right side. It lies dorsal to the proximal loop and is typically smaller in diameter (Fig. 4-27). The ascending colon joins the very short **transverse colon** at the **right colic flexure**; the transverse joins the **descending colon** at the **left colic flexure**, and the latter courses caudally to the pelvic cavity. *As you have seen, no part of the ruminant colon is haustrated, and no tenia are present.*

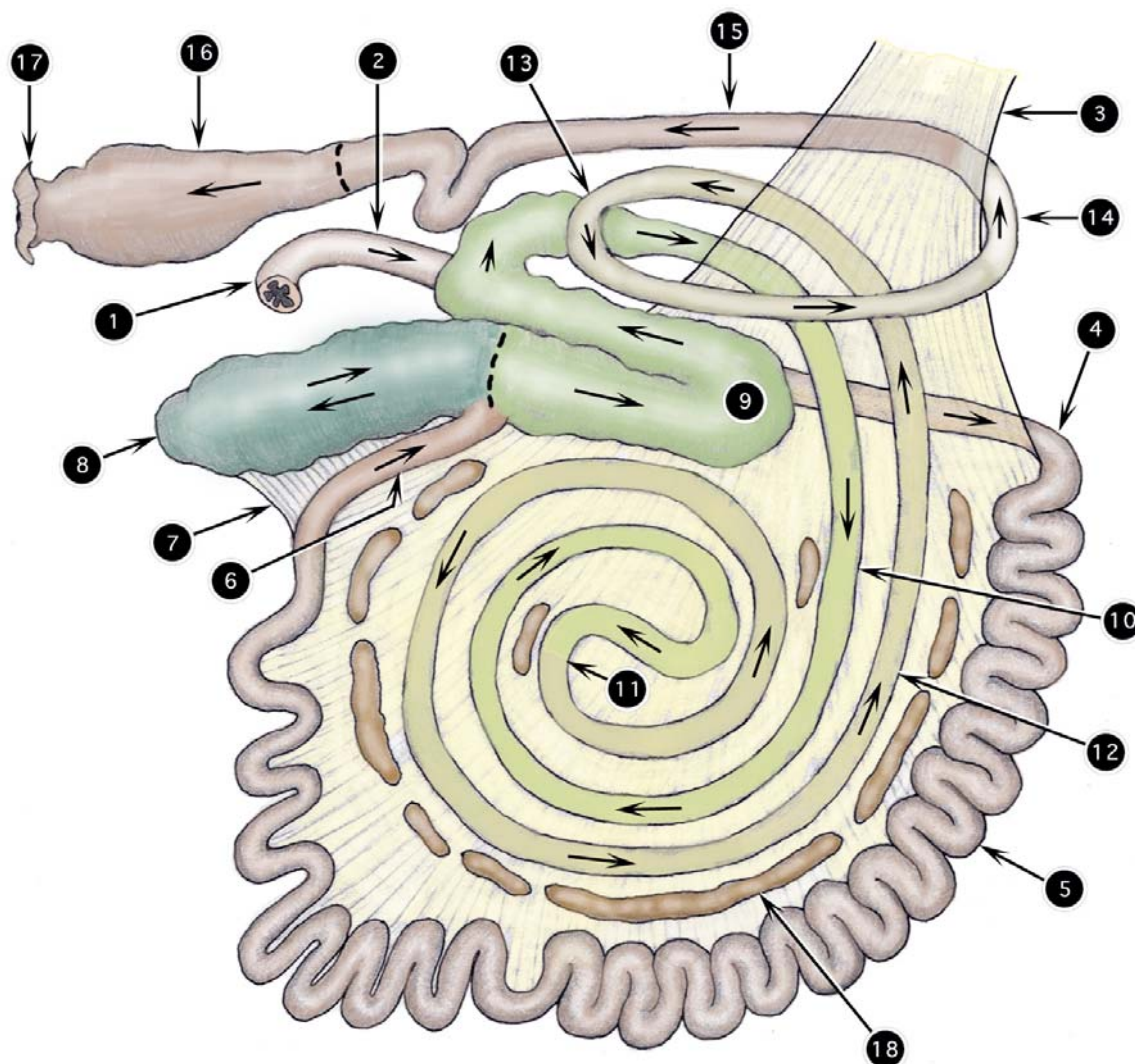


Figure 4-27. Bovine intestinal tract, right lateral view: (1) caudal flexure of duodenum; (2) ascending duodenum; (3) root of mesentery; (4) duodenojejunal flexure; (5) jejunum; (6) ileum; (7) ileocecal fold; (8) cecum; (9) proximal loop of ascending colon; (10) centripetal coil of spiral loop; (11) central flexure of spiral loop; (12) centrifugal coil of spiral loop; (13) distal loop of ascending colon; (14) transverse colon; (15) descending colon; (16) rectum; (17) anus; (18) jejunal lymph nodes.

Intestinal atresia, a complete absence of a segment of the intestinal lumen, is a well recognized congenital defect in calves. The most frequently affected area is the spiral loop of the ascending colon. Although an hereditary basis has been suggested by some, the exact cause of atresia coli in calves has not yet been established. In fact,

there is growing evidence that atresia coli is not inherited.¹⁷

¹⁷ Smith, D. F., Durcharme, N. G., Fubini, S. L., *et al.* Clinical management and surgical repair of atresia coli in calves: 66 cases (1977-1988). JAVMA 199 (1991): 1185-1190.

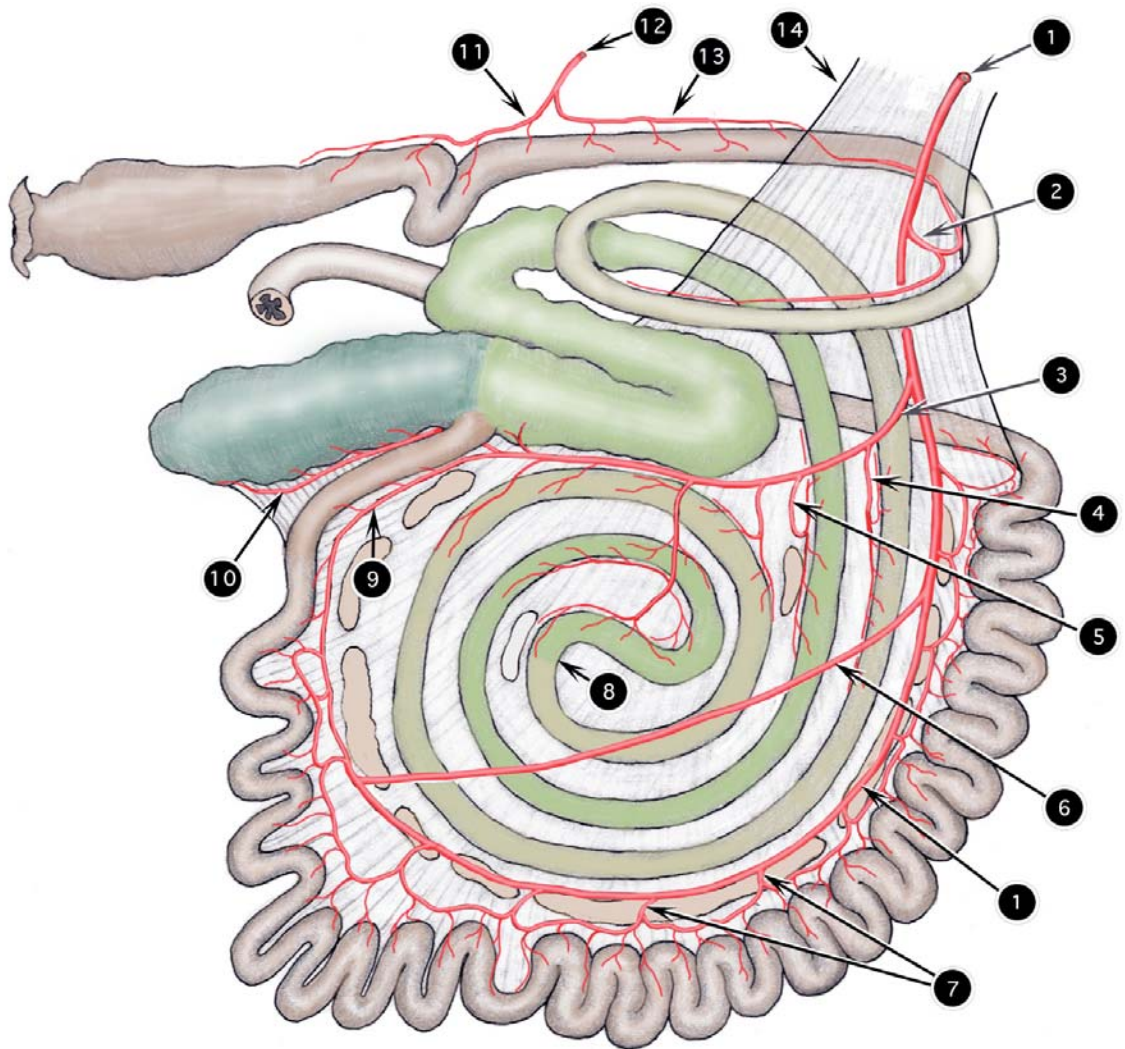


Figure 4-28. Semischematic representation of blood supply to bovine intestinal tract, right lateral view: (1) cranial mesenteric artery; (2) middle colic artery; (3) ileocolic artery; (4) right colic artery to centrifugal coil; (5) colic branch of ileocolic artery to centripetal coil; (6) collateral branch of cranial mesenteric artery (not present in small ruminant); (7) jejunal arteries; (8) central flexure of spiral loop; (9) ileal artery; (10) cecal artery; (11) cranial rectal artery; (12) caudal mesenteric artery; (13) left colic artery; (14) root of mesentery.

GI Tract of Pig: The **duodenum** of the pig follows the typical pattern of flexures (Figs. 4-20 & 4-22), and the **jejunum** is very long, consisting of many small loops supported by a fan-shaped mesentery (Fig. 4-29). Because the cecum and spiral colon usually dominate the left side, the jejunal mass is somewhat crowded into the right half of the abdominal cavity. The **ileum**, defined by

the ileocecal fold, joins the large bowel at the ileoceccocolic junction.

The branching pattern of the **jejunal arteries** is rather unique in the pig (Fig. 4-29). Primary jejunal arteries leave the cranial mesenteric and form a series of anastomotic arches that give rise to hundreds (if not thousands) of small secondary branches to form a “brush-like” arterial

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supply to the bowel wall. As previously noted, the **cecum** of the pig is on the left. Thus, a proximal loop of the ascending colon is unnecessary, and the **spiral loop** begins immediately from the cecum (Figs. 4-22 & 4-29).

The cecum and **centripetal coils** are haustrated with tenia, whereas the smooth **centrifugal coils** of the ascending colon are concealed within the cone of **centripetal coils**. However, you can identify the **distal loop** as it emerges from the cone and carries the colon around the mesenteric root to the right side (Fig. 4-29). The transverse and descending colon of the pig are not remarkable.

STOMACH

Now that the intestinal arrangement has been followed *in situ*, let's take a closer look at the stomach.

Stomach of Horse: *Open the stomach by incising and removing part of the parietal (cranial) wall. Clean the inside of the stomach to observe the mucosa.* The **fundus** is enlarged to form a **saccus cecus** (blind sac), which is lined by a nonglandular, stratified squamous epithelium (Fig. 4-17 & 4-23). The junction of the nonglandular and glandular regions is marked by a ridge, the **margo plicatus** (Fig. 4-17). Because many ponies used in the laboratory haven't been on the most vigorous of worming programs, it is not uncommon to find parasite residents in the stomach. The larvae of the common botfly, *Gasterophilus intestinalis*, may be found attached to the stomach wall.

The **glandular part** of the stomach is divided into three regions (Fig. 4-17): (1) a narrow zone of mixed cardiac and pyloric glands just distal to the margo plicatus; (2)

the **region of proper gastric glands**,¹⁸ and (3) a pyloric gland region. Note that the shortest path between the cardia and pylorus is right along the lesser curvature. This most direct path is known as the **gastric groove**, even though it is not visible on the mucosal surface of the horse. Remove a strip of mucosa including the area around the cardia and extending about 8 cm along the lesser curvature to observe the gastric groove.

As you recall, the tunica muscularis of the stomach consists of three layers: longitudinal (outer), circular (middle), and oblique (inner). The oblique layer is thickest along the gastric groove, where it forms the lips of the groove and a distinct **cardiac loop** around the cardia. *Try to push your finger back up through the cardiac opening.* Not so easy, huh? The cardiac loop, together with circular fibers, forms a very strong **cardiac sphincter** in the horse.

This sphincter, combined with the strong muscular tunic of the more distal part of the esophagus, makes it practically impossible for the horse to vomit or even eructate (belch). Rapid gas accumulation in the equine stomach can cause tearing or even complete rupture of the organ. When horses do vomit, it usually (not always) indicates a grave condition, because there has been concurrent tearing of the stomach with possible leakage of gastric contents into the peritoneal cavity.

From the body of the stomach, the organ narrows distally to form the **pyloric antrum**, which leads to the **pyloric canal**. *Open the pyloric part of the stomach out through the duodenal ampulla.* The **pyloric**

¹⁸ Note: This region is *not* in the fundus of the stomach. Thus, the term “fundic gland region”, which actually refers to the deep gastric pits, is misleading and should not be used.

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sphincter of the horse is well developed, consisting primarily of a thickening of the circular muscle layer, but the longitudinal

layer is also thickened in this area (Fig. 4-17).

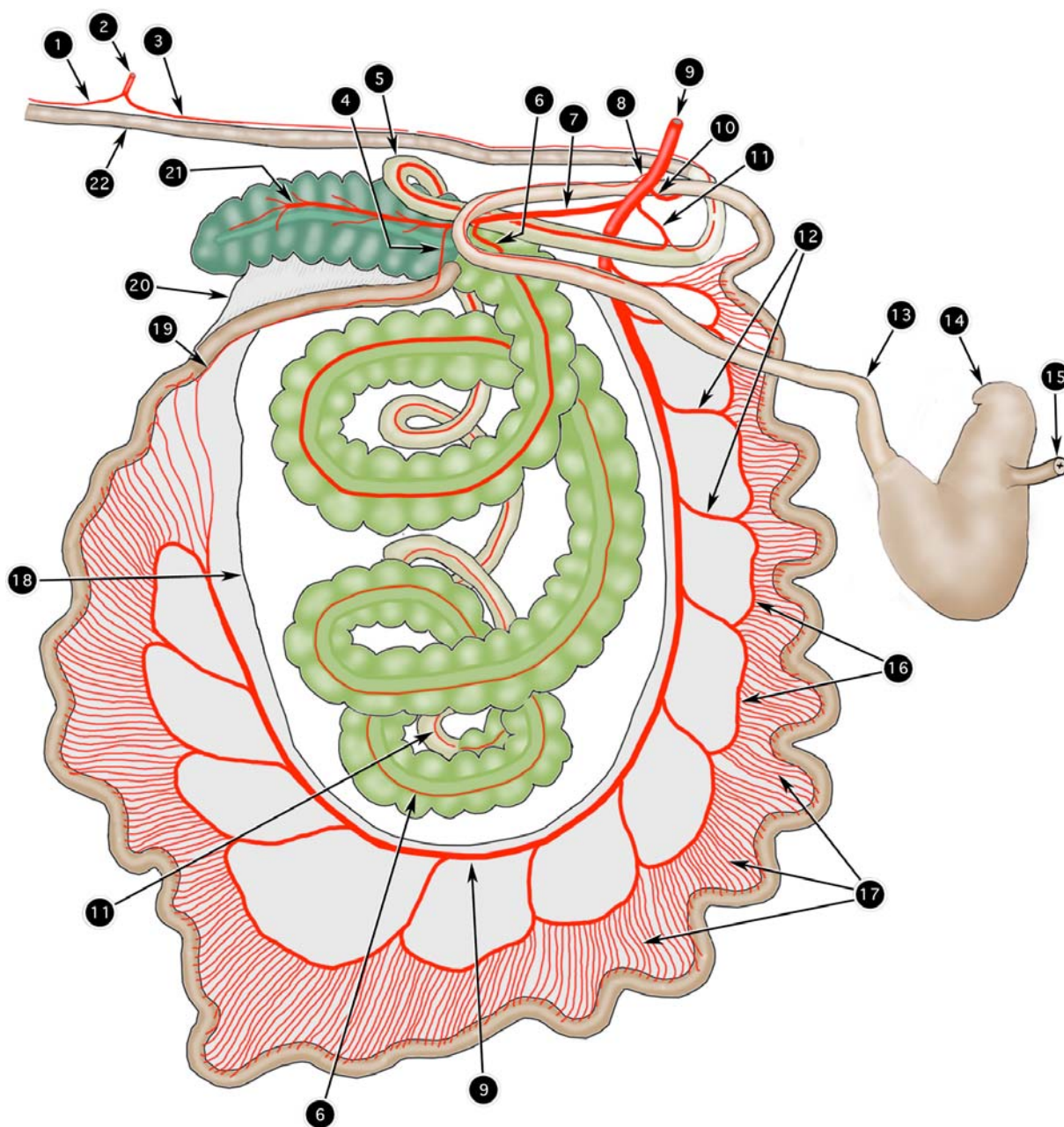


Figure 4-29. Semischematic representation of blood supply to porcine intestinal tract, right lateral view with much of mesojejunum removed: (1) cranial rectal artery; (2) caudal mesenteric artery; (3) left colic artery; (4) ileal branch of ileocolic artery; (5) distal loop of spiral colon; (6) colic branch of ileocolic artery to centripetal coils of spiral colon; (7) ileocolic artery; (8) caudal pancreaticoduodenal artery; (9) cranial mesenteric artery; (10) middle colic artery; (11) right colic artery to centrifugal coils of spiral colon; (12) jejunal arteries; (13) cranial flexure of duodenum; (14) gastric diverticulum; (15) esophagus; (16) anastomotic arches between jejunal arteries; (17) hundreds of secondary branches to jejunum; (18) cut edge of mesojejunum; (19) ileal branch of cranial mesenteric artery; (20) ileocecal fold; (21) cecal artery from ileocolic artery; (22) descending colon.