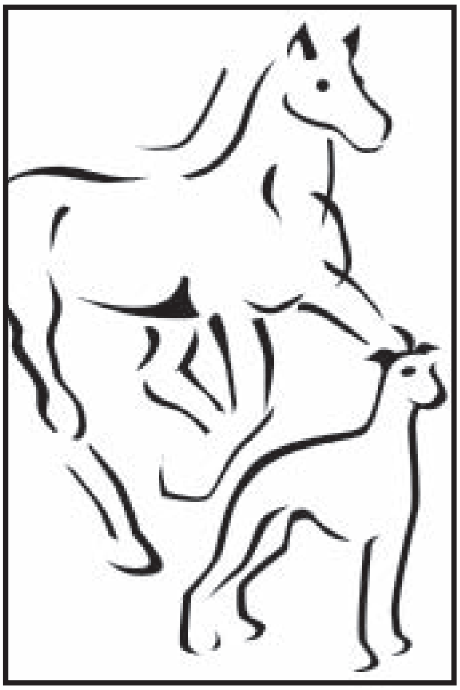
THE UNIVERSITY
OF QUEENSLAND

Master of Animal Studies (Animal Physiotherapy)



STUDY BOOK

Course Code: **ANIM7101**

Course Name: **COMPARATIVE ANIMAL ANATOMY**

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Chapter 1

General Considerations in Anatomy of Animals

Anatomical terminology

Differences between human and animal anatomical terms

Much of the terminology used in describing anatomy of animals is the same as that used in human anatomy. The principle differences can be explained by remembering that an animal is generally considered standing on all fours. As a result

a) Structures that in the human would be referred to as anterior, are referred to as ventral, i.e. directed towards the ground.

b) Structures that in the human are referred to as posterior, are referred to as dorsal.

An additional but crucial difference, is that in the human anatomical position, the palms of the hands are directed anteriorly, such that the ulna and 5th digit are medial. In animals, the palms face posteriorly (inevitably, if the animal is to walk on them!), so as a result, the radius and 1st digit are medial. This is an important distinction to remember in considering the anatomy of the forelimb in animals, for those with training in human anatomy.

Finally, in the quadripedal position in which the vertebral column is parallel with the ground, the direction of the head is referred to as cranial, and the direction of the tail is caudal. When referring to structures within the head, the term rostral, meaning towards the nose, is substituted for cranial.

Another possible source of confusion may come from the terms upper and lower limb. In humans, "upper limb" refers to the arm, and "lower limb" to the leg. The terms tend to be applied more loosely in animal anatomy, as essentially all four limbs are regarded as legs. Hence, "upper limb" tends to refer to the part of the limb above carpus or hock (ankle), while "lower limb" refers to the part of the limb below these points.

Although physiotherapists will be familiar with anatomical terminology, the following glossary is included to help overcome any confusion that may arise from differences in human and animal anatomy.

Topographical terms

(A) TERMS USED TO INDICATE THE **PRECISE POSITION AND DIRECTION OF PARTS OF THE BODY**

N.B. It is to be assumed that the terms listed below apply to a quadruped (four-legged) animal in an ordinary standing position.

PLANE: A flat surface, real or imaginary, passing through the animal, or part of it.

TYPES OF PLANES: (See **Figs. 1-A and 1-B**)

1. **MEDIAN OR LONGITUDINAL**: (divides the body into similar halves) divides the head, body of the limb longitudinally into equal right and left halves.
2. **SAGITTAL**: passes through the head, body or limb parallel to the median plane.
3. **TRANSVERSE OR SEGMENTAL**: cuts perpendicular to the median plane, or at right angles to its long axis or an organ or limb.
4. **FRONTAL (OR CORONAL)**: perpendicular to the median and transverse planes.

SURFACES: The outer or external aspects of an object or body.

TYPES OF SURFACES: (see **Figs. 1-C and 1-D)**

1. **VENTRAL**: the surface directed towards the ground. Towards or relatively near to the underside of the head or body.
2. **DORSAL**: the opposite surface to the preceding (i.e. towards or relatively near to the top of the head, back of the neck, trunk or tail). On the limbs, it applies to the upper or front surfaces of the carpus (knee),, tarsus (hock), metapodium (homologous to the hand and foot), and digits.
3. **MEDIAL OR INTERNAL**: a surface or structure which is nearer than another to the median plane (i.e. towards or relatively near to the median plane).
4. **LATERAL OR EXTERNAL**: a surface which is further than another from the median plane (i.e. away from or relatively further from the median plane).
5. **CRANIAL**: is the head-end of the body. A surface towards or relatively near to the head. On the limbs, it only applies to structures above the carpus and tarsus. You may also encounter the term **CEPHALIC** which means the same thing.

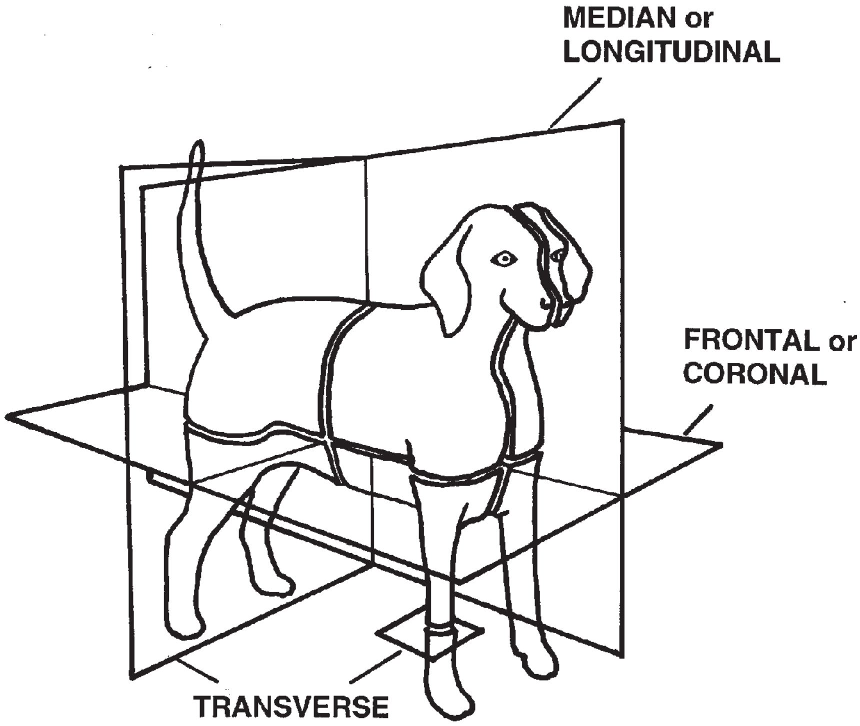


Figure 1-A: Terms of planes and of direction(*Redrawn from Sisson and Grossman)*

6. **CAUDAL**: is the tail-end of the body. A surface towards or relatively near the tail. On the limbs, again it applies to structures above the carpus and tarsus.

7. **ROSTRAL**: applies to the head region only. A surface towards or relatively near to the nose.

8. **ORAL**: applies to the mouth region only. A surface towards or relatively near to the mouth.

9. **ABORAL**: applies to the surface opposite to or away from the mouth region.

(B) TERMS **APPLIED TO THE LIMBS** (see **Fig. 1-D**)

1. **PROXIMAL**: refers to relative distances of different parts from the long axis of the body; viz., those parts of the limb or limb structures that are nearest to the body or main mass. Thus, we have the proximal extremity of limb bones being the upper extremity and the proximal part of bone structures being mostly the upper parts.

2. **DISTAL**: refers to that part of a structure that is furthest away from the main mass of tissue. In the appendages, it applies to the lower end of say a limb bone or even the free end of the limb.

With reference to the thoracic limb (pectoral limb) or forelimb (see **Fig. 1-D**)

3. **DORSAL**: refers to the cranial face of the distal part of the forelimb. In addition, it can refer to the dorsum of the manus (homologue of the hand).

4. **PALMAR**: (the older term is **VOLAR**) refers to the face opposite the dorsal face.

5. **RADIAL (EQUIVALENT TO MEDIAL)**: that side of the forearm in which the radius is located.

6. **ULNAR (EQUIVALENT TO LATERAL):** that side of the forearm in which the ulna is located.

7. **BRACHIUM (OR ARM):** specifically the region from the shoulder to the elbow. Also, a general term used to designate an arm-like process or structure.

8. **AXILLA**: is the space between the thoracic limb and the thoracic wall.

With reference to the pelvic limb or hindlimb (see Fig. 1-D)

9. **DORSAL**: the anterior face of the distal part of the pelvic limb. In addition, it can refer to the dorsum of the pes (foot).

10. **PLANTAR**: refers to the face opposite the dorsal face.

11. **TIBIAL (EQUIVALENT TO MEDIAL):** that side of the leg on which the tibia is located (medial).

12. **FIBULAR (EQUIVALENT TO LATERAL):** that side of the leg on which the fibula is located (lateral).

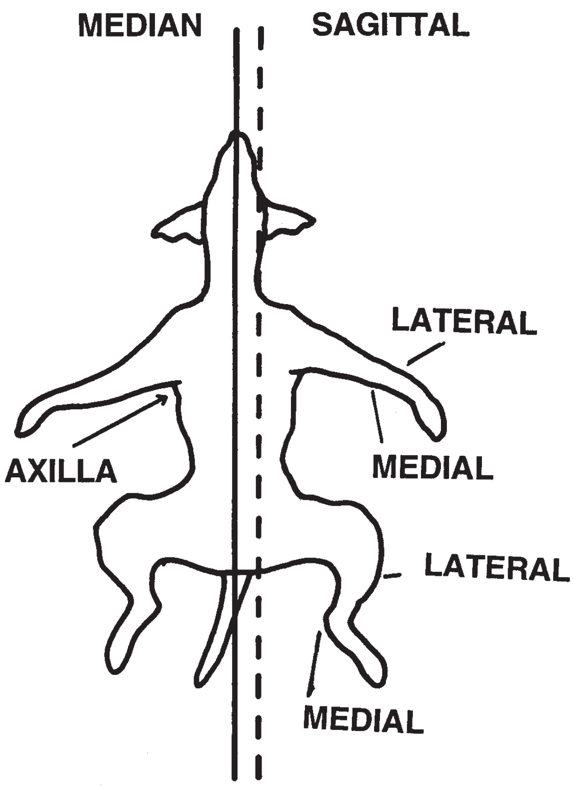


Figure 1-B: Relative distances to the body centre

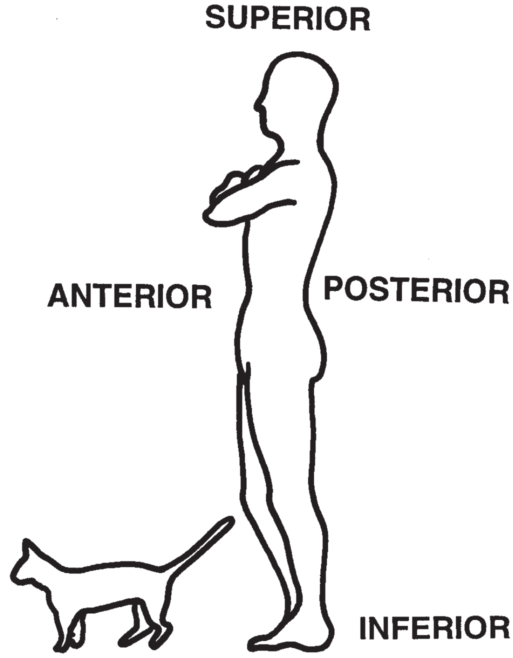


Figure 1-C: Directional terms for a quaduped and a biped

(Re-drawn from Taylor & Weber)

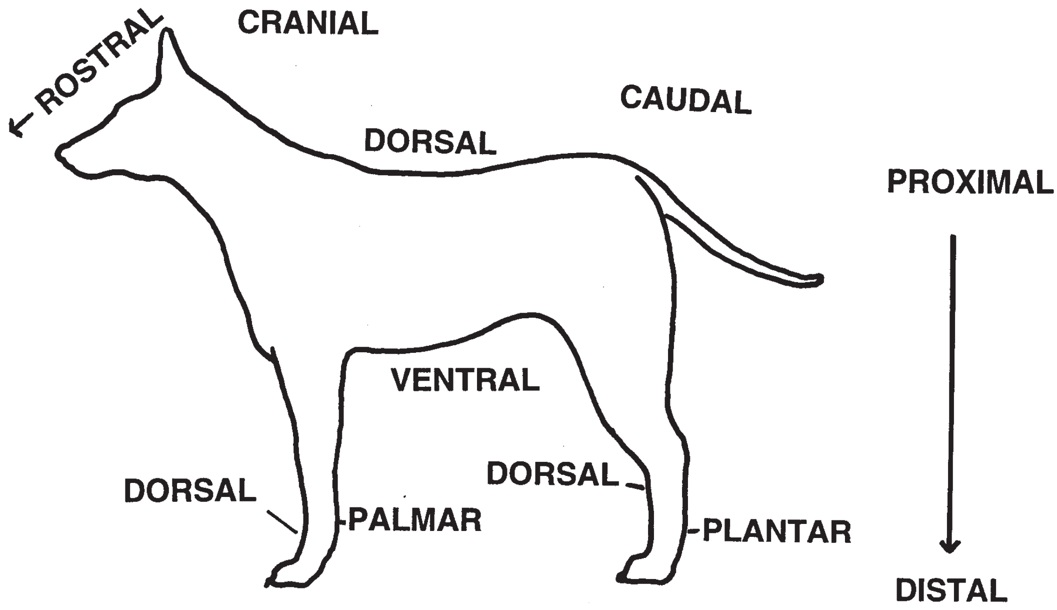


Figure 1-D: Terms of the oral cavity, body and limbs

(C) TERMS TO INDICATE **RELATIVE DISTANCES FROM THE CENTRE OF THE LIMB** (see **Fig. 1-E**)

AXIS: is the centre line of the body or any of its parts.

In ARTIODACTYLA (RUMINANTS and PIGS) and in CARNIVORA (DOGS AND CATS), the functional axis of the limb passes between the 3rd and 4th digits. In PERISSODACTYLA (HORSE), the functional axis of the limb passes along the centre line of the only digit present.

1. **AXIAL** and 2. **ABAXIAL**

are terms meaning pertaining to or being relative to the axis. e.g. the AXIAL SURFACE of a digit faces the axis while the ABAXIAL SURFACE faces away from the axis.

(D) TERMS TO INDICATE **RELATIVE DISTANCES FROM THE SURFACE OF THE BODY**

1. **SUPERFICIAL**: relatively near to the surface of the body, or to the surface of a solid organ.
2. **DEEP**: relatively near to the centre of the body or the centre of a solid organ.
3. **EXTERNAL OR OUTER**: away from the centre of a hollow organ.
4. **INTERNAL OR INNER**: close to, or in the direction of the centre of a hollow organ

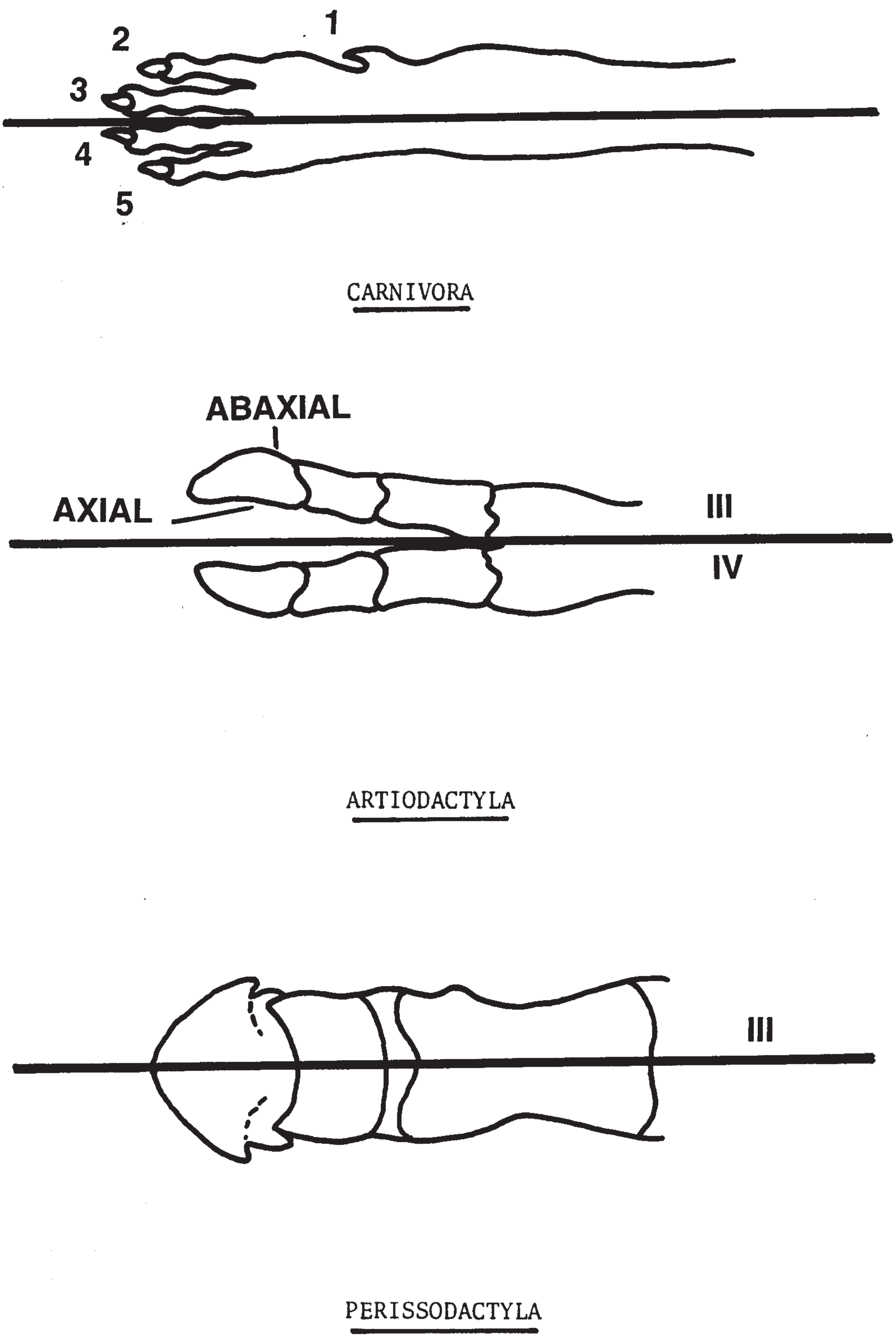


Figure 1-E: Axis of the limbs in different orders of animal

(E) TERMS WHICH APPLY TO **THE BASIC MOVEMENT OF THE PARTS OF THE BODY** (see and complete **Fig. 1-F)**

1. **PROTRACTION**: taking the whole limb forward.

2. **RETRACTION**: taking the whole limb backward.

3. **EXTENSION**: the movement of one bone upon another in such a way that the angle formed at their joint is increased. Thus, the limb reaches out or is extended; the digits are straightened. Referring to the back it means that it is straightened.

4. **FLEXION**: the movement of one bone in relation to another in such a way that the angle formed at their joint is reduced. Thus, the limb may be retracted or folded; the digits are bent. Referring to the back it is arched.

5. **PRONATION**: as applied to the manus (hand or paw), the act of turning the palm backward (posteriorly) or downward, performed by medial rotation of the forearm. This is the normal position of the manus in quadripeds.

6. **SUPINATION**: as applied to the manus (hand), the act of turning the palm forward (anteriorly) or upward, performed by lateral rotation of the forearm. Dogs have some limited ability to supinate the manus; horse forelimbs are fixed in pronation and the manus cannot be supinated at all.

7. **ABDUCTION**: the movement of a part away from the median plane.

8. **ADDUCTION:** the movement of a part towards the median plane.

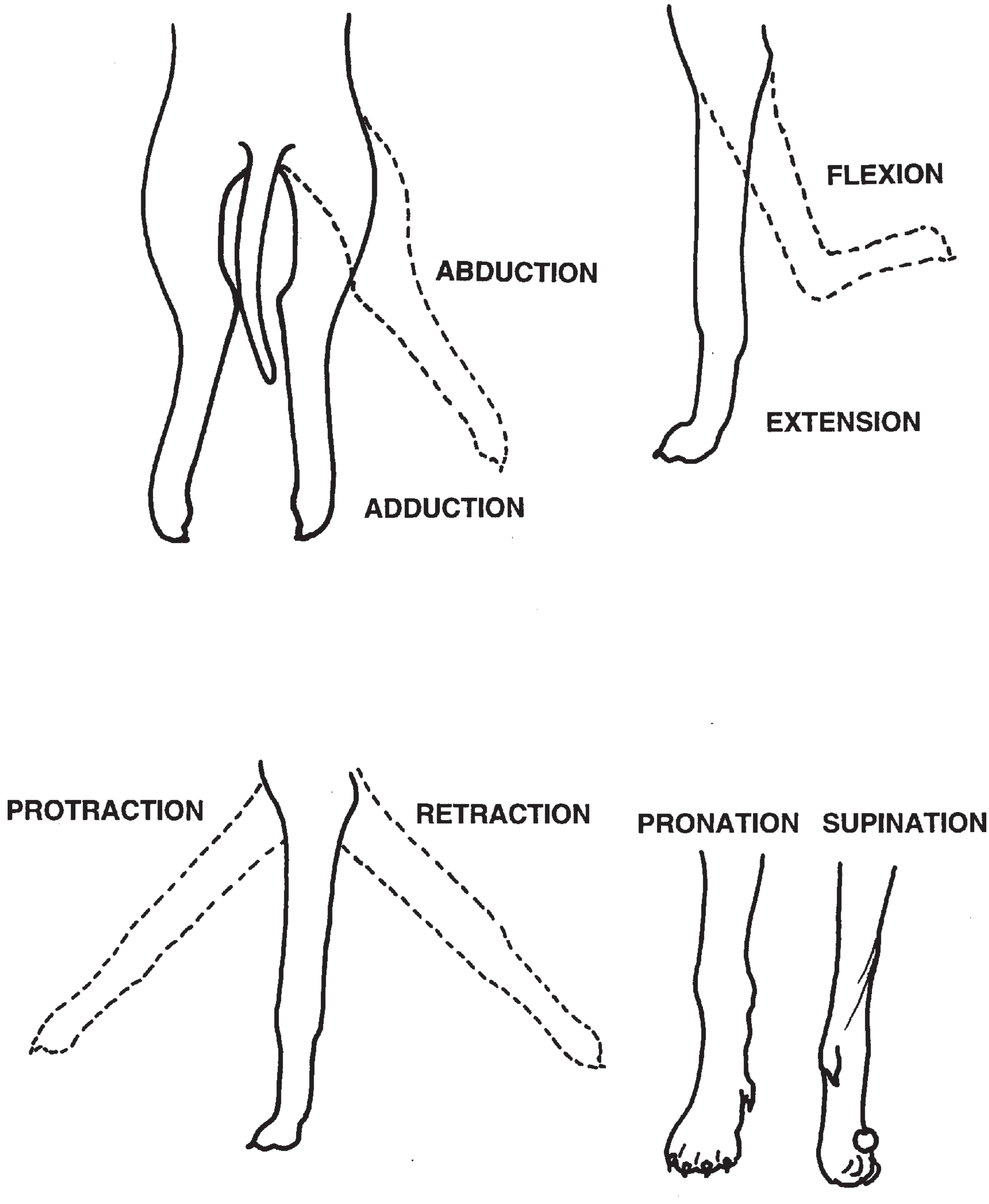


Figure 1-F: Terms applied to basic movements

Outer body form – shape and general appearance of horse and dog

The following drawings (**Figs. 1-G and 1-I**) illustrate the outward appearance of the horse and the dog. Opposite each drawing is another drawing which shows the skeleton of the species in relation to the outer shape of its body (**Figs. 1-H and 1-J**).

The purpose of these drawings is to illustrate:

(a) the general organization of the skeleton as it relates to each species; and

(b) how the skeleton contributes as a protective and supportive element to the overall shape of each animal.

Study each of these pairs of pictures, therefore, so that when you see an animal, you will be able to envisage the arrangement of its bony framework. Take particular notice of those areas that appear to have bone as protection and which appear to be supported by the skeleton.

There are also a few lay terms with which human anatomists may not be familiar, but which owners of these animals will inevitably use. These are explained in this section illustrating general appearance of the horse and dog. Take particular note of the following:

a) The carpus of the horse is generally referred to as the “knee”; in the dog, some will use the term “knee”, others “wrist”.

b) The tarsus (human ankle joint) is referred to in all animals as the “hock”.

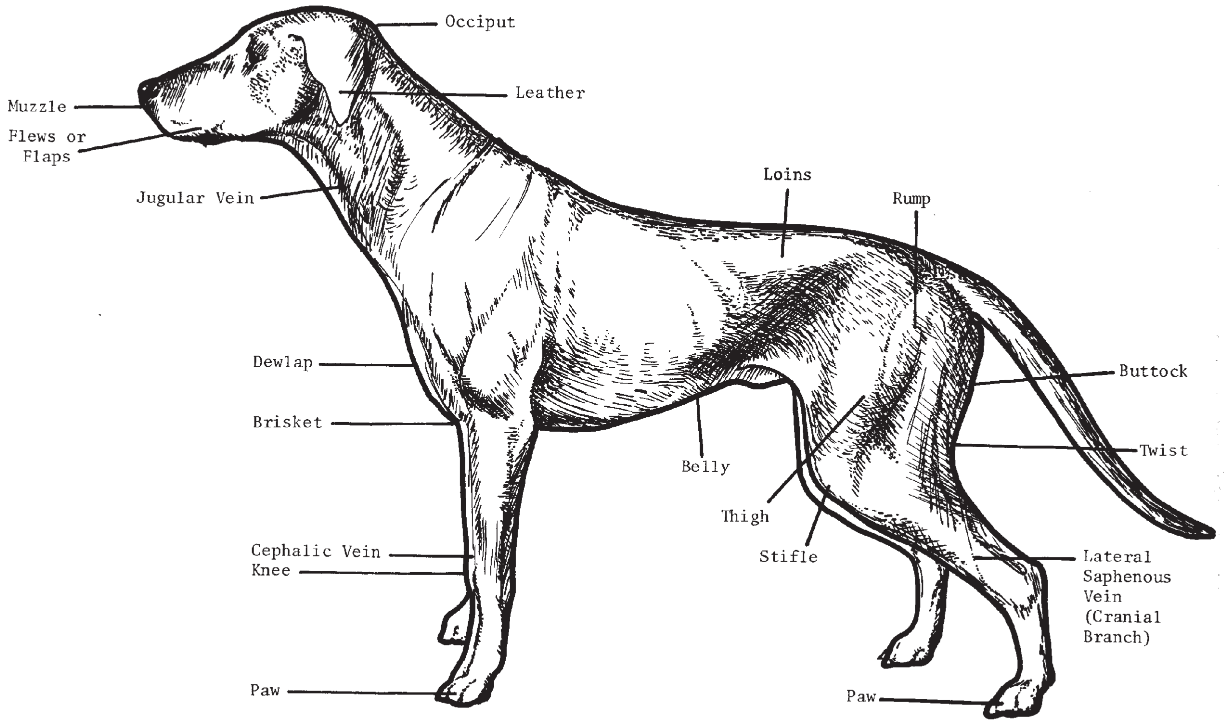
c) The femorotibial and femoropatellar joints (which form the true knee joint in humans) are referred to together in all animals as the “stifle”.

d) The part of the forelimb of the horse below the carpus and tarsus (which is in fact the metacarpus and metatarsus respectively), is referred to as the cannon (or shin, in the forelimb). An old term for this region of the hind limb is “shannon”, but this is usually also referred to as cannon.

e) The metacarpophalangeal and metatarsophalangeal joints in the horse are referred to as the “fetlock” joints.

f) The proximal interphalangeal joints in the horse are referred to as the “pastern” joints, and the region between the fetlock and the hoof in which this joint is situated is referred to generally as the “pastern”.

g) The distal interphalangeal joints in the horse are referred to as the “coffin” joint.



Note: Some breeds have long hairs on the legs and tail. These are referred to as Feathers, or on the tail they are sometimes called the "Flag".

Figure 1-G: Points of a dog (outward appearance)

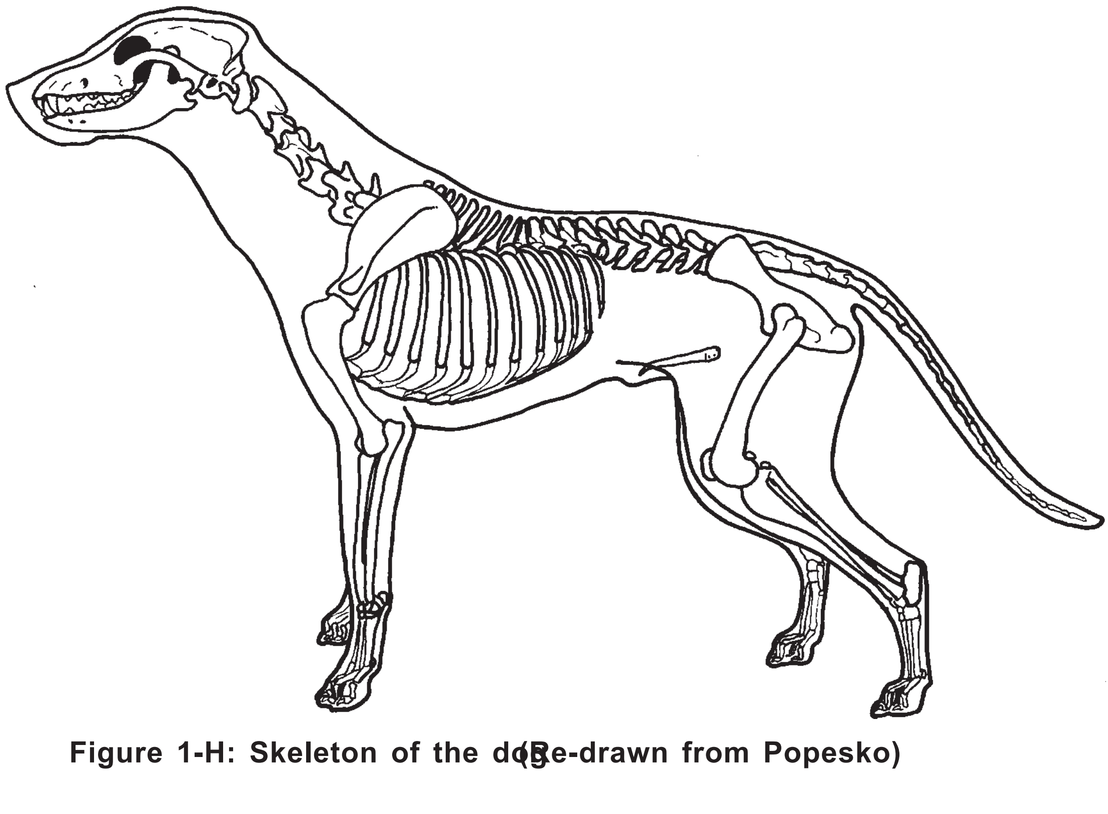


Figure 1-H: Skeleton of the dog (Re-drawn from Popesko)

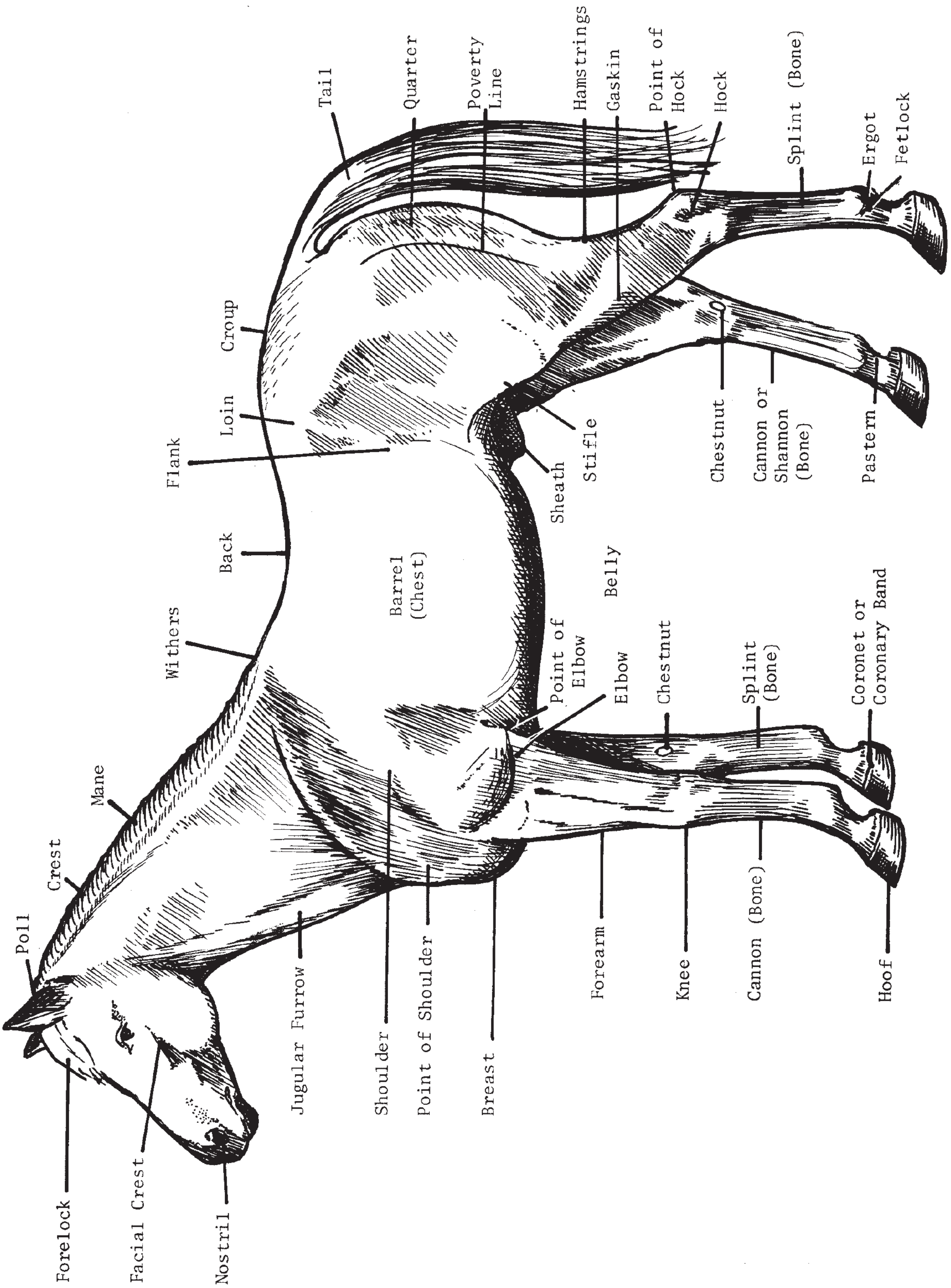


Figure 1-I: Points of the horse (outward appearance)

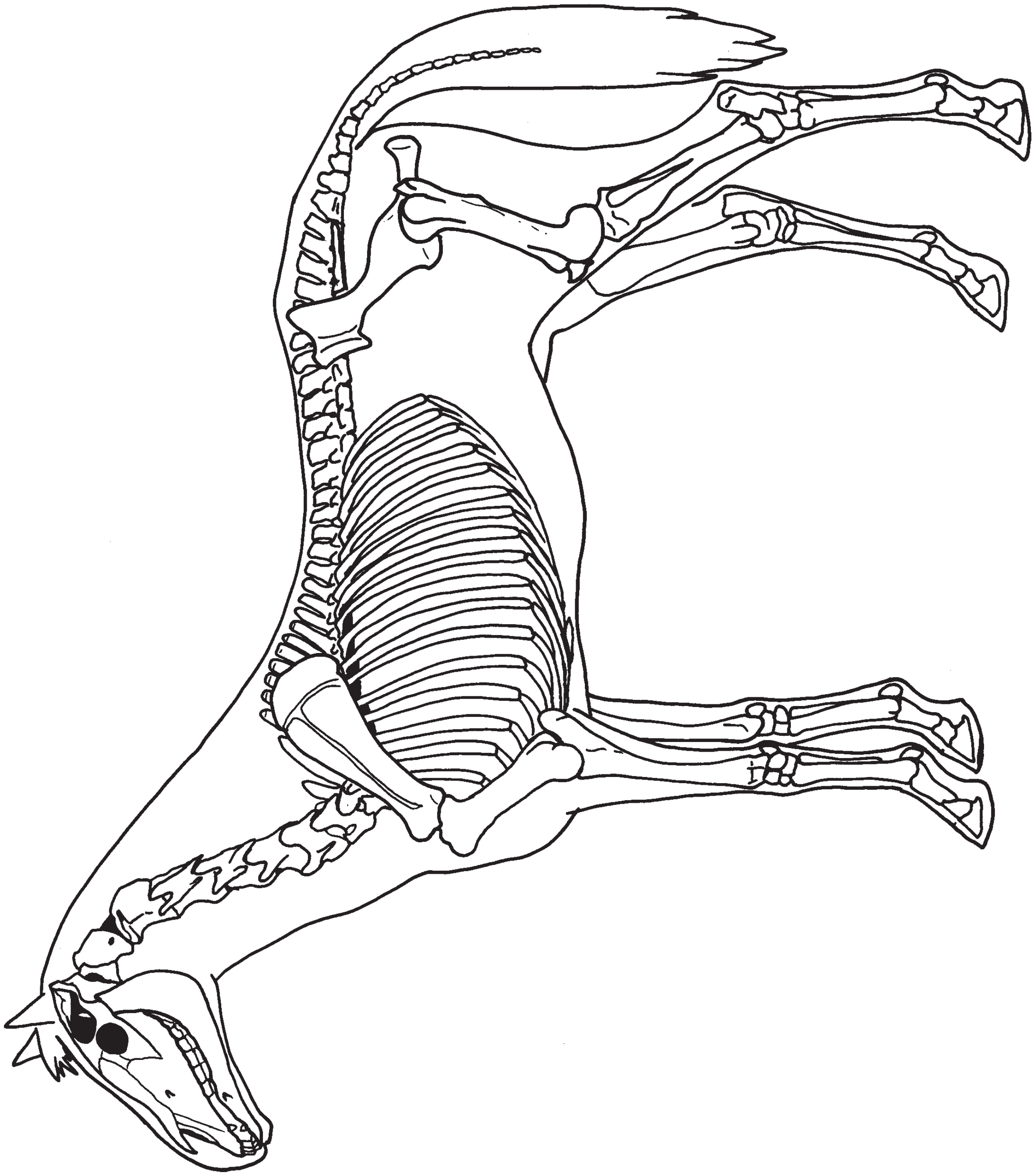


Figure 1-J: Skeleton of the horse (Re-drawn from Popesko)

The skeleton

These notes provide **basic information** on the skeleton which is intended to help you understand the general osteology of the horse and dog. Much of this is also revision, and more detailed information is provided where relevant, in subsequent chapters.

Introduction

The skeleton consists of the framework of hard structures which **protect and support** its soft tissues. These include **bones, cartilages** and **ligaments**.

The skeleton can be divided into **cranial (head)** and post-cranial parts. The latter can be divided into three parts:

(1) AXIAL SKELETON - the vertebral column, ribs and sternum.

(2) APPENDICULAR SKELETON - the bones of the limbs including the pelvic and pectoral girdles

(3) SPLANCHNIC or VISCERAL SKELETON - bones developed within some soft organs; e.g. os penis of the dog.

The **number of bones in the skeleton varies** with age (fusion in older animals) and between individuals (e.g. caudal vertebrae and, in the horse, tarsus 6 or 7, carpus 7 or 8).

The bones can be roughly divided into four classes, depending on shape:

(1) LONG BONES - act as columns and levers in the limbs and consist of cylindrical shafts (diaphyses) containing marrow and enlarged extremities (epiphyses). They develop from at least three centres of ossification, one for the shaft (diaphysis) and one for each extremity (epiphysis).

(2) FLAT BONES - provide protection for underlying organs (e.g. brain) and a large area for muscle attachment (e.g. scapula).

(3) SHORT BONES - diffuse concussion (e.g. in the carpus and tarsus) or reduce friction and modify the action of muscles and tendons (e.g. sesamoid bones developed in some joints and tendons). They generally have only **one centre of ossification.**

(4) IRREGULAR BONES - varied functions (include the median, unpaired bones of the vertebrae and base of skull).

Bone structure (see Fig. 1-L)

Bone consists of an external layer of **dense compact bone** which varies in thickness according to the forces applied to it. This encloses the **cancellous (spongy) bone** of more loosely arranged bony plates and spicules which are aligned according to the mechanical stresses experienced. The cavities between plates are occupied by marrow (marrow spaces). Cancellous bone forms the bulk of short bones and the extremities of long bones. The hollow shaft of long bones is termed the **medullary cavity** and contains marrow. Much of the bone marrow in the body is red marrow in young animals (haemopoietic; blood forming), but this is largely replaced by adipose tissue to form yellow marrow in older animals.

Some regions, such as the sternum, vertebrae, ribs, skull, pelvis and proximal epiphyses of the femur and humerus, contain **red marrow** throughout life. The wing of the ileum and the sternum provide a convenient location for its collection.

The **periosteum** envelops the outer surface of the bone and consists of two parts - an outer protective layer and an inner osteogenic layer. It is critically important in repair of bone following injury, and excessive stripping of the periosteum during surgery or fracture is detrimental to new bone formation. The thin fibrous **endosteum** lines the medullary cavity, and is important in early callus formation during fracture repair.

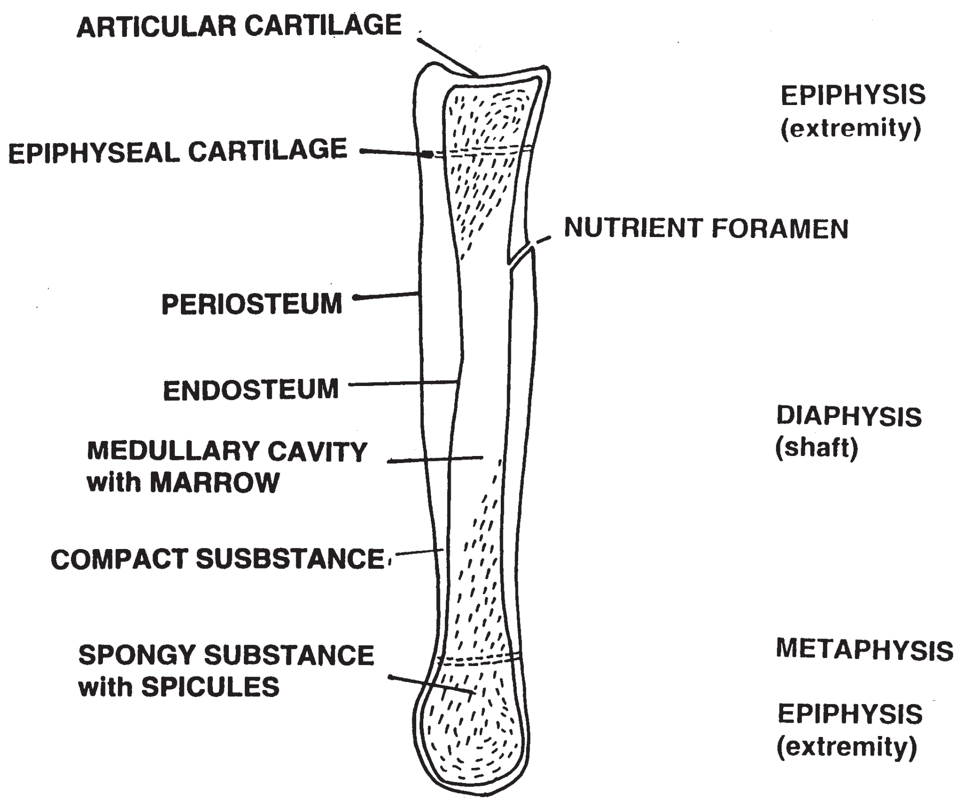


Figure 1-L: Sagittal section of a long bone

Blood supply to bone (see Fig. 1-K)

The blood supply to bone is of critical importance in maintaining the health of normal bone and in assisting the repair process after damage, fractures, etc. There are 3 sources of afferent blood to a typical long bone:

a) Nutrient Artery (usually single)

This passes to the medulla via the nutrient foramen where it branches to proximal and distal medullary arteries through the marrow. These further divide to provide the major blood supply to the diaphysis and may anastomose with epiphyseal and metaphyseal arteries at each end of the bone.

b) Metaphyseal Arteries

Numbers of these enter the proximal and distal metaphyses at all sides. Their final branches anastomose with the medullary arteries. Normally this anastomosis is at a capillary level so the metaphyseal arteries make little contribution to the medullary blood supply but if the nutrient artery is blocked they can enlarge to take over the medullary supply.

c) Periosteal arterioles

Pass to the diaphyseal cortex only at areas of strong fascial attachment. They supply the outer third of the cortex where they anastomose with branches of the medullary artery. Their extent and significance is questioned, but they may be important in bone repair following fracture.

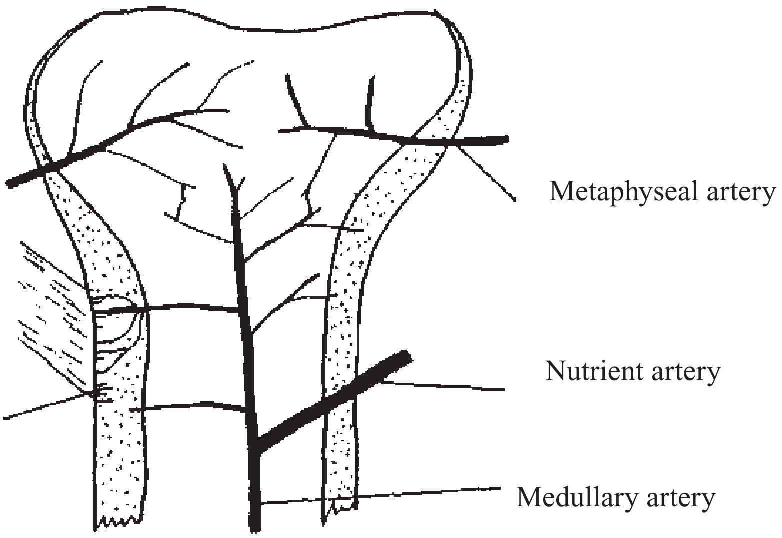


Figure 1-K: Blood supply of bone

In a young animal arteries do not usually penetrate the epiphyseal cartilage.

Most drainage of blood from the bone is by veins following the path of the arteries - nutrient and medullary. The cortex is drained by venous channels and capillaries to the periosteum, always centrifugal (medulla to periosteum).

Nerves are largely distributed to the blood vessels. The periosteum is richly endowed with sensory nerve endings, and is second only to skin in sensitivity. This explains why fractures, infections and tumours involving bone are so exquisitely painful, and always require early attention to pain relief.

Young growing bones have a separate circulation to the epiphysis since arteries do not generally penetrate the epiphyseal cartilage.

Bone composition

Dried bone consists of roughly **1/3 organic matter** and **2/3 inorganic salts** ($CaPO_4$ 57%, $CaCO_3$ 4%, $MgPO_4$ 2%, NaCl and Na_2CO_3 3%). Most of the inorganic salt is a form of calcium phosphate called calcium hydroxyapatite.

Bone derives its **hardness** from the deposition of mineral salts within the soft organic matrix. It has a compressive strength of 20,000 lbs/in2 and a tensile strength of 15,000 lbs/in2. In behaviour, bone is **similar to reinforced concrete:** the organic matter (collagen fibres, equivalent to steel girders) resist **tension** and the inorganic matter (mineral salts equivalent to concrete) resist **compression**.

Mineralization of bones is a compromise between increasing strength and increasing stiffness (making them more brittle). The combination of lightness and compressional strength is achieved by internal sculpturing with trabeculae (from the Latin: little beams) orientated parallel to compressional cortices.

Bone is ALIVE: it requires oxygen and nutrients, it can grow, change shape, erode, become infected and die.

Bone development

Bones develop either in fibrous tissue (**membranous or dermal bones** – flat bones; mainly cranial or facial) or in cartilage (**cartilage bones** – long bones). Some bones eg the ethmoid and temporal bones of the skull, have components of both.

Membranous ossification

The loose mesenchyme in the region of the future bone is invaded by osteoprogenitor cells, which develop into **osteoblasts.** These lay down calcium salts on a randomly arranged framework of collagenous fibres to form **woven bone.**

Osteoclastic erosion of and osteoblastic remodelling coverts this weaker woven bone into **lamellar bone.** This takes the form either of a continuous latticework of **trabeculae** i.e. **cancellous (spongy) bone**, or **compact bone** with Haversian systems, according to the stresses each region of the bone is required to endure.

Osteoblasts in the periosteum lay down trabeculae in **dense parallel sheets** to form **circumferential lamellae** of compact bone.

Blood vessels carry stem cells which colonize the marrow forming haemopoietic tissue.

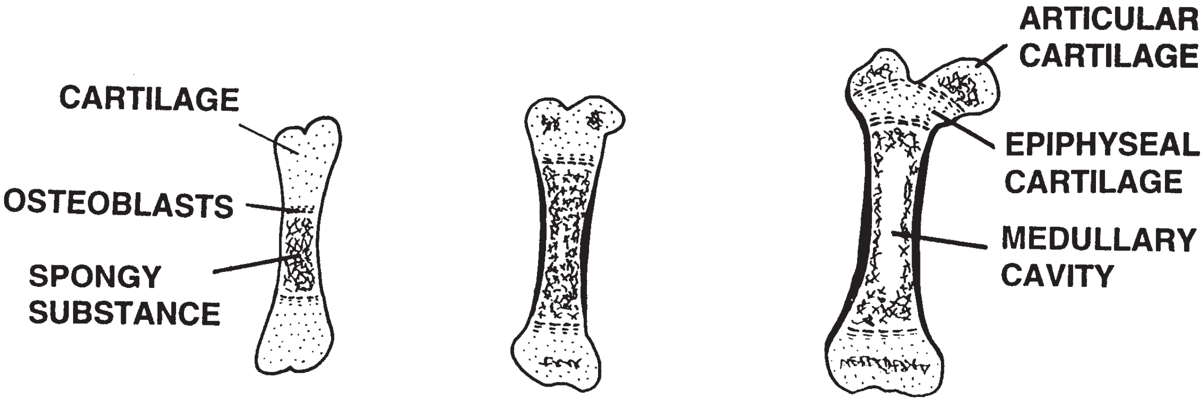


Figure 1-M: Ossification in a long bone

Endochondral ossification (see Fig. 1-M)

This occurs by replacement of a pre-existing cartilage model with bone. Ossification begins in the mid-diaphyseal region (primary ossification centre), when osteoprogenitor cells of the perichondrium differentiate into osteoblasts, forming a periosteal collar of woven bone. This is remodelling into lamellar bone, as described above. Trabeculae of cancellous bone and compact bone Haversian systems are formed, and haemopoietic cells colonise the marrow.

Increase in length of the bones takes place by the continued growth of either end of the cartilage model. Eventually secondary ossification centres begin to form in each epiphysis, but a collar of epiphyseal cartilage (the **growth plate)** is retained and continues to grow between the primary and secondary ossification centres. It is steadily replaced by endochondral ossification on the diaphyseal side of the growth plate

The chondrocytes of the epiphyseal cartilage multiply (zone of hyperplasia) to form columns, and then increase in size (zone of hypertrophy). The hyaline matrix thins out and mineral crystals appear in it (zone of calcification), until the nutrient supply of the chondrocytes is cut off and they die (zone of regression). Osteoprogenitor cells migrate along the scaffold of the calcified matrix and differentiate into osteoblasts which secrete collagen fibres and the matrix material of bone (**osteoid**) which becomes mineralised (zone of ossification). Finally, remodelling by osteoclasts and osteoblasts forms compact bone.

Increase in diameter occurs by the periosteal deposition of compact bone around the spongy core. Finally, there is a breakdown of spongy bone to leave a hollow interior filled with marrow.

Components of the skeleton

(i) Vertebral Column (See **Figs. 1-N and 1-O**)

The vertebral column consists of a series of unpaired, median irregular bones, the **vertebrae**, extending from the skull to the tail. Some vertebrae may become fused (e.g. in the sacral region). The number of vertebrae in each body region **(cervical, thoracic, lumbar sacral, caudal)** is fairly constant so a vertebral formula can be expressed (e.g. $C_7T_{18}L_6S_5Cd_{15\text{-}21}$ for the horse, $C_7T_{13}L_7S_3Cd_{20\text{-}23}$ for the dog). Note the differences from the human vertebral formula, particularly in the number of thoracic vertebrae (and hence ribs). Note also the differences between the two species, again especially in the thoracic region.

A typical vertebra consists of:

(1) BODY - cylindrical mass articulating cranially (convex) and caudally (concave) with other vertebrae.

(2) ARCH - two lateral halves which, together with the body, form the vertebral foramen containing the spinal cord and its vessels. The base of the arch (pedicel) has vertebral notches for the passage of spinal nerves and vessels.

(3) PROCESSES

articular processes, two anterior and two posterior articulate with adjacent vertebrae.

spinous process projects from the middle of the arch for the attachment of muscles and ligaments

transverse process, two project laterally from the arch.

mammillary process, in most mammals on the posterior thoracic and anterior lumbar vertebrae, between the transverse and anterior articular process.

Vertebrae from different regions are distinguished by characteristic features:

Cervical – transverse foramina (except C7), atlas and axis unique

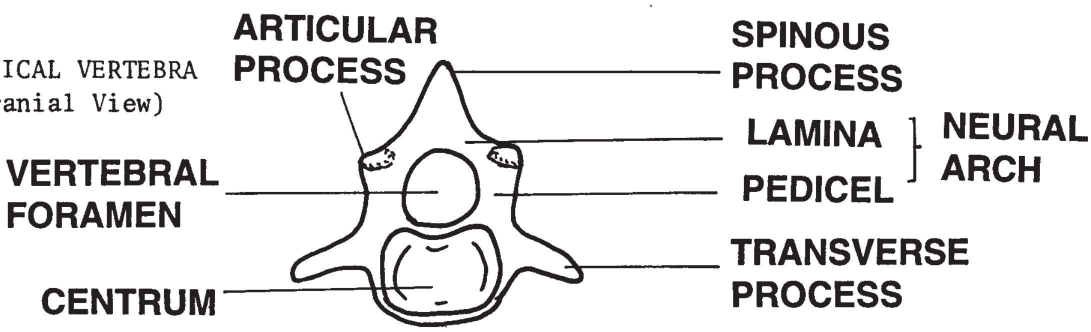
Throacic – long, caudally pointing spinous processes until T11 (anticlinal); Costal fovae for ribs

Lumbar – long cranially pointing transverse processes

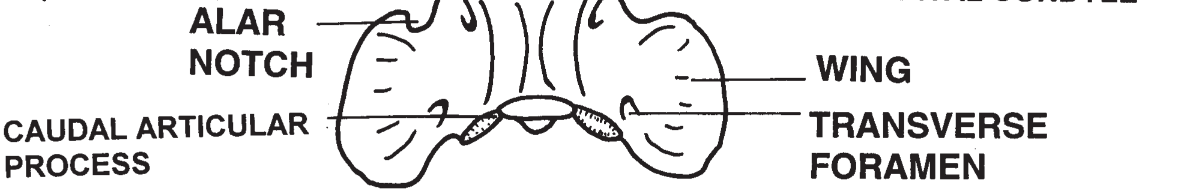
Sacral – fusion, processes become crests, notches for nerves become foramina

Caudal – reduction in processes

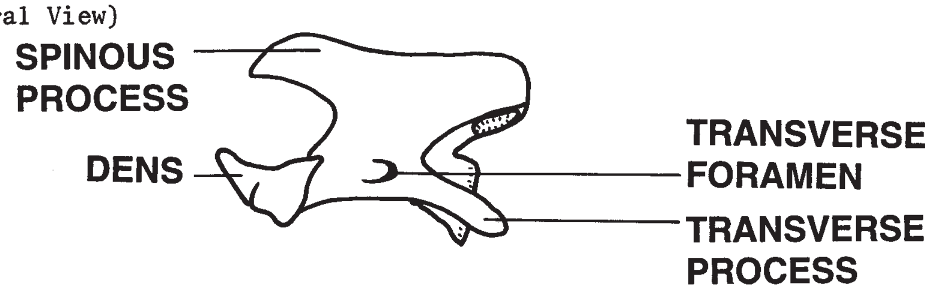
A TYPICAL VERTEBRA
(Cranial View)



ATLAS
(Dorsal View)



AXIS
(Lateral View)



CERVICAL VERTEBRA
(Cranial View)

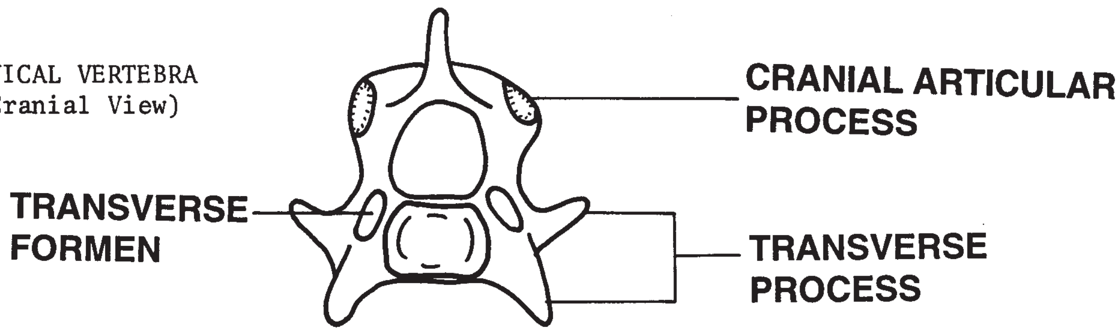


Figure 1-N: Cervical vertebrae of the dog

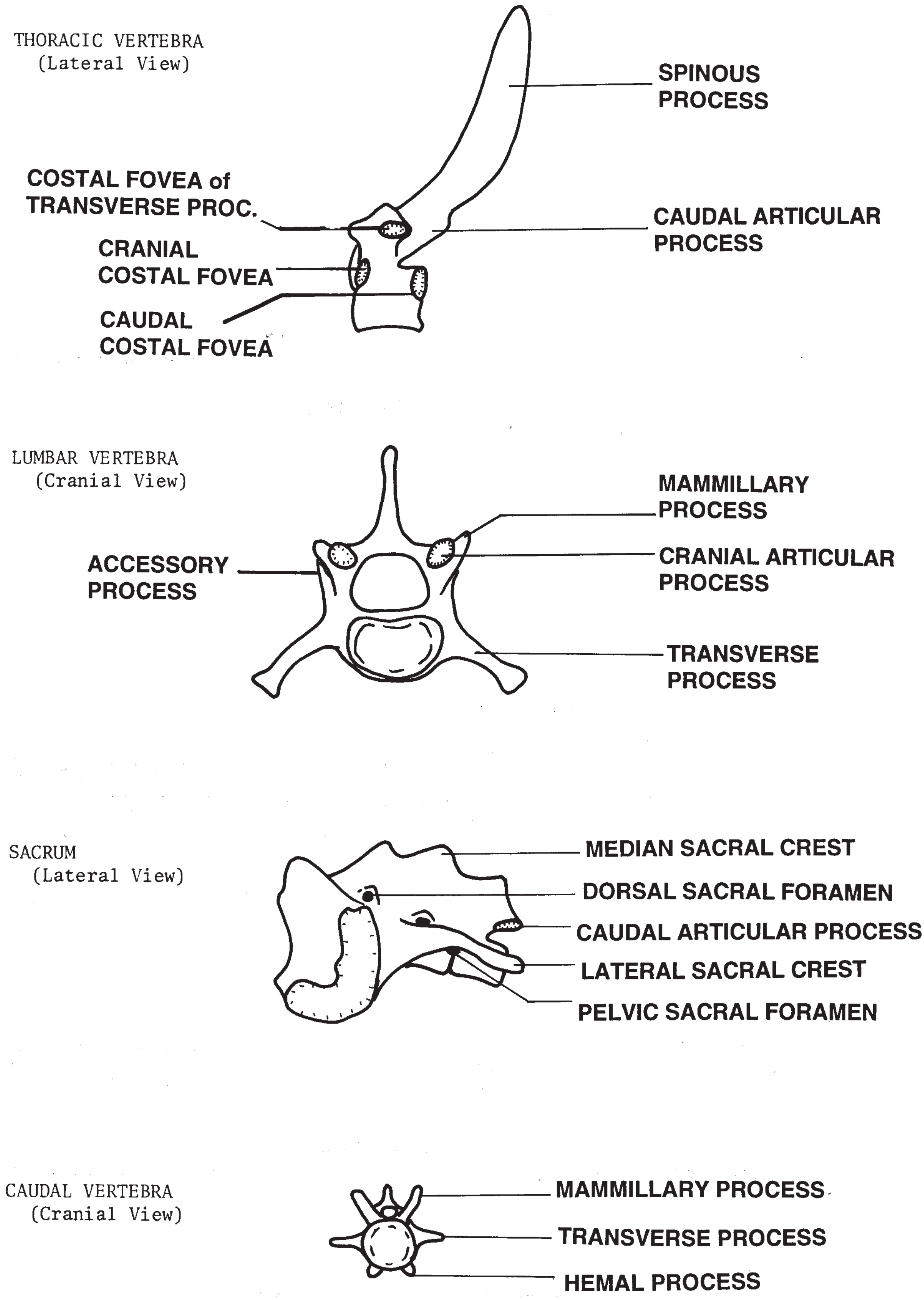


Figure 1-O: Vertebrae of the dog (Thoracic, lumbar, sacral and caudal vertebrae)

(ii) Ribs and Sternum (See Fig. 1-P)

Ribs are paired curves bones which form the skeleton of the thoracic wall. The **shaft** of the rib varies in length, width and curvature. The **costal groove** on the medial surface contains the intercostal vein. The **head** is at the end of the rib and articulates with two adjacent vertebrae. It is connected by a **neck** to the shaft and the **tubercle** which is directed caudally, articulating with the transverse process of the vertebra.

The sternal (ventral) end of the ribs is usually slightly enlarged and roughened where it joins the costal cartilage.

Three types of ribs can be distinguished:

(1) STERNAL RIBS - articulate with the sternum by the costal cartilage.

(2) ASTERNAL RIBS - do not articulate with the sternum, but may have overlapping costal cartilages, united by elastic tissue to form a costal arch.

(3) FLOATING RIBS - ventral ends free and not attached to adjacent ribs.

The **sternum** is composed of 6-8 unpaired median bony segments (**sternebrae**). Its shape varies considerably. The cranial end (**manubrium**) is relatively small and terminates in cartilage (**cariniform**) providing attachment for breast and neck muscles. The body of the sternum articulates with the costal cartilages of sternal ribs and gives attachment to pectoral muscles. The ventral border of the sternum may have a prominent crest. The sternum terminates caudally in a thin plate of **xiphoid cartilage** which provides attachment for the diaphragm and abdominal muscles.

(iii) Thoracic Limb (See Fig. 1-Q)

The **shoulder (pectoral) girdle** typically consists of three parts, (**scapula**, **coracoid** and **clavicle**):

- **The scapula** is the only well developed component in domesticated mammals. It is a flat bone, with its lateral surface divided by a spine. This terminates in the **acromion** in the dog. The **glenoid cavity** articulates with the head of the humerus and the **supraglenoid tubercle** provides attachment for biceps brachii muscles.
- **The coracoid process** has fused with the scapula
- **The clavicle is either absent (horse) or rudimentary in the brachiocephalicus muscle (dog).** Thus, the shoulder has no articulation with the axial skeleton, but is supported by a syndesmosis (see chapter 3).

Humerus:

A long bone, with a cylindrical, slightly twisted shaft. The anterior surface of the shaft has a **deltoid tuberosity**. The proximal end has a **head** (which articulates with the glenoid cavity) a **neck** and **greater and lesser tubercles**. The distal extremity consists of an oblique **trochlear surface** for articulation with the radius and ulna, and **medial and lateral epicondyles** separated caudally by the **olecranon fossa** and cranial by the **radial (coronoid) fossa**. The radial and olecranon fossae are often joined by a large **supratrochlear foramen**.

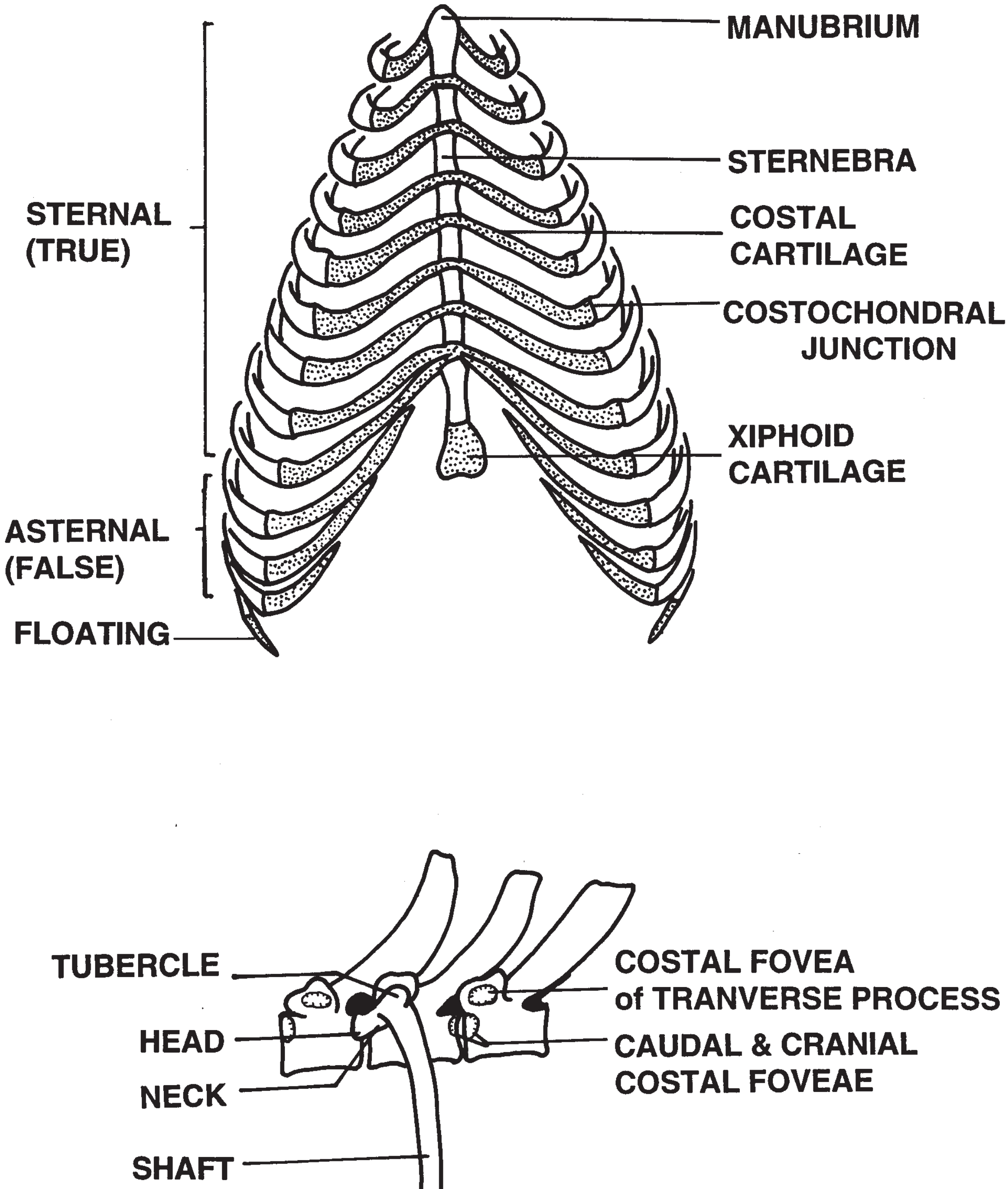


Figure 1-P: Ribs and sternum of the dog
(Re-drawn from Evans and deLahunta)

Radius and ulna:

These vary in relative size and mobility. In the horse, they are fused with the radius craniomedially (pronation), supporting the body weight. The ulna is only large proximally where it acts as a lever for the extensor muscles of the elbow. In the dog, the ulna remains separate from the radius, and some movement is possible between the two. The proximal end of the ulna consists of the **olecranon** and a large **trochlear notch** for articulation with the **trochlea** of the humerus. Distally, the ulna and radius both have **carpal articular surfaces -** larger in the radius.

Manus (fore paw or foot) consists of three sub-divisions: the carpus, metacarpus and digits.

- The **carpus** typically consists of **eight bones in two rows:**

  proximally: radial, intermediate, ulnar and accessory;

  distally: first, second, third and fourth carpal bones.

  However, there is considerable variation between species; the dog has 7 (fusion of radial and intermediate) and, in the horse, the first is inconstant.

- The **metacarpus** consists typically of five long bones, one for each digit, numbered from radial to ulnar (medial to lateral).

  In the dog: all five are present;

  In the horse, the third is the large weight-bearing metacarpal with a single digit; the second and fourth are much reduced, and first and fifth are absent.

- There are typically **five digits**, each with **three phalanges** (proximal, middle and distal) except in the case of digit 1 which has two phalanges. The horse has only the third digit.

Sesamoid bones develop along tendons or in joint capsules where there is increased pressure; these are considered in greater detail later.

(iv) Pelvic Limb (See Fig. 1-R)

Pelvic girdle:

Consists of two **os coxae** (hip bones), joining ventrally at the **pelvic symphysis** and articulating with the **sacrum** dorsally. The os coxae consist of three bones, ilium, ischium and pubis, which join to form the **acetabulum**, articulating with the **femur** (a fourth bone, the acetabular bone, is included in the formation of the acetabulum in the juvenile).

- The **ilium** can be divided into a body and a flattened wing which extends cranially. The internal surface of the wing is roughened (auricular portion) and articulates with the sacrum. The crest of the ilium is curved (concave in ox and horse, convex in dog and pig) and connects the **coxal and sacral tubers** - roughened tuberosities.

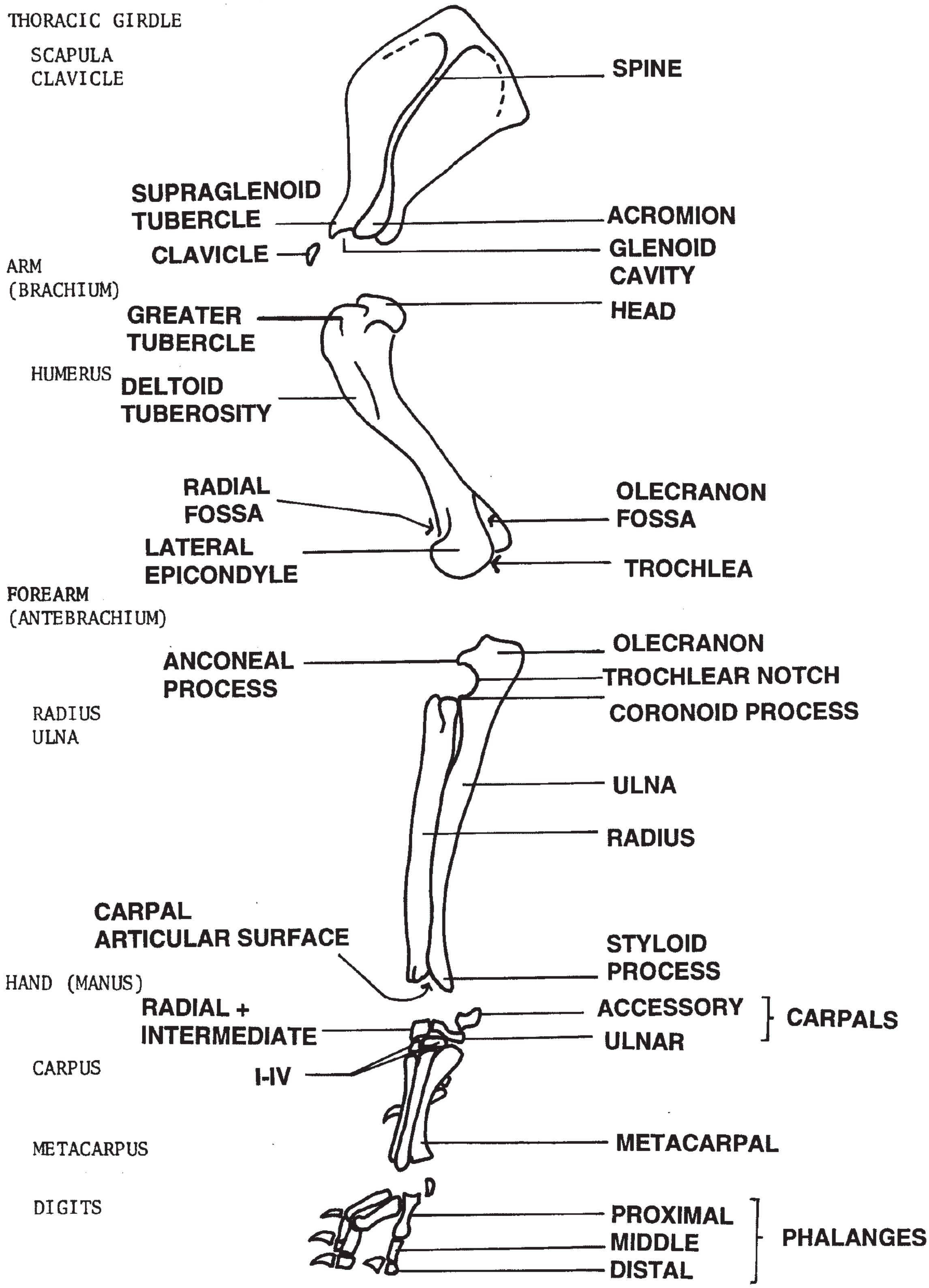


Figure 1-Q: thoracic limb of the dog (lateral view)

- The **ischium** forms the caudal part of the hip bone and forms a part of the acetabulum, obturator foramen and pubic symphysis. It consists of a body, ramus and tuberosity for muscle attachment.

- The **pubis** consists of a body (cranial to obturator foramen), a cranial ramus extending to the acetabulum and a caudal ramus to the pubic symphysis. The acetabulum faces ventrolaterally and consists of a notch and articular part.

Femur:

Consists of a cylindrical body and two expanded extremities. The smooth hemispherical **head** articulates in the acetabulum and the short **neck** gives attachment for the joint capsule. The **greater trochanter** lies lateral to the head and provides attachment for the middle and deep gluteal muscles. The **lesser trochanter** may be present medial to the greater trochanter. The caudal surface of the body has a roughened surface for muscle attachment. The distal end of the femur has several articular surfaces. The **trochlea** is a smooth groove for articulation with the **patella** (knee cap), a sesamoid bone in the tendon of the quadriceps femoris muscle which extends the **stifle**. **Medial and lateral condyles** are separated by a large intercondylar fossa. Proximal to the condyles are medial and lateral **epicondyles** and two sesamoid bones (**fabellae**).

Tibia and **fibula:**

The **tibia** is a large prismatic long bone which carries the weight. It articulates with the femur proximally (**medial and lateral condyles**) and with the **talus** of the **tarsus** distally (**medial malleolus).** The **tibial tuberosity** on the cranial border serves as attachment for the quadriceps femoris, biceps femoris and sartorius by means of the patella and patellar ligament.

The **fibula**, on the lateral border of the tibia, is much more slender and does not articulate with the femur. In the pig and dog, it is complete, but is much reduced in horse and ox.

Pes (hind paw or foot): three divisions **- tarsus**, **metatarsus** and **digits**.

- **Tarsus consists of 5-7 short bones**. The proximal row consists of **talus** and **calcaneus** (tibial and fibular tarsals), the latter has a calcaneal tuber extending proximally and acting as a lever for extension of the hock joint. The **distal row** consists typically of four bones (pig and dog) designated first tarsal, second tarsal, etc. The **central tarsal** is between the two rows.

- The **metatarsals** and **digits** resemble the corresponding regions of the forelimbs. The first digit (dew claw) in dogs is often missing or not fully developed.

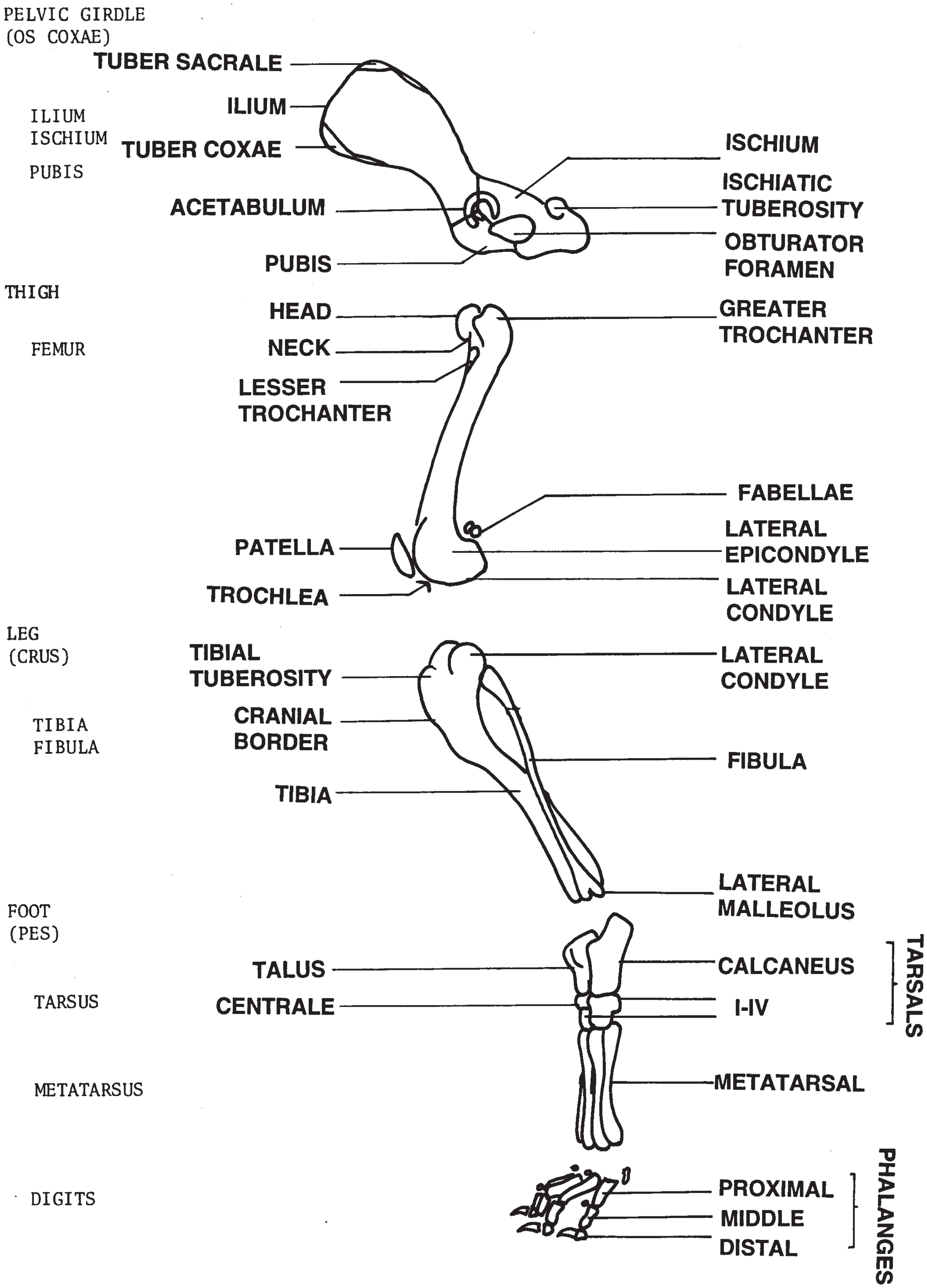


Figure 1-R: Pelvic limb of the dog (lateral view)

(v) **The skull (see Figs. 1-S and 1-T)**

The bones of the skull develop in two different ways. Most of the bones of the skull are **paired flat bones** (developed in membrane) but those of the cranial base are **median irregular bones** (developed in cartilage). Thus the braincase consists of:

(1) **Dermal Bones** forming the **roof (calvarium**) of cranial vault (frontal, parietal, interparietal, occipital and most of the temporal); also the vomer and all facial bones.

(2) **Cartilage Bones** forming the **cranial base** (ethmoid, sphenoid, occipital and petrous temporal).

Only two movable joints persist in the skull, the temporomandibular joint, and the articulation of the hyoid apparatus with the temporal bone. The other joints (**sutures**) between the bones ossify with increasing age.

The skull has numerous **foramina** through which nerves and blood vessels pass.

The skull is a very complex organ consisting of about 50 bones. The bones that form the skull can be divided into two groups:

(1) **Cranial bones** (neurocranium) enclose the brain and the organs of hearing.

(2) **Facial bones** form the skeleton of the oral and nasal cavities and also support the pharynx, larynx and the root of the tongue.

These two groups meet at the **nasal** and **orbital cavities**. The precise shapes of these bones vary between horse and dog, depending largely on the diet of the species and hence the dentition. These differences are examined in greater detail later.

1. **Cranial Bones:** some single midline bones, some paired

The **occipital:** at the caudal end of the skull, composed of both dermal and cartilage precursors. The **foramen magnum** lies ventrally and conveys the spinal cord. Two occipital condyles articulate with the atlas. The **paracondylar process** provides attachment for the muscles opening the jaw (digastricus). The **nuchal crest** provides attachment for the nuchal ligaments.

The **sphenoid:** lies at the base of the cranium (**basisphenoid**) and extends laterally into the orbit containing the **optic and orbital foramina**. It also extends rostrally between the palatines as the **presphenoid**. The **pterygoid** crest, for the attachment of pterygoid jaw muscles, is formed from the pterygoid and the palatine.

The **ethmoid:** lies rostral to the sphenoid, deep in the skull. It consists of:

(a) **Cribriform plates** through which the olfactory nerves pass

(b) **Perpendicular plate** of the nasal septum

(c) **Ethmoidal labyrinth** of many fine scrolls (turbinates) attached to the cribriform plate, extending dorsally into the frontal sinus and ventrally to the vomer.

The **vomer:** a single median bone which forms the ventral part of the nasal septum.

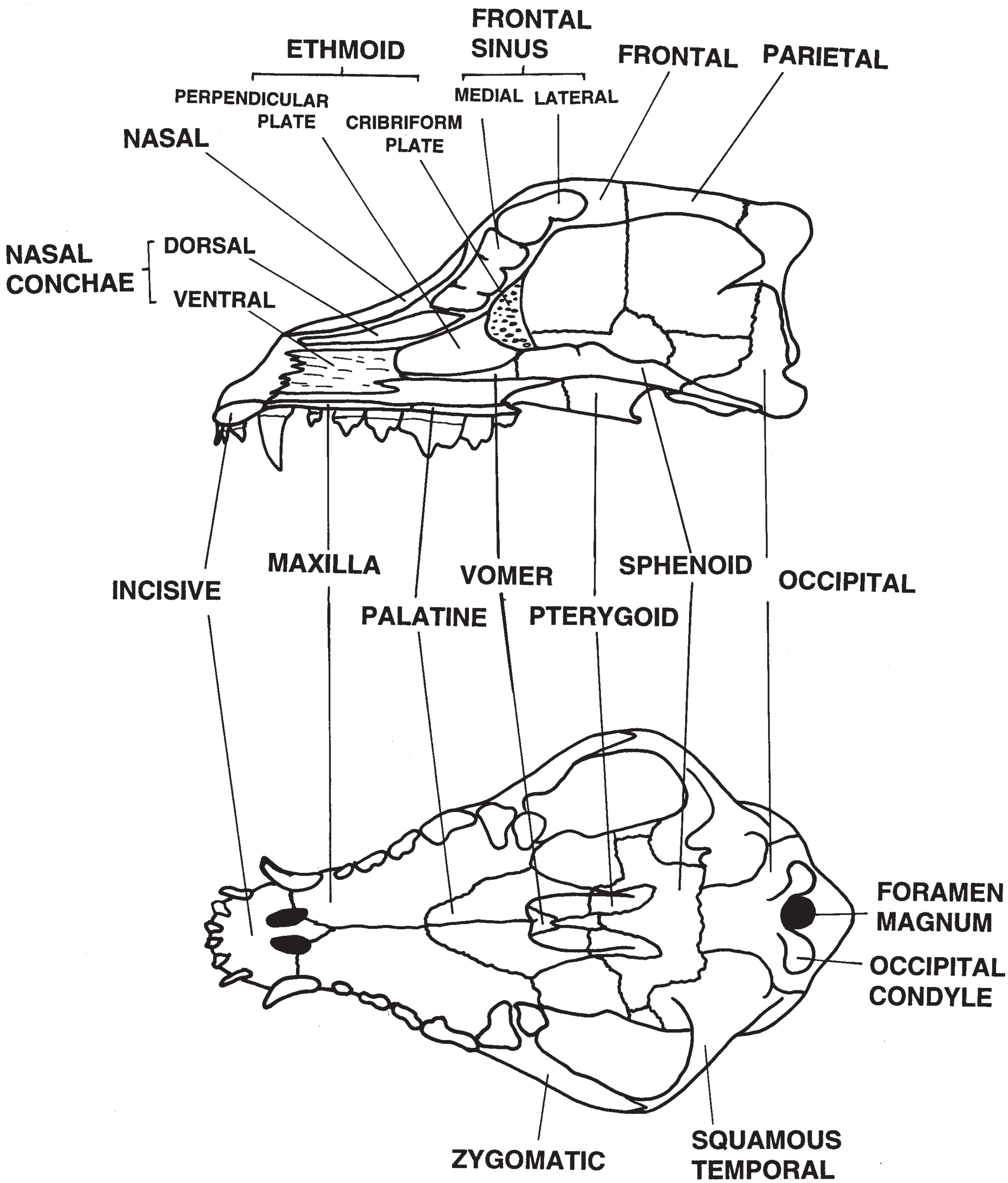


Figure 1-S: Skull of the dog (sagittal section and ventral view (re-drawn from Evans and deLahunta)

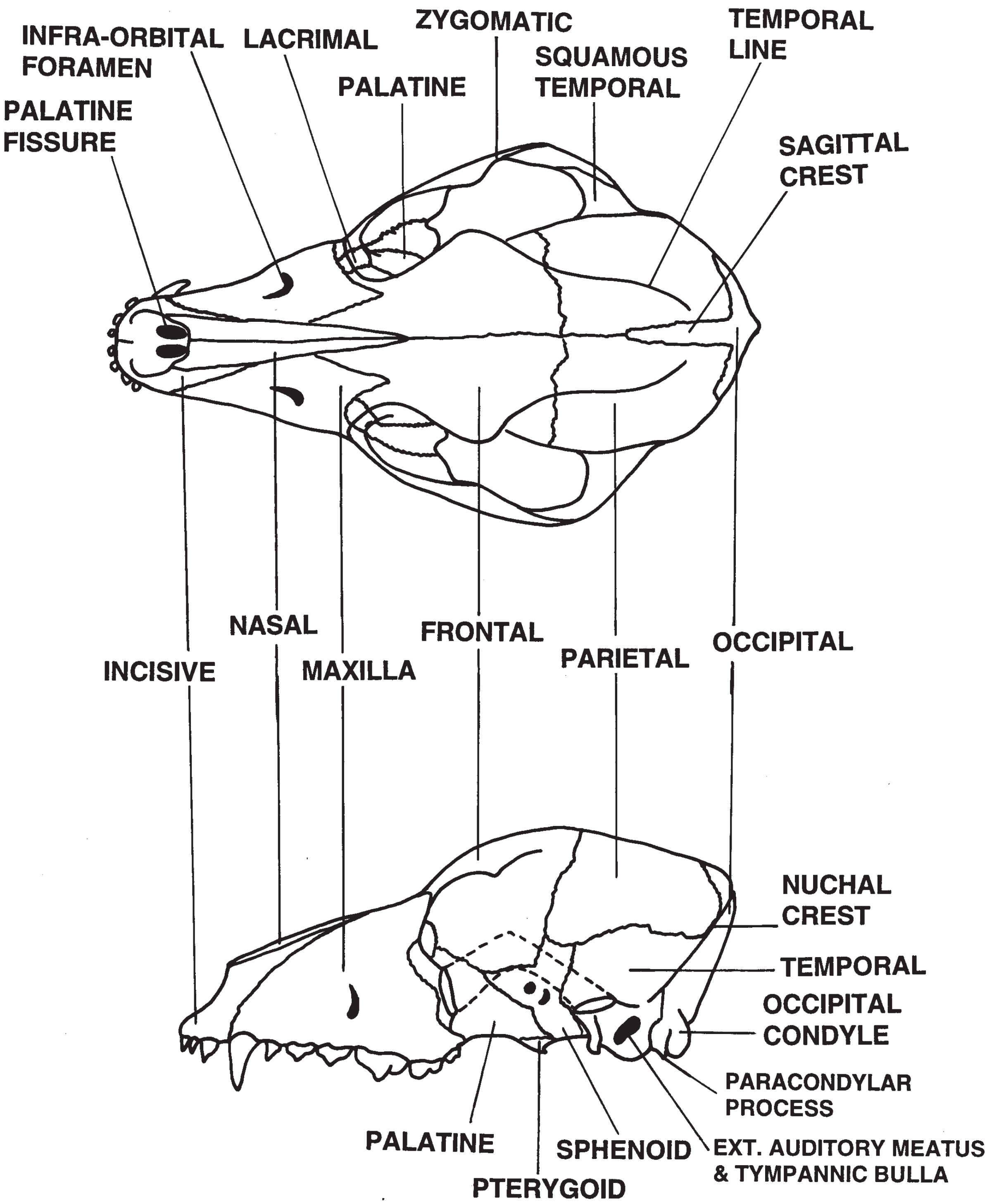


Figure 1-T: Skull of the dog (dorsal and lateral views
(re-drawn from Evans and deLahunta)

The paired **frontals:** lie dorsal and rostral to the brain, forming **zygomatic processes** above the orbits. The two plates of bone separate rostrally forming part of the frontal sinus.

The paired **parietals:** form the dorsum of the cranium, with the frontals. Caudally the **interparietal** (which fuses with the occipital) separates the parietals and forms the **sagittal crest** for muscle attachment. Paramedian temporal lines extend rostrally to the zygomatic process.

The paired **temporals:** form most of the lateral surface of the cranium. They are divided into three parts:

(a) **Squamous temporal** forms the ventral part of the temporal fossa and extends rostrally into the zygomatic process of the caudal zygomatic arch.

(b) **Tympanic temporal** has the tympanic bulla which encloses the middle ear cavity and opens laterally via the external acoustic meatus.

(c) **Petrosal temporal** contains the cochlea, vestibule and semi-circular canals of the inner ear.

On the ventral surface of the temporal there is a glenoid cavity for articulation with the mandible.

2. **Facial Bones:** all paired

The **maxillae:** the principal bones of the upper jaw, carrying the cheek teeth in large cavities (dental alveoli). Medially, the palatine process forms the major part of the hard palate. The infra-orbital canal traverses the maxillary sinus and gives off a small canal carrying vessels and nerves to the teeth. The dorsal and ventral **nasal conchae** are attached to the lateral walls of the maxillae. They are delicate, scroll-like and greatly reduce the size of the nasal cavity.

The **incisives:** form the rostral part of the skull and bear the incisors. They have nasal and palatine processes.

The **nasal bones:** meet at the dorsal mid-line.

The **palatines:** form the caudal part of the hard palate and the lateral wall of the choanae (openings of the nasal cavities into the nasopharynx).

The **lacrimal** bones: form part of the anterior border of the orbit. They each have a funnel-like fossa leading to the lacrimal canal.

The **zygomatic (malar)** bones are placed between the lacrimal and maxilla and contribute to the rostral part of the zygomatic arch.

The **mandibles** (lower jaw): carry the lower teeth and join rostrally at a symphysis soon after birth. On the lateral surface, caudally, is the triangular masseteric fossa for insertion of the masseter muscle. Dorsal to this is the **coronoid process** for insertion of temporal muscles. Medially, the mandibular foramen carries vessels and the mandibular alveolar nerve to the rostral mental foramina. The **condyloid process** lies caudal to the mandibular notch and articulates with the temporal. The **angular process** lies ventrally for insertion of the digastricus muscle (see **Fig. 1-U**).

The **hyoid bones** form the hyoid apparatus which gives support to the tongue and larynx (see **Fig. 1-V**). Note that the hyoid apparatus in animals consists of several small bones with cartilaginous joints between them; the precise arrangement of these bones again varies with the shape of the head of the species, depending on it's diet and dentition.

You do NOT need to know in detail the different hyoid bones.

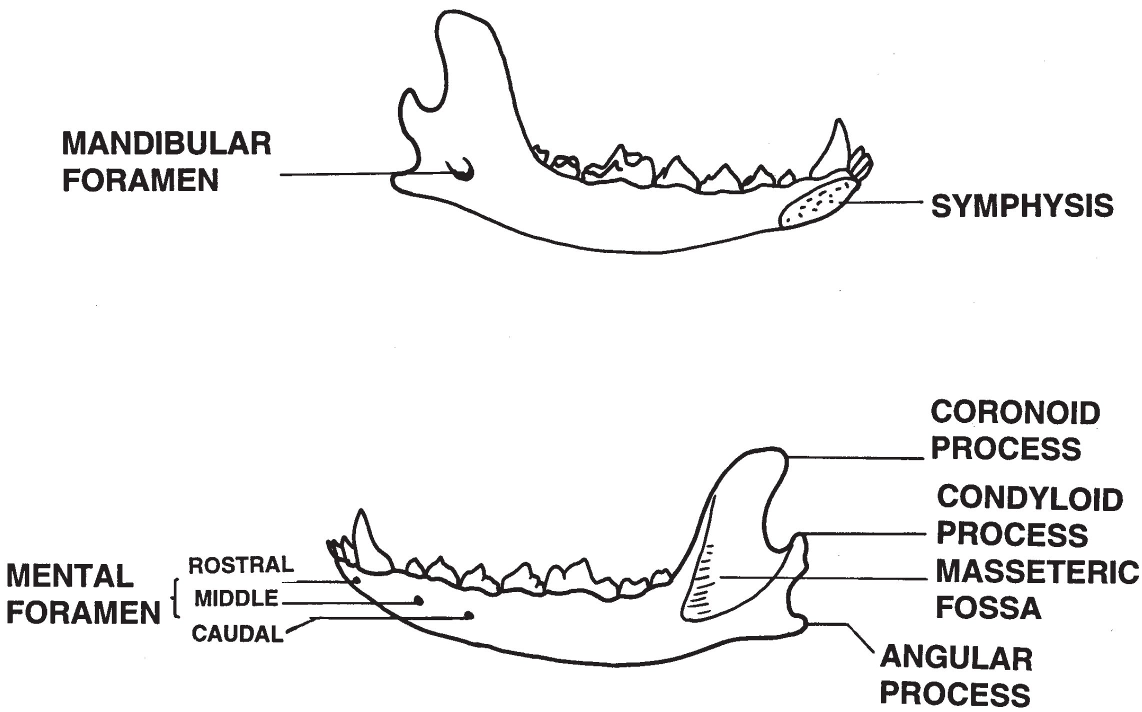


Figure 1-U: Mandible of the dog (medial and lateral views) (Re-drawn from Evans and deLahunta, 1971)

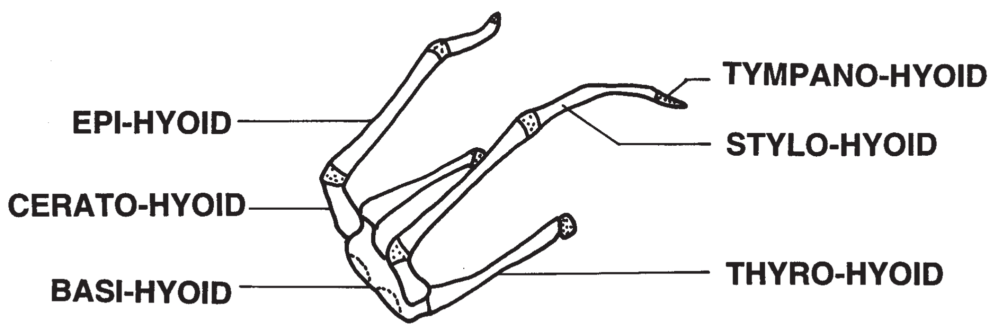


Figure 1-V: Hyoid apparatus of the dog (Re-drawn from Getty)

Table 1-1: Bones forming cavities of the skull

	Floor	Sides	Roof
Cranial cavity			
Nasal cavity			
Orbital cavity			

Questions

Using the bones of the thoracic limb, indicate the relation of form and function and illustrate some of the ways of classifying bones.

Describe the functional anatomy of the vertebrae.

Describe the bones surrounding the brain and compare and contrast their development and shape.

Complete Table 1.1.

Chapter 2

Animal Locomotion

Animal movement: General considerations

There are various kinds of movement in animals:

A: Regional movements

1. **Involuntary movement involving smooth and cardiac muscle**

   E.g.: Peristalsis and other spontaneous movements (e.g. sacular and pendular movements) of the alimentary tract

   Contraction of the uterus and opening and closing of the cervix

   Erection of hair

   Heartbeat

2. **Voluntary or involuntary movement involving skeletal muscles**

   E.g.: Action of intercostal muscles and diaphragm in breathing

   Action of muscles of the pharynx in deglutition

   Movement of the nostrils

   Opening and closing the eye and blinking

   Tossing of the head

   Kicking with one leg

B. Whole body movement in the vertical plane

Standing up or lying down, i.e. adoption of recumbent posture from standing or the opposite action, without changing ground.

Kicking with both legs in horses, e.g. rearing or bucking without forward or backward progression.

Begging in dogs.

Environmental factors involved include

- atmospheric resistance
- gravity

C. Whole body movement in horizontal plane: locomotion

Progressive movement of whole animal from one point to another; consists of a combination of movements whereby the animal interacts with the environment in such a way that the whole body moves horizontally from one position to another, either forwards, backwards or sideways.

Environmental factors involved include:

- friction with ground (or water if swimming)
- atmospheric resistance
- gravity

The locomotory system

Much of this material will be revision, but an understanding of the components of the locomotory system is a prerequisite for understanding the way in which they combine to produce locomotion.

Components of the locomotory system
- bones
- joints
- skeletal muscles

A. Bones

Locomotion involves movement of the
- head
- vertebral column (spine)
- limbs

Skeletal structures are necessary for maintaining rigidity of the body and for providing attachment for skeletal muscles, which are only able to exert their moment of action by virtue of being attached to bones.

a) The role of bones

1. **The head and vertebral column in locomotion**

   In carnivores: the column bends in rapid locomotion behind the anticlinal vertebra (T11).

   In horses: the column is rigid, even in rapid locomotion.

   In rapid locomotion, the head is typically stretched and the tail is elevated, giving a streamlining effect and a caudal balancing effect (rudder).

   Change of direction may involve lateral flexion of the column, but this is slight.

   Jumping: the final phase may involve some rotation (torsion) of the column.

2. **The limb bones in locomotion**

   In quadrupeds such as the domestic animals, the limbs serve as struts. But they are not rigid, having breaks or joints in them throughout their length. The significance of this type of structure is discussed in section 3.

3. **The sternum**

   Sternebrae provide attachment for the ribs, which themselves move in relation to respiration.

b) Comparative bone structure

In this manual, the dog is used to illustrate the general features of the bones and their role in locomotion. Where differences exist between horse and dog, these are explained in the sections dedicated to equine anatomy.

The bones of horse and dog follow the same basic mammalian pattern. Differences arise where characteristic of the species affect the function of particular bones. For example, the horse exhibits greater cursorial adaptation (for sustained speed), and inevitably is adapted for greater weight-bearing.

c) Vitality of bone

To understand fully the role of bones in animal movement, it is imperative that their vitality and dynamic qualities are appreciated. This demands an understanding of the development of bone, its blood and nerve supply, and strengths and weaknesses in the adult animal. It also demands recognition of the

– **strains**: forces acting on a structure
– **stresses**: processes involved in responding to strains

to which bones are subjected in normal posture and movement. These are considered in greater detail in the course which covers biomechanics of the locomotory system, but a broad outline of the principle features is considered below.

d) Characteristics of bone

Bone has great strength per unit weight, due to its:

– **tensile strength** provided by collagen fibres
– **compressional strength** provided by salts of calcium and phosphate.

Function of bone:

i. Internal support for the body
ii. Attachment for muscles and tendons including those of the locomotory apparatus
iii. Protection for internal organs and bone marrow
iv. Central role in regulation of plasma calcium
v. Haemopoiesis (production of blood cells).

Bone is a dynamic, living material and is constantly being renewed and remodelled. It is responsive to the following physiological influences:

– **mechanical**
– **metabolic**
– **nutritional**
– **endocrinological**

(e) Mechanics of bone in locomotion

1. Adaptation to function

In order to provide a framework for the body and a firm attachment for muscles, bones need the following characteristics:

a) To be relatively rigid.

b) To withstand compressive (crushing) forces.

c) To withstand tensile forces (disruptive forces, such as pulling and bending).

d) To be light.

In long bones, lightness is achieved by the shaft being hollowed out to form the **marrow cavity**.

Fig. 2-A demonstrates that this hollowing-out does not weaken the bone: it shows that a beam supported between two verticals tends to sag in the middle. Thus:

On the underside - tensile force tends to pull the beam apart.
On the upper side - crushing force tends to compress.
In the central axis - zone where the two forces are neutralised.

Therefore, the presence or absence of a central core (neutral zone) does not affect the strength of the bone. In fact, a hollow tube is the best structural arrangement for resisting bending forces, because as may be seen from the above, such forces exert their effect on the surface of a cylindrical tube not at the core.

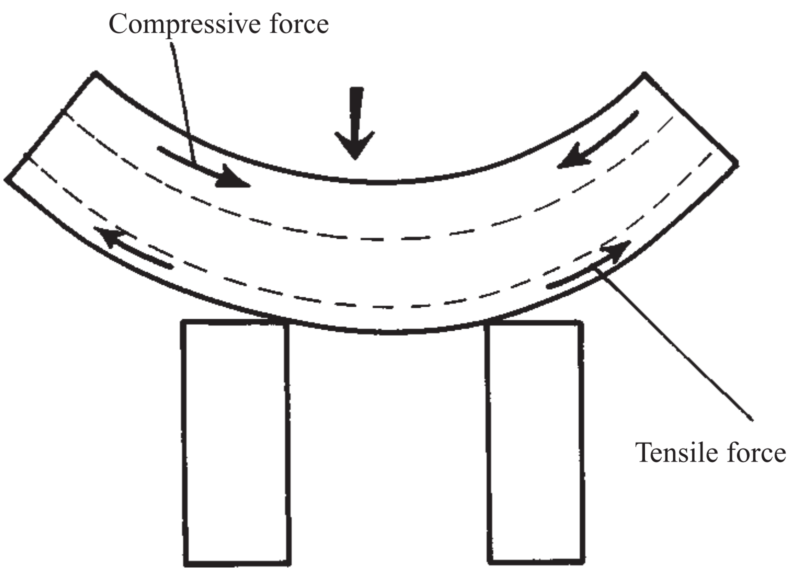


Figure 2-A: Forces operating in a supported hollow beam

2. **Stress lamellae**

In cancellous bone, notably at the epiphyses of long bones, the bony trabeculae appear to be related to the lines of stress to which the epiphysis is exposed. The trabeculae are disposed as bony lamellae (Fig.- 2-B):

– **Pressure lamellae** (associated with compression forces)

– **Tension lamellae** (associated with tensile forces)

The relationship is not simple or easy to explain, because if it were direct, the lamellae would intersect precisely at right angles and unfortunately they do not. It is unlikely, however, that the arrangement of the lamellae is inconsequential and mechanical forces are undoubtedly important in the shaping of bones.

Compressive and tensile forces acting on bone stimulate ossification. Thus, the pull of muscles is an essential ingredient of bone formation, and contribute to the shape of the bone.

Note: The patella is formed in response to friction (as probably are all **sesamoid bones** ie bones which redirect the force of tendons where they cross a bony prominence).

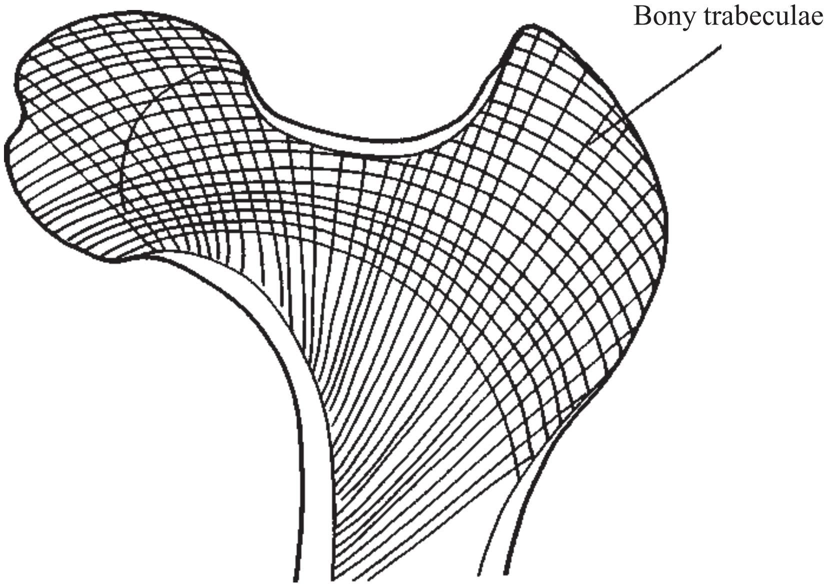


Figure 2-B: Disposition of bony lamellae (redrawn from a radiograph in Le Gros Clarke's "Tissues of the body")

B. Joints

Joints are formed when two or more bones are united by fibrous, elastic or cartilaginous tissue. The three main types of joints are named according to their characteristic structural features.

(a) Fibrous joints (Synarthroses) (Fig. 2-Ca,b)

A fibrous joint is found where little movement is necessary. The bones are held together by fibrous connective tissue. The union is short, direct and often transitory, since the bones may fuse and ossify later in life. No joint cavity is present.

(i) Sutures (Fig.- 2-Ca)

Sutures are largely confined to the flat bones of the skull.

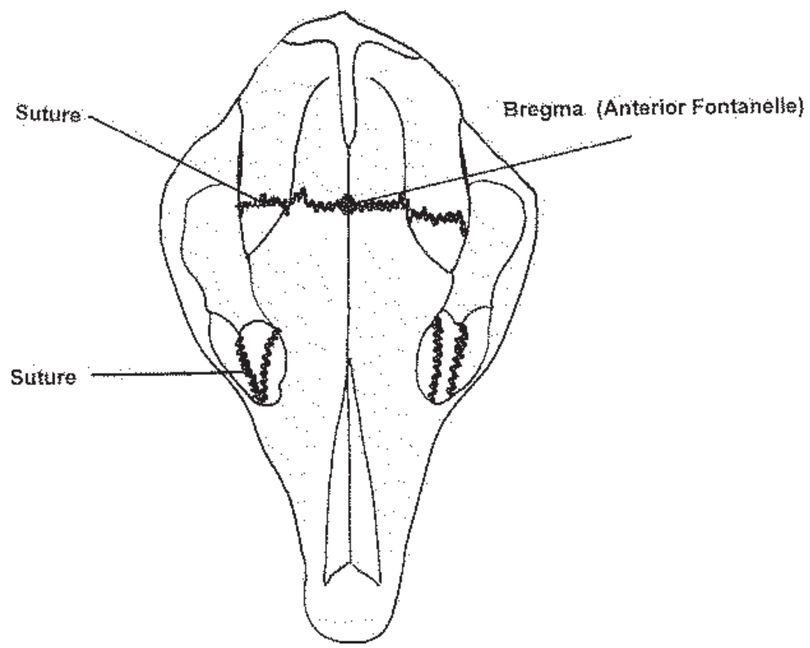


Figure 2-Ca: Fibrous joint (synarthrosis); skull sutures

They can be further classified by the shape of the opposing bones (e.g. serrate, squamous, etc.).

Endocranial sutures are simpler than those on the surface of the skull, and they do not quite correspond to the outside skull sutures.

The time of closure of sutures (to form a **synostosis**) varies in different species. Further growth of the brain is allowed while the sutures are open. Thus, if they close too early, the development of the brain may be affected.

The **bregma** is the point on the top of the skull where the **sagittal and coronal sutures** meet. In young animals, this is occupied by a space (**anterior fontanelle**), which allows continued growth of the skull.

(ii) Syndesmosis (Fig. 2-Cb)

This is a fibrous joint with much intervening connective tissue, e.g. attachment of hyoid to skull, tibiofibular articulation.

(iii) Gomphosis

This is the joint formed between a tooth and its socket. It allows slight movement, but firm attachment.

FIBROUS JOINT (SYNARTHROSIS)

(b) Syndesmosis

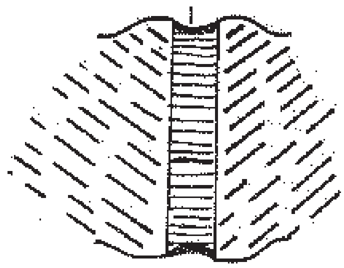


Figure 2-Cb

CARTILAGINOUS JOINTS (AMPHIARTHROSES)

(c) Symphysis

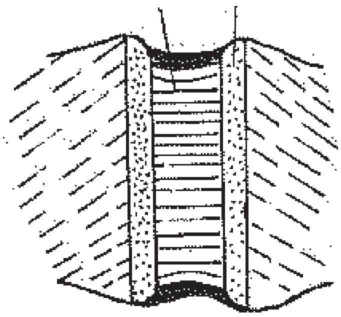


Figure 2-Cc

(d) Synchondrosis

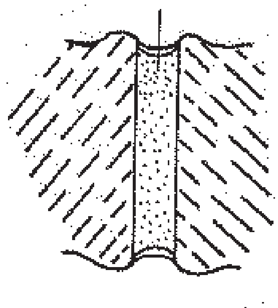


Figure 2-Cd

(b) Cartilaginous joints (Amphiarthroses) (Fig. 2-Cc,d)

These allow only limited movement, e.g. compression or stretching.

They may be formed from cartilage (synchondrosis), fibrocartilage, or a combination of both. There is no joint capsule.

(i) Fibrocartilaginous Joints (Symphyses) (Fig.- 2-Cc)

These are found in symphyses (pelvic and mandibular), and are important joints between vertebral bodies and sternebrae. No joint capsule is involved, and yet there may be movement.

Between the vertebrae lie discs **-intervertebral discs** (intervertebral fibro-cartilages). The discs consist of a central **nucleus pulposus** (derived from the **notochord**). This acts as a water cushion and augments elasticity of the joint. It is surrounded by an **annulus fibrosum** which is normally fibrous and relatively pliable (Fig. 2-D).

In ageing animals (and sometimes in younger ones), the annulus may become brittle and areas of weakness may result in cracks being formed in it. The outcome of these changes may be that the nucleus pulposus herniates or ruptures at the site of weakness, usually in a caudal direction.

This may cause the two associated vertebrae to come in closer apposition. This, in turn, may give rise to abnormal pressure on an associated spinal nerve. The outcome could be great pain in the back and even lameness. The condition has been referred to as a "'slipped disc", but this is a misnomer. Better terms are disc prolapse and disc herniation.

(ii) Hyaline Cartilage Joints (Synchondroses) (Fig. 2-Cd)

These are mainly transitory joints found in growing bone. In the adult, osseous fusion mostly occurs. However, the **costochondral joints** remain throughout life.

(c) Synovial joints (Diarthroses)

Synovial joints allow the greatest degree of movement.

They are characterised by
- a joint cavity containing synovial fluid,
- a joint capsule, and
- articular cartilage.

Synovial joints can be classified in various ways:

(i) **Simple Joint** - when there are two articular surfaces within the capsule.

(ii) **Compound Joint** - when there are more than two articular surfaces within the same capsule.

(iii) **Ball-and-Socket Joint** (**Enarthrosis**) - when a convex hemispherical head fits into a cavity (shallow, e.g. shoulder joint; deep, e.g. hip joint).

(iv) **Hinge Joint (Ginglymus)** – allows flexion and extension with limited rotation. The movable surface is usually concave (e.g. elbow joint).

(v) **Condylar Joint -** has similar movement to a hinge joint, but the articular surfaces are rounded condyles (e.g. knee joint, which is also complex).

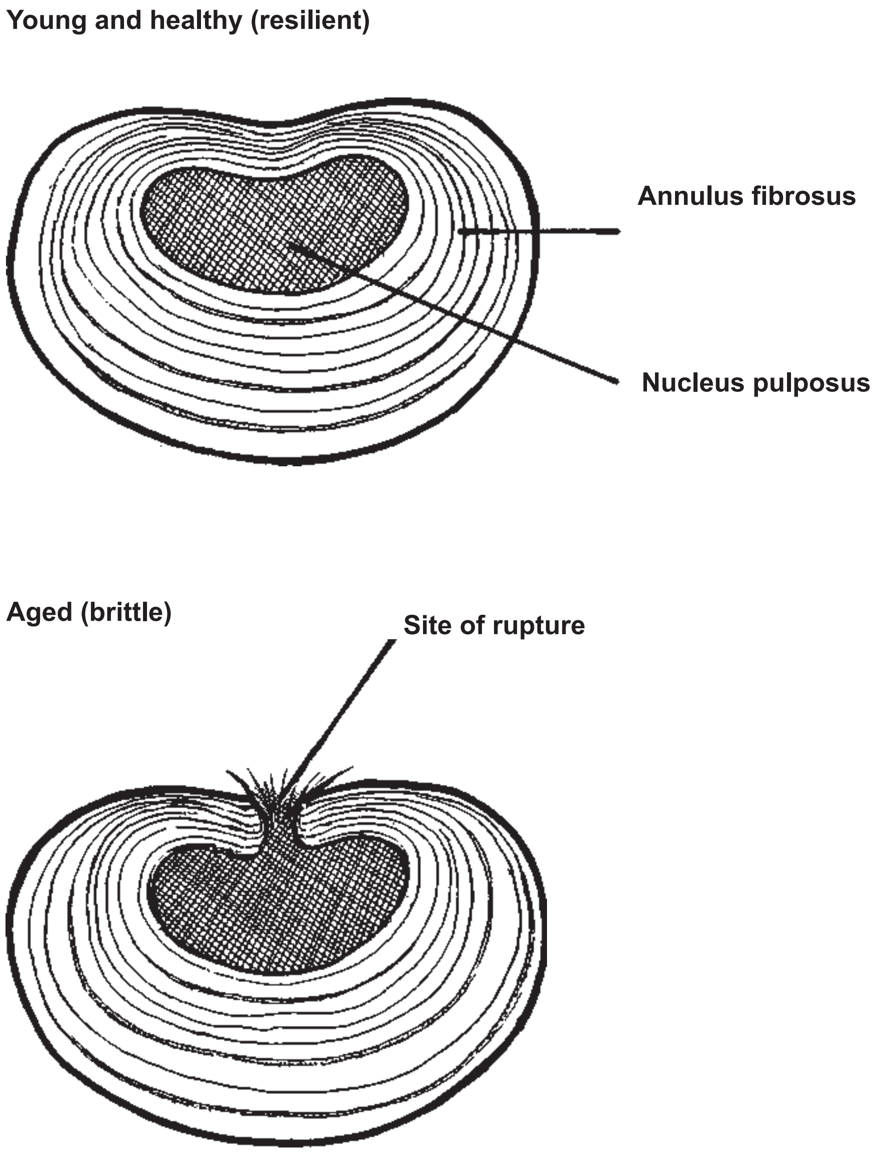


Figure 2-D: Intervertebral fibrocartilage

(vi) Pivot Joint (Trochoid) - has most movement around a longitudinal axis through the bones (e.g. atlanto-axial joint, radioulnar joint).

(vii) Arthrodial Joint - allows a gliding motion (e.g. carpometacarpal joints)

The generalised structure of a synovial joint is shown in Fig. - 2-E

The articular surfaces of the bones are covered with **hyaline cartilage**. Between the surfaces is a cavity - joint cavity. This is a virtual rather than a real cavity, because the articular cartilages are usually in contact with each other (except for a thin layer of synovia1 fluid).

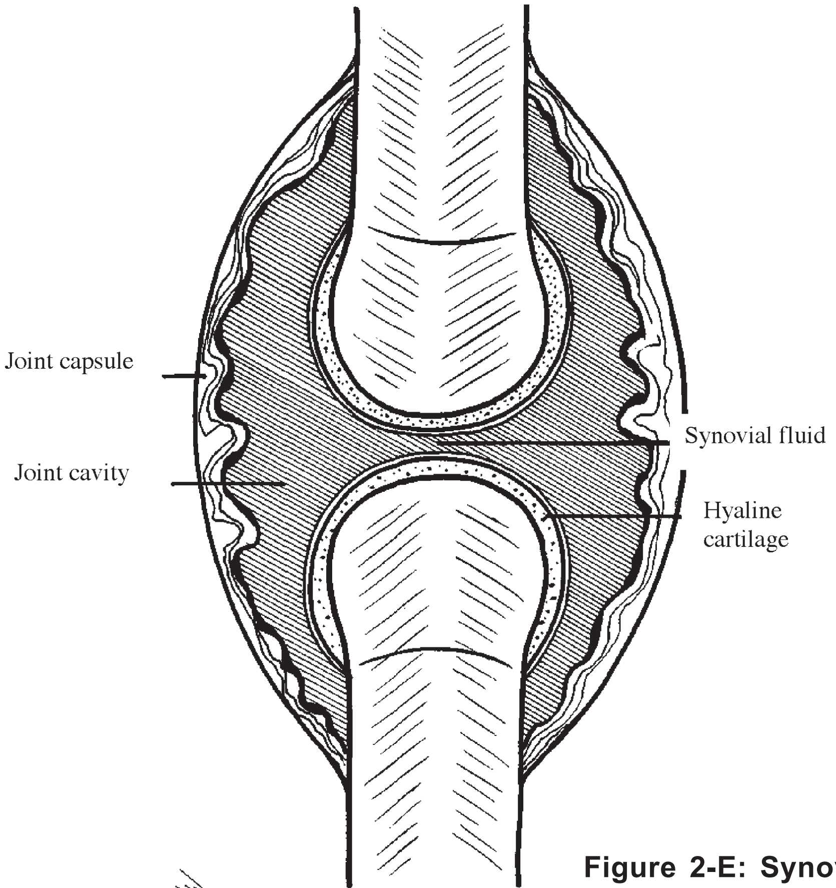


Figure 2-E: Synovial joint

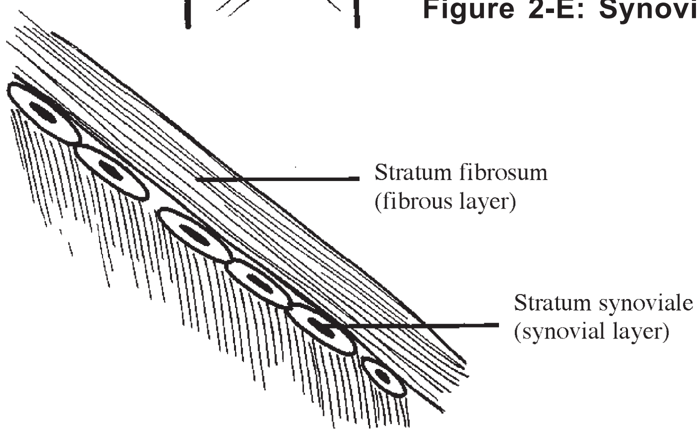


Figure 2-F: Joint capsule

The cavity is enclosed by the **joint capsule** which consists of two layers:

a) the outer **stratum fibrosum** (fibrous tissue), and

b) the inner **stratum synoviale** (synovial layer): this consists of loose connective tissue and a cellular layer 2-3 cells thick. These cells sometimes become detached and float around in the synovial fluid.

Type A cells in the synovial membrane are phagocytic and aid in removing debris from the joint space.

Type B cells in the synovial membrane are secretory and produce hyaluronan, an important constituent of synovial fluid.

Both layers of the joint capsule form a **synovial membrane** (Fig. 2-F).

The membrane is absorptive in nature and absorption is accelerated by movement.

a. Joint capsules are not always simple and many have folds, pouches and fat pads.

b. These may help in general lubrication of the joint and, in some cases, fat pads may add extra protection for the joint, e.g. the **subsynovial fat pad** in the olecranon fossa of the humerus.

Development and function of synovial joints

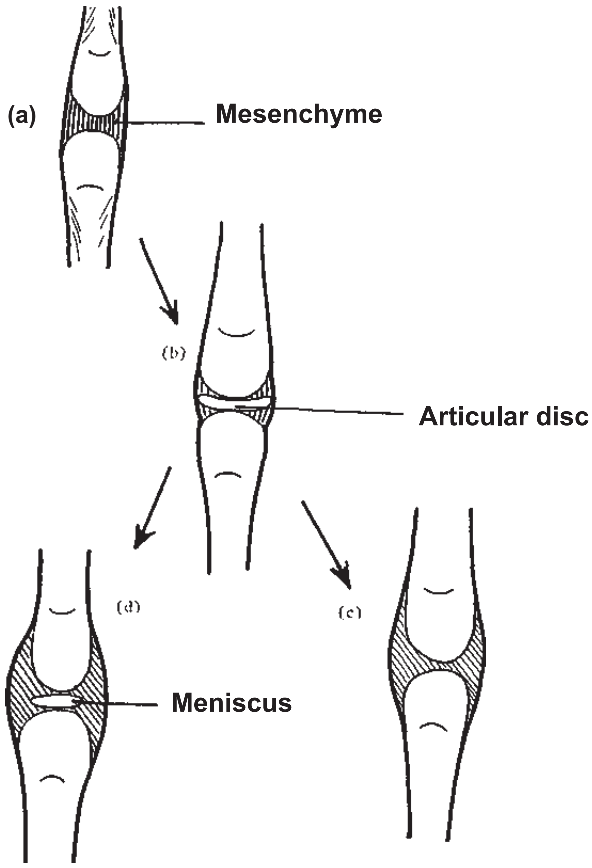


Figure 2-G: Development of a synovial joint

Initially, the precursors of the skeletal components of the joints are joined to each other only by **mesenchyme**.

But later the mesenchyme is compressed and forms an **articular disc** (Fig. 2-G). This disc is normally absorbed, but if this does not happen, remnants of the disc are found - **menisci** (singular -meniscus).

Joints that contain menisci are called compound joints, e.g. the stifle joint and the mandibular joint.

Components of the synovial joint

1. **Articular Cartilage**

Normally articular cartilage is **hyaline cartilage**; but if the surfaces are formed from membranous bone, the cartilage is **fibro-cartilage**, e.g. in the mandibular joint.

(i) The function of articular cartilage is to reduce friction.

(ii) But it only does so if the fluid in the joint is fairly viscous.

Remember: **Articular cartilage is avascular and has no nerves**. It receives its nutrient via the synovial membrane which has a rich blood supply. Regeneration of the cartilage is, therefore, most successful at the periphery where it is nearest to the synovial membrane.

When the cartilage is damaged, it regenerates by:

a) Multiplication of existing healthy cartilage cells.

b) Conversion of cells of the stratum synoviale into cartilage cells (metaplasia of the cells of the joint capsule).

Cells in the centre of the cartilage do not multiply readily and the stratum synoviale is relatively distant. Thus, in the centre of articular cartilage repair is frequently inadequate, leaving the **subchondral bone** exposed (one component of arthritic change).

Normal articular cartilage is smooth, white and glistening. Histologically it is composed of chondrocytes, collagen fibres and matrix (ground substance).

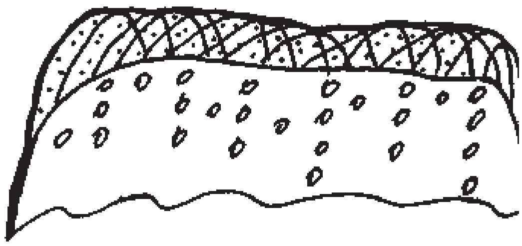
Chondrocytes are sparse but quite active. They synthesise collagen, protein and other components of the matrix.

Collagen fibres are embedded in the matrix arranged in hoops. This leads to an irregular (corrugated) surface which prevents adhesions of adjacent surfaces and also may help to trap synovial fluid for better lubrication.

The superficial layer of tightly packed fibres (tangential zone) resists shear forces.

When the surface experiences pressure, the fibres move laterally but can rebound due to their elasticity. This resilience also requires the fibres to be 'buoyed' by proteoglycans and bound water in the matrix.

Matrix of articular cartilage consists of **proteoglycans** (mainly **chondroitin sulphate**) which is strongly hydrophilic, so binds water. This provides a cushion for shock absorption.



2. **Synovial Fluid**

Synovial fluid is a dialysate of blood to which mucoprotein (**hyaluronan**) has been added by cells lining the synovial membrane. This increases its viscosity.

Synovial fluid provides a source of nutrition for articular cartilage and maintains electrolyte and metabolite balance. A major function is lubrication, decreasing friction between articular surfaces and reducing wear and tear.

3. **Ligaments**

These are thickenings of the stratum fibrosum. They develop in response to tensional forces. (They may even develop post-natally if the demand is there). They strengthen joints and restrain movement. They are often assisted in their function by tendons.

Some ligaments are considered to be remnants of tendons (e.g. the medial ligament of the elbow joint in horses has been considered by some to be a remnant of the pronator teres muscle).

4. **Menisci**

These structures serve as shock absorbers. They may:

a. Be associated with a demand for special movement, e.g. the mandibular joint allows two types of movement of the jaw, both lateral and vertical.

b. Be evolutionary left-overs. They have a nerve supply and are thus atypical cartilages. Thus, it is possible that menisci have a sensory function. They occur in the stifle and mandibular joints.

(d) Stability of joints

The correct apposition of articular surfaces is sometimes disrupted by abnormal movement or by a blow - dislocation or **luxation** of the joint. A number of features normally prevent this.

1. The **shape of articular surfaces**. If you observe these, you will see how this works. For instance, the proximal articular surface of the femur is not entirely round (it is slightly longer transversely than vertically). Thus, it is screwed deeper into the acetabulum or out of it, according to the movement of the femur.
2. The **action of ligaments**. These are relatively inelastic structures. Note, for example, that the collateral ligaments of a hinge joint (ginglymus) such as those between the humerus and the radius, are always taught, irrespective of the movement. Ligaments, therefore, restrict movement.
3. The **action of muscles (or tendons)**. Good examples of such stabilizing tendons are the tendons of insertion of the supraspinatus and infraspinatus muscles of the forelimb. These tendons act like collateral ligaments.
4. The **cohesive force of synovial fluid**. There is always a thin layer of fluid separating the articular surfaces.

(e) Different types of movement in joints

(i) Flexion and Extension

This is movement between two bones which normally lie at an angle to each other.

– If the angle is reduced - flexion.

– If the angle is increased - extension.

Typical examples are in a ball-and-socket joint such as the shoulder joint or a hinge joint such as the tibiotarsal joint.

(ii) Gliding: This occurs in the joints between carpals and tarsals.

(iii) Abduction: Occurs in both fore and hind limb.

(iv) Adduction: Default position for both fore and hind limbs.

(v) Rotation: For instance, the shaft of a long bone may rotate about its long axis.

(vi) Circumduction: (This movement has been described as a potential movement of the hip joint, but it is usually pathological).

(f) Other synovial structures (bursae and tendon sheaths)

These structures occur where there is likely to be excessive friction between tendons and bones. Thus, they are more important in horses than in dogs because horses' limbs are more tendinous.

Fundamentally, the structure of bursae and tendon sheaths is the same: each is lined by **mesothelium** – fibroblasts, and each contains fluid, just like a synovial joint.

Tendon sheaths are simply modified **bursae**, where the tendon has indented the synovial structure.

- The outer layer of the sheath is then called the **ectotendon** (or **paratenon)**.
- The inner layer - the **endotendon**.
- The virtual gap giving access to the tendon - the **mesotendon**.

The principle is illustrated in Fig. 2-H.

There are "**false bursae**", e.g. "capped elbow". These are entirely due to the accumulation of fluid due to trauma and do not represent the presence of a true bursa.

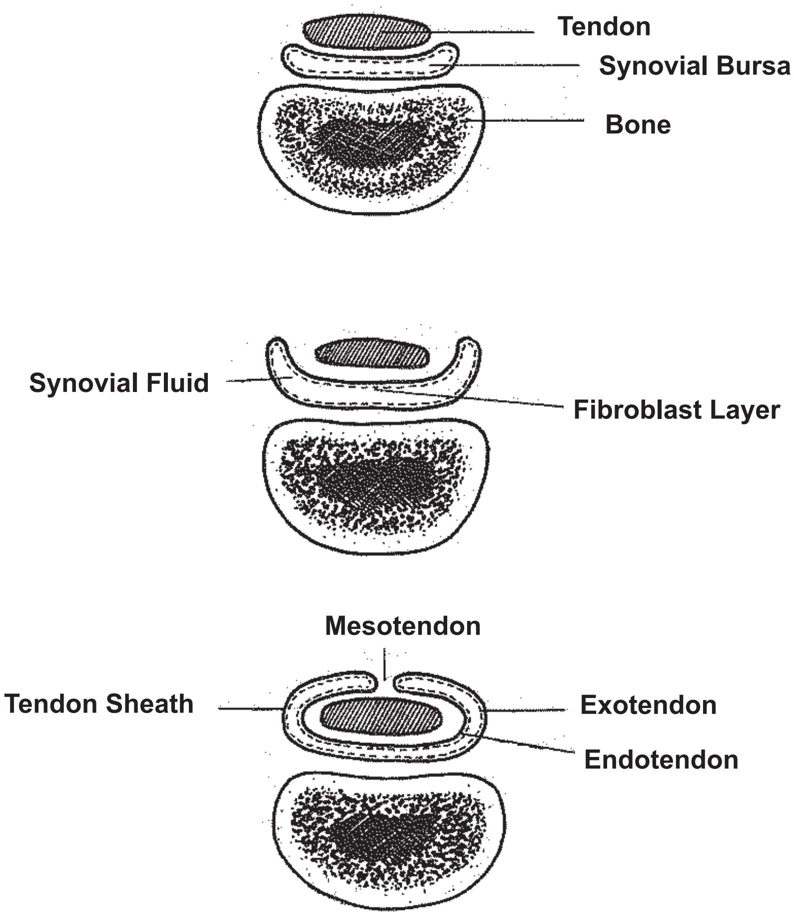


Figure 2-H: Development of a tendon sheath

C. Muscles

Movement is brought about by a series of contractile elements in the body:

Visceral Muscle (Smooth, plain, non-striated, unstriped)

Has the ability to contract spontaneously even without a nervous impulse, but contraction may be initiated and modified by autonomic nerves, e.g. gut, bladder wall, scrotal skin.

Somatic muscle (Skeletal, striated, striped

Is dependent upon nervous stimulation. Is normally in a partially contracted state - muscle tone.

Cardiac Muscle (Intermediate in quality between somatic and visceral muscles)

Only found in the heart.

Myoepithelium (Specialized epithelial cells with contractile properties)

Found in association with sweat glands and mammary glands. Considered to be primitive contractile elements, similar to musculo-epithelial cells of coelent-erates.

Other special contractile tissue e.g. **Myoid cells** of the seminiferous tubules of the testis.

Functions of muscle

- Produces movement
- Restrains movement
- Produces heat in homeothermic (warm blooded) animals (because skeletal muscle is in a state of tone and thus generates heat even when at rest).

Functional morphology of muscle

The detailed structure of muscle has been dealt with elsewhere so at this time you are recommended to consult your teaching guide on Basic Tissues.

Skeletal Muscle Types

Mammalian muscle fibres can be divided into two types, **fast twitch** or **slow twitch**, depending on their contraction time to a peak of tension. These two types of fibres produce different **myosin isoenzymes** which allows them to be detected in histological sections.

- Muscles with many fast twitch fibres, which use energy at a higher rate, are found where rapid acceleration (i.e. propulsion) is required ie the **locomotory muscles**.
- Muscles with many slow twitch fibres are found where a force to slow down or prevent movement is needed. They are economical and use little energy and are common in **postural muscles** where they oppose the force of gravity.

Some muscles have both propulsive and postural roles e.g. the semitendinosus m. uses areas dense in slow twitch fibres during standing or quiet walking and uses areas dense in fast twitch fibres during violent action.

Endurance is the ability of muscle fibres to sustain contraction over long periods, and is dependent on energy obtained from aerobic metabolism. A typical high endurance fibre is relatively small to allow for diffusion of oxygen and nutrients; has a rich blood supply; a high density of mitochondria; and a high density of cytochromes and myoglobin. Thus high endurance fibres are sometimes called red fibres and provide the colouring of red meat. Postural muscles are aerobic, but some propulsive muscles also have high endurance qualities.

Muscles used infrequently rely on anaerobic metabolism, using an intrinsic glycogen store. This is much less efficient than aerobic metabolism and produces a build up of lactic acid and a consequent oxygen debt.

Skeletal muscles are of different sizes and shapes. They are named according to:

a. Function - e.g. long digital extensor, deep digital flexor, supinator
b. Position - e.g. lateral ulnar (ulnaris lateralis), caudal tibial, subscapular
c. Direction of fibres - e.g. external abdominal oblique, rectus (straight) femoris
d. Shape - e.g. deltoid (delta-triangular - Greek, deltoideus - Latin), soleus (shape of a fish), quadratus femoris (quadrangular - oblong)
e. Form - e.g. triceps, biceps, quadratus

Muscles are separated from each other and bound into position by connective tissue - fascia.

- **deep fascia** - immediate investment of the muscle
- **superficial fascia** - looser fascia beneath the skin

Deep fascia varies in thickness according to the muscle with which it is associated and in a typical flexor or extensor muscle of a limb, it continues at the end of the muscle as a consolidated mass of connective tissue - a tendon. This provides an attachment (usually distal attachment) for the muscle and is usually thinner than the muscle.

Tendinous attachments may produce rough prominences (**tubercles, tuberosities**) on a bone and in areas where tendons run over bone, grooves are often formed. Fleshy attachments are smoother but may include less distinct lines on the bone. **Prominences** and **lines** are often named according to the muscle or muscles associated with them, e.g. teres tubercle, deltoid tuberosity.

Typically, muscles that flex or extend the carpus, tarsus and digits have an upper fleshy attachment (origin) and a lower tendinous attachment (insertion).

The **origin** of a muscle may be defined as the attached end that is the most stationary.

The **insertion** of a muscle is the attached end where there is most movement.

As explained previously, muscles exert their action by contraction of the bundles of muscle fibres of which they are composed.

The total force exerted (F) = the sum (n) of forces exerted by all the individual fibres (f), i.e.F = fn.

The fibres

Muscles with long fibres and long fasciculi usually have a greater range of movement than those with short fibres. Short fibres reduce bulk and increase muscle strength.

Muscle fibres may run parallel to each other in some muscles. (This is seen in some long thin muscles and in some broad flat muscles). The parallel fibres may be perpendicular, oblique or horizontal.

When a muscle is spindle-shaped and the fibres converge on the tendon, the muscle is referred to as being **fusiform**.

But when the parallel fibres attach to the tendon at an angle, the muscle is called **pennate**.

There may be **unipennate**, **bipennate** or **multipennate** muscles (see Fig. 2-I).

Sometimes a tendon runs throughout the length of a muscle, dividing it into two **bellies**, e.g. digastric muscle.

There may also be **tendinous inscriptions** or intersections, e.g. in the rectus abdominis muscle (see Fig. 2-J).

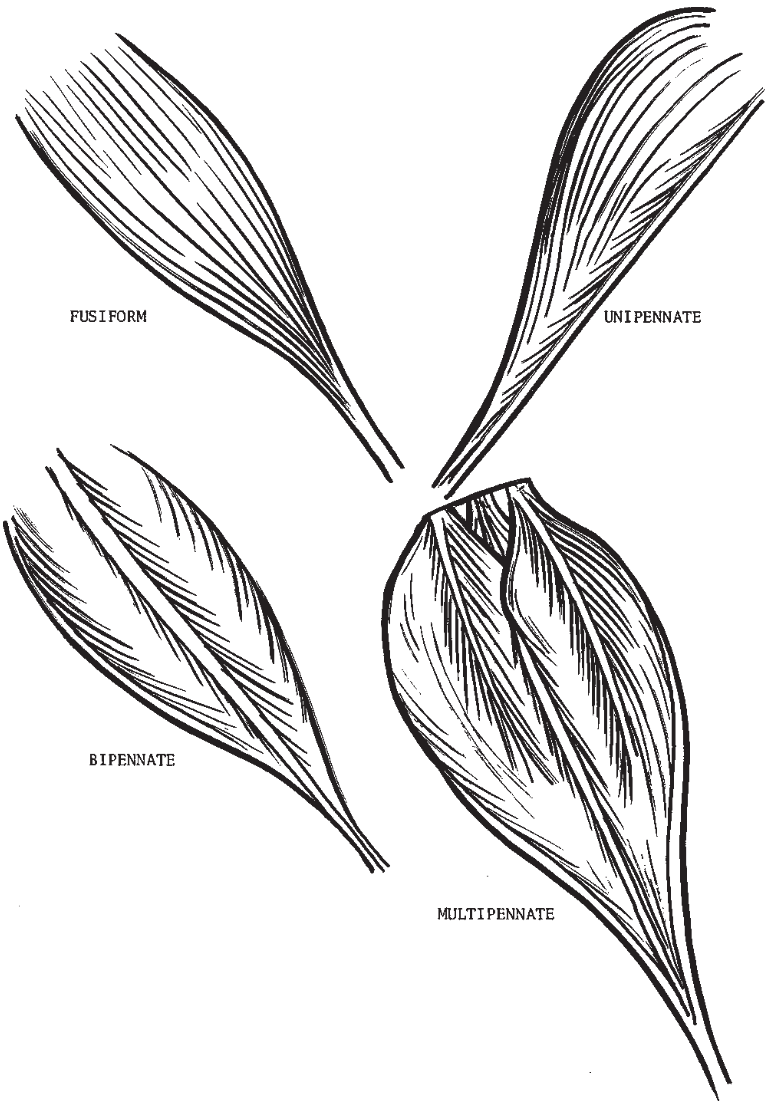


Figure 2-I: Muscle types

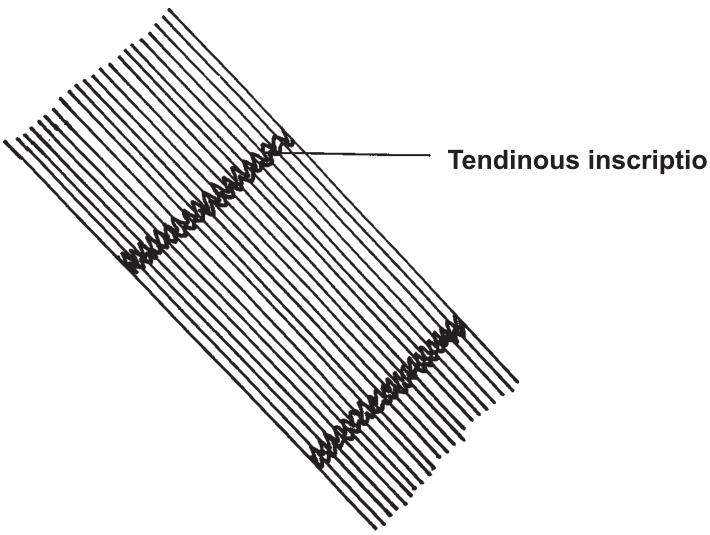


Figure 2-J: The rectus abdominis muscle

Growth and repair of skeletal muscle

Normally, new skeletal muscle fibres are not formed in postnatal life. Therefore, if a muscle increases in size with exercise, it is due to an increase in the size of muscle fibres. However, there is evidence that if a muscle is damaged, new muscle fibres can be formed.

But - the area of damage is usually invaded by connective tissue before the muscle has a chance to regenerate. Thus, it is usually considered that skeletal muscle does not regenerate after it is damaged.

Questions

Why is the regeneration of cartilage more successful at the periphery of a joint rather than in the centre?

Why is a synovial joint likely to swell after injury?

How is it that the menisci in the stifle joint have a nerve supply whilst the cartilage of the articular surfaces of the femur and tibia have not?

On the basis of functional demand, how would you expect the gross structure of a typical locomotory muscle to differ from a typical postural muscle?

Why are limb muscles in animals that are modified for running, shorter than the maximum length required for exerting a force?

What advantages, in terms of its action, might a pennate muscle have over a fusiform muscle?

Why is it usually considered that a limb muscle does not regenerate after it is severely damaged?

Principles of locomotion

A. Basic laws

The principles of animal movement are incorporated in Newton's Laws of Motion.

1st Law

"A body at rest remains at rest, a body in motion continues to move with uniform velocity unless acted upon by some external force".

Thus, If an animal is to move its body by its own unaided effort, it must:

(a) Elicit a force from its environment, and

(b) An outside force must be brought in if the animal is to change speed or direction.

2nd Law

"If a body moves, the velocity of movement (V) is directly proportional to the magnitude of the force and the period of time during which it acts (t). Moreover, it is inversely proportional to the mass of the body (m)".

3rd Law

"To every action there is an equal and opposite reaction".

In order to subject its body to a forward propulsive force, an animal must exert an exactly equal but opposite force against the environment. In other words, animals move because the environment resists their movement of fins, legs or wings, relative to the body. In limbless animals, the ground (including gravity) resists the whole surface of the body.

Thus, we see that limbs may exert:

(i) A downward vertical force

(ii) A horizontal longitudinal force (forward and backward swing)

(iii) A lateral horizontal force (outward swing)

A horse may be able to pull a cart heavier than itself because the frictional resistance operating against the wheels of the cart is relatively small. If it is muddy, the frictional resistance against the horse is reduced (the hooves slip) and the resistance against the wheels increases (the mud sticks), so the ability to pull may be lost.

B. The animal as a self-propelling machine

Locomotory machinery consists of:

– **engine**: muscles (converting chemical energy into mechanical tensile energy)
– **transmission**: bones (operating as levers)
– **propellor**: foot surface (exerting its effort against the environment)

On land, most inanimate self-propelling machines operate by means of wheels. This is possible because of an axle, but an animal cannot do this because there can be no axle, since each bit of the machine is fastened to another bit and because it is necessary to avoid the twisting of blood vessels. Thus, a limb can only move less than one revolution, then it must be reversed.

Except for this severe limitation, a limb is analogous to a wheel, where the Foot = the rim of a wheel, and the Limb = the spokes of the wheel. (See Fig. 2-K).

A limb is less efficient than a wheel. When a wheel is turning at constant speed, its kinetic energy is constant, but a limb, during its action, must periodically leave the ground. When a limb is off the ground, it is stationary relative to the body and energy is required to swing it forward (protraction) where it can be put on the ground again.

The energy comes from the protractor muscles, but it does not contribute to the forward propulsion of the body. On the contrary, the raised limb acts as a brake, because while it is no longer exerting propulsive force, the body may decelerate.

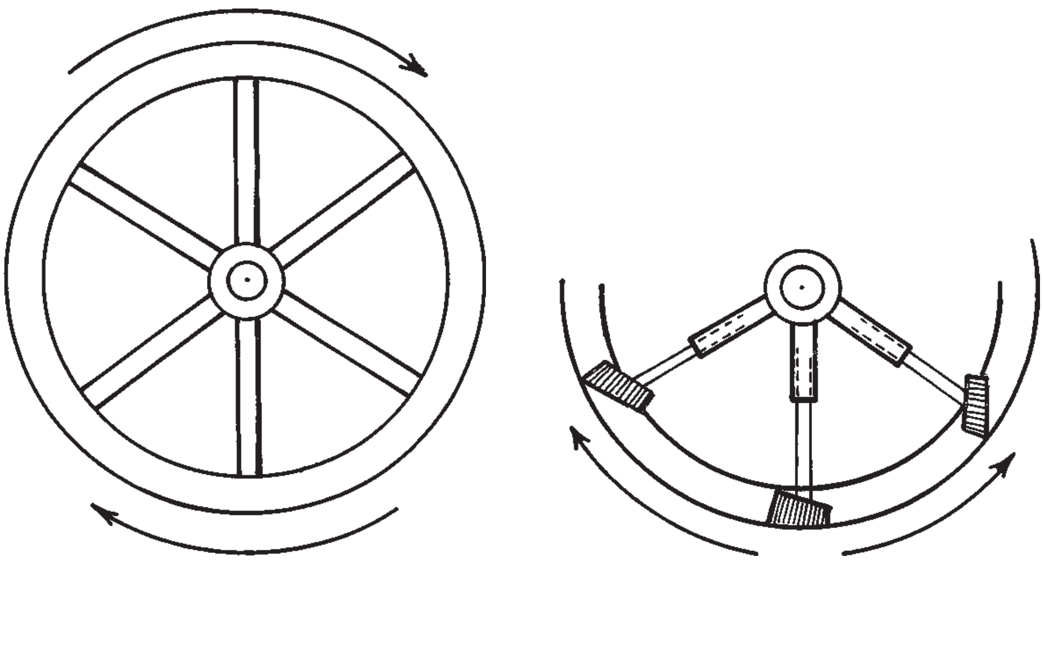


Figure 2-K

However, the limb has one major advantage over a wheel. A wheel is only efficient on rigid surfaces and has no "give" on rough surfaces. A limb, by contrast, is less likely to stick in mud and is able to vary its step (i.e. vary the diameter of the wheel) on rough ground and thus has built in shock absorbers. A limb therefore has some advantages over a wheel.

C. The limbs of mammals (Physical considerations including mechanical forces)

In birds and reptiles, the intrinsic joints of the limbs are not all in the same plane: the upper part of the forelimb points outward. In terrestrial mammals, all intrinsic joints of the limbs lie in the same plane, i.e. vertically under the shoulder or hip. This means that the feet are under the shoulder or hip and the body is well off the ground (See Fig. 2-L).

Thus, in comparison with reptiles, the mammal lacks static transverse stability (viz: the ability to allow its centre of gravity to be displaced from the mid-line without falling over. This is offset, however, by a dynamic stability resulting from a quick response of muscles to stimuli transmitted via the semicircular canals and the eye. These developments in eutherian mammals (which do not include marsupial and monotreme mammals), have involved certain changes in the shoulder girdle.

In birds and reptiles the forelimb is connected directly to the rest of the body via the coracoid bone which articulates with the sternum. The glenoid cavity (the articular surface between the scapula and the limb bones) points outwards.

But in mammals, by contrast:

a) The forelimb is not connected directly to the body, and

b) The glenoid cavity points downwards. (See Fig. 2-L).

c) The shoulder girdle is represented entirely by the scapula (the coracoid has become fused to it and the only indication of a clavicle in a dog is a clavicular tendon which lies in the brachiocephalic muscle).

In quadrupeds, the shoulder girdle has two functions:

a) To transmit the weight of the body to the limbs.

b) To give adequate resistance so that the locomotory muscles are able to exert horizontal propulsive forces against the body.

The limb is closely attached to the body in eutherian mammals by an alliance of muscles - a **synsarcosis**. This is illustrated in Figs. 2-M and 2-N in which the direction of pull in these muscles is shown.

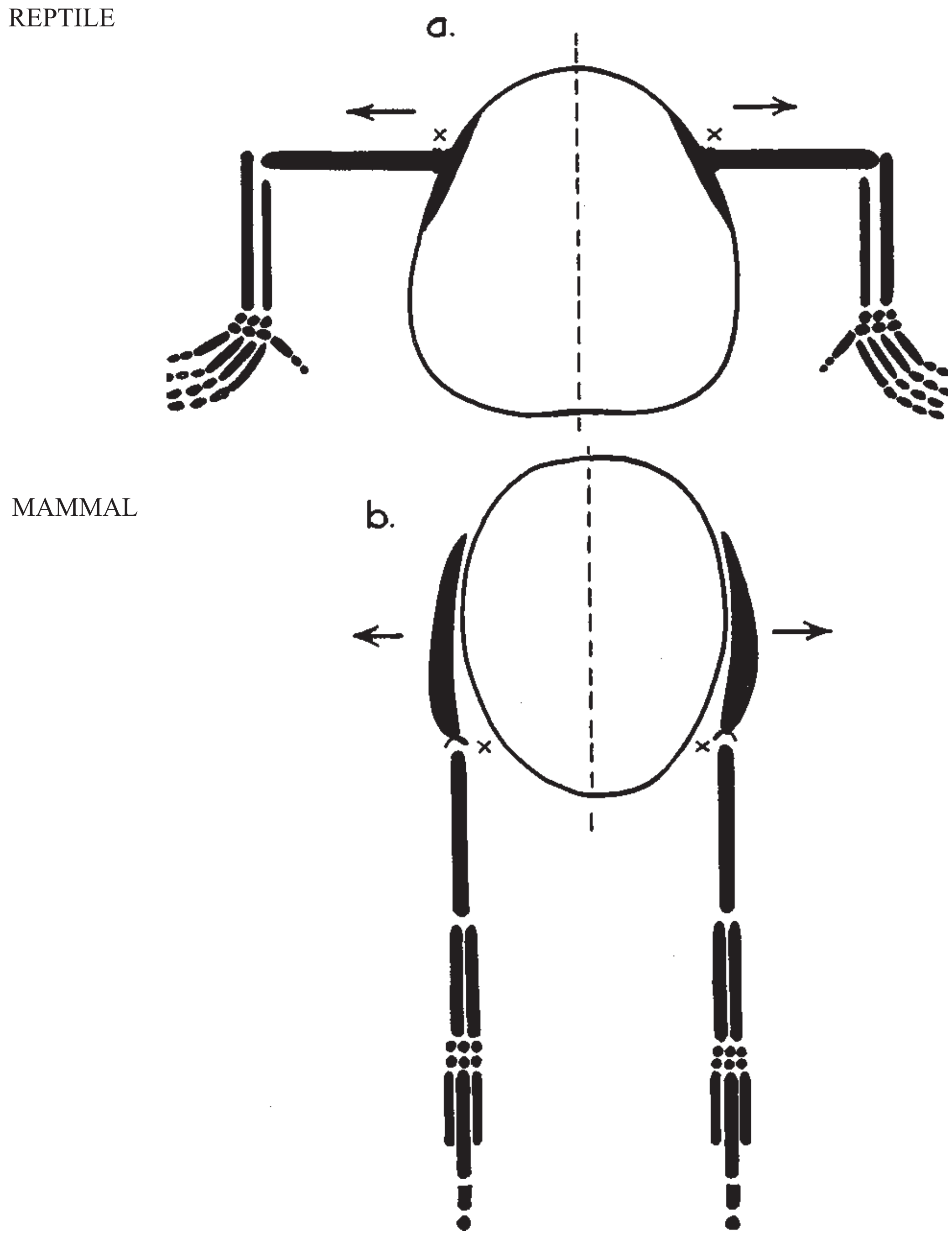


Figure 2-L: Balance and centre of gravity

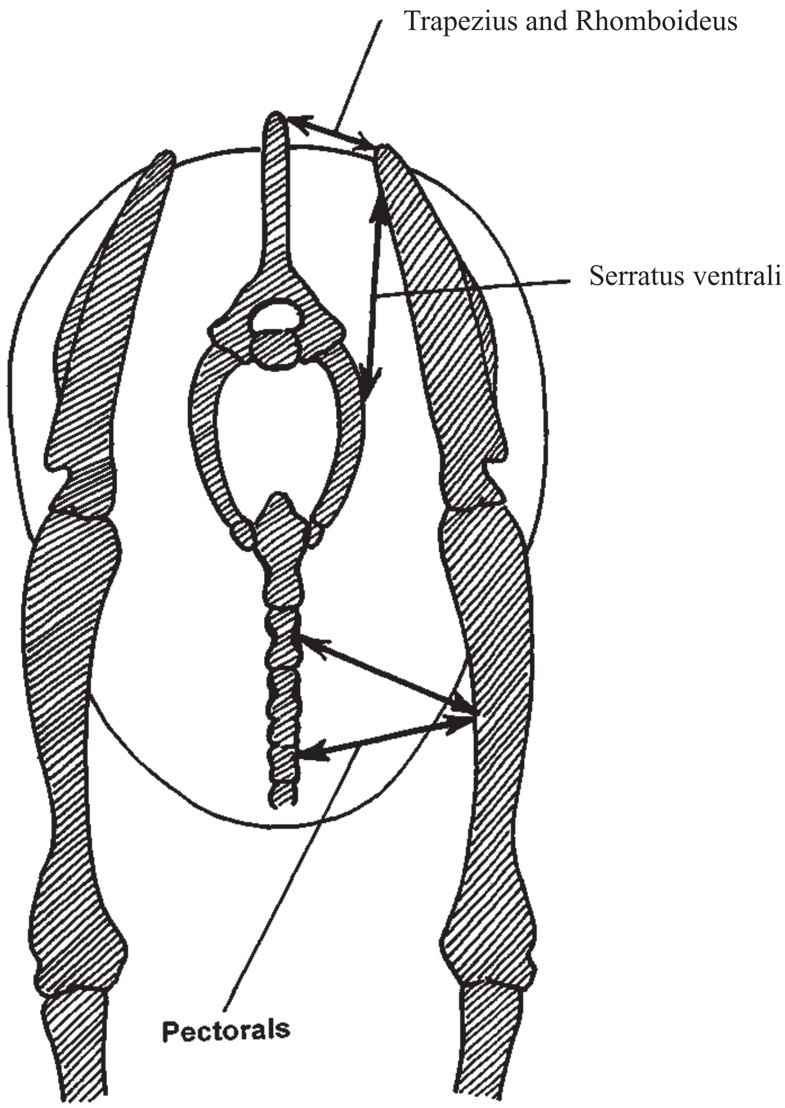


Figure 2-M: Action of medial muscles in the shoulder synsarcosis

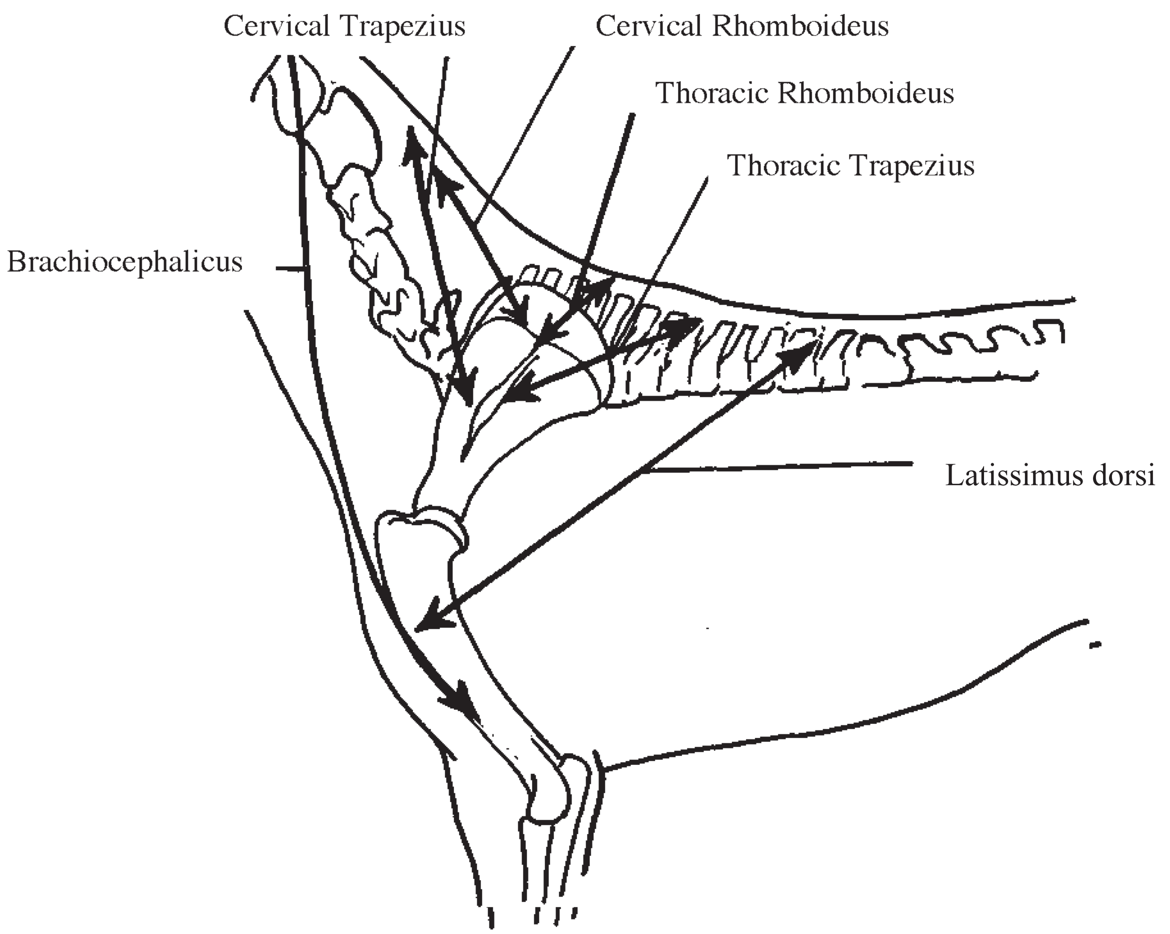


Figure 2-N: Action of shoulder muscles

Eutherian mammals may have:

– Weight bearing limbs (**graviportal**) e.g. elephant, rhinoceros.
– Limbs adapted for running (**cursorial**) e.g. dog, horse.

Characteristics of Graviportal Limbs: (Figure 2-O)

– Limb bones are short and thick, better able to resist longitudinal compression.
– The feet are short and the calcaneous is large. This allows powerful movements of the ankle, but with limited range.

Characteristics of Cursorial Limbs:

– The bones are long and thin and so act like extensible struts.
– The feet are long but most of their surface does not touch the ground. In the hind limb, the calcaneous is smaller, allowing a larger but weaker movement of the feet.

(a) Graviportal

(b) Cursorial

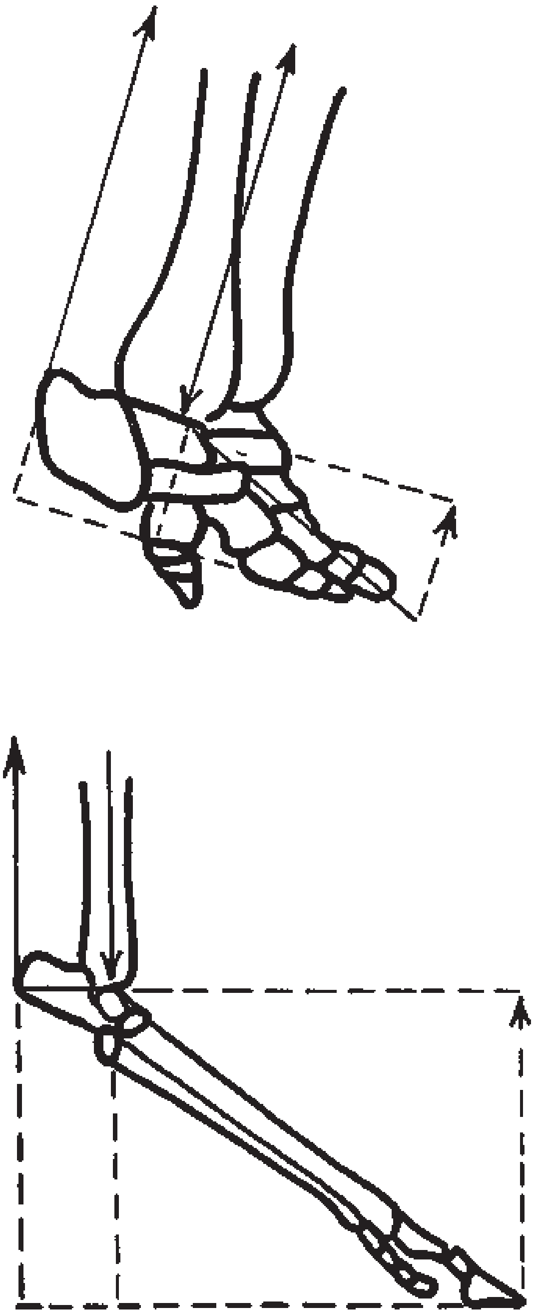


Figure 2-O: Characteristics of graviportal and cursorial limbs the ankle (redrawn from Gray - reproduced from Gregory 1912)

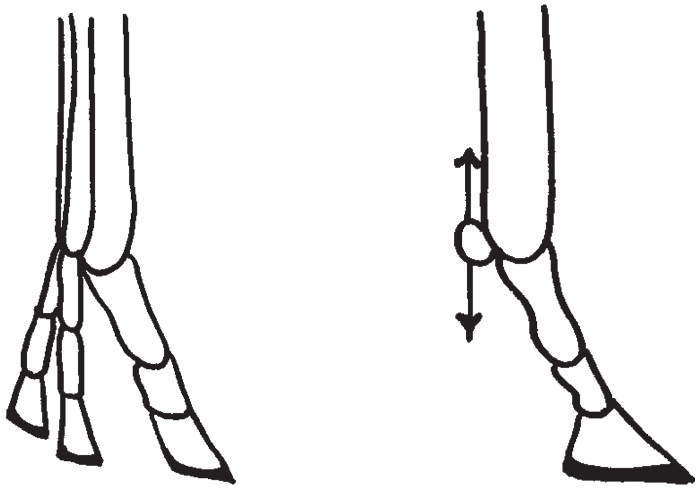
Designs for Speed in Cursorial Mammals

1. Capacity for speed is directly proportional to the length of the limbs. This lengthening of the limbs in cursorial mammals is achieved especially by long metacarpal and metatarsal bones.
2. In addition, the bearing surface is not the underside of the foot (**Plantigrade**) which includes the ankle, but only the digits (**Digitigrade**), or even the ends of the digits only (**Unquligrade** - hooved). This condition has special advantages in running.

   It is exemplified in the horse, where, only the end of the third digit contacts the ground. The feet are much lighter and require less power to overcome inertia (proportional to mass).

   The unguligrade condition (especially in the horse) presents some problems of support at the end of the metacarpal or metatarsal bones (e.g. the fetlock). These support problems are the source of many of the injuries that occur in horses, especially high performance animals such as racehorses and eventers.

ANCESTRAL FORM MODERN FORM



3. Reduction of the extensor muscles of the wrists and ankles (carpus and tarsus) has increased the muscles of the hip, shoulder, stifle and elbow.

   The diqitiqrade condition results in loss of stability, so it is difficult for a dog, or horse in particular, to maintain its balance for any length of time. In most normal gaits, therefore, limbs alternate in coming to the ground and thus a balance is maintained, e.g. when a limb is raised off the ground, the animal tends to fall to that side, but the limb is put down before it can do so and the opposite limb is raised, and so on.

A cursorially modified animal has to use its limbs more definitely than, say, a reptile. Compare the walk of a horse with that of a reptile for an example.

The pattern of footfall is the same:

Right Fore - Left Hind –

Right Fore - Left Hind

but in the horse, each foot is on the ground for a much shorter period than that of the reptile, so it has less feet on the ground at any one time.

Reptile: 4-3,4-3,4-3,4-3

Horse: 3-2,3-2,3-2,3-2

As the animal moves faster, this sequence changes.

This is discussed more fully in Chapter 6, where quadripedal gait of the horse and dog is analysed in some detail.

Questions

Why are the shoulder muscles so important in eutherian mammals compared to non-mammalian vertebrates?

The rhinoceros and the horse are both perissodactyls. What evolutionary differences are there in the limbs, particularly at the hock joint?

Compared with a reptile, a horse has much less static transverse stability. How does it maintain its balance?

Evolution of locomotion

A. Introduction

This section is intended to illustrate how, during evolution, the use of appendages has changed with the terrestrial habitat overtaking an earlier predominantly aquatic habitat and how the limbs of mammals have become modified for locomotory movement (cursorial adaptation).

The changes that have occurred involve alterations in:

(a) The shape and position of bones.

(b) Corresponding re-positioning of muscle masses, especially significant in the forelimb.

(c) Associated deviations in the course of the nerves supplying those muscle masses.

B. Underlying principles

The main shift of emphasis with movement from an aquatic to a terrestrial life has been:

That trunk muscles are no longer the main muscles of movement. Limb muscles have developed most and trunk muscles have, relatively, degenerated.

However, in fish, muscles above the notochord or vertebral column are epaxial muscles, those below are hypoaxial muscles (see Fig. 2-Pa and b), and in mammals, the back muscles of myotomic origin are similarly named (see Fig 2-Pc) .

Thus, mammals have and

– Epaxial musculature: above the vertebral column
– Hypaxial musculature: below the vertebral column

C. Evolutionary changes in bones in cursorial adaptation of the mammals

a) Pectoral girdle

In amphibia:

The development of limb muscles brought about the development of a scapula and a coracoid (for the attachment of limb muscles).

The clavicle consisted of a bar joining the scapula to the sternum.

In Eutherian mammals:

The clavicle is present in primates, but in most domestic mammals, it has either disappeared or remains as a tendon, e.g. in dogs.

The coracoid is greatly reduced.

b) Pelvic girdle

In early reptiles:

A primitive pelvis occurred: it was vertical, had a caudal development of the ilium, and a well-developed pubis, which provided the main attachment for muscles.

In mammals:

Larger limb muscles developed, leading to

– Vertical development of the limb
– Cranial development of the ilium

The pubis is reduced in size and each pelvic bone is joined to the other by the pelvic symphysis.

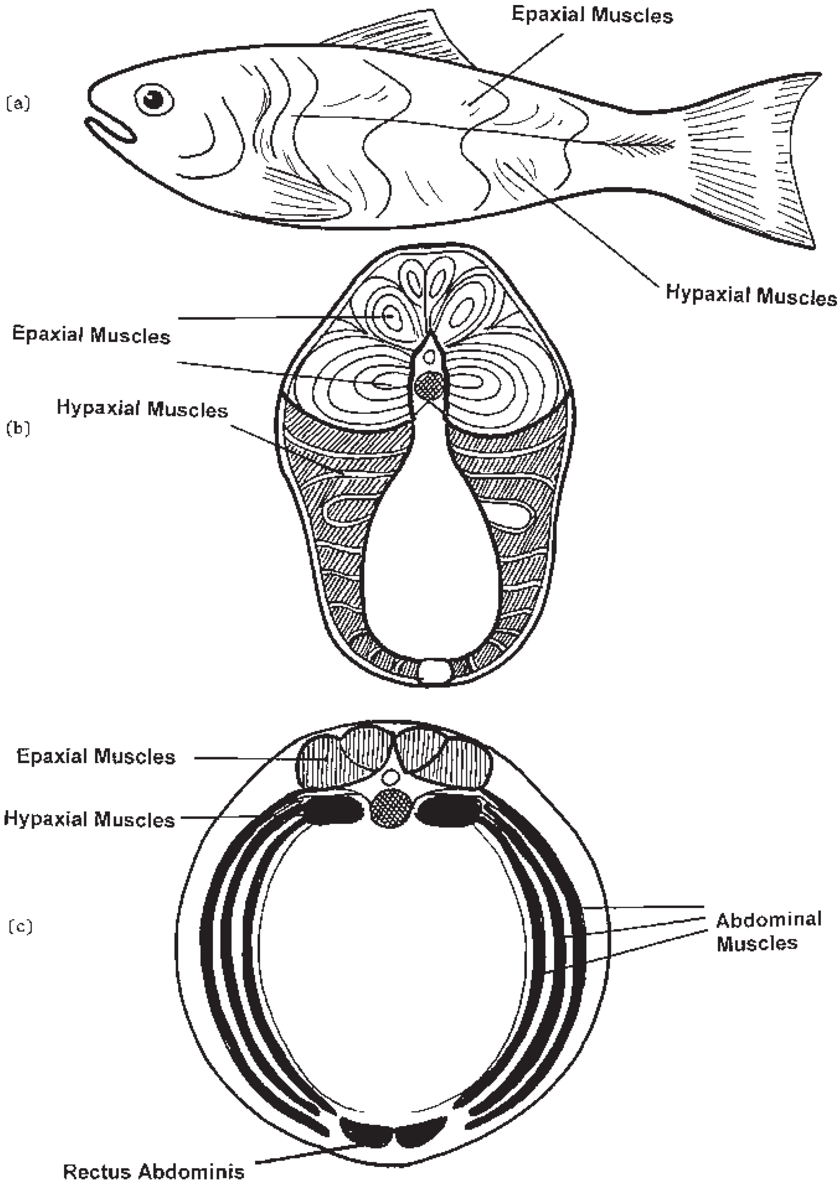


Figure 2-P: Evolution of trunk muscles

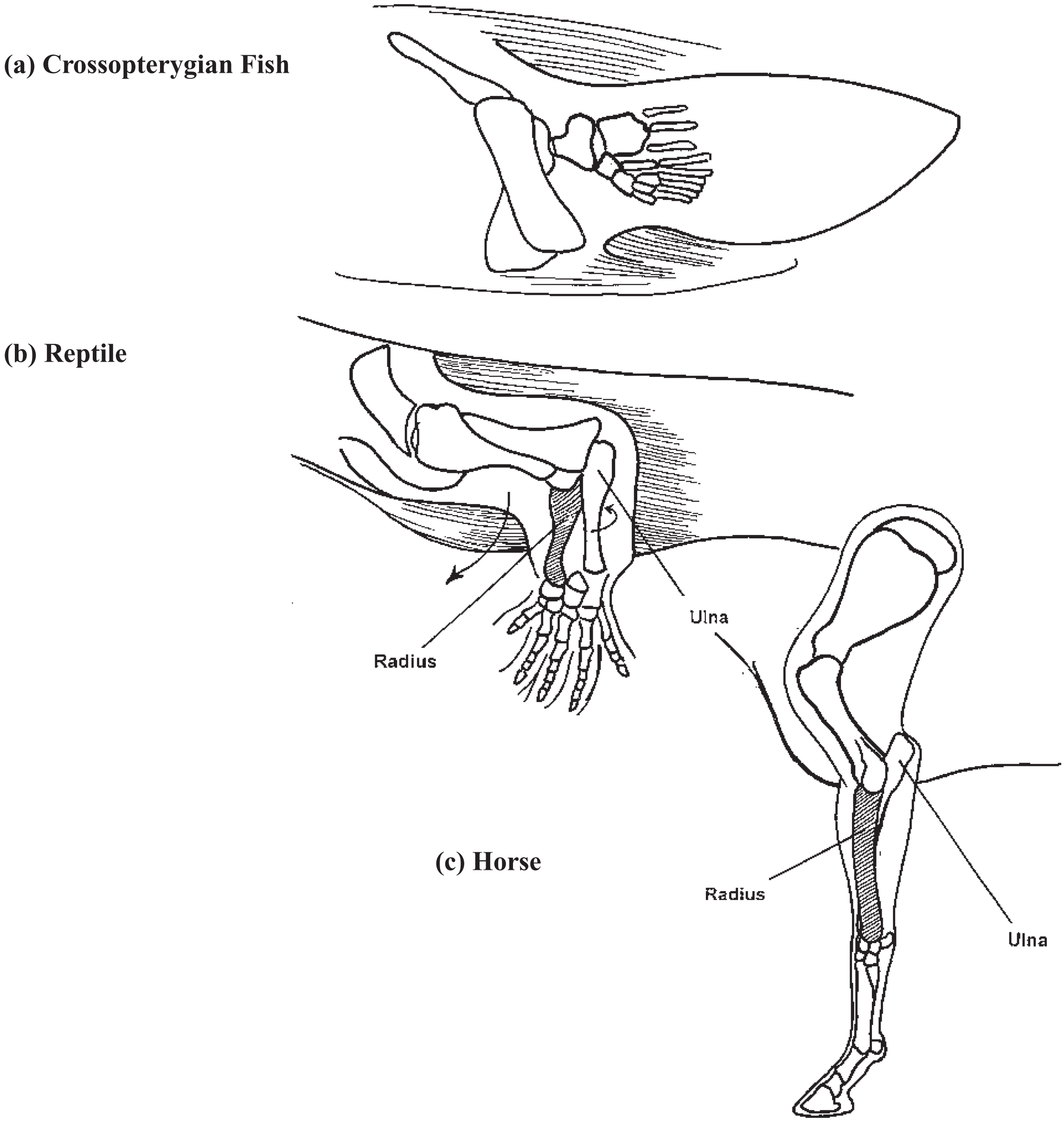


Figure 2-Q: Fore limb changes (literal) in arrrangement of bones

c) Upper limb bones

Non-mammalian vertebrates:

The glenoid cavity is directed outwards so that the humerus is horizontal and points laterally. This applies also to the femur.

In lobe-finned fish, the entire limb was horizontal (see Fig 2-Qa)

In reptiles, the radius, ulna, tibia and fibula are vertical (see Fig 2-Qb)

Mammals:

Two major events have occurred in the transition from reptilian form:

1. The glenoid cavity has become directed ventrally, so that in the humerus (and thus the limb in general) is vertical (see Fig 2-R). The femur is also vertical by virtue of its having developed a particular articulation with the acetabulum (see Fig 2-R).

2. The limbs have rotated. Rotation in the humerus has been more obvious in its distal rather than its proximal end. It has resulted in rotation of the radius and movement of the ulna from a lateral

   This is particularly well demonstrated in the horse, in which the limbs are permanently fixed in a position of pronation. Thus, the musculo-spiral groove in the horse is especially deep (see Fig 2-Q).

   In modern mammals, this rotation occurs in the embryo during development of limbs from the limb buds.

D) Effect of evolutionaly limb rotation on muscles, nerves and blood vessels

a) Muscles

Limb muscle develops in the limb bud of any embryo. Originally, this muscle was thought to be segmental, but this is now disputed. It is not usually regarded as myotomic in origin.

There are two muscle masses:

- Dorsal muscle mass
- Ventral muscle mass

It may be assumed that these muscle masses were distributed in the limbs of ancestral forms, as illustrated in Fig 2-S (Reptile). Movement of these masses has occurred as part of the cursorial adaptation for speed.

Forelimb

The straightening and rotation of the forelimb in evolution (and in embryological development) has moved the dorsal muscle mass caudal to the limb bones above the elbow and cranial to the limb bones below the elbow.

The ventral muscle mass has done exactly the opposite. (Fig. 2-S).

Hindlimb

Since the angle of the stifle joint is opposite to that of the elbow, changes in the position of muscles in the hind-limb have been much simpler than in the fore-limb. (Fig. 2-S).

– Dorsal muscle mass cranial throughout.

– Ventral muscle mass caudal throughout.

(Although some of each may have been slightly displaced during rotation to become medial or lateral).

These dispositions of the muscle indicate also how the nerves have become distributed, since specific nerves are associated with specific muscle masses.

(a) Reptile

(b) Horse

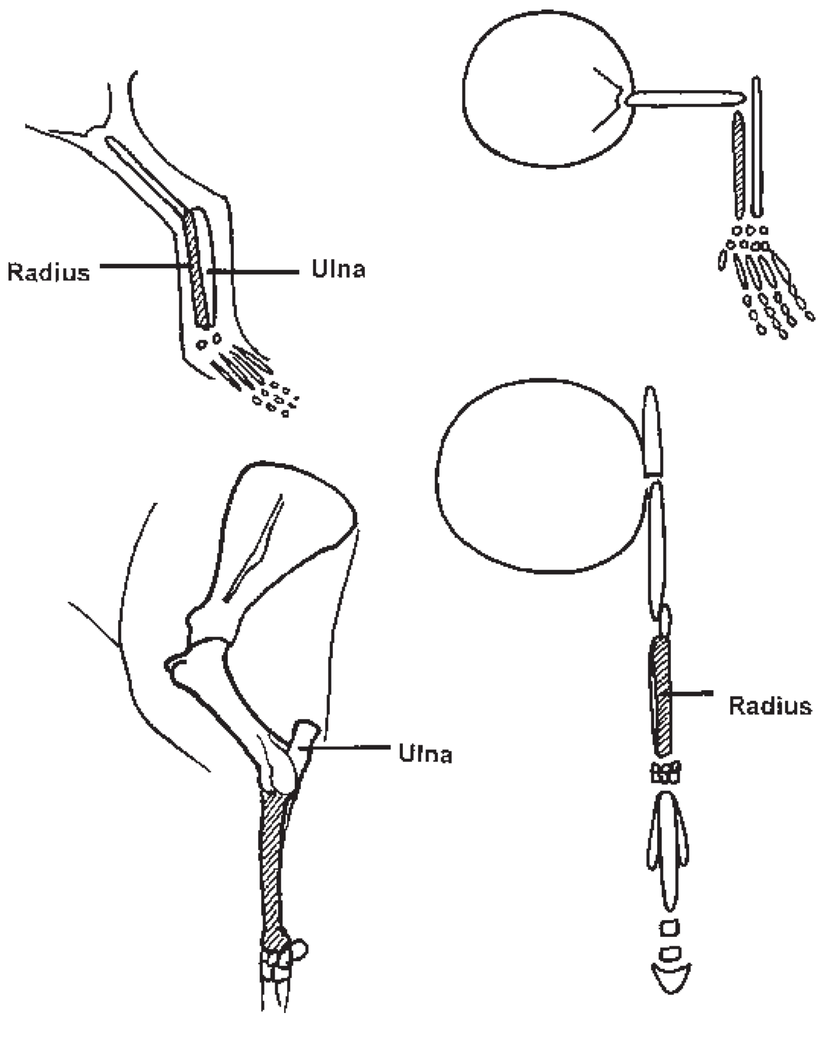


Figure 2-R: Forelimb changes in position of bones (diagramatic)

b) Nerves and their muscle mass associations

Forelimb:

Dorsal muscle mass:	Radial
Ventral muscle mass:	Musculo-cutaneous
	Median
	Ulnar

Hindlimb:

Dorsal muscle mass:	Femoral
Ventral muscle mass:	Sciatic

Questions

What indications are there in the dog of an ancestral clavicle and coracoid?

The quadriceps group of muscles which extend the stifle is derived from the dorsal muscle mass of the hindlimb.” From this information, name the nerve that supplies this group of muscles.

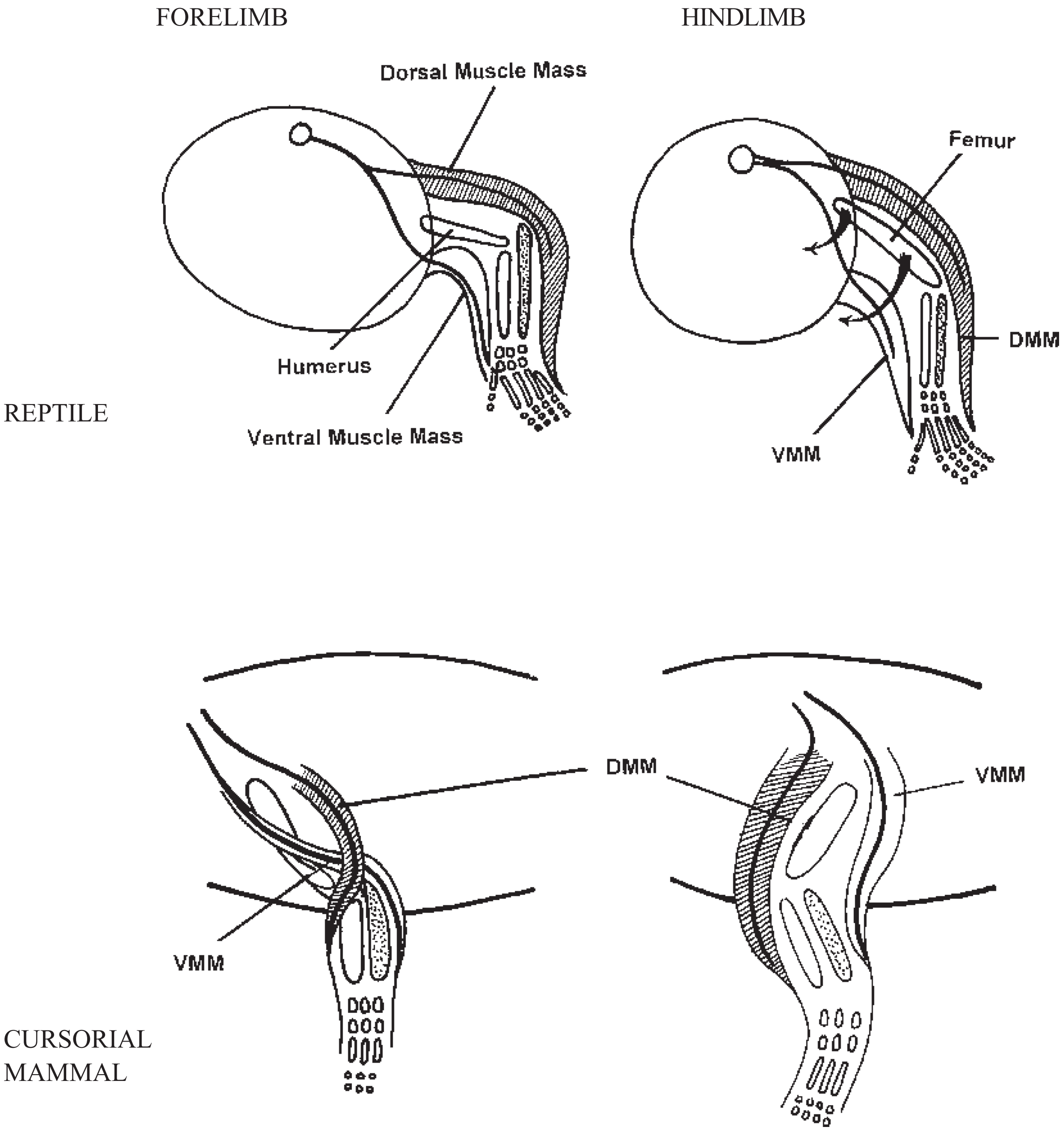


Figure 2-S: Movement of muscle and nerve in association with skeletal changes during evolution

Chapter 3

Anatomy of the Thoracic Limb of the Dog

The forelimb of the dog

1. Bones and muscles

Bones and muscles will be discussed together in this section, and then joints and other synovial structures will be discussed afterwards. There are three reasons for this order:

1. The manner in which muscles move the limb bones in relation to each other needs to be considered as a simple package and this demands some knowledge of both the bones and the muscles.
2. In practical classes, synovial structures including joints cannot be properly examined until the more superficial structures have been dissected.
3. In horses, the occurrence and extent of synovial structures other than synovial joints requires a good knowledge of the musculature, since these structures are associated with muscles and tendons. It is, therefore, appropriate that muscles are dealt with first.

Study the angles of the limb joints in Figure 3-A, and understand how the limb may be extended or withdrawn by extension or flexion of these joints. When you have a good understanding of the information in this Chapter, turn to Appendix 1 to relate underlying anatomical structures to topographical features in the live animal. This is an essential skill for veterinary health practitioners.

A. Muscles of the limb (See Fig. 3-A)

Muscles of the forelimb either:

– Attach the limb to the trunk (extrinsic muscles) - these muscles, e.g. the Superficial Pectoral, may move the trunk when the limb is fixed
– Move the limbs (intrinsic muscles)

Different intrinsic muscles of the limbs perform different actions:

– FLEXORS and EXTENSORS: exert their action at joints, most of which connect bones with each other at an angle. Most limb muscles are of this functional type.
– ROTATORS: this movement is limited to a small amount of pronation and supination, as the limbs are fixed in pronation to a species variable degree.

- ELEVATORS In the forelimb, the whole limb may be elevated
- PROTRACTORS carry the limb forward
- RETRACTORS carry the limb backward
- ABDUCTORS move the limb away from the trunk – limited in most quadrupeds
- ADDUCTORS move the limb towards the trunk

Remember the definitions of movement:

FLEXION - reducing the angle of the joint from 180°

EXTENSION - increasing the angle of the joint to 180°

Note: extension of the digit causes movement beyond 180 at the metacarpo-phalangeal joints. This is known as over-extension or dorsiflexion. (Fig. 3-A).

In the forelimb:

- **extensor muscles of the digits also extend the carpus**
- **flexor muscles of the digits also flex the carpus**

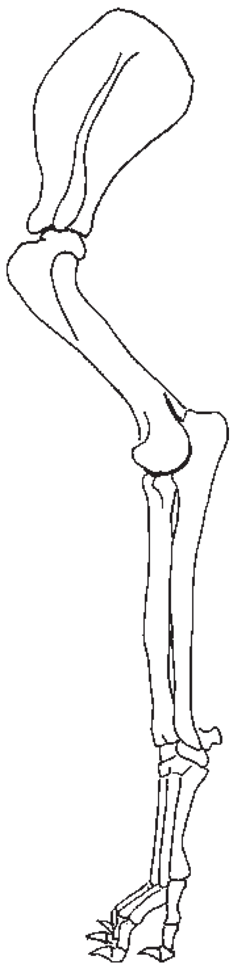


Figure 3-A: Flexion and extension in the fore limb

Consider which movements at each joint constitute flexion or extension.

It is important to realise that limb muscles may have two or more functions and that one may be a primary function whilst the other is secondary. In most cases, however, there is only one clear action. This action is normally obvious from a muscle's attachments, i.e. from its ORIGIN and INSERTION.

It is not required that the origins and insertions of the muscles are known in precise detail. But it pays to know with relative accuracy origins and insertions of major muscles, because it is only from this information that the action of a muscle may be deduced (see Figs 3-B to 3-D for examples).

Muscles, muscle groups and their actions

The following series of diagrams are presented as exercises for you to complete. By working through the diagrams and identifying muscles, their innervations and actions, you will gain a better understanding of the anatomy of the fore limb.

The origin and insertion of limb muscles are presented in Table 3-1. Use this table to identify the muscles in Figs 3-B to 3-D. From this information and your knowledge of the bony structure of the dog's limbs, WORK OUT THE ACTION OF EACH MUSCLE.

Usually, there is more than one muscle acting on any one joint, and so the muscles are grouped together according to their function (see Fig. 3-B to 3-D).

Innervation of muscle groups, and relationship to their actions

Frequently, all the muscles in a group are innervated by the same nerve. Use the information on the brachial plexus and nerve supply to the forelimb, presented later in this chapter, to fill in the nerves for each muscle in Figs 3-B to 3-D.

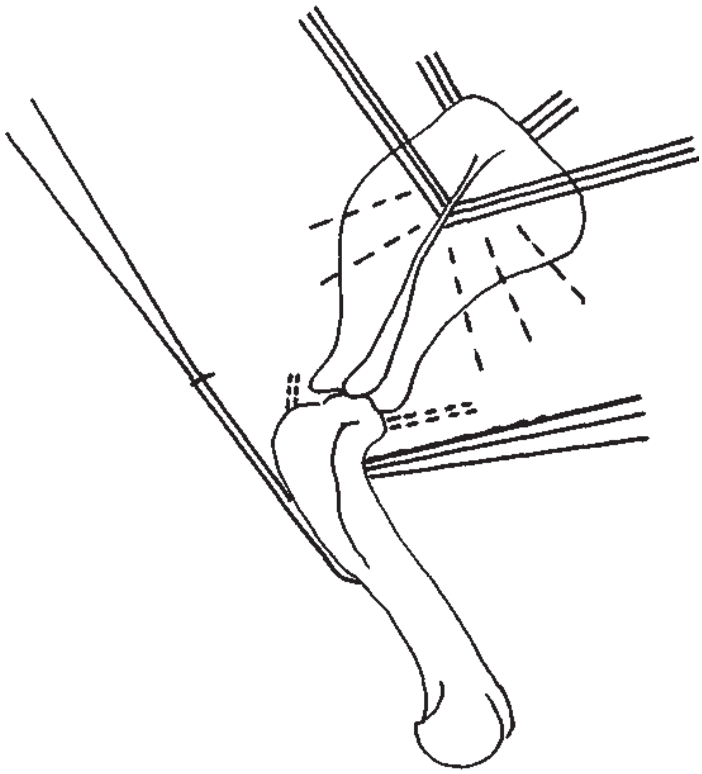


Figure 3-Ba

SUPPORT		NERVE
1.	Serratus ventralis	______________________
2.	Rhomboideus	______________________
3.	Superficial Pectoral	______________________
4.	Deep Pectoral	______________________
5.	Trapezius	______________________
6.	Brachiocephalus	______________________
7.	Latissimus dorsi	______________________

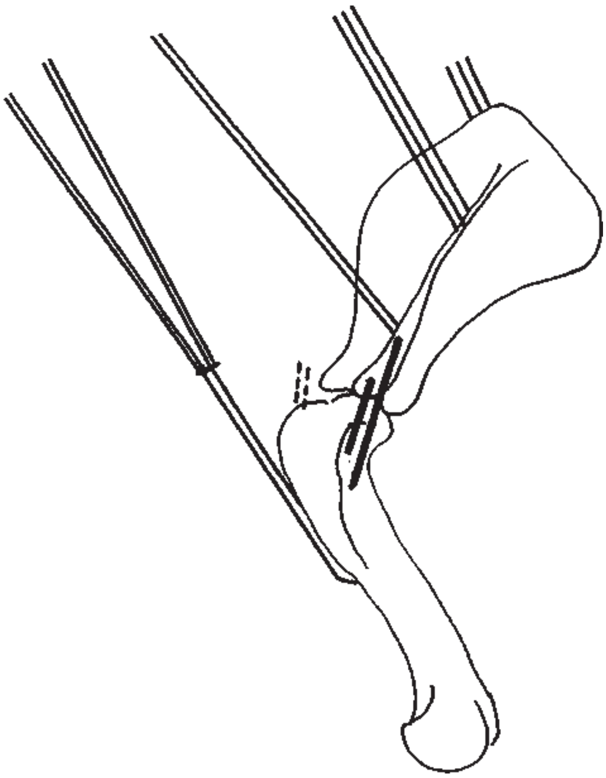


Figure 3-Bb

PROTRACTORS	**NERVE**
1. Brachiocephalicus	______________
2. Omotransversarius	______________
3. Rhomboideus	______________
4. Superficial Pectoral	______________
5. Trapezius	______________

ADDUCTOR	**NERVE**
1. Superficial Pectoral	______________

ABDUCTOR	**NERVE**
1. Deltoideus	______________

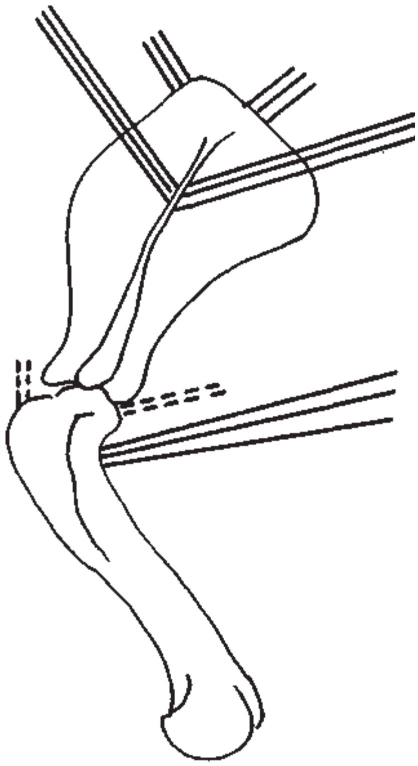


Figure 3-Bc

RETRACTORS	**NERVE**
1. Latissimus dorsi	____________________
2. Rhomboideus	____________________
3. Superficial Pectoral	____________________
4. Deep Pectoral	____________________

ELEVATORS	**NERVE**
1. Trapezius	____________________
2. Rhomboideus	____________________

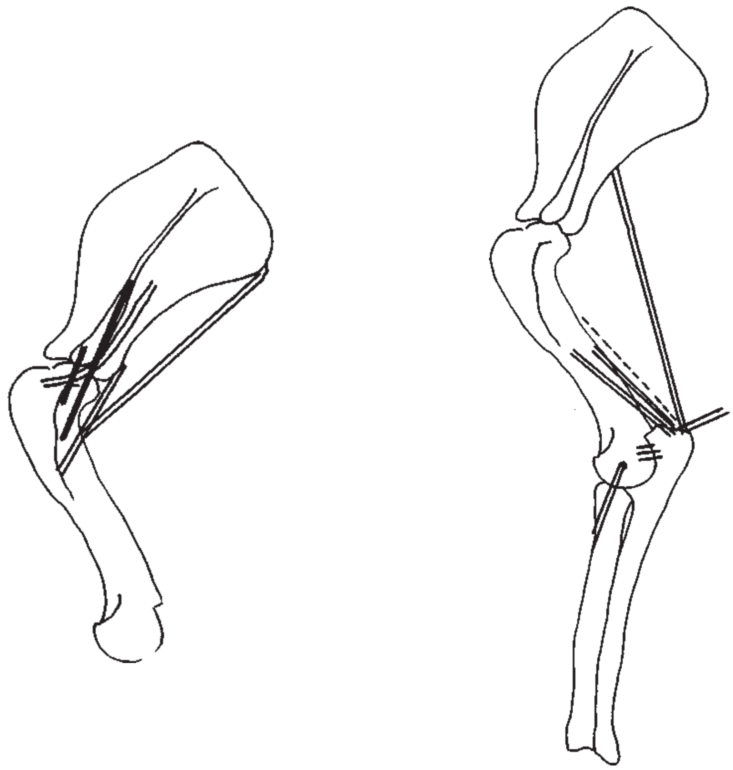


Figure 3-Ca

FLEXORS OF SHOULDER **NERVE**

1. Teres major ______________________
2. Teres minor ______________________
3. Deltoideus ______________________
4. Infraspinatus ______________________

EXTENSORS OF ELBOW **NERVE**

1. Triceps brachii ______________________
2. Anconeus ______________________
3. Tensor fasciae antibrachi ______________________

SUPINATOR **NERVE**

1. Supinator ______________________

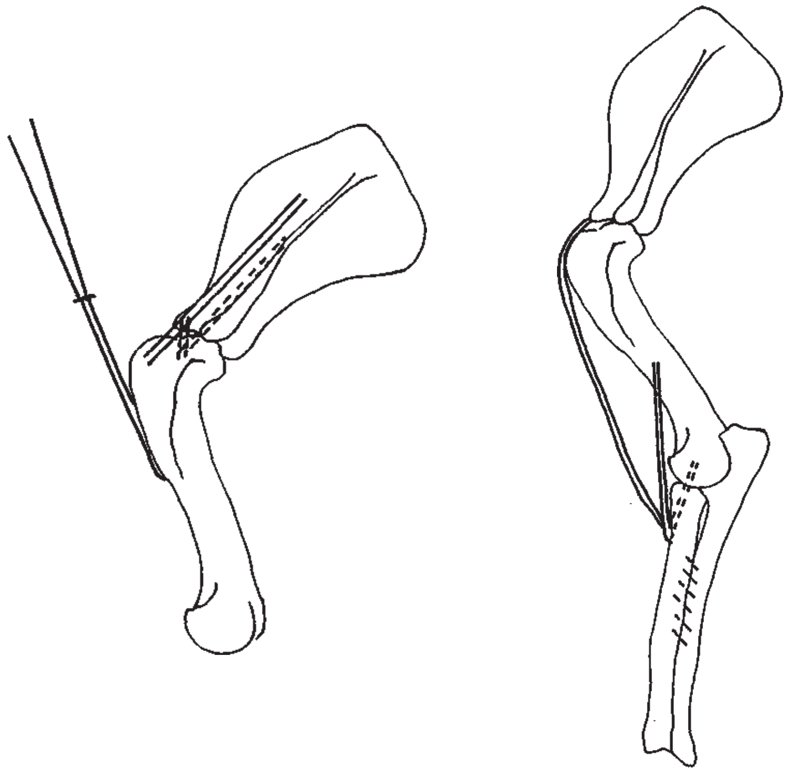


Figure 3-Cb

EXTENSORS OF SHOULDER	NERVE
1. Brachiocephalicus	____________________
2. Supraspinatus	____________________
3. Subscapularis	____________________
4. Coracobrachialis	____________________

FLEXORS OF ELBOW	NERVE
1. Biceps brachii	____________________
2. Brachialis	____________________
3. Pronator teres	____________________

PRONATORS	NERVE
1. Pronator teres	____________________
2. Pronator quadratus	____________________

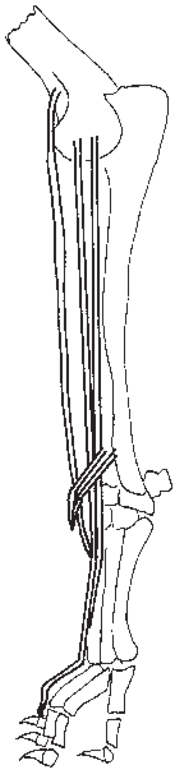


Figure 3-Da

EXTENSORS OF CARPUS	**NERVE**
1. Ext. carpi radialis	____________________
2. Common digital extensor	____________________
3. Lateral digital extensor	____________________

EXTENSORS OF DIGITS	**NERVE**
1. Common digital extensor	____________________
2. Lateral digital extensor	____________________
3. Ext. pollicis longus	____________________
4. Abductor pollicis longus	____________________

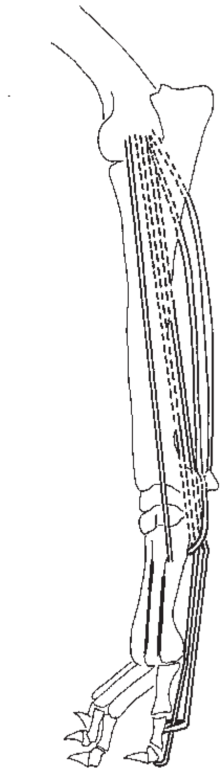


Figure 3-Db

FLEXORS OF CARPUS		NERVE
1.	Flexor carpi radialis	________________
2.	Flexor carpi ulnaris	________________
3.	Ulnaris lateralis	________________
4.	Superficial Digital Flexor	________________
5.	Deep Digital Flexor	________________

FLEXORS OF DIGITS		NERVE
6.	Superficial Digital Flexor	________________
7.	Deep Digital Flexor	________________
8.	Interosseous mm.	________________
9.	Lumbricales	________________
10.	Interflexorius	________________
11.	Digital mm.	________________

TABLE 3-1: Fill in the ACTION of each muscle. (All muscles listed here apply to the dog.)

Muscles of the forelimb

EXTRINSIC MUSCLES	ACTION
Trapezius (2 parts - Cervical and Thoracic) Origin - Median raphe of neck and supraspinous ligament between C3 and T9 Insertion - Spine of scapula (cervical extends lower than thoracic)	
Omotransversarius Attachments: Distal - Distal part of spine of scapula Proximal - Wing of the atlas	
Rhomboideus (2 parts - Cervical and Thoracic) Origin - Nuchal crest and median raphe of neck; spinous processes of T1-T7 Insertion - Dorsal border of scapula	
Serratus Ventralis Origin - Serrated part of medial surface of scapula Insertion - Cervical vertebrae from axis or C3; 1st 7 or 8 ribs	
Brachiocephalic Developmentally consists of 3 parts: **Cleidomastoideus** - attaching to the head **Cleidocervicalis** - attaching to the neck **Cleidobrachialis** - attaching to the limb. The remnant of the clavicle is interposed between the cleidocervicalis and cleido-brachialis as the Clavicular Tendon. Thus, the cleidobrachialis is that part of the muscle below the clavicular tendon. Attachments: Distal - Lower cranial border of humerus (cleidobrachialis) and axillary fascia Proximal - Median raphe of neck (cleidocervicalis); Mastoid process of temporal bone of skull (cleido-mastoideus) We should not properly speak of origin and insertion with this muscle, because it depends whether the head or limb is the fixed point. Correctly, the clavicle is the origin of the different points of the muscle.	a) Head fixed b) Limb fixed

EXTRINSIC MUSCLES (continued)	ACTION
Latissimus Dorsi Origin - Lumbar vertebrae and T6-T13 thoracic vertebrae Insertion - Teres tubercle of humerus (medial border)	
Superficial Pectoral Origin - First 3 sternebrae Insertion - Greater tubercle of humerus	
Deep Pectoral Origin - Sternebrae of sternum and deep abdominal fascia of xiphisternum Insertion - Lesser tubercle of humerus and medial brachial fascia	
INTRINSIC MUSCLES	
MUSCLES OF THE SHOULDER **LATERAL** **Supraspinatus** Origin - Supraspinous fossa of scapula Insertion - Greater tubercle of humerus	
Infraspinatus Origin - Infraspinous fossa of scapula Insertion - Greater tubercle of humerus	
Teres Minor Origin - Caudal border of scapula Insertion - Tricipital line of humerus	
Deltoideus (2 parts in the dog) Origin - Spine of scapula Insertion - Deltoid tuberosity of humerus **MEDIAL**	
Subscapularis Origin - Subscapular fossa of scapula Insertion - Lesser tubercle of humerus	

INTRINSIC MUSCLES (continued)	Action
Teres Major Origin - Caudal angle of scapula Insertion - Teres tubercle of humerus	

MUSCLES OF BRACHIUM	Action
CRANIAL	
Biceps Brachii Origin - Supraglenoid tubercle (bicipital tubercle) Insertion - Radial and ulnar tuberosities	
Brachialis Origin - Upper third of lateral and caudal surface of humerus Insertion - Radial tuberosity and upper part of ulna	
Coracobrachialis Origin - Coracoid process of scapula (on the supraglenoid tubercle] Insertion - Lesser tubercle of humerus **CAUDAL**	
Triceps Brachii Origin Long Head - Caudal border of scapula Lateral Head - Lateral surface of the shaft of the humerus (tricipital line) Medial Head - just below the lesser tubercle of humerus (neck) Insertion - Olecranon of ulna	
Anconeus Origin – Epicondyles of humerus and lateral epicondyloid crest Insertion - Lateral part of olecranon of ulna	
Tensor Fasciae Antebrachii Origin - Fascia covering latissimus dorsi Insertion - Olecranon of ulna	

MUSCLES OF FOREARM ANTIBRACHIUMI/DIGITS	Action
LATERAL FOREARM	
Extensor Carpi Radialis (most cranial) Origin - Lateral epicondylar ridge of humerus Insertion - Dorsal surfaces of metacarpals II and III	
Common Digital Extensor Origin - Lateral epicondyle of humerus Insertion - Dorsal surfaces of 3rd phalanx in IInd-Vth digits	
Lateral Digital Extensor Origin - Lateral epicondyle of humerus and proximal extremity of radius Insertion - Tendons of common digital extensor	
Ulnaris Lateralis (Extensor Carpi Ulnaris) Action Origin - Lateral epicondyle of humerus Insertion - Upper lateral surface of metacarpal V	

SMALL MUSCLES OF FOREARM	Action
Brachioradialis (when present) A small slip of muscle attached to the cutaneous surface of antibrachial fascia. Origin - Supracondylar ridge of humerus Insertion - Distal % of dorsal (cranial) surface of radius	
Supinator Origin - Lateral epicondyle of humerus Insertion - Proximal third of cranial surface of radius	
Extensor Pollicus Longus et Indicus Proprius Origin - Craniolateral border of ulna Insertion - Metacarpal I and tendon II of common digital extensor	
Abductor Pollicus Longus Origin - Lateral surfaces of radius and ulna Insertion - Metacarpal	

MEDIAL FOREARM	**Action**
(Note: Extensor Carpi Radialis may be seen on the medial side cranial to the radius. Flexors, by contrast, are ALL caudal to the radius).	
Flexor Carpi Radialis Origin - Medial epicondyle of humerus Insertion - Upper palmar surface of metacarpals II and III	
Deep Digital Flexor Origin - Medial epicondyle of humerus and upper medial surface of radius and ulna Insertion - Palmar surfaces of 3rd phalanx in digits II-V	
Superficial Digital Flexor Origin - Medial epicondyle of humerus Insertion - Palmar surface of 2nd phalanx in digits II-V	
Flexor Carpi Ulnaris Origin - Medial surface of olecranon of ulna and medial epicondyle of humerus Insertion - Accessory carpal bone	
Pronator Teres Origin - Medial epicondyle of humerus Insertion - Medial surface of radius	
Pronator Quadratus Origin - Medial surface of ulna Insertion - Medial border of radius	

MUSCLES OF THE PAW	**Action**
PALMAR SIDE OF THE METACAEPAL BONES	
Interosseous Muscles (four) Origin - Upper palmar surface in metacarpals II-V Insertion - Upper sesamoid bones (metacarpo-phalangeal) and tendons of common digital extensor muscle	
BETWEEN THE FLEXOR TENDONS **Interflexorius** Origin - Deep flexor (passes through carpal canal with deep flexor. Therefore, Interflexorius extends from the region of the carpus to digits III and IV, and sometimes II.) Insertion - 2nd phalanx of digits III and IV; may be a third one going on to digit II	

BETWEEN THE FLEXOR TENDONS (continued)	Action
Lumbricales (three)	
Origin - Deep digital flexor tendons	
Insertion - 1st phalanx of digits II-V	

OTHER DIGITAL MUSCLES		Action
These are associated with digits I, II and V:		
I = Pollicis (thumb)		
II = Secundi		
V = Quinti		
Digit I -	Flexor Pollicis Brevis	Flexor
	Abductor Pollicis Brevis et Opponens Pollicis	Abductor
	Adductor Pollicis	Adductor
Digit II -	Adductor Digiti Secundi	Adductor
Digit V -	Flexor Digiti Quinti	Flexor
	Abductor Digiti Quinti	Abductor
	Adductor Digiti Quinti	Adductor

These muscles **mostly arise from the Palmar Carpal Ligament.**

B. Bones of the forelimb

This section is intended to extend your knowledge of the osteology of the dog, with respect to the locomotory apparatus. Knowledge of bones in isolation is of little value. All the bone landmarks listed in the following checklists have some importance for locomotion, those terms which have little importance have been omitted. Therefore, you should eventually know the relevance of most features to the animal's locomotion.

Use the checklist of bones and labelled diagrams in Figures 3-E to 3-G, to familiarise yourself with the bones of the limbs. Much of this will be revision of information presented in the first chapter, but some extra features are now included because they have importance for locomotion. These new terms are identified by an asterisk.

During the residential part of the course, make sure that you are also quite familiar with actual specimens of these bones.

Under the heading "Significance", write in the importance of each feature to locomotion. In many cases, this will be a muscle attachment and the diagrams of origins and insertions of muscles in "Guide to the Dissection of the Dog" (Evans and Delahunta) and in "Miller's Anatomy of the Dog" will be useful to identify them. In other cases, it may be an articular surface (consider the other articulating body) or the pathway for a tendon.

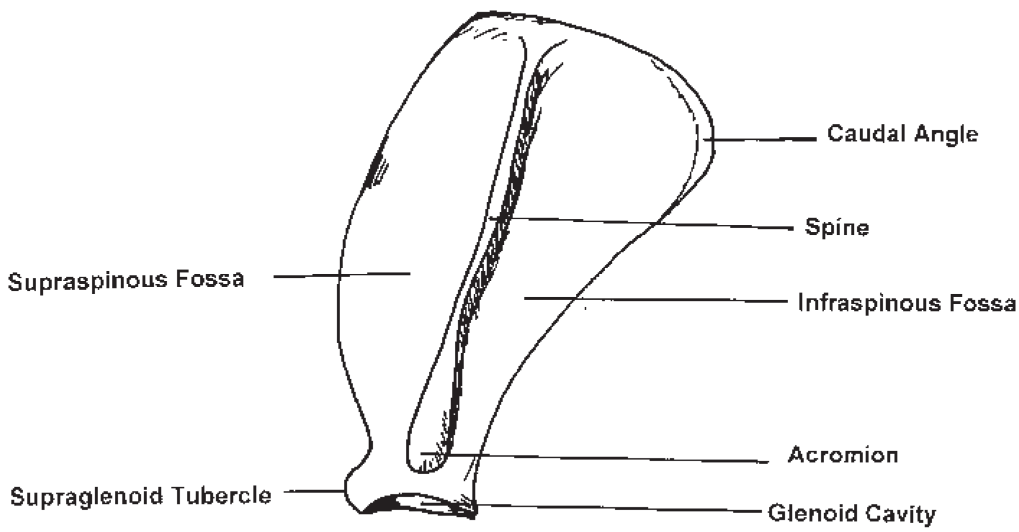
You are unlikely to be able to complete this initially, but as you acquire knowledge of the limb muscles, attempting this exercise will reinforce your knowledge of both the bones and muscles and increase your understanding of how they operate together.

FORELIMB

SCAPULA	**Significance**
*Caudal angle	______________________
Spine	______________________
Acromion	______________________
*Supraspinous fossa	______________________
*Infraspinous fossa	______________________
*Facies serrata	______________________
*Subscapular fossa	______________________
Glenoid cavity	______________________
Coracoid process	______________________
Supraglenoid tubercle	______________________
*Infraglenoid tubercle	______________________

CLAVICLE
Vestigial in the dog, may be totally absent or represented as cartilage associated with the clavicular tendon between the cleidomastoideus and cleidobrachialis muscles.

SCAPULA: LATERAL VIEW



SCAPULA: MEDIAL VIEW

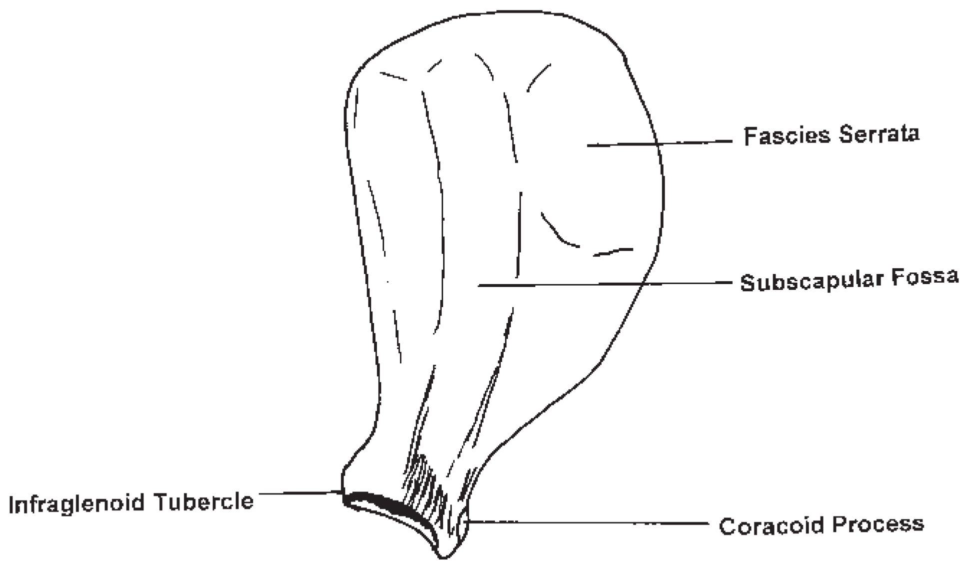
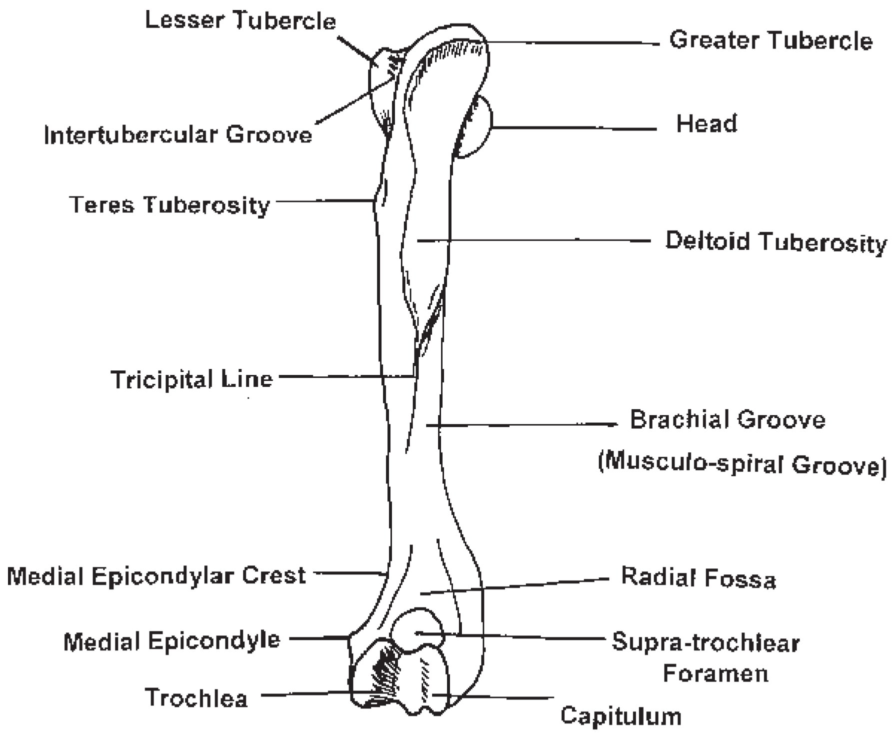


Figure 3-E

HUMERUS	Significance
Head	
Greater tubercle	______________________
Lesser tubercle	______________________
*Intertubercular groove	______________________
Neck	
*Tricipital line	______________________
Deltoid tuberosity	______________________
*Brachial (musculo-spiral) groove	______________________
*Teres tuberosity	______________________
Shaft	
*Capitulum	______________________
Trochlea	______________________
Medial epicondyle	______________________
Lateral epicondyle	______________________
*Medial epicondylar crest	______________________
*Lateral epicondylar crest	______________________
Radial fossa	______________________
Olecranon fossa	______________________
Supratrochlear foramen	______________________

HUMERUS: CRANIAL VIEW



HUMERUS: LATERAL VIEW

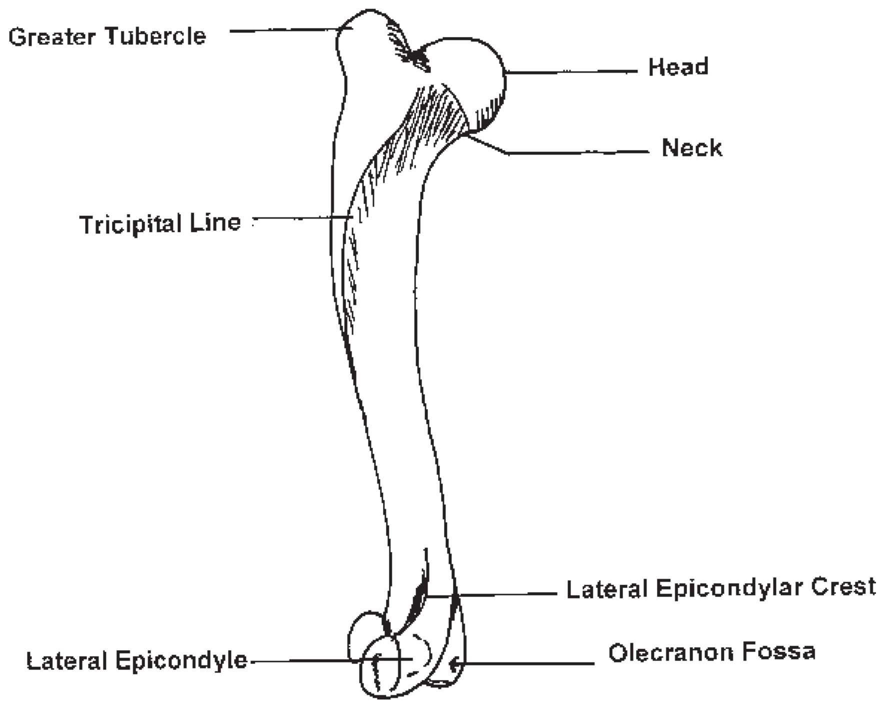
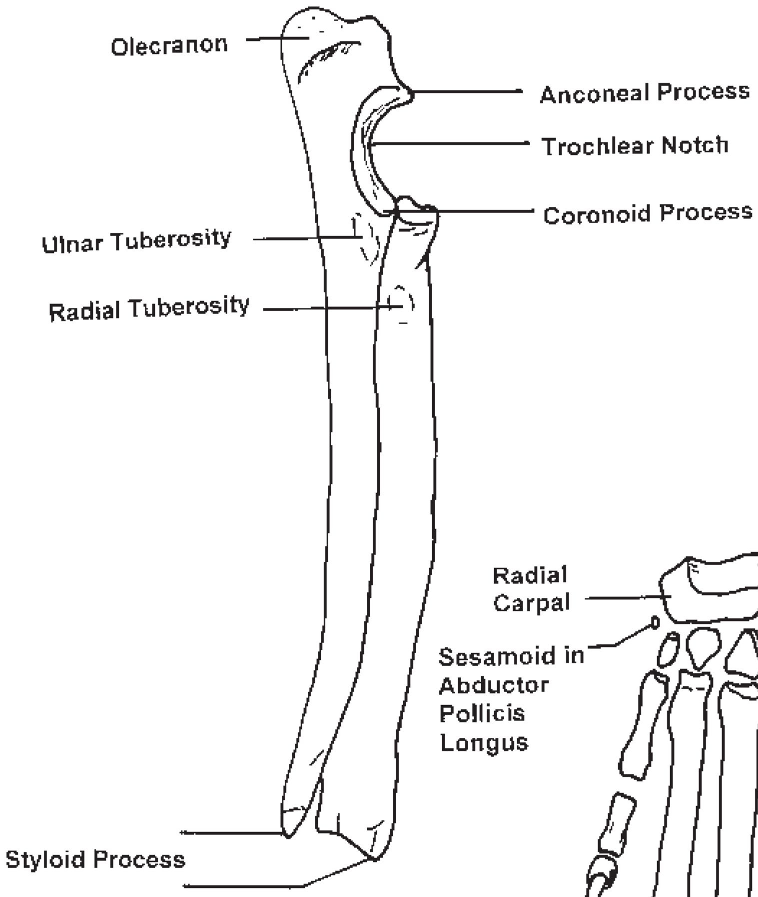
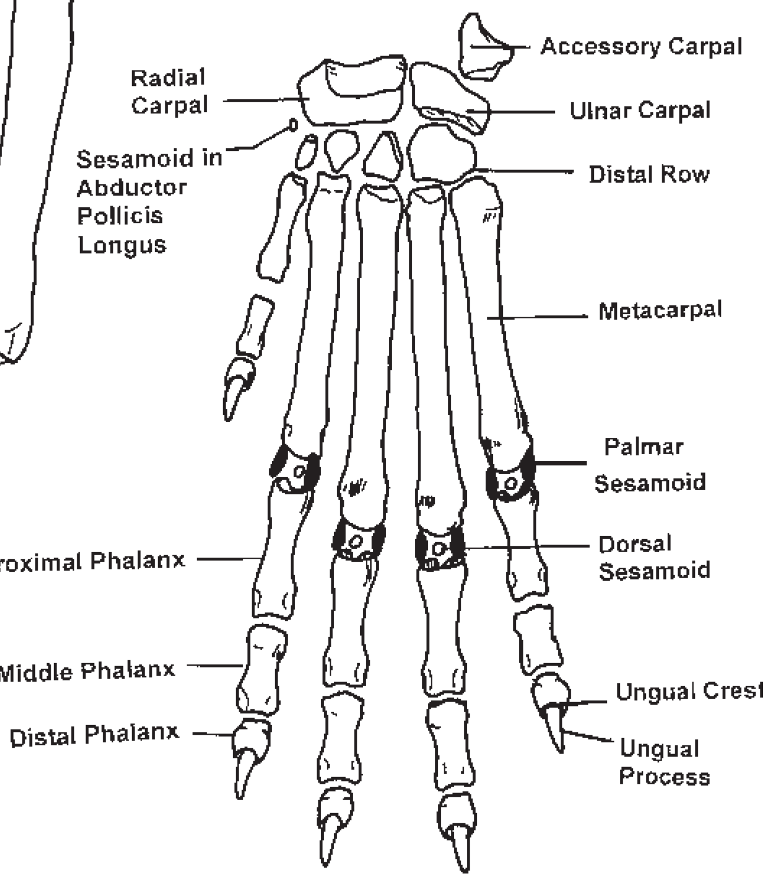


Figure 3-F

RADIUS	**Significance**
*Radial tuberosity	________________
Styloid process	________________
* Distal grooves	________________
ULNA	
Olecranon	________________
Trochlear notch	________________
Anconeal process	________________
Coronoid process	________________
*Ulnar tuberosity	________________
Styloid process	________________
CARPUS	
Radial (+ intermediate) carpal bone	________________
Ulnar carpal bone	________________
Accessory carpal	________________
Distal row: carpal bones 1-4	________________
METACARPALS I-V	________________
DIGITS I-V	________________
Proximal, middle and distal phalanges	________________
SESAMOIDS	________________
*Dorsal	________________
*Palmar	________________
*Abductor pollicis longus	________________

ULNA AND RADIUS: MEDIAL VIEW





MANUS: DORSAL VIEW

Figure 3-G

2. The limbs of the dog – nerves

Innervation of the limbs

It is recommended that you study carefully Fig 3-H, which illustrates the arrangement of nerves in the brachial plexus.

IMPORTANT NOTE: Dorsal Division Nerves and Ventral Division Nerves referred to in Fig. 3-H, do NOT refer to nerves supplying Dorsal and Ventral Muscle Masses respectively. They refer to the relative topographical position of the nerves in the plexuses.

Next, observe Fig. 3-I, which shows the nerves of the forelimb of the dog. From these diagrams, and your knowledge of muscle groups, complete the exercise in Figs 3-J and 3-K.

An example is given in Fig. 3-Ja and b. Complete the others for the forelimb in the same way.

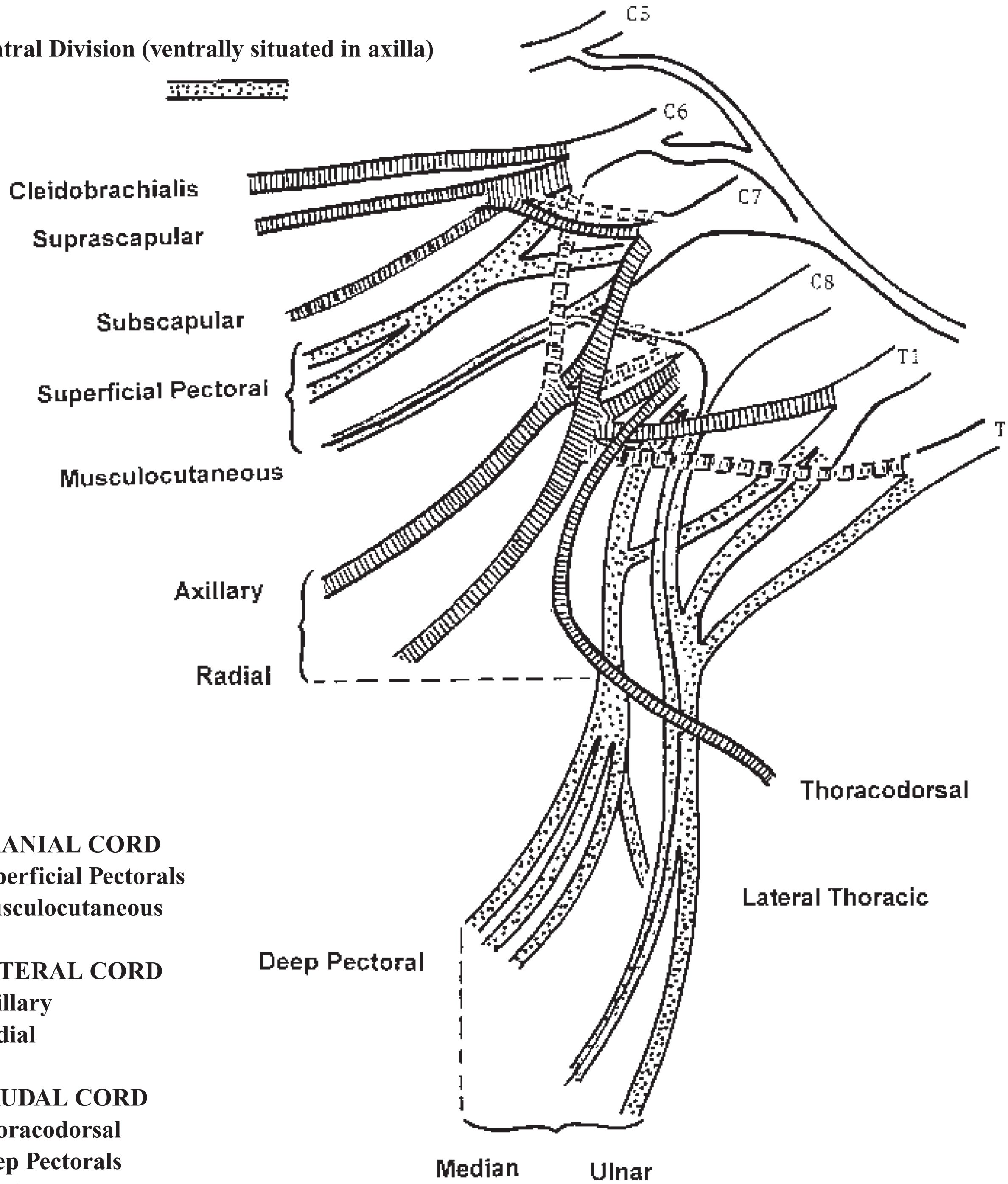
(When you have finished this exercise, you will then be in a position to fill in the nerve supplies to the different muscles and muscle groups in Figs 3-B to 3-D).

Cutaneous (sensory) innervation of the trunk and limbs

Familiarize yourself with Fig. 3-M to 3-N which represent the cutaneous innervation of the limbs. This knowledge, together with understanding of innervation of muscles and muscle groups, can be important in identifying lesions in particular nerves.

Dorsal Division (Emerge dorsally in plexus)

Ventral Division (ventrally situated in axilla)



CRANIAL CORD
Superficial Pectorals
Musculocutaneous

LATERAL CORD
Axillary
Radial

CAUDAL CORD
Thoracodorsal
Deep Pectorals
Median
Ulnar

Figure 3-H: Brachial plexus

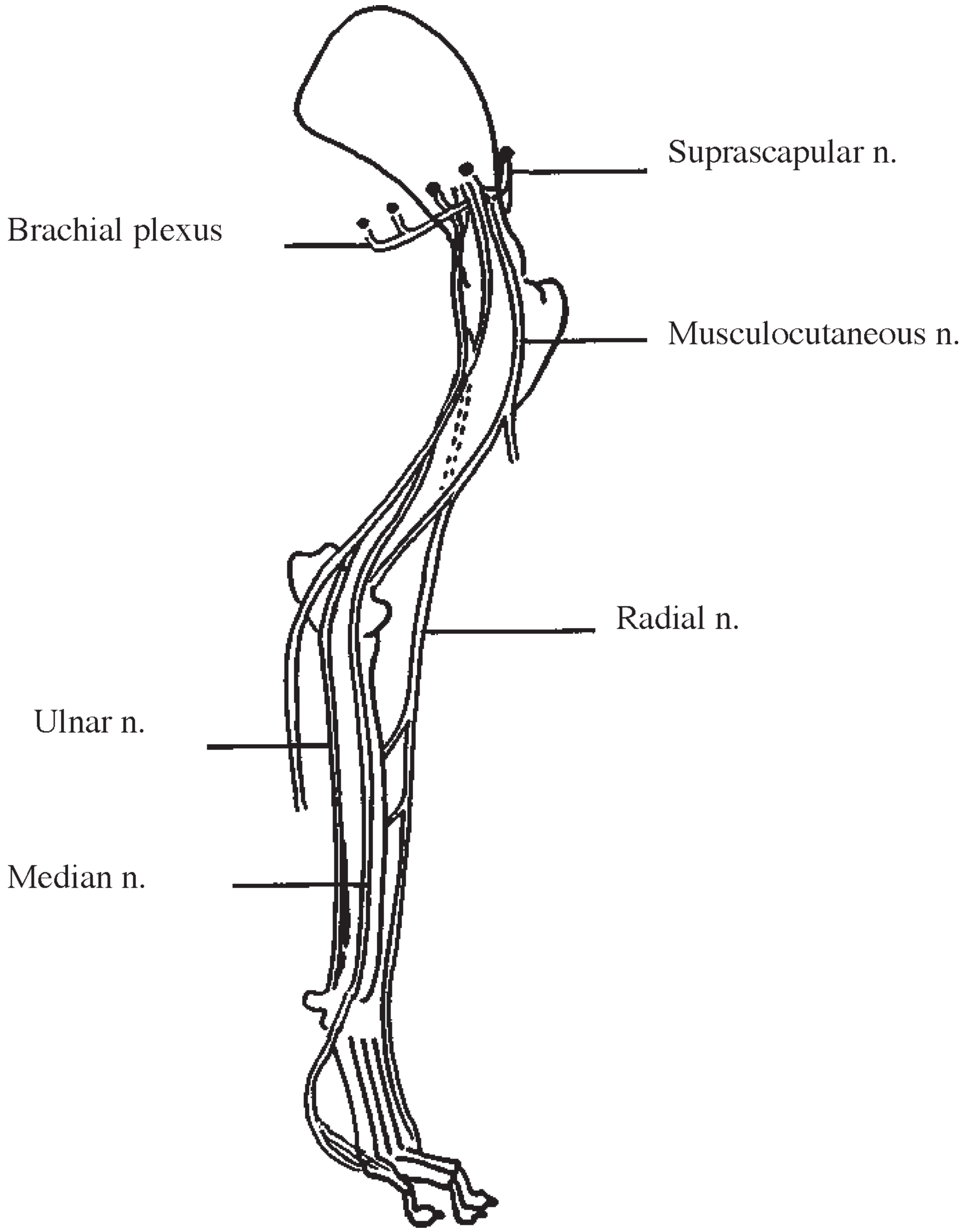


Figure 3-I Nerves of the forelimb (Medial view)

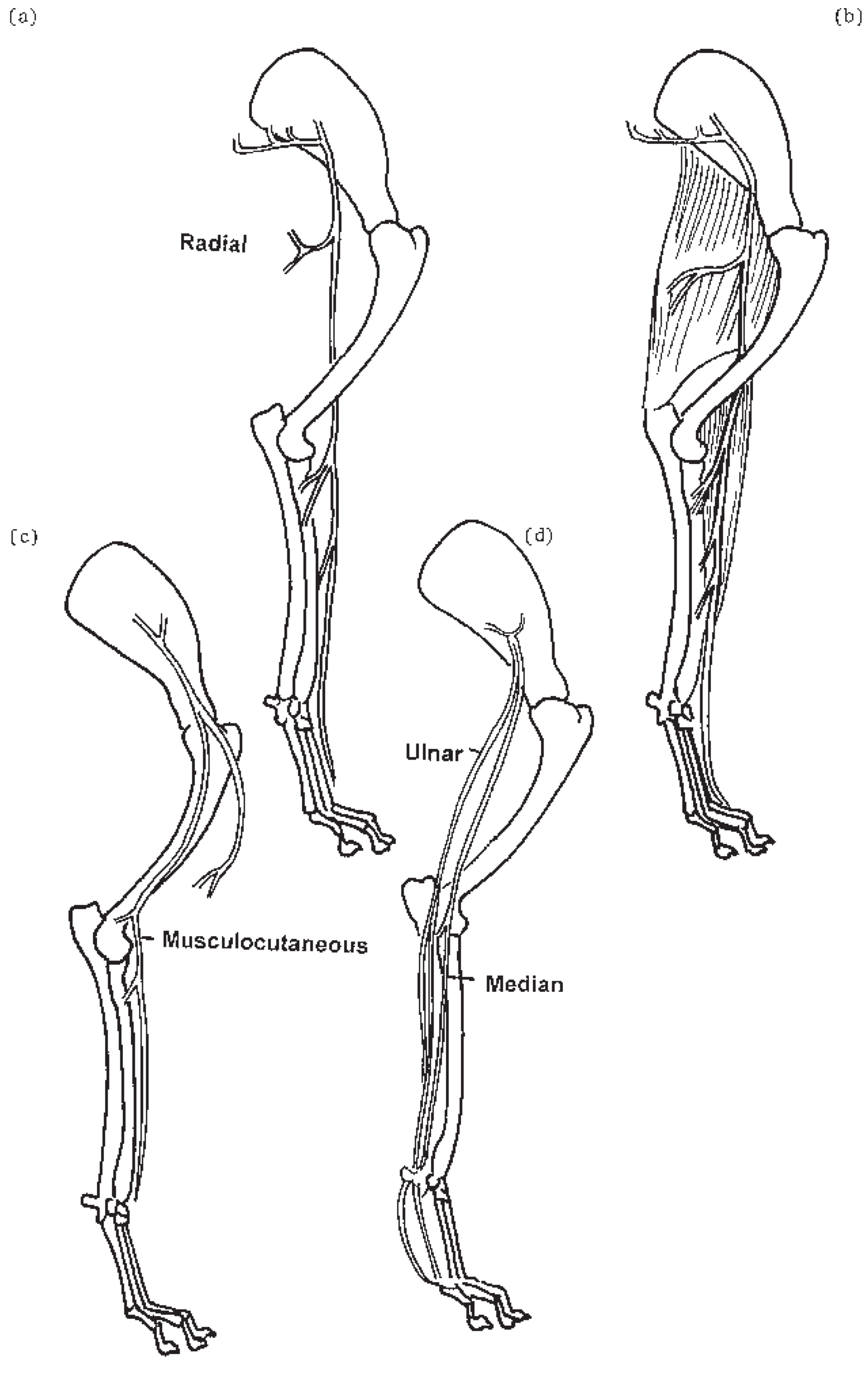


Figure 3-J: Fill in the muscle groups

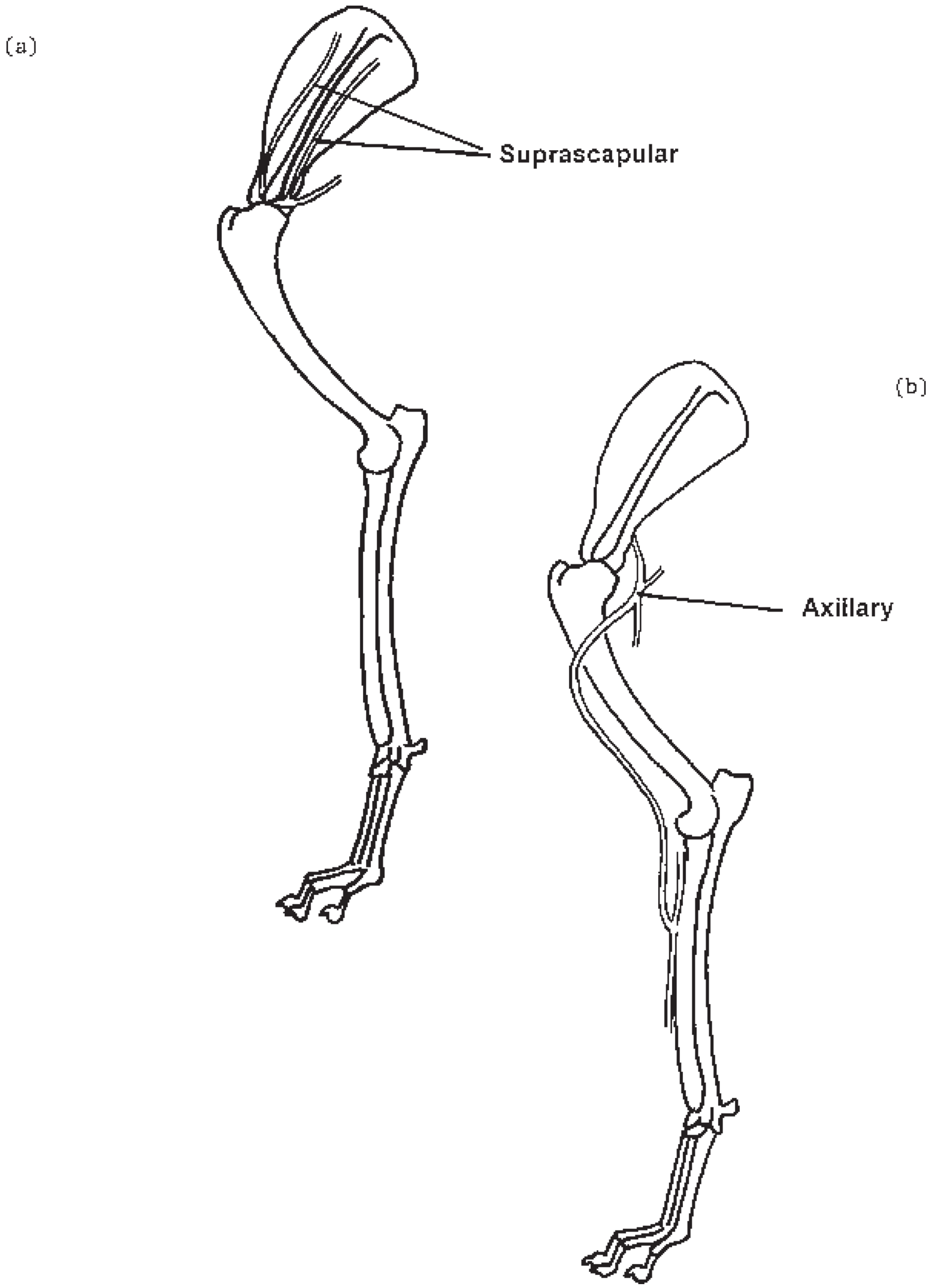


Figure 3-K: Fill in the muscle groups

Cutaneous nerves of the trunk (Fig 3-L)

These are included at this point for completion, although they are not involved in locomotion.

1. Dorsal branches of C3-C6
2. Ventral branches of C5
3. Ventral branches of C4
4. Lateral cutaneous brachial (Axillary Nerve)
5. Dorsal and lateral cutaneous branches of T1-T15
6. Proximal cutaneous branches of lumbar nerves
7. Intercostobrachial Nerve (T2)
8. Lateral Thoracic Nerve (C8-T1) and distal cutaneous branches of Intercostals and also T13
9. Cranial Iliohypogastric (LI)
10. Caudal Iliohypogastric (L2)
11. Ilioinguinal (L3)
12. Lateral Cutaneous Femoral (L4)
13. Dorsal branch of SI
14. Ventral branch of SI and S2
15. Ventral branch of S3
16. Caudal Cutaneous Femoral
17. Lateral Cutaneous Sural (Sciatic-Fibular branch)

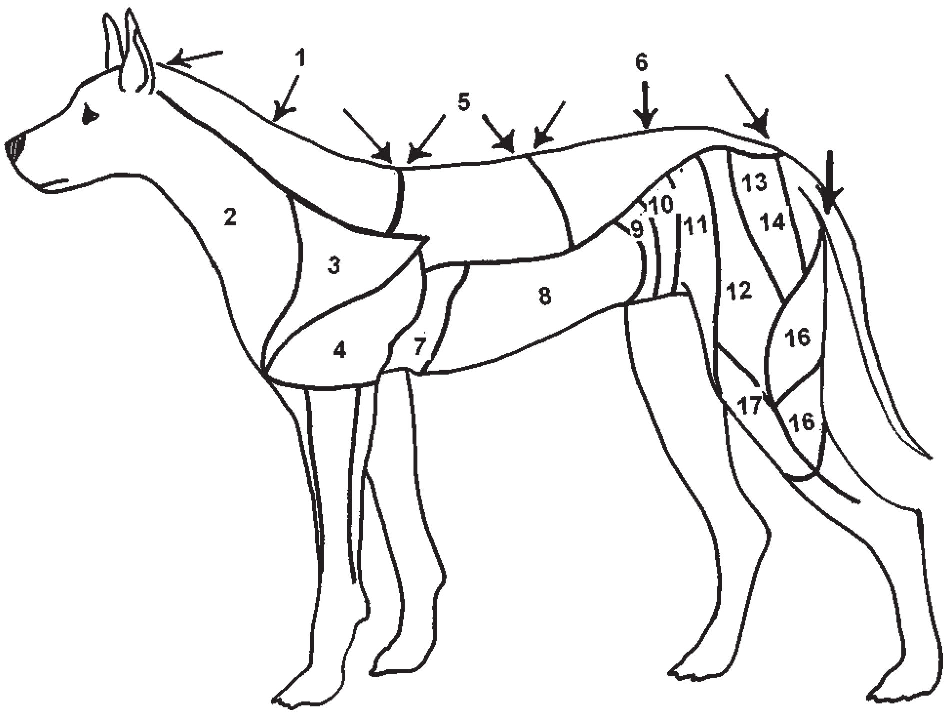


Figure 3-L

Cutaneous (sensory) branches of the major nerves of the forelimbs are listed below (see Figs 3-M and 3-N):

A - Axi11ary

M - Median

Mu - Musculocutaneous

R - Radial

U - Ulnar

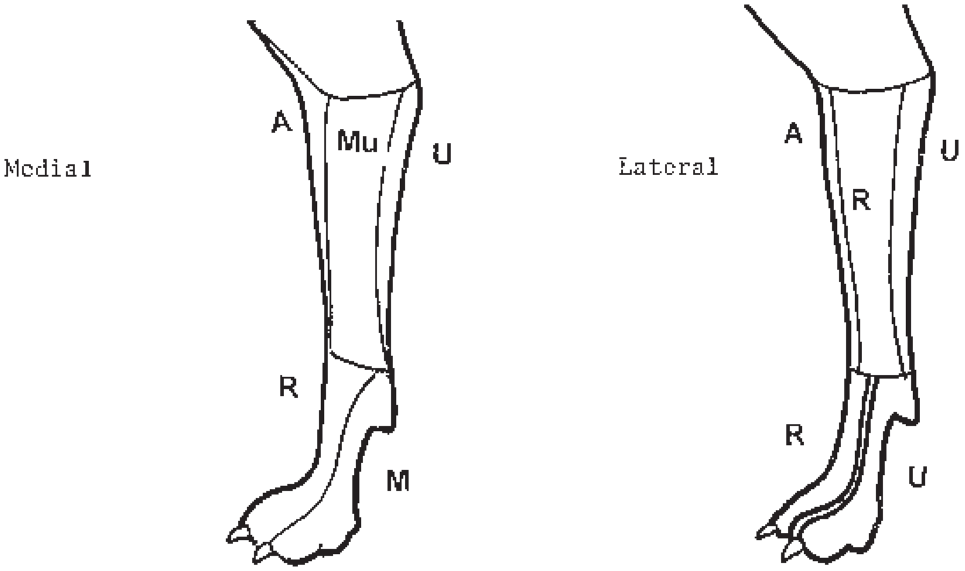


Figure 3-M

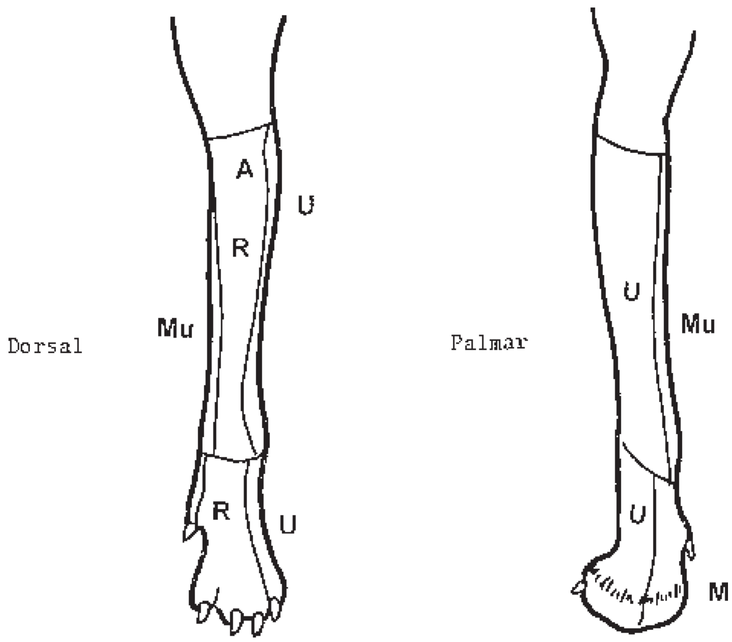


Figure 3-N

3. The forelimbs of the dog – Joints

At this stage, joints may be considered under the following headings:

– Type of Movement
– Joint Capsule
– Ligaments

The shoulder joint (Fig. 3-O)

Type of Movement: Flexion, extension and a degree of gliding (basically, enarthrosis).

Joint Capsule: Simple and unremarkable.

Ligaments:

1. Medial and Lateral - only feeble thickenings of the stratum fibrosum of the joint capsule – Glenohumeral Ligaments. These protrude into the joint cavity.
2. Transverse Humeral Ligament (runs across the origin of the biceps in the bicipital groove of the humerus)

Most support for this joint is provided by the Supraspinatus, Infraspinatus, Subscapular and Teres muscles. These muscles are known collectively as the Rotator Cuff in humans, and their tendons form a conjoint tendon around the humeral head. In animals their tendons are much more discrete, and they function principally to provide medial and lateral support to the joint. Rotation and abduction are virtually eliminated in the canine shoulder. Medial support is reinforced by the positioning of the shoulder joint in close apposition to the body.

The elbow joint (Fig. 3-P)

Type of Movement: Flexion and extension at the articulation with the humerus (ginglymus). Radio-ulnar articulations allow rotation of the forearm antebrachium (pivotal movement).

Lateral movements are minimal.

(i) **Humeral Articulation** (with radius and ulna)

Joint Capsule: Rather tight and extends down between the radius and ulna as the Extensor Pouch. This extends upwards to the supratrochlear foramen, but is here covered with a fat pad so in this region it does not communicate with the Flexor Pouch (cranial part of the joint capsule). The cavity is patent below the humerus, however.

Ligaments:

1. Lateral (Ulnar and Medial (Radial Collateral Ligaments - These are strong thickenings of the joint capsule which prevent lateral movement. There are two crura to each, the cranial one passing to the radius and caudal to the ulna.

2. Oblique Ligament - This is on the flexor (cranial) surface of the joint.
3. Annular Ligament of the Radius – This ligament holds the radius and ulna in apposition to each other.
4. Olecranon Ligament - This ligament extends from the lateral surface of the medial epicondyle to the cranial border of the ulna.

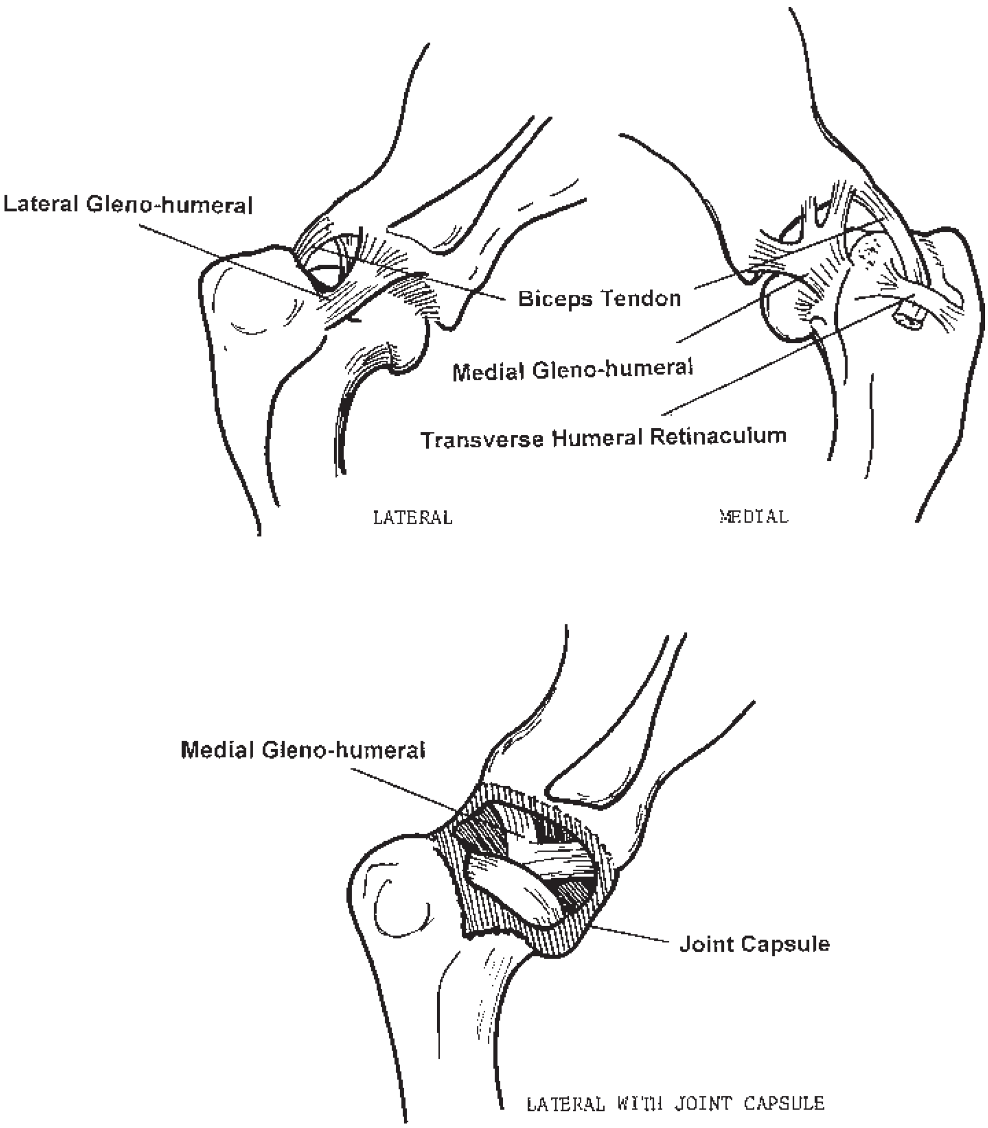
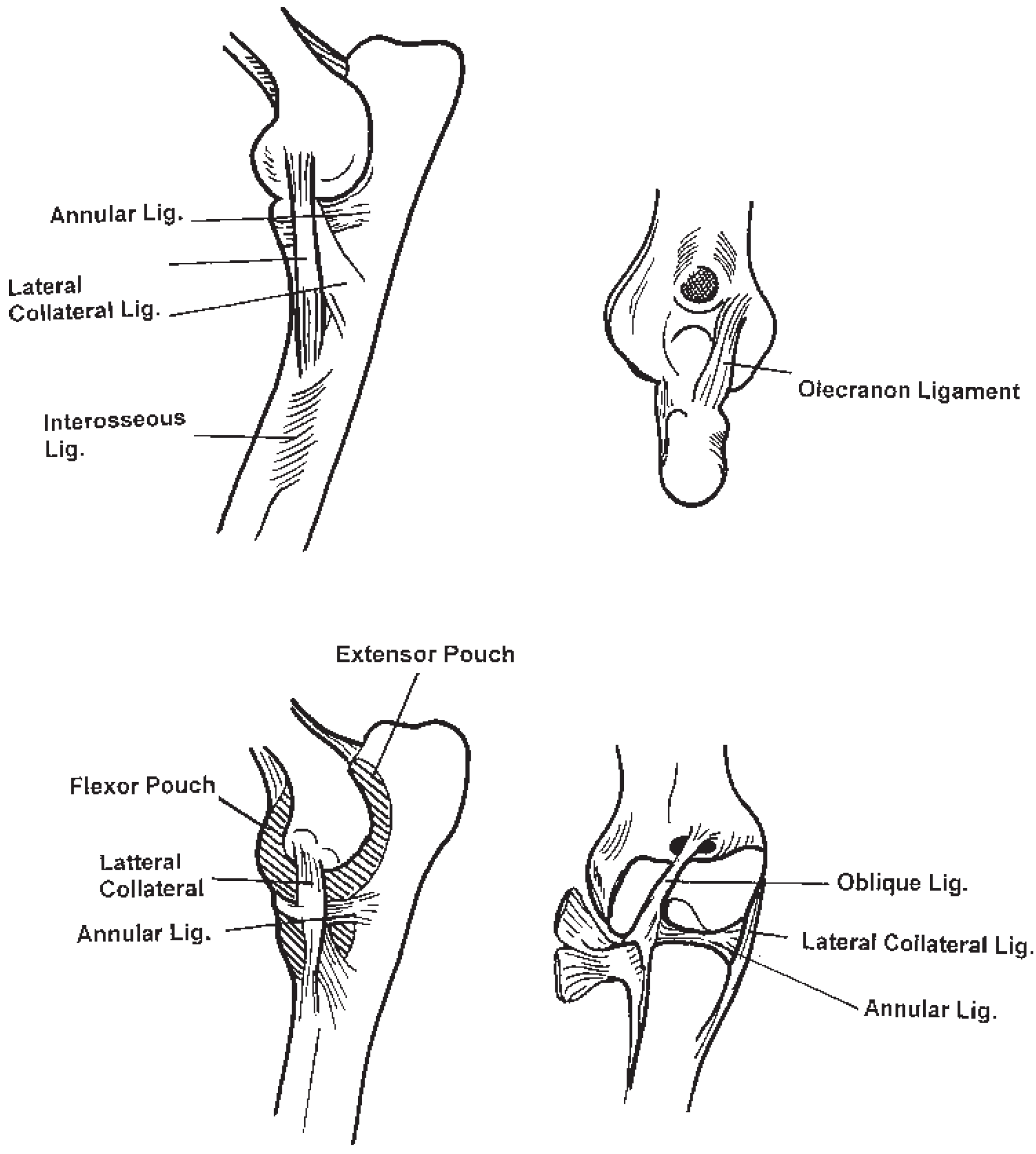


Figure 3-O The shoulder joint of the dog



WITH JOINT CAPSULE

Figure 3-P Elbow joint of the dog

ii) **Proximal Radio-Ulnar Articulation**

Joint Capsule: Pouch from main joint capsule.

Ligaments: Interosseus Ligament - This ligament occurs between the radius and the ulna and is about half-way up the shaft of the two bones.

(iii) **Distal Radio-Ulnar Articulation**

Joint Capsule: From antebrachiocarpal joint (see below).

Ligaments: Short Radio-Ulnar Ligament.

The carpal joints (Fig. 3-Q)

Type of Movement: Overall, movement of the carpus is flexion and extension. Most movement occurs at the articulation of the radius and ulna with the proximal row of carpals, and also between the proximal and middle carpals (ginglymi). There is less movement between the distal carpals and the metacarpals (arthrodia).

Joint Capsule: Is like a sleeve, but it contains compartments. The radio-carpal part of the capsule is separate, whilst the intercarpal and carpometacarpal joint cavities join.

Ligaments:

1. Dorsal Carpal Ligament - The cranial surface of the stratum fibrosum of the joint capsule is thickened to form this ligament.
2. The stratum fibrosum on the palmar surface is thickened and partly cartilaginous to form the deep wall of the carpal canal (Palmar Carpal Fibrocartilage) which contains the superficial and deep flexor tendons. The superficial wall of the canal is formed; by the collagenous flexor retinaculum which extends from the accessory carpal to the medial carpals. In the dog, it is split into two layers and encloses the superficial digital flexor tendon.
3. Collateral Ligaments - These ligaments do not run the whole length of the joint, but are broken up into short bands extending between the radius, ulna, carpals and metacarpals.
4. Special Ligaments: Interosseus Ligaments These ligaments bind the carpal bones together in variable fashion, but it is not necessary to know each one precisely. They may be considered, therefore, as a group, i.e. in a collective sense.

Joints of the manus (Fig. 3-Q)

(i) **Intermetacarpal Joints**

Type of Movement: Gliding (arthrodia)

Joint Capsule: The synovial membrane of the carpometacarpal joint extends over the upper surface of the metacarpals and also passes between them.

Ligaments: Interosseus Metacarpal Ligaments -Intervene between, the upper borders of metacarpals.

(ii) **Metacarpophalangeal and Phalangeal Joints**

Type of Movement: Flexion and extension.

Joint Capsule: Simple.

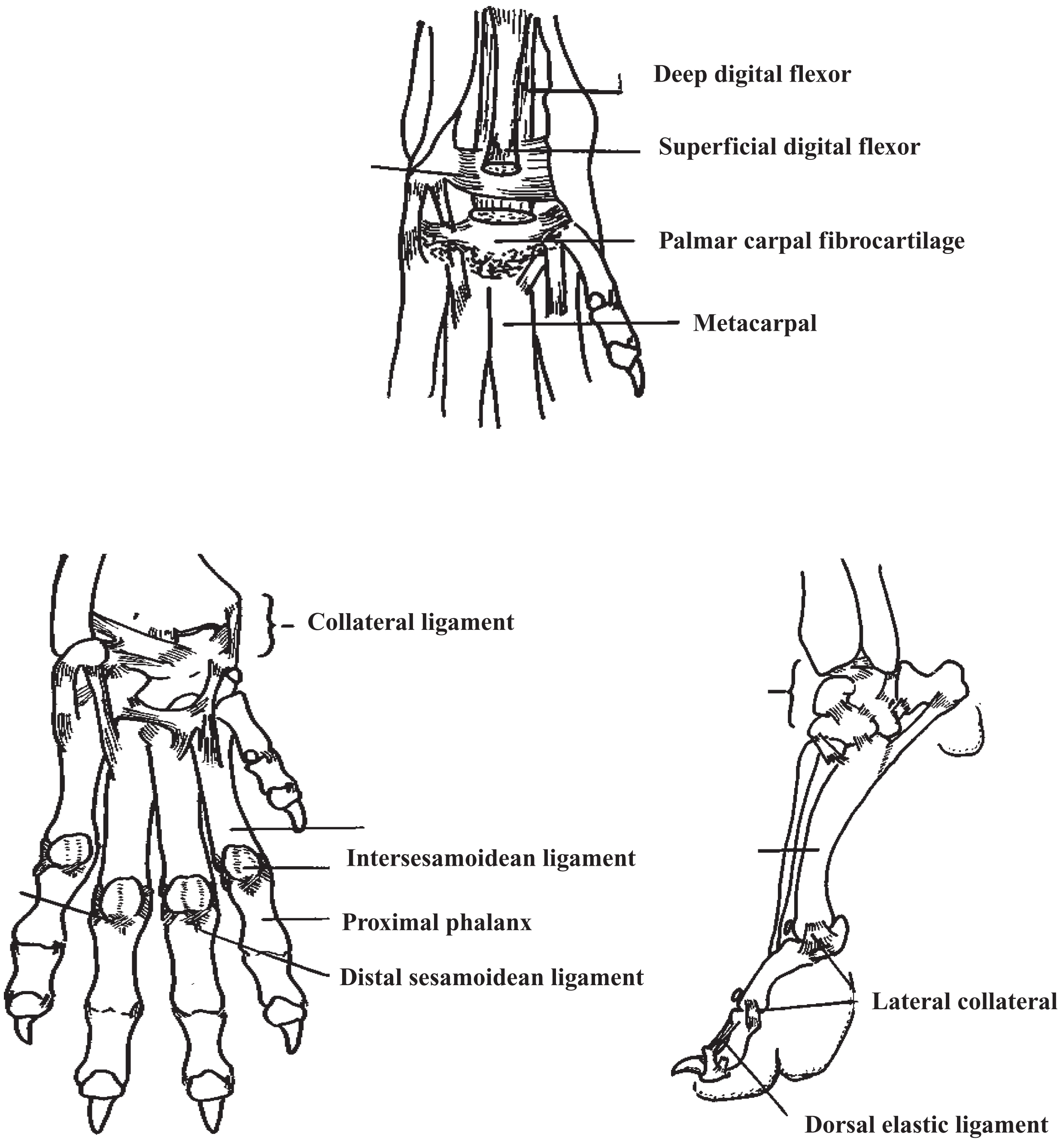


Figure 3-Q: The carpal and phalangeal joints of the dog

Ligaments:

1. Lateral and Medial Collateral Ligaments - These are present in each joint as thickenings of the stratum fibrosum.
2. Dorsal (Elastic) Ligaments of the Distal lnterphalangeal Joint - This ligament extends from the upper dorsal surface of the 2nd phalanx to converge on the ungual crest of the 3rd phalanx. Because of the angle between the two phalanges, this ligament passes remotely from the joint capsule (see Fig. 3-Q).

(iii) **Attachments to the Sesamoid Bones**

1. Palmar Sesamoids

   These are attached by Lateral and Medial Sesamoidean Ligaments and anchored ventrally by a Distal Sesamoidean Ligament and Cruciate Ligaments.

   There is no dorsal ligament but the dorsal part of the lateral and medial ligaments would seem to prevent the sesamoids from moving downwards.

   The sesamoids are bound together by an Intersesamoidean Ligament.

2. Dorsal Sesamoids

   Only the metacarpophalangeal sesamoids are osseus.

   Proximally, these sesamoids are held by the Interosseus Muscles and the tendon of the Common Digital Extensor.

   Distally, they have their own ligament which attaches to the dorsal distal surface of the 2nd phalanx.

Note: There are also Proximal, Middle and Distal Retinacula associated with the distal palmar surface of the metacarpals and the palmar surface of the 1st and 2nd phalanges, but these ligaments are nothing to do with the joints. They bind together the flexor tendons and hold them in position close to the limb (retinacula).

4. The forelimbs of the dog – blood vessels

You should be aware of the general vascular architecture, the position and distribution of major vessels; and especially those areas where the blood vessels are superficially situated.

This last piece of information is important for appreciating where major vessels are particularly vulnerable to damage and which veins are especially suitable for venipuncture.

The distribution of the main vessels is illustrated in Figs. 3-R and 3-S.

A. Arteries (see Fig 3-R)

Forelimb

The main stem artery of the forelimb is the **Axillary Artery**, an extension of the **Subclavian Artery**. After coming round the first rib and crossing the axilla, it continues down the medial surface of the limb. It gives off several muscular branches, and the **Subscapular** and **Thoracodorsal Arteries** are conspicuous among these.

From the upper 1/3 of the humerus, it is called the **Brachial Artery**. The Brachial Artery lies between the biceps brachii (and its associated musculocutaneous nerve) and the medial head of the triceps brachii (giving off the **Deep Brachial** which passes between the medial and long heads of the triceps). Pulsation in the Brachial Artery may be palpated at this point, so the pulse rate can be taken here.

The Brachial Artery passes over the medial surface of the elbow cranially, and gives off **Cranial Superficial Antebrachial** and **Collateral Ulnar Arteries**. It then continues as the **Median artery.**

The median artery gives off the **Radial Artery** which runs along the medial border of the radius to the paw. The Median Artery in particular supplies blood to the paw with its terminal branches being similar in distribution to the digital nerves.

B. Veins (see Fig 3-S)

In both fore and hindlimb, there are two divisions of venous drainage, a deep division (which basically follows the pattern of the arteries) and a superficial division.

Forelimb

Deep venous division:

The **Palmar** and **Digital Veins** drain into the **Radial** and **Median Veins**, which join to continue as the Median Vein.

Superficial venous division:

The dorsal surface of the digits is drained by the **Accessory Cephalic Vein**. Above the carpus, this vein loins the **Cephalic Vein**. This vein crosses the limb on the medial surface just above the carpus, and comes to lie subcutaneously close to the tendon of the extensor carpi radialis muscle. The Cephalic Vein is thus most accessible for venipuncture and is the most commonly used site in the dog for intravenous injections or for obtaining blood samples.

The Cephalic Vein continues up the leg and passes over the cranial surface of the elbow. At this point, it is joined by the **Median Cubital Vein** from the Median (this vein is commonly used for venipuncture in man).

The Cephalic Vein joins the Median vein via the **Axillobrachial vein** at the level of the upper part of the humerus, but also sends a branch directly to the **External Jugular Vein**. Another superficial branch, the **Omobrachial vein**, connects the Axillobrachial vein with the External jugular, so there are several routes by which venous blood is returned to the great veins from the forelimb.

MEDIAL VIEW

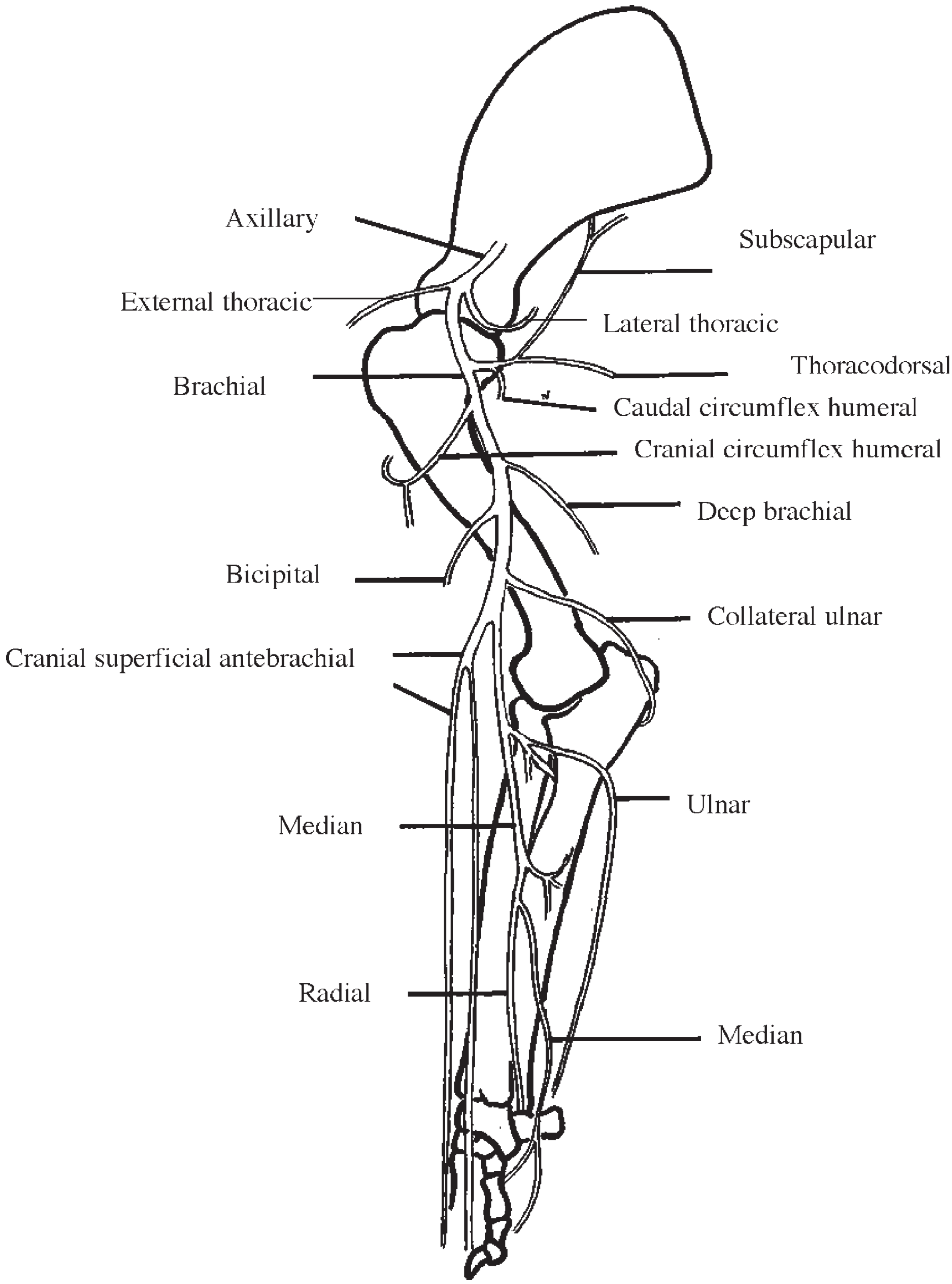


Figure 3-R: Arteries of the forelimb of the dog

MEDIAL VIEW

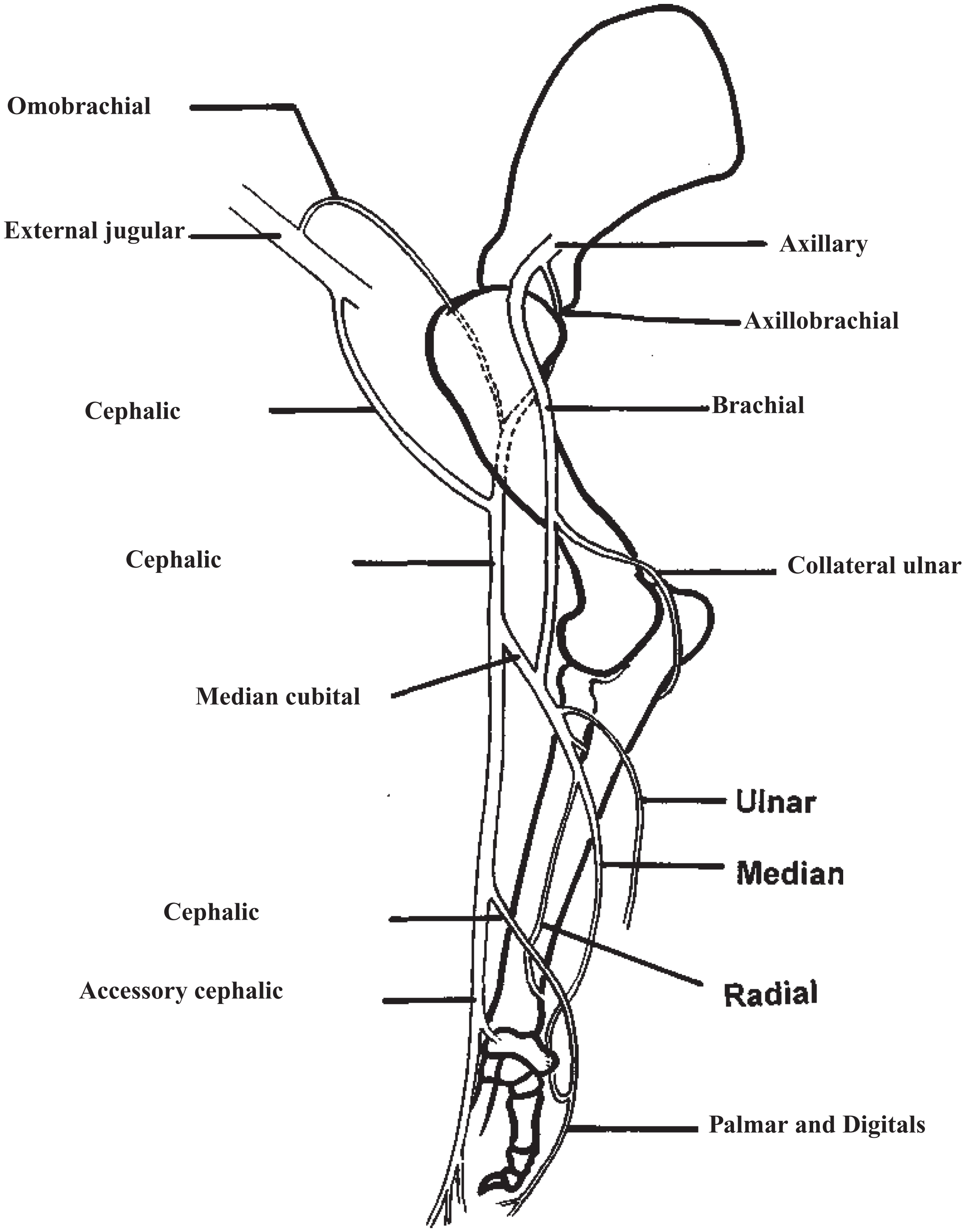


Figure 3-S: Veins of the forelimb of the dog

5. The limbs of the dog – the paws

The part of the limb that contacts the ground in locomotion is modified for wear and tear according to whether the animal is digitigrade or unguligrade.

The contact surface in the dog (digitigrade) is depicted in Fig. 3-T (X). Compare this with that of ungulates, shown later in this chapter.

Main characteristics of the paw

1. 4 digital pads (II, III, IV, V) contact the ground. They are fibroelastic structures which also contain fat and are covered in thick cornified epidermis. They are joined to the phalanges by collagenous and elastic fibres. They are homologous to the frog of the horse's hoof or the bulbs of a bovine hoof.
2. Digital Pad I does not touch the ground. .It is smaller than the others and lies medially.
3. The metacarpal or metatarsal pad is large and contacts the ground caudally. It is homologous to the ergot on the horse's fetlock.
4. A carpal pad (homologous to the chestnut in the horse) is present in the forepaw only.
5. Claws emerge dorsal to the digital pads, attached to the ungual process of the distal phalanx

Blood supply and innervation of the digits

Metacarpals:

Terminal branches of the **dorsal and palmar/plantar** blood vessels subdivide into **deep** (**dorsal or palmar/plantar metacarpal/tarsal arteries and veins**) and **superficial branches** (**dorsal or palmar common digital arteries and veins**).

Metatarsals:

These anastomose at the level of the metacarpophalangeal joints, then bifurcate to course down the axial and abaxial sides of the digits (**proper digital arteries and veins**).

The nerves branch similarly and follow the same path as the blood vessels (Fig. 3-U).

Relationship of muscles and tendons of the digits

In the foreleg, the **common digital extensor** divides into 4 parts distally which insert on the distal phalanx of digits II-V. As each tendon passes over the proximal phalanx it is joined by a supporting tendon from the **interosseus muscle** (Fig. 3-V).

The **lateral digital extensor** divides into 3 tendons distally which unite with the common digital extensor tendon at the level of the proximal phalanx of digits 3-5.

There is a similar relationship for the extensor tendons and interosseus muscles for the hind leg.

The **superficial digital flexor tendon** divides into 4 parts which insert on the middle phalanx of digits 2-5 and is "perforated" by the deep digital flexor tendon passing to the distal phalanx. The superficial flexor tendon forms a tube-like enclosure around the deep flexor tendon called a **Manica Flexoria** (Fig. 3-V).

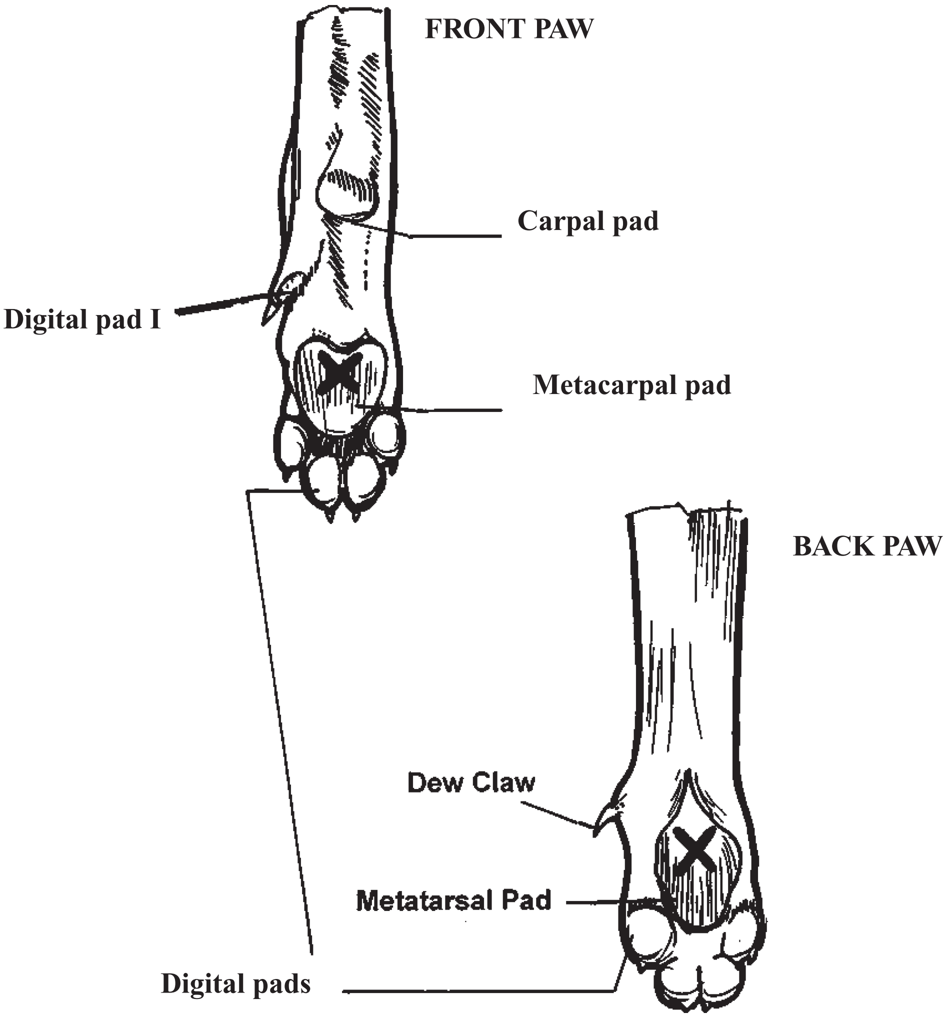


Figure 3-T: The paws of a dg

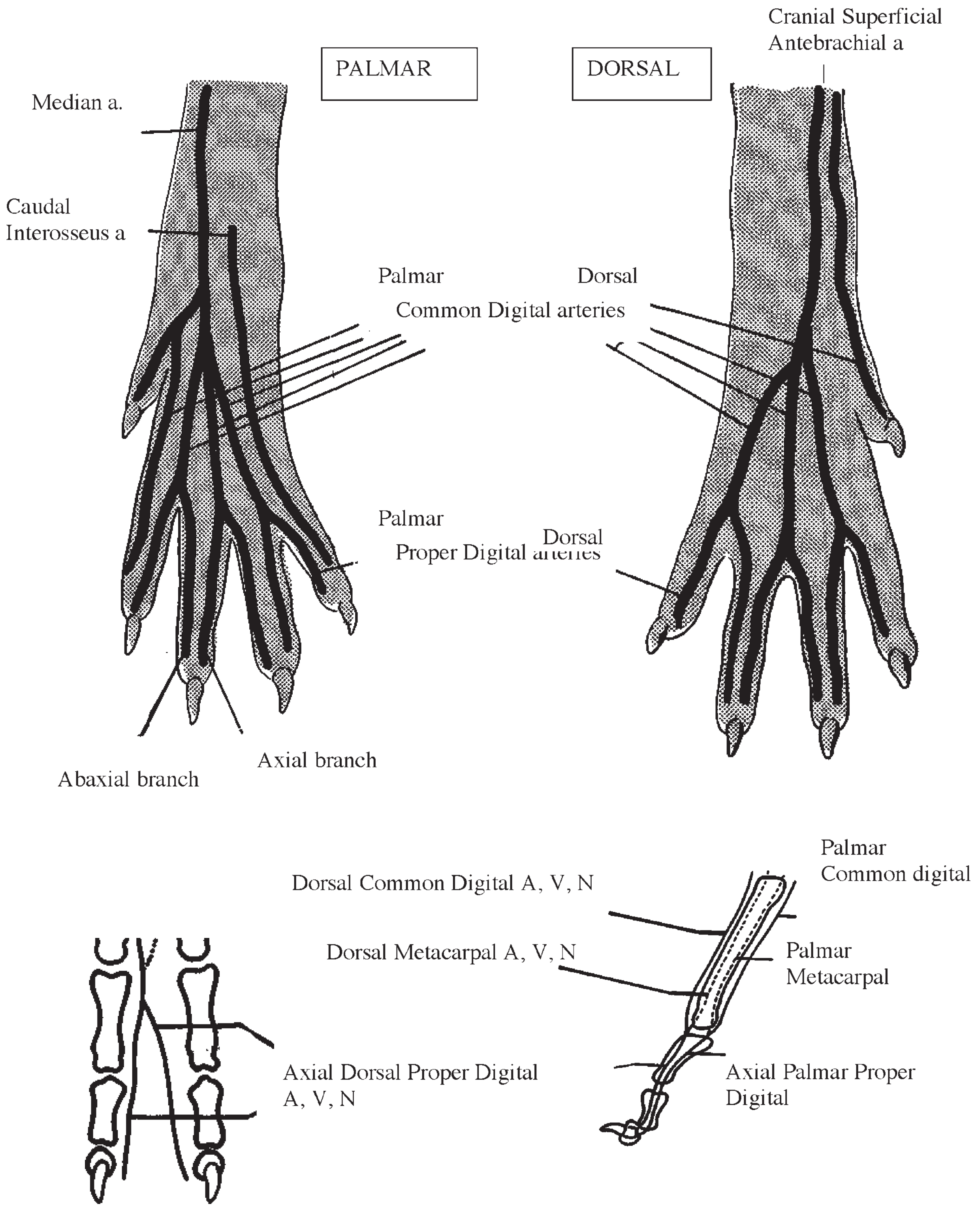


Figure 3-U: Schema of blood supply and innervation of the digits (Redrawn from Evans and de Lahunta)

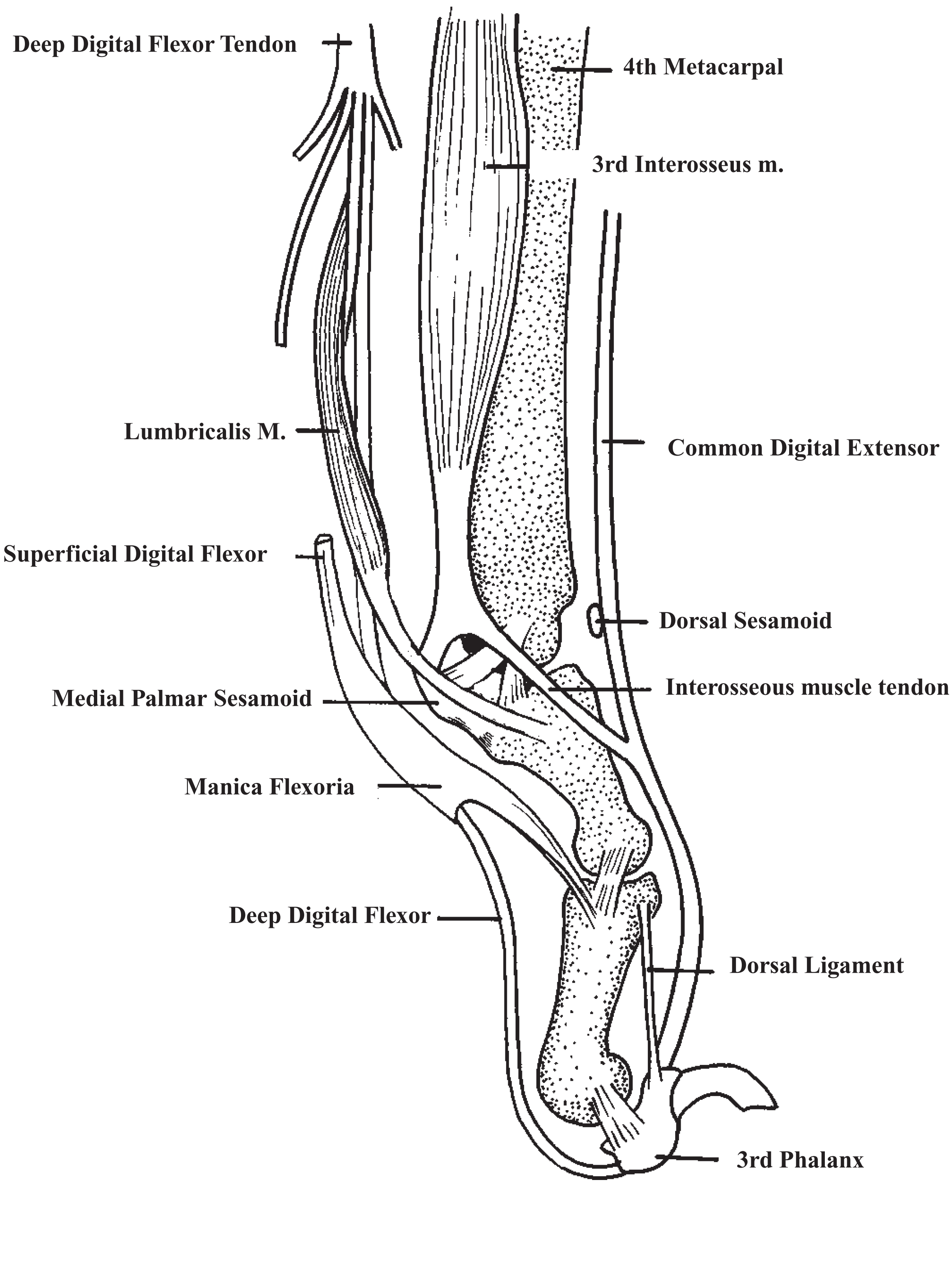


Figure 3-V: Relationship of muscles and tendons of the digit (Redrawn from Evans and Christensen)

Questions

A dog is lying down and decides to lick its right forepaw. It then returns it to the ground. As far as the limb is concerned, what anatomical changes occur during these movements?

Can you explain how the forelimb of the dog acts as an extensible strut?

What anatomical features of the shoulder joint reveal why dislocations of that joint are rare?

What anatomical structures restrict supination in the dog?

Chapter 4

Anatomy of the Thoracic Limb of the Horse

Abbreviations used in following text

Me	Metacarpal
Mt	Metatarsal
P	Phalanx
DDFT	Deep digital flexor tendon
SDFT	Superficial digital flexor tendon

Suggested reading

*DYCE KM, SACK WO & WENSING CJC (1995) Textbook of Veterinary Anatomy Chapters 23, 24, 32, 33 & 38.

SISSON & GROSSMAN'S (1975) The anatomy of the Domestic Animals Chapters 15, 16, 17.

*ADAM'S LAMENESS IN HORSES (1974) Ed. Ted S Stashak Chapters 1 and 2.
GRAY Sir J (1968) Animal Locomotion Pages 265-286

MUYBRIDGE E (1957) Animals in Motion Pages 29-57

* Highly recommended

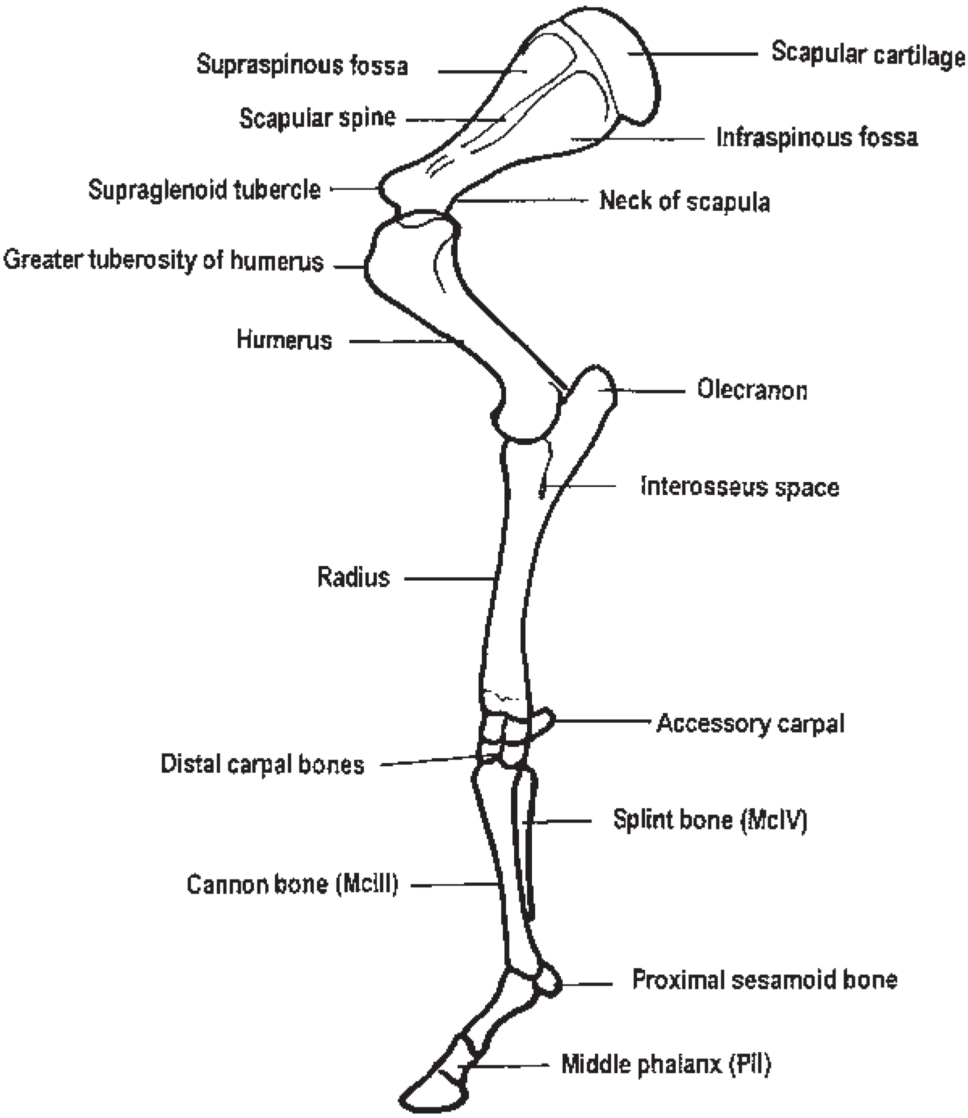


Figure 4-A: Bones of horse's limbs (left lateral aspect)

Cursorial adaptation of the horse

The features of the skeletal and muscular apparatus in the dog arises from cursorial adaptation, resulting in digitigrade locomotion. Horses show extremes of digitigrade locomotion, with only the end of the third digit in contact with the ground. The end of the single weight-bearing digit is encased in hoof, so the horse thus falls into the order **perissodactyla** (odd-toed ungulates).

Principle equine cursorial adaptations:
- reduction in number of digits
- limbs fixed in pronation
- abduction and adduction of limb reduced
- limb ends in highly specialised hoof
- extreme shortening of muscle bellies
- increase in length and strength of metacarpals and phalanges

Changes in bony structure of the horse's limbs associated with cursorial adaptation have been accompanied by modifications in the muscles, synovial structures, tendons, ligaments, feet and circulation. In the following notes, only those features concerned with these modifications, and those which make interesting comparisons with the dog, are discussed.

The Stay Apparatus, the mechanisms which have evolved to support weight-bearing and absorb the shock through a single digit, is of particular clinical importance, especially in the equine athlete.

Bones of the thoracic limb (Figure 4.A)

The fore limbs **carry 55-60% of the body weight,** and therefore perform a greater **shock-absorbing** role than the hind limbs. They also contribute **thrust** which propels the body.

Modifications in the bones of the fore limb (Fig 4.A)

- **Clavicle: absent** in the horse
- **Scapula**: Large **cartilage of prolongation**, incorporated into withers, for muscle attachment. **Acromion process absent**, but scapular spine is thickened forming the **scapular tuberosity**.
- **Humerus**: relative **short and thick**, with **deep musculospiral groove**. Large tuberosities for muscle attachment:
  - **Greater and lesser tuberosities** both divided into cranial and caudal parts. Cranial part of the greater tuberosity is palpable as point of the shoulder.
  - **Intermediate tuberosity** helps prevent the biceps tendon from slipping laterally.
  - Large palpable **deltoid tuberosity.**
- **Radius** flattened craniocaudally, and close to vertical. Medial surface of radius is mostly subcutaneous.

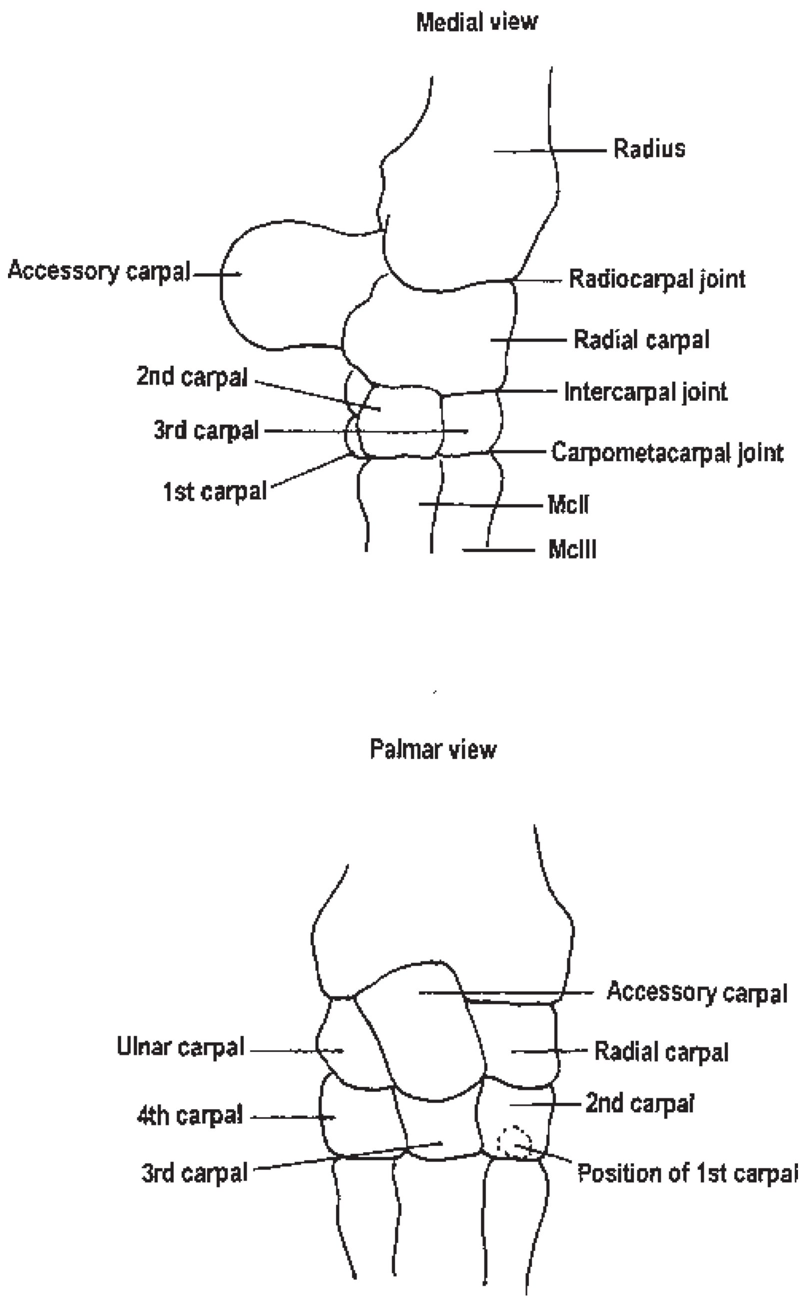


Figure 4-B: Left carpus

- **Ulna** Shaft greatly reduced, and united with radius by interosseus ligament (ossifies in adults).
- **Carpal bones** (Fig 4.B) Large accessory carpal bone.

  Proximal row:

  - **radial, intermediate, ulnar and accessory** carpal.

  Distal row:

  - **2nd, 3rd** and **4* (& occasionally tiny 1st)** carpal

Bones of lower limb (Figs 4.C and 4.D)

These are essentially the same in the fore and hind limb, so use the following diagrams in reference also to the hind limb (although the term metatarsal obviously replaces metacarpal in the hind limb).

Metacarpals

- **McIII (cannon bone)** is the only weight-bearing element; strong, reduced medullary cavity.
- **MII and IV (splint bones)** greatly reduced. In young horses, joined to McIII by fibrous attachment which eventually ossifies. *Shearing between splint and cannon is associated with acute inflammation - **throwing a splint, splints** - commoner in medial splint.*

Phalanges

- **Proximal phalanx PI (long pastern):**
  - decreased medullary cavity, grooved proximally to conform with condyle of McIII
- **Middle phalanx PII (short pastern):**
  - no medullary cavity, partly enclosed within hoof
  - palmar fibrocartilage for ligament and tendon insertion
- **Distal phalanx PIII (coffin/pedal bone):**
  - wedge-shaped, enclosed within hoof, perforated by many vascular foramina
  - **extensor process** proximally, **medial and lateral palmar processes** caudally
  - solar surface concave, forming **semilunar crest** on caudal border for attachment of deep digital flexor tendon
  - **solar foramina** and **parietal grooves** carry arteries
  - **lateral cartilages** extend proximally from palmar processes, palpable above heels. *Can ossify in response to concussion - **sidebone**; infection and necrosis of lateral cartilages is termed **quittor**.*

Sesamoids

- **Proximal:**

  Paired, **articulating with McIII** dorsally. Axial surfaces joined by thick **intersesamoidean ligament.**

- **Distal (navicular bone):**

  Boat-shaped, articulates with PIT and PHI. Provides **bearing surface for deep digital flexor tendon,** and therefore under enormous compressive stress.

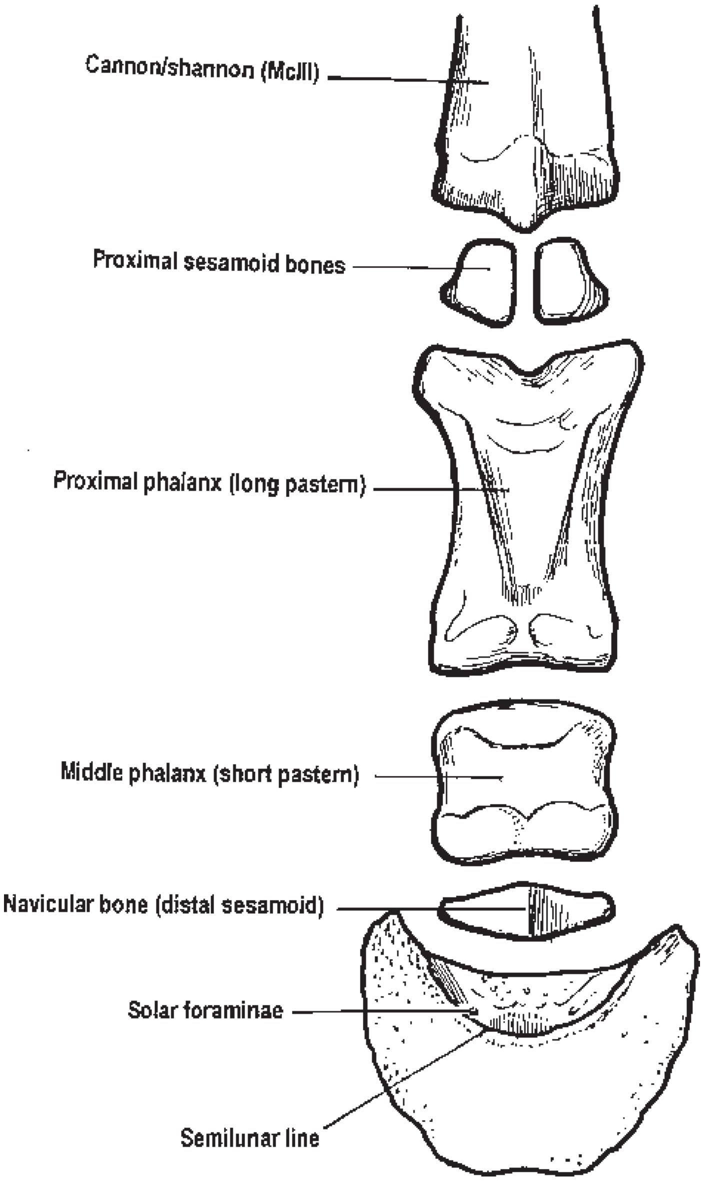


Figure 4-C: Distal limb of horse, exploded palmar/plantar view

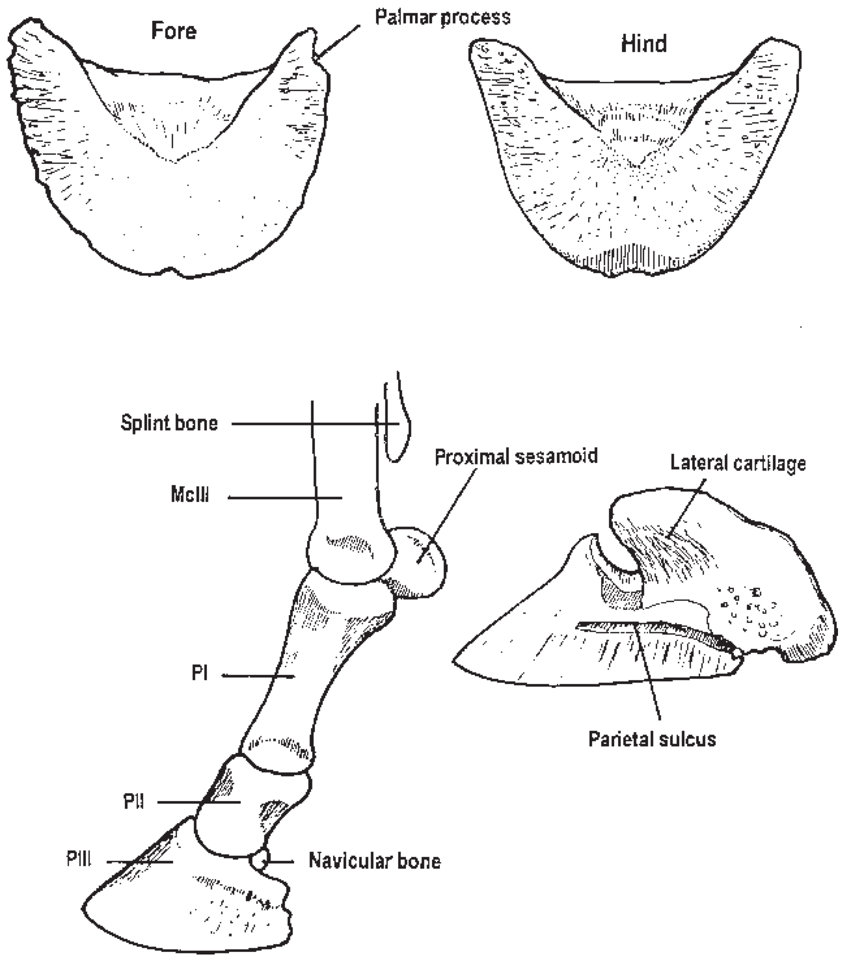


Figure 4-D: Distal phalanges

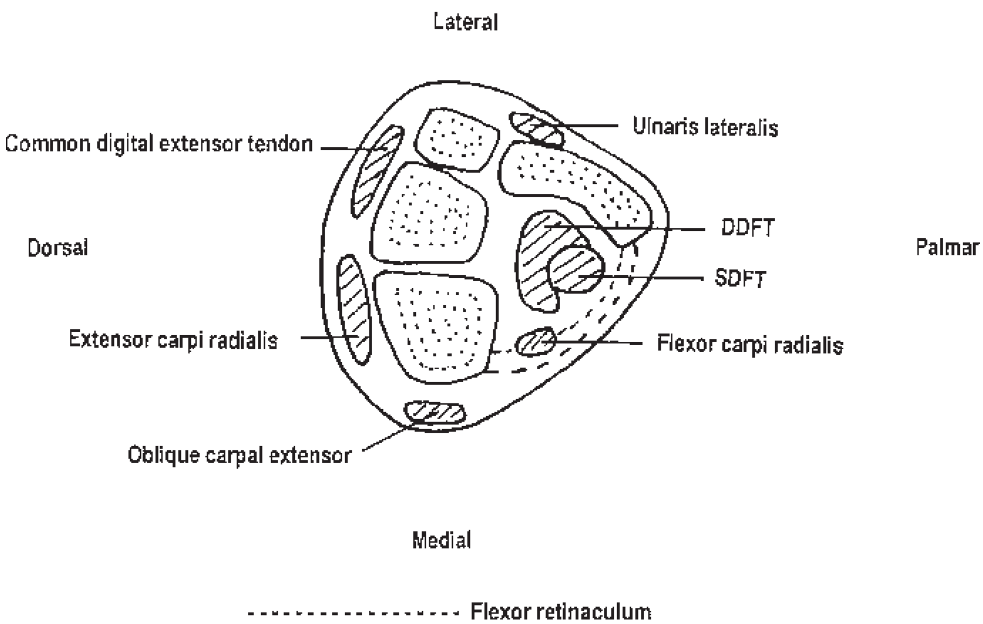


Figure 4-E: Tendons in region of carpal canal of right forelimb

Synovial joints of the fore limb

Shoulder joint

Large **spheroidal joint,** with no collateral ligaments. Wholly limited to movement in a sagittal plane by close fit of fibrocartilaginous plate in biceps brachii tendon over intermediate tuberosity. Thus, the tendons of supraspinatus and infraspinatus muscles laterally, and subscapularis medially, act as collateral ligaments in supporting the joint during extension and flexion, but have no role in rotation or abduction as these movements do not occur in the equine shoulder joint. The term “rotator cuff” is not applied in veterinary anatomy.

Joint capsule can be accessed for aspiration between the tendons of the supraspinatus and infraspinatus.

Elbow joint

A ginglymus or hinge joint, restricted to movement in a sagittal plane.

Ligaments of elbow joint:

a) **Medial collateral ligament:** divided into long and short parts. Long part is remnant of pronator teres muscle.

b) **Lateral collateral ligament:** short and strong

Joint capsule forms a pouch in the olecranon fossa under the anconeus muscle. Joint is accessible for aspiration either side of lateral collateral ligament.

Carpal joint

A compound joint maintained in full extension in standing horse. Degreee of flexion and extension varies between the three levels of the joint:

- most at **radiocarpal joint** (approx 100°)
- some at **midcarpal joint** (approx 45°)
- no significant flexion/extension at **carpometacarpal joint**

These three joints share a common fibrous capsule, but have **separate synovial compartments,** with a narrow communication between middle and distal compartments.

Ligaments of carpal joint

a) **Palmar carpal ligament:** thick, continuous with fibrous joint capsule. Extends to deep flexor tendon as **carpal (accessory) check ligament, restricting** over-extension of knee. Forms deep wall of carpal canal.

b) **Dorsal carpal ligament (extensor retinaculum):** large, enclosing extensor tendons passing over carpus.

c) **Flexor retinaculum:** Large, extending from accessory carpal to medial aspect of joint. Encloses the **carpal canal** (Fig 4.E) through which the flexor tendons pass en route to distal limb.

d) **Medial and lateral collateral ligaments:** complete, running from styloid processes of radius to metacarpus.

e) Also many ligaments linking adjacent carpal bones.

Joints of manus (Fig 4.F)

The anatomy of fetlock, pastern and coffin joints is of particular clinical importance because, in a single weight-bearing digit, the distal joints are most susceptible to injury. They must -withstand **compressive** forces in the process of shock absorption, and **tensile** forces caused by the natural tendency to over-extend. This is particularly true in the fore limb, -which supports a greater proportion of the horse's weight, especially when ridden, or at speed or landing from a jump.

Although the following descriptions are of the joints of the thoracic limb, the anatomy is essentially similar in the pelvic limb.

Metacarpophalangeal joint (fetlock)

Some compressive force offset in standing position by angulation of approx 55° **to the horizontal.** Joint has extreme range of movement through approx 220° in the sagittal plane, and at speed or landing from a jump the dorsal angle can reach as little as 90°.

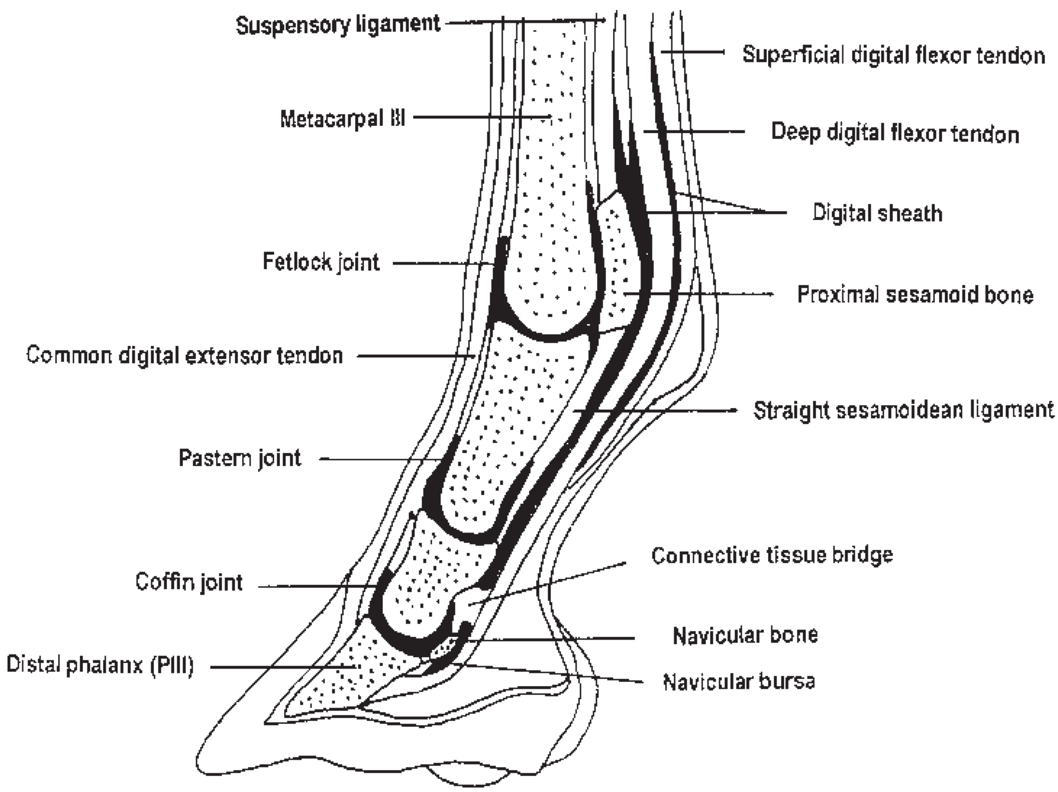


Figure 4-F: Axial section of digit

Joint is formed between McIII, PI and the proximal sesamoids. Large common joint capsule accessible for aspiration from **caudal pouch** between McIII, end of splint bone and suspensory ligament - distension at this site is referred to as **“articular windgalls”.**

Ligaments of fetlock joint (Figs 4.G and 4.H)

1. **Collaterals: Medial and lateral collaterals -** short and stout
2. **Suspensory ligament (see also Fig 4.I and 4.K):** Remnant of **interosseus muscle,** arising from distal row of carpals and palmar surface of proximal Mc III. Lies between McIII and deep digital flexor tendon as courses distally.

   Attaches to proximal sesamoids, and also divides into two **extensor branches** which pass over their abaxial surfaces. Extensor branches unite dorsally with common/long (fore/hind) digital extensor tendon.
3. **Proximal sesamoidean ligaments**
   - **a) Intersesamoidean:** fibrocartilage running between sesamoids, forming smooth bearing surface for flexor tendons.
   - **b) Lateral and medial collateral sesamoidean:** from abaxial surface of sesamoids to McIII, and PI
4. **Distal sesamoidean ligaments:**
   - **a) Straight (superficial) sesamoidean: inserts** on proximal end of PII
   - **b) Oblique (middle) sesamoideans:** paired, deep to straight ligament, inserts on palmar surface of PI
   - **c) Cruciate (deep) sesamoideans:** paired, deep to obliques, crossing to opposite side of proximal PI
   - **d) Short sesamoideans:** paired, deep to cruciates, inserting close to articular surface of PI.

Distal sesamoidean and suspensory ligaments are important components of the stay apparatus of distal limb and are therefore clinically important.

Proximal interphalangeal (pastern) joint

Restricted movement in sagittal plane only. Oblique angle of phalanges reduces concussive forces.

Joint capsule is accessible for aspiration at level of union of extensor branch of suspensory ligament with extensor tendon (see Figure 4.I).

Ligaments of pastern joint

a) Lateral and medial collaterals

b) Paired abaxial and axial palmar ligaments (four in total) between palmar surface PI and fibrocartilage of PII. Prevent extension of joint beyond 180°.

Distal interphalangeal (coffin) joint

Lies deep within hoof *Forms* ***dorsal pouch*** *that extends just above boundary of hoof - accessible for aspiration here.*

Small **medial and lateral pouches** are in contact with lateral cartilages.

Navicular (distal sesamoid) bone is an integral part of coffin joint. **The navicular (podotrochlear) bursa** lies between the navicular bone and the deep digital flexor tendon (see Figure 4.F).

Ligaments of coffin joint

a) **Medial and lateral collateral ligaments:** short, thick.
b) **Collateral navicular ligaments:** suspend navicular bone from distal PI.
c) **Distal navicular ligament:** short, wide, from distal border of navicular bone to PIII. Separates coffin joint from navicular bursa distally. (Connective tissue Bridge forms proximal separation).

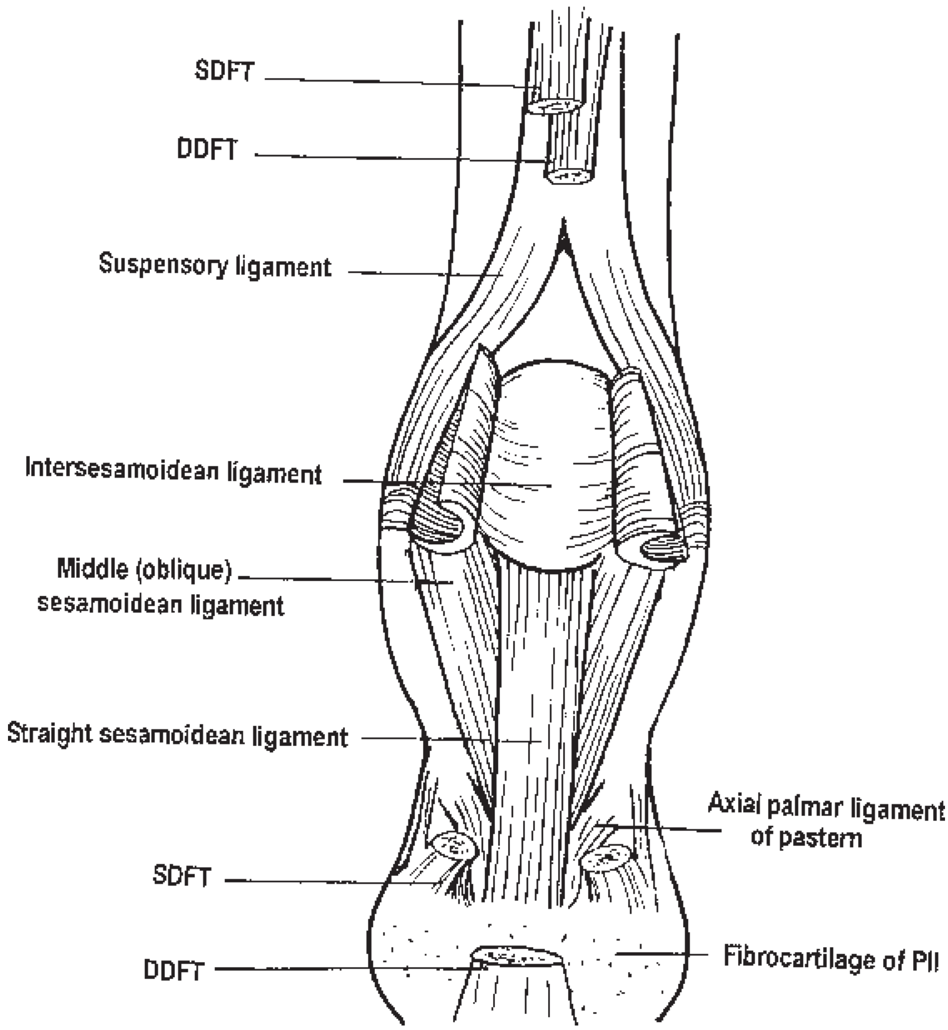


Figure 4-G: Sesamoidean ligaments in the horse (Palmar/plantar view)

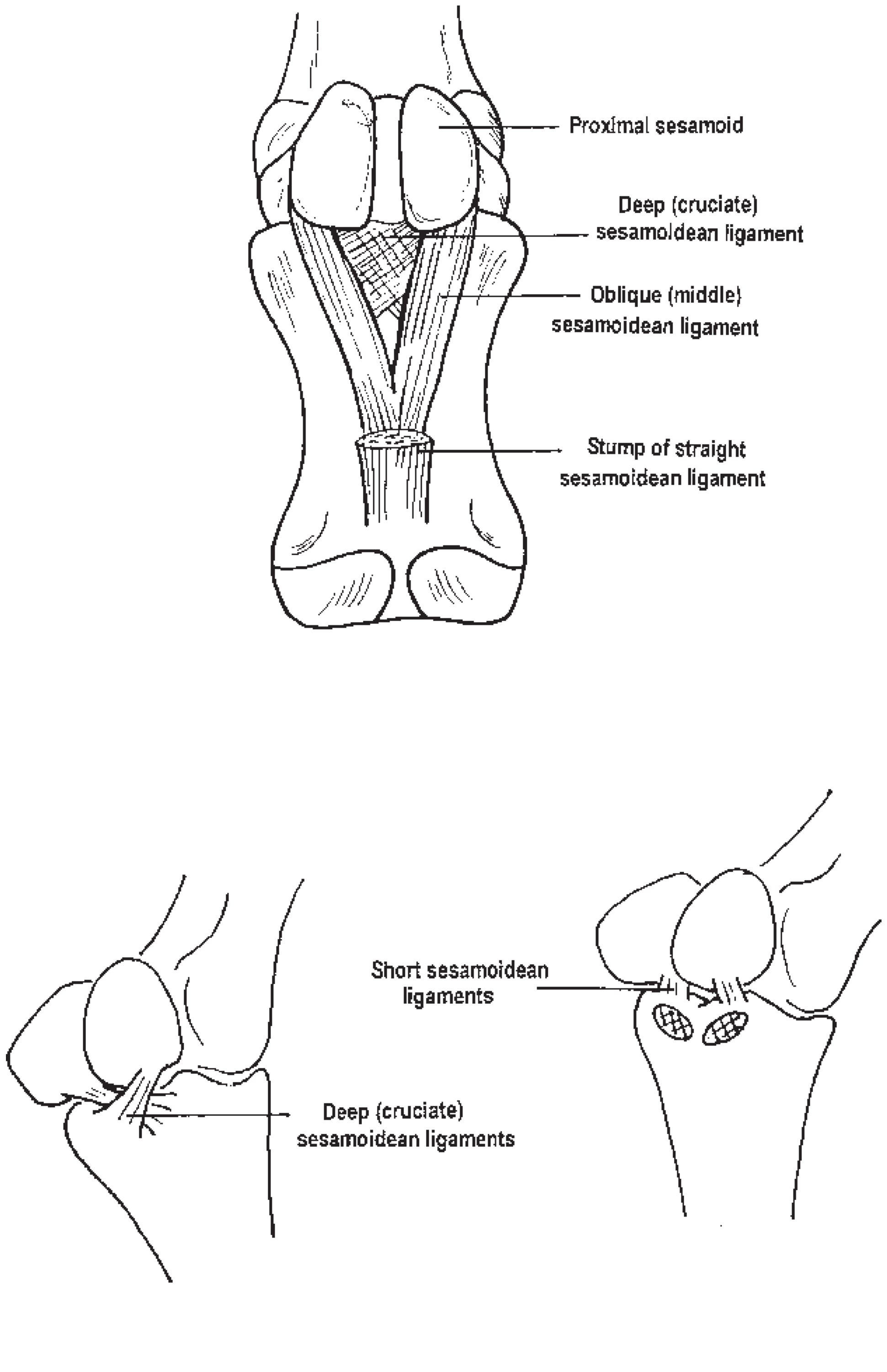


Figure 4-H: Ligaments of proximal sesamoid bones

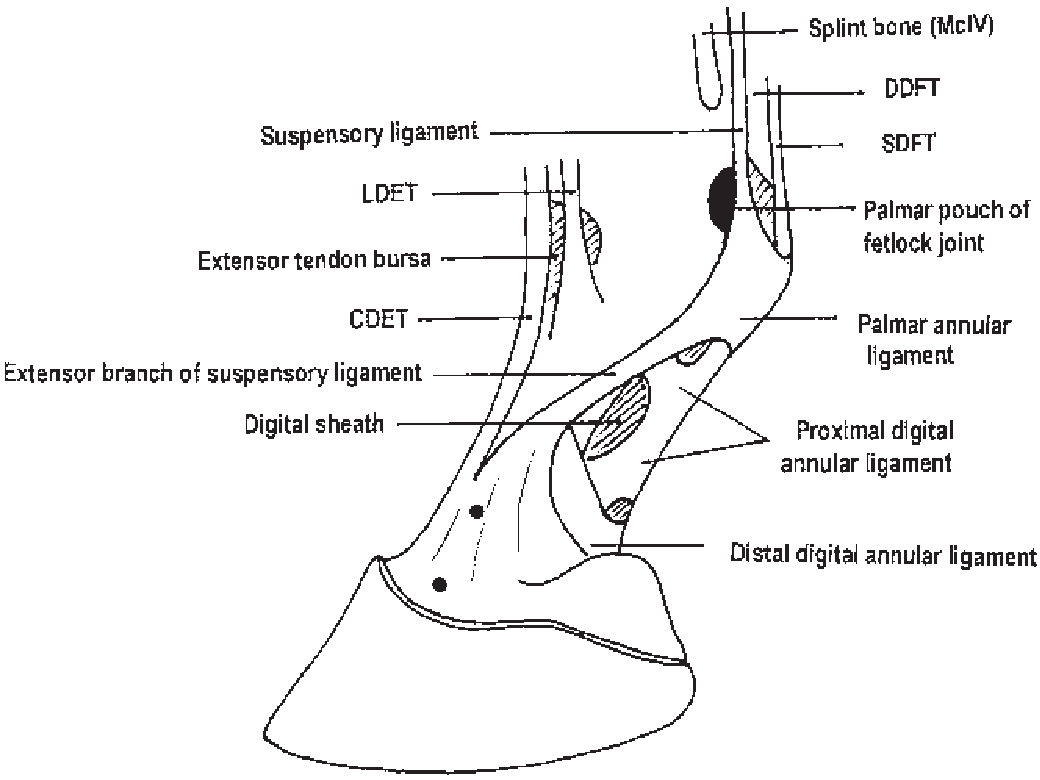
Annular ligaments of distal limb (Fig 4.I)

Flexor tendons are held in position by three annular ligaments (retinacula) below carpus/tarsus.

a) **Palmar/plantar annular ligament** - between abaxial borders of proximal sesamoid bones. *If chronically distended, digital sheath can be constricted at fetlock by palmar annular ligament, forming visible notch,*

b) **Proximal digital annular ligament** - X-shaped, attached to proximal and distal borders of PI.

c) **Distal digital annular ligament** - forms sling from PI, blending with palmar/plantar surface of deep digital flexor tendon distally.



● Site of puncture of pastern & coffin joints

Figure 4-I : Annular ligaments of digit (lateral aspect)

Muscles of horse limbs

General points

a) Muscle arrangement

Generally, this is the same as the dog, in both species due to cursorial adaptation. However, in horses the arrangement tends to be simpler; the muscles which rotate, adduct and abduct the limbs are reduced or absent, fixing the limbs in pronation. The muscles which move the limbs in a craniocaudal plane are well developed. (Figure 4.13 shows some of these muscles).

b) Muscle length

Muscle size is governed mechanically by two equations:

$$\text{Muscle strength} \propto \text{cross sectional area } (x^2)$$

$$\text{Muscle mass} \propto \text{volume } (x^3)$$

Therefore, as size increases, muscle strength increases more slowly that weight, and the animal must work harder to be as efficient. Shortening the muscle bellies reduces bulk, but shorter fibres produce a smaller direct change in length. This is offset by lengthening the limbs and tendons, employing leverage to increase efficiency. In the horse, extreme shortening of the muscle bellies leaves only tendons below carpus and tarsus, which reduces weight of the distal limb.

Fast, efficient locomotion is achieved in horses by a long limb and relatively slow action. Sustained speed can be used to evade a faster predator, whose shorter, more rapidly moving limbs tire more quickly.

c) Muscle fibre types

Different preponderance of Type I (slow twitch, red fibres) and Type II (fast twitch, white fibres) within muscles confers postural or propulsive function. Differing proportions of these fibre types within individuals is thought to account for suitability for different uses e.g. sprinting vs. endurance work.

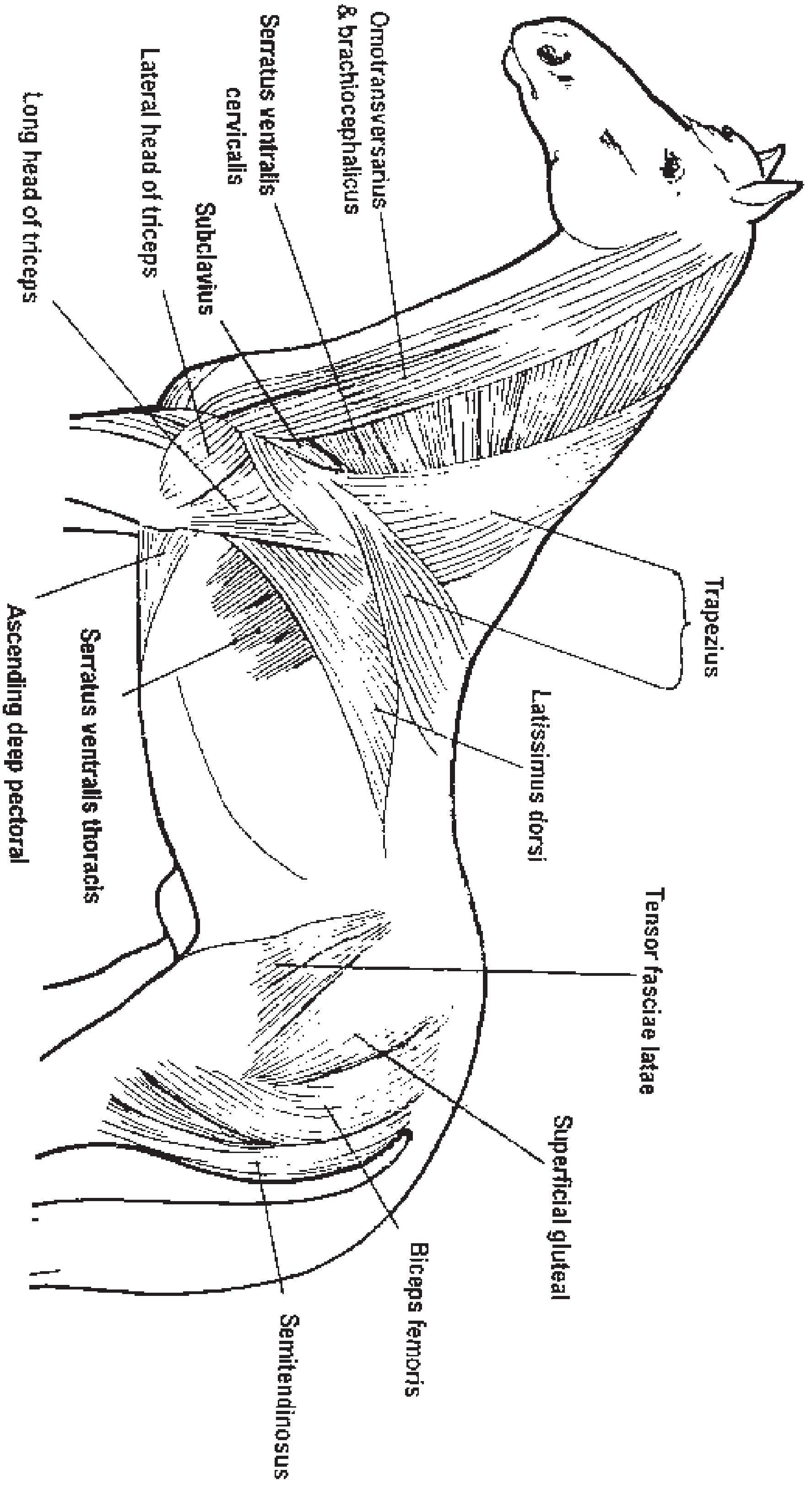


Figure 4-J: Major muscles of limb movement in the horse

Muscles of the thoracic limb

Note: only features that vary from the dog are described in this section

1. Extrinsic muscles (Fig 4-J)

a) **Brachiocephalicus** - only tendinous remnant of clavicle.

b) **Omotransversarius** - intimately associated with brachiocephalicus.

c) **Pectoral muscles**

i) **Superficial pectorals** - transverse and descending parts

ii) **Deep pectoral** in two parts

Ascending deep pectoral: large, inserts on humerus

Subclavius: inserts on cranial border of scapular muscles

d) **Trapezius, rhomboideus, serratus ventralis and latissimus dorsi -** similar to dog.

2. Lateral shoulder muscles

a) **Deltoideus:** only one part, aponeurotic origin from scapular spine.

b) **Supraspinatus:** inserts on cranial parts of both tuberosities of humerus, either side of tendon of origin of Biceps. Stabilises and extends shoulder.

c) **Infraspinatus:** tendon of insertion to caudal part of greater tuberosity divided into deep and superficial parts. Synovial **bursa** underlies superficial tendon.

d) **Teres minor** as dog

3. Medial shoulder muscles

Subscapularis and teres major: similar to dog

4. Caudal muscles of antebrachium

a) **Triceps brachii:** no accessory head. Small **bursa** between tendon of insertion and olecranon.

b) **Anconeus and Tensor fasciae antebrachii:** as dog.

5. Cranial muscles of brachium

a) **Biceps brachii:** short, broad fibrocartilaginous tendon of origin, and large **bicipital bursa** protect tendon as it passes over intermediate tuberosity in intertubercular groove.

Deep internal tendon runs from origin to insertion; a slip **(lacertus fibrosus)** detaches to join fascia of extensor carpi radialis.

b) **Brachialis:** inserts only on radius.

c) **Coracobrachialis:** as dog

Note: pronator and supinator muscles are absent.

6. Extensors of carpus and digit

These muscles occupy the craniolateral fore limb. The tendons are secured over the carpus by the extensor retinaculum, and some possess synovial sheaths. All are innervated by the radial nerve.

a) **Extensor carpi radialis:** joined by **lacertus fibrosus** from biceps brachii. Inserts on Mc III.

b) **Common digital extensor:** small tendon slip fuses with that of lateral digital extensor at metacarpus. Main tendon passes over **extensor bursa** at fetlock and inserts on extensor process of PHI (also PI and PII).

c) **Lateral digital extensor:** Tendon joined by slip from common digital extensor, passes over extensor bursa then inserts on PI.

d) **Abductor pollicis longus** referred to in horse as **oblique carpal extensor, small** and functionally insignificant.

Note: the Ulnaris lateralis has radial nerve innervation and extensor group origin (craniolateral forearm), but its insertion is such that it functions as a flexor muscle.

7. Flexors of carpus and digit

These muscles occupy the caudomedial forearm. All except the ulnaris lateralis (see above), are innervated by the median and ulnar nerves.

a) **Ulnaris lateralis:** note flexor action despite extensor origin and innervation. Inserts on accessory carpal, and proximal McIV.

b) **Flexor carpi radialis: originates** on medial epicondyle of humerus, inserts on McII

c) **Flexor carpi ulnaris:** originates on medial elbow region, inserts on proximal surface of accessory carpal.

d) **Superficial digital flexor : (Fig 4.K)**
Origin has two heads:

i) Humeral - from medial epicondyle of humerus

ii) Radial - consists of fibrous band, referred to as accessory ligament or **radial (superior) check ligament** of superficial digital flexor tendon (SOFT).

SDFT forms a tube around deep digital flexor tendon (DDFT) as they pass between proximal sesamoids (equivalent to the manica flexoria of the dog digit). The SDFT then divides and runs laterally and medially to insert at pastern joint.

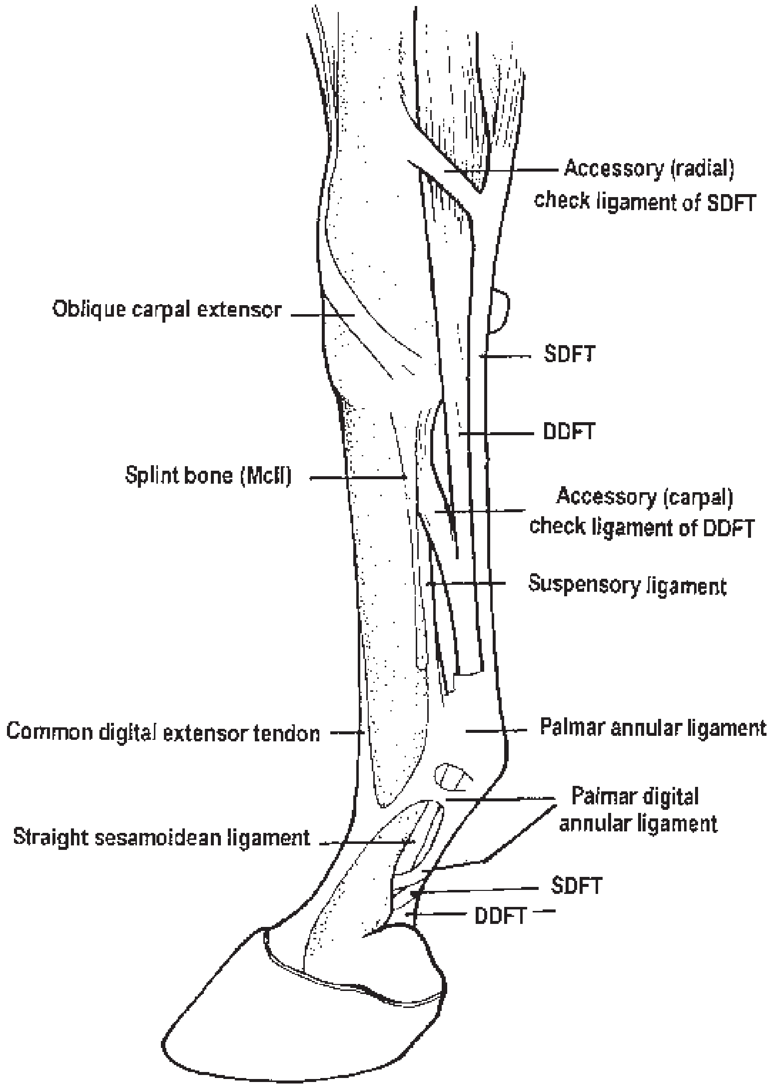


Figure 4-K: Tendons and ligaments of distal limb

e) **Deep digital flexor:** three heads as in dog, all originating from medial elbow region.

i) Humeral - (largest) from medial epicondyle

ii) Ulnar - from medial olecranon

iii) Radial - (sometimes absent) from caudal radius

An extension of the fibrous carpal joint capsule attaches to DDFT just below carpus. This is the accessory ligament or **carpal (inferior) check ligament (Fig 4.K).**

Insertion: flexor surface (semilunar line) of PHI. Podotrochlear or **navicular bursa** between flexor surface of navicular bone and DDFT.

Figure 4.K shows the relationship between tendons and ligaments of the lower limb.

Synovial bursae and tendon sheaths

Synovial bursae

A synovial bursa is a thin-walled connective tissue sac, lined by **synovial membrane** and containing a small quantity of **synovial fluid.** Its function is to **reduce friction,** and it is found between a tendon and a bony prominence or other hard structure. Several bursae have developed in the horse following the lengthening of the limbs and increased lever effect.

Bursae are of clinical importance because they can become inflamed, a condition associated with pain and distension referred to as **bursitis.**

Adventitious or acquired (false) bursae can develop subcutaneously over bony prominences in response to wear.

Synovial bursae of the fore limb (Fig 4.L)

i) Intertubercular (bicipital) bursa

Under tendon of origin of biceps, spreading onto cranial aspect of shoulder. Usually does not communicate with joint (unlike dog). *Injury results in shortening of stride.*

ii) Infraspinatus bursa

Between superficial tendon and greater tuberosity. Injury results in abduction of limb.

iii) Bursa of triceps brachii

Between olecranon and tendon of insertion. Note: an adventitious (false) bursa also commonly develops here -capped elbow.

iv) Extensor bursa

Under extensor tendons on dorsal surface of fetlock. Distension referred to as capped fetlock.

v) Navicular (podotrochlear) bursa

Between DDFT and navicular bone. Clinically very important as vulnerable to injury from penetration of the foot by foreign bodies.

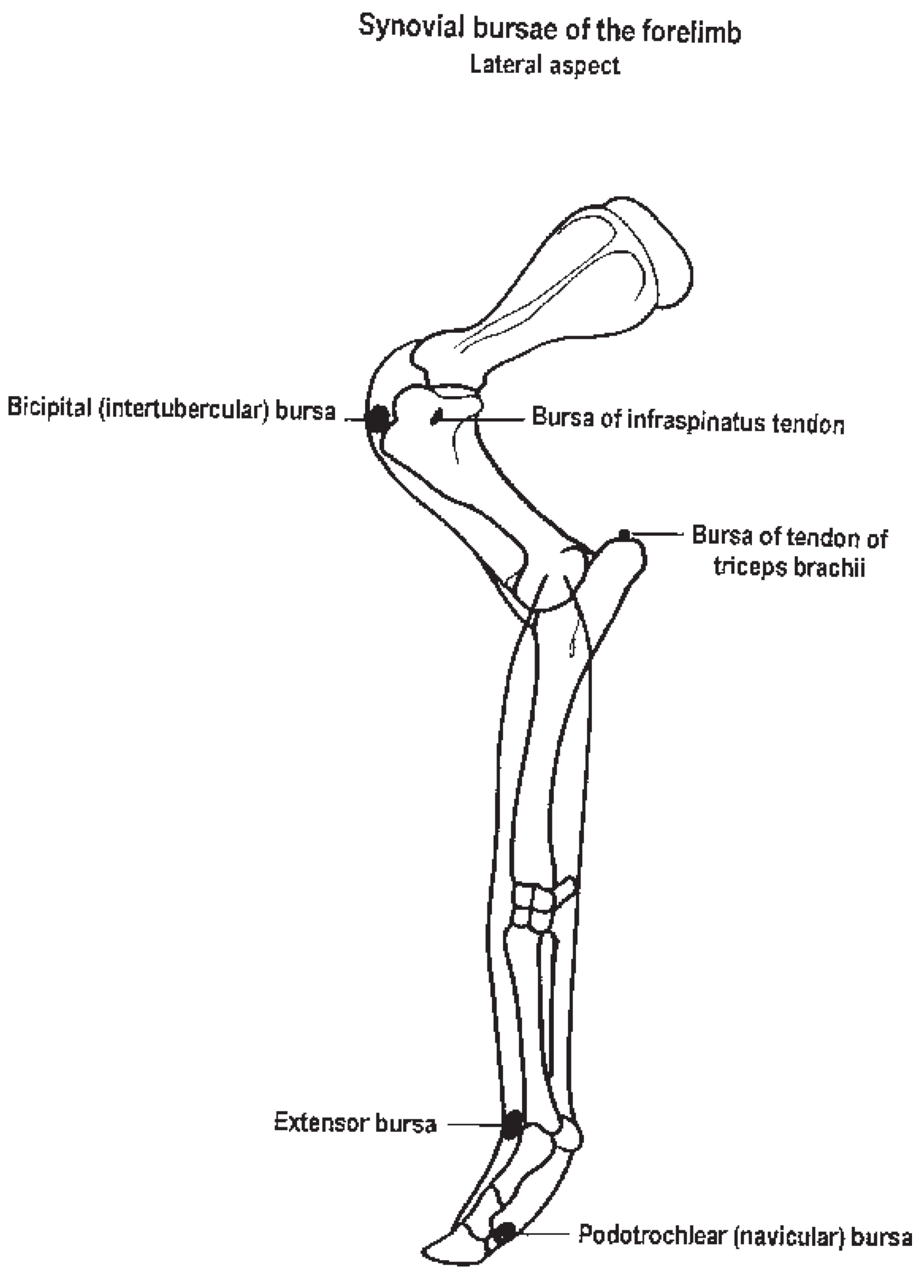


Figure 4-L: Synovial bursae of the fore limb

Synovial tendon sheaths

Tendon structure

Tendons are comprised of dense regular connective tissue arranged in parallel bundles.

- **peritendon** surrounds each bundle
- **epitendon** surrounds the tendon unit; both carry the sparse intrinsic blood supply to the tendon.
- **paratendon** (or paratenon) is a connective tissue sleeve enclosing entire tendon which carries the extrinsic blood supply and allows the tendon to glide within.

Tendon injury is common in the horse, and heals slowly as a consequence of the poor intrinsic blood supply. Scar tissue which forms following tearing or penetration of tendon tissue is weak, due to the irregular arrangement of the collagen fibres. As a result, previous or subclinical tendon injury predisposes to recurrent damage.

Tendon sheaths

At points of friction or pressure, a synovial sac, the **tendon sheath,** folds around the tendon. *Injury to a tendon is usually accompanied by inflammation of its associated sheath. Chronic distension may sometimes occur following recurrent low-grade injury. In addition, tendon sheaths are vulnerable to infection from penetrating injuries.*

The carpal and digital sheaths are of primary importance because of their association with the major flexor tendons.

a) Carpal sheath (Fig 4.M)

Tendon sheath surrounding both SDFT and DDFT as they pass through the carpal canal. Extends from just above accessory carpal bone to 1/4 way down metacarpus.

Distension of sheath is more noticeable above knee, where the sheath is less well supported.

b) Digital sheath (Fig 4.I)

A complex sheath shared by the DDFT and SOFT in both fore and hind limbs.

Extends from just above fetlock to mid PII, lubricating tendons over bearing surfaces and under annular ligaments.

Distension more noticeable above fetlock **- tendinous windgalls.**

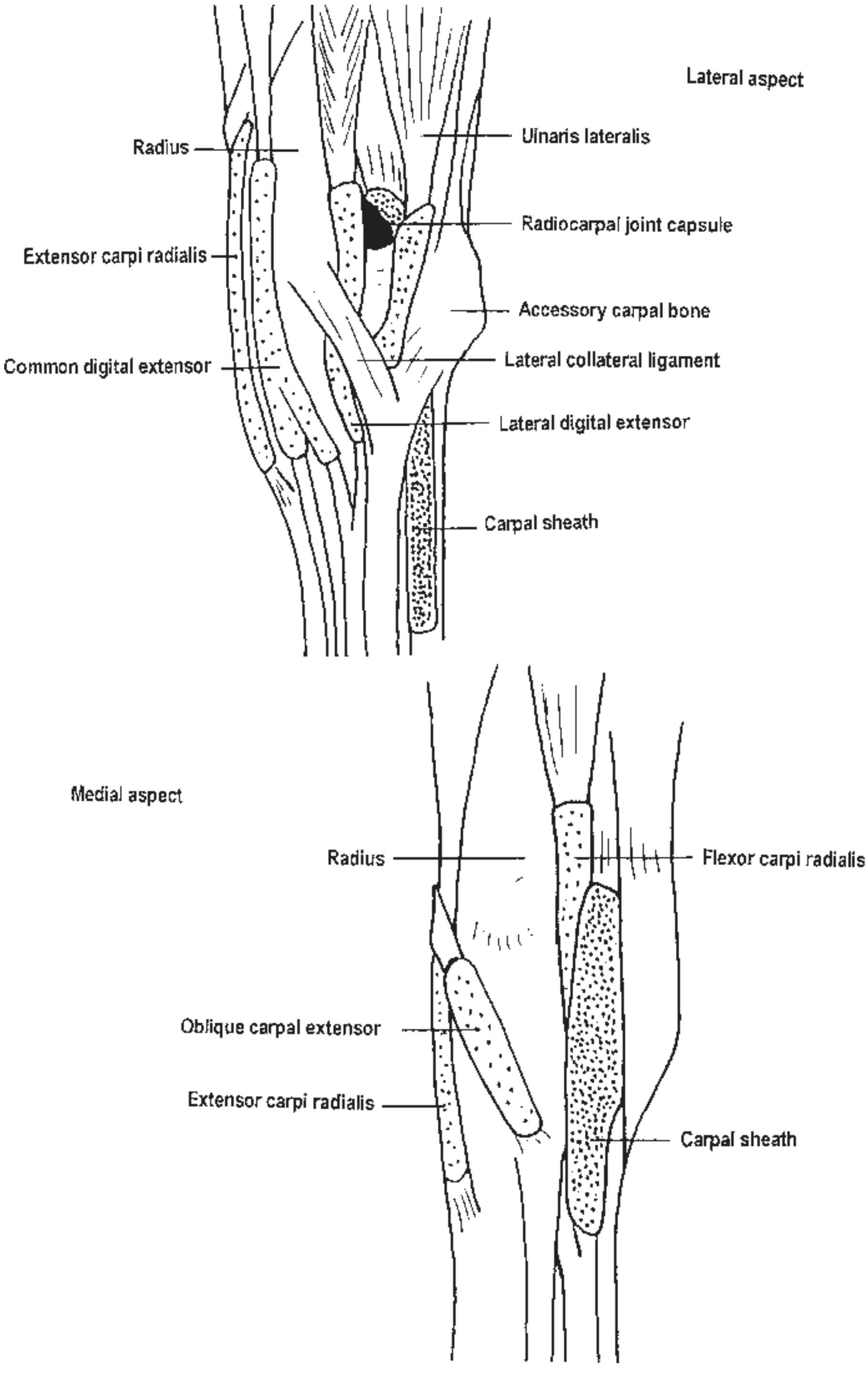


Figure 4-M: Synovial structures of left forelimb

The stay apparatus

Equidae lack extremes of speed and agility in comparison with many predators. They rely on sustained speed to tire their pursuers. It is therefore essential that the predator does not have the advantage of surprise, when superior speed will achieve a kill.

Two mechanisms assist equidae in remaining alert and ready to move quickly in response to danger:

1) An elastic **nuchal ligament.** Energy stored while the head is down assists the muscles which raise the head to observe the environment.
2) The **stay apparatus,** a mechanism which enables them to remain standing for prolonged periods, without excessive muscle fatigue.

   The fore and hind limbs each have their own mechanism for support above the carpus and tarsus. The distal limbs of both fore and hind legs are essentially identical, and have a common mechanism known as the **suspensory apparatus.**

A. Stay apparatus of fore limb (Fig 4.N)

a) Support of carpal joint:

Overextension prevented by

i) **Palmar carpal ligament**

ii) Close packing of **flat carpal bones** dorsally

Flexion prevented by tension on extensor carpi radialis maintained by **lacertus fibrosus.**

b) Support of elbow joint:

Flexion of joint in standing position prevented by:

i) Tonic activity **of triceps brachii**

ii) Positioning of **collateral ligaments** caudal to axis of rotation - tense in standing position

iii) Origins of flexor muscles - tensed in standing position.

c) Support of shoulder joint:

Flexion prevented by musculotendinous arrangement of **biceps brachii, lacertus fibrosus** and **extensor carpi radialis.** Biceps muscle under tonic tension due to body weight acting on fascia.

B. Suspensory apparatus (Fig 4.O)

Most clinically important region of stay apparatus as it is most susceptible to injury.

Below the knee and hock, the support mechanism is similar, consisting of a **ligamentous continuum** referred to as the **suspensory apparatus.** This prevents the fetlock and pastern over-extending.

a) Support of fetlock

- **Suspensory ligament**
- **Proximal sesamoids**
- **Straight and oblique sesamoidean ligaments**

Reinforced by tension in the **DDFT and SDFT, and check ligaments.**

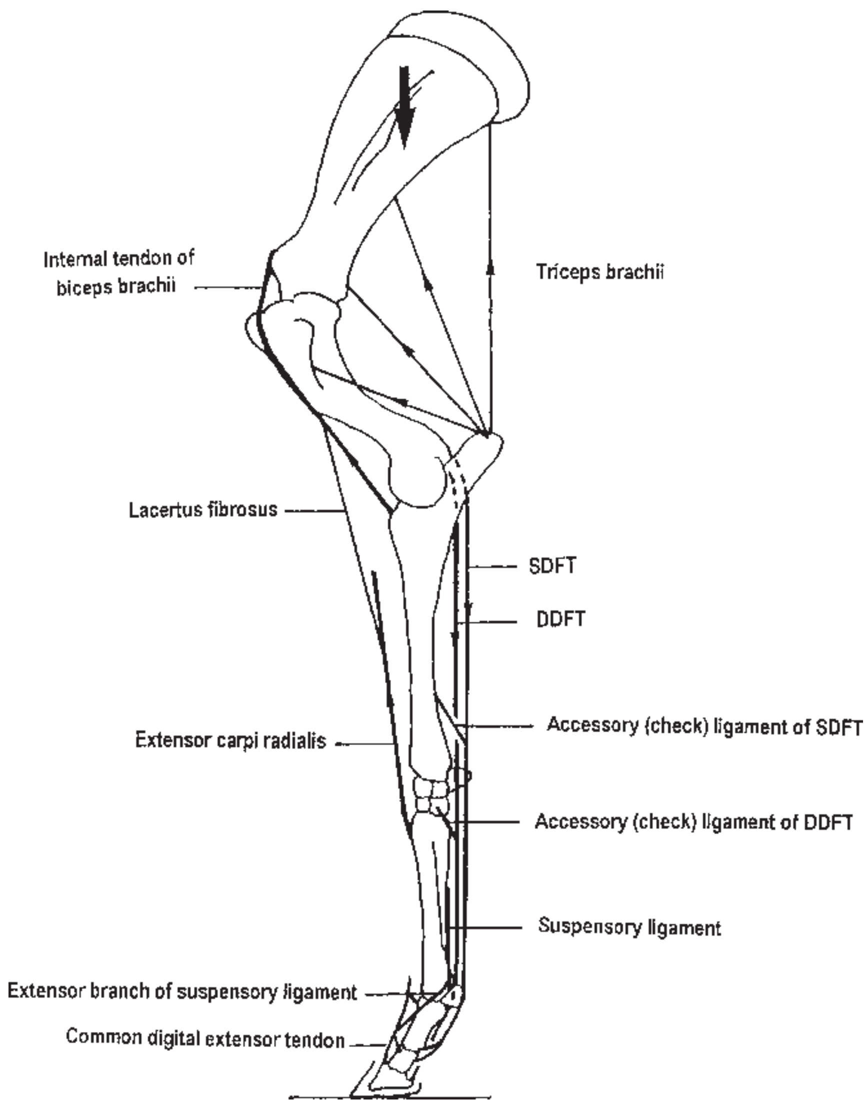


Figure 4-N: Stay apparatus of forelimb of horse

b) **Support of pastern**

Four **palmar ligaments,** stretched tightly in standing position, prevent over-extension, assisted by **tension in SDFT and DDFT**

c) **Support of the coffin joint:**

Attachment of the powerful DDFT has a tendency to flex coffin joint. This effect is balanced by two factors:

- Tension on **extensor branches of suspensory ligament, transmitted** via the common digital extensor
- Integrity of the **laminar junctions between** the lamellar corium and the hoof wall. *The importance of this component is graphically illustrated in acute laminitis, when the integrity of this attachment is lost and the coffin bone rotates within the hoof.*

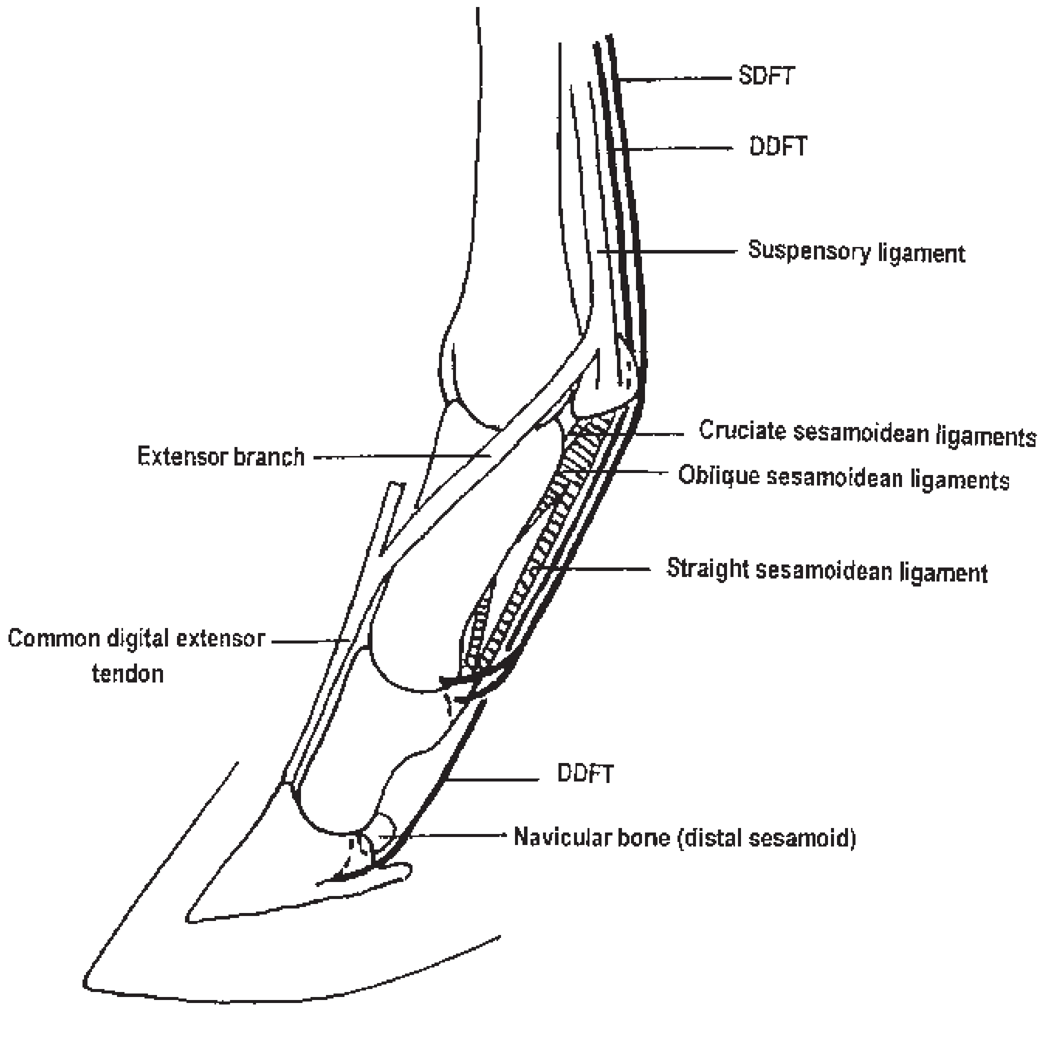


Figure 4-O: Suspensory apparatus of the lower limb

Blood supply to the limbs

The principal arteries of the fore and hind limb are similar to the dog. Because the horse has a single weight-bearing digit the pattern changes from the canine arrangement at carpus and tarsus, but in both fore and hind limbs a single artery provides the main supply to the foot.

The supply to the foot itself is discussed afterwards, with its important clinical implications.

Arteries of the fore limb (Figs 4.P and 4.Q)

Main trunk is **median artery,** arising from brachial artery. Just above the carpus, the median artery becomes the:

- **Medial palmar -** main supply to foot, runs down medial side between DDFT and suspensory ligament, then gives rise to **palmar digital arteries.**
- **Lateral palmar and radial arteries** are branches of the medial palmar artery, which provide a sparse supply to the dorsal metacarpal region, and also give rise to deeper **palmar metacarpal branches** which lie deep to the suspensory ligament.

Arteries of digit and hoof (Figs 4.Q and 4.R)

The blood supply to the distal limb is effectively the same in fore and hind limbs, except that the arteries are termed **palmar** in the fore, and **plantar** in the hind foot. The following description may seem excessively detailed, but a vast proportion of lamenesses in the horse involve the foot, especially the corium of the hoof and the navicular bone. A complete understanding of the anatomy of this region and its blood supply is a prerequisite for those intending to practice in the field of equine health.

- **Medial and lateral palmar/plantar digital arteries** arise, just above the fetlock, from the main artery supplying the foot. They cross the abaxial surface of the proximal sesamoids (palpable here), and continue into the digit either side of the flexor tendons.
- **Paired arterial branches arise at mid PI**, and each further divides into dorsal and palmar/plantar branches. These branches anastomose with their opposite branch, thus forming a complete arterial ring around each phalanx.
- At the level of the pastern joint, two additional branches arise:
  - The **bulbar artery**, supplying the **digital cushion** and associated structures
  - The **coronal branch** supplying the perioplic corium of the **coronary band** and heel**.**
- **Paired arterial branches arise at mid PII** (similar to those at PI), and further divide into dorsal and palmar/plantar branches which anastomose to form arterial loops around the phalanx. The palmar/plantar branches are important as they contribute **some of the arterial supply to the navicular bone.**

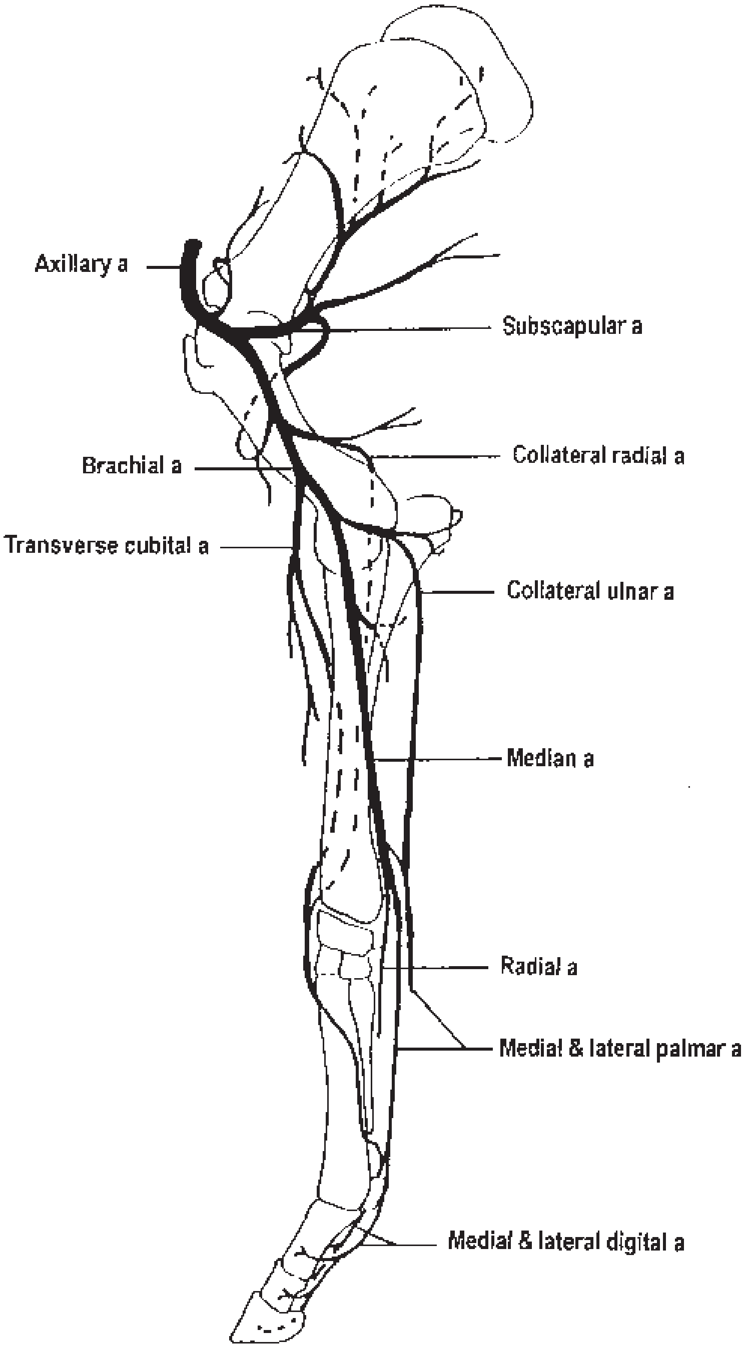


Figure 4-P: Arterial supply to the forelimb (medial aspect right forelimb)

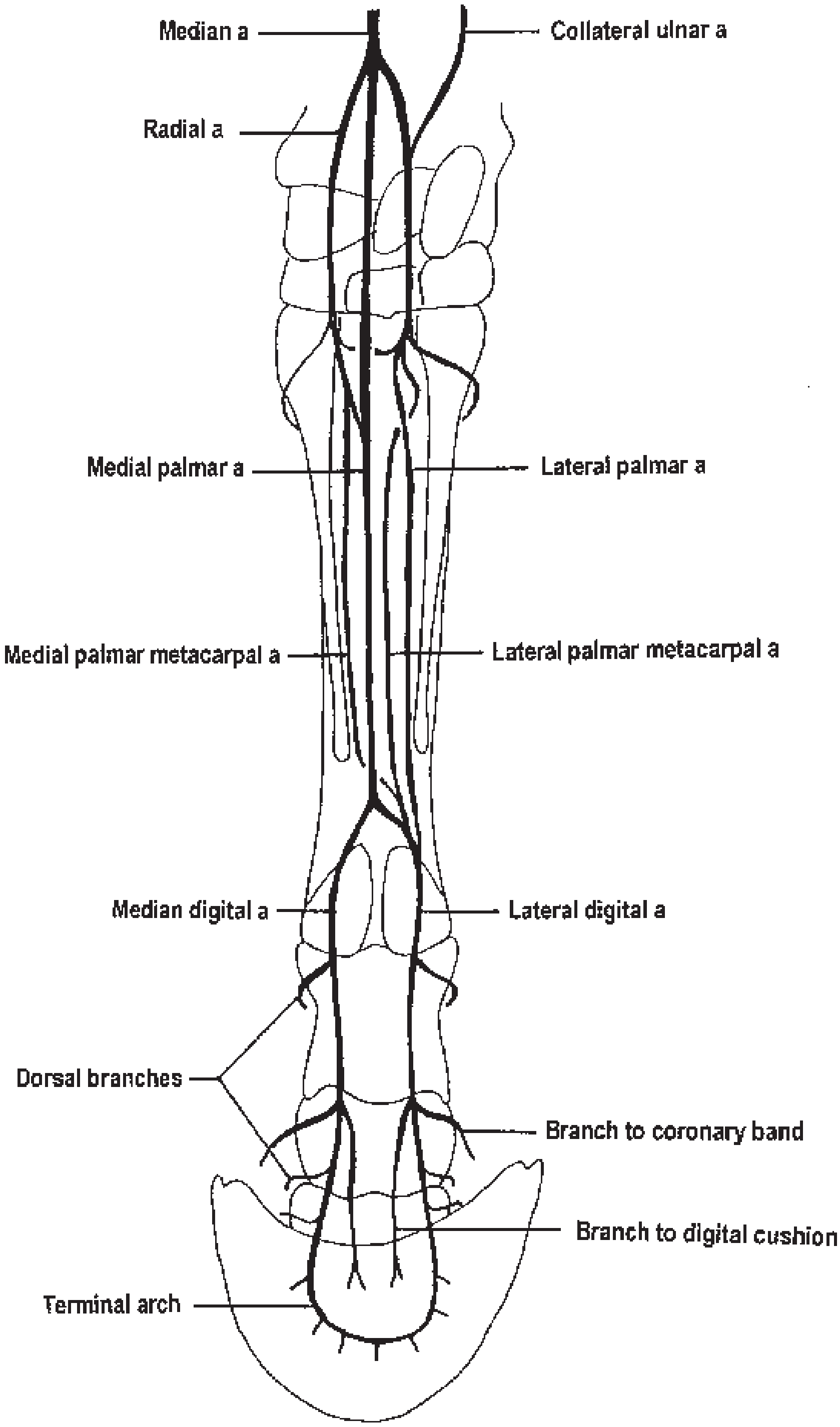


Figure 4-Q: Arterial supply to lower forelimb (Palmar aspect right fore-limb)

Within the foot, at the level of PIII, paired dorsal braches of the digital arteries arise adjacent to the navicular bone. These immediately branch again into:

- The **dorsal branches of PIII:** these pass through notches in the palmar processes and run in the parietal sulci. Terminal branches supply the laminar corium of heels, quarters and toe, and anastomose with the **circumflex arteries** (see below).
- The **palmar branches of PIII:** these contribute supply to the digital cushion and corium of the frog.

- The main digital arteries continue in grooves in the distal phalanx, giving off branches which contribute **most of the supply to the navicular bone**. Each then enters the **solar foramen** and medial and lateral digital arteries finally anastomose within the **solar canal** to form the **terminal arterial arch.**
  - Dorsal branches of the terminal arch perforate the dorsal surface of PIII and supply the **coronary and laminar corium.** They also form the **distal circumflex arteries** which receives tributaries from the dorsal branches of PIII, then runs over the toe to supply the **solar corium.**
  - Distal branches of the terminal arch open on the rim to form the **marginal artery** of the sole, which anastomoses extensively with the circumflex arteries. Note: *the central solar corium is heavily dependent on the circumflex arteries for its supply. Damage to these vessels by bruising pressure from tight toe clips, or excessive trimming of the wall results in necrosis of the sole.*

Veins of limbs (Fig 4-R)

Follow a similar pattern to those of the dog.

Veins which lie subcutaneously are vulnerable to laceration. Most important are:

- **cephalic** - on medial surface of radius
- **digital veins** at fetlock and pastern

Venous return from the distal limb of the horse presents a specialized problem. The muscular pump, which aids venous return in other animals, is compromised because:

- the terminal part of the digit is encased in a horny hoof
- extremes of cursorial adaptation have resulted in absence of muscle below carpus and tarsus.

Specialised mechanisms have therefore evolved to avoid vascular stasis, and to provide adequate blood drainage both during prolonged locomotion, and in periods of standing rest.

Venous drainage of the distal limb is characterised by a number **of venous plexuses,** which converge at the proximal edge of the lateral cartilages to form the **medial and lateral palmar/plantar digital veins,** which run proximally to become the **medial and lateral palmar/plantar veins.**

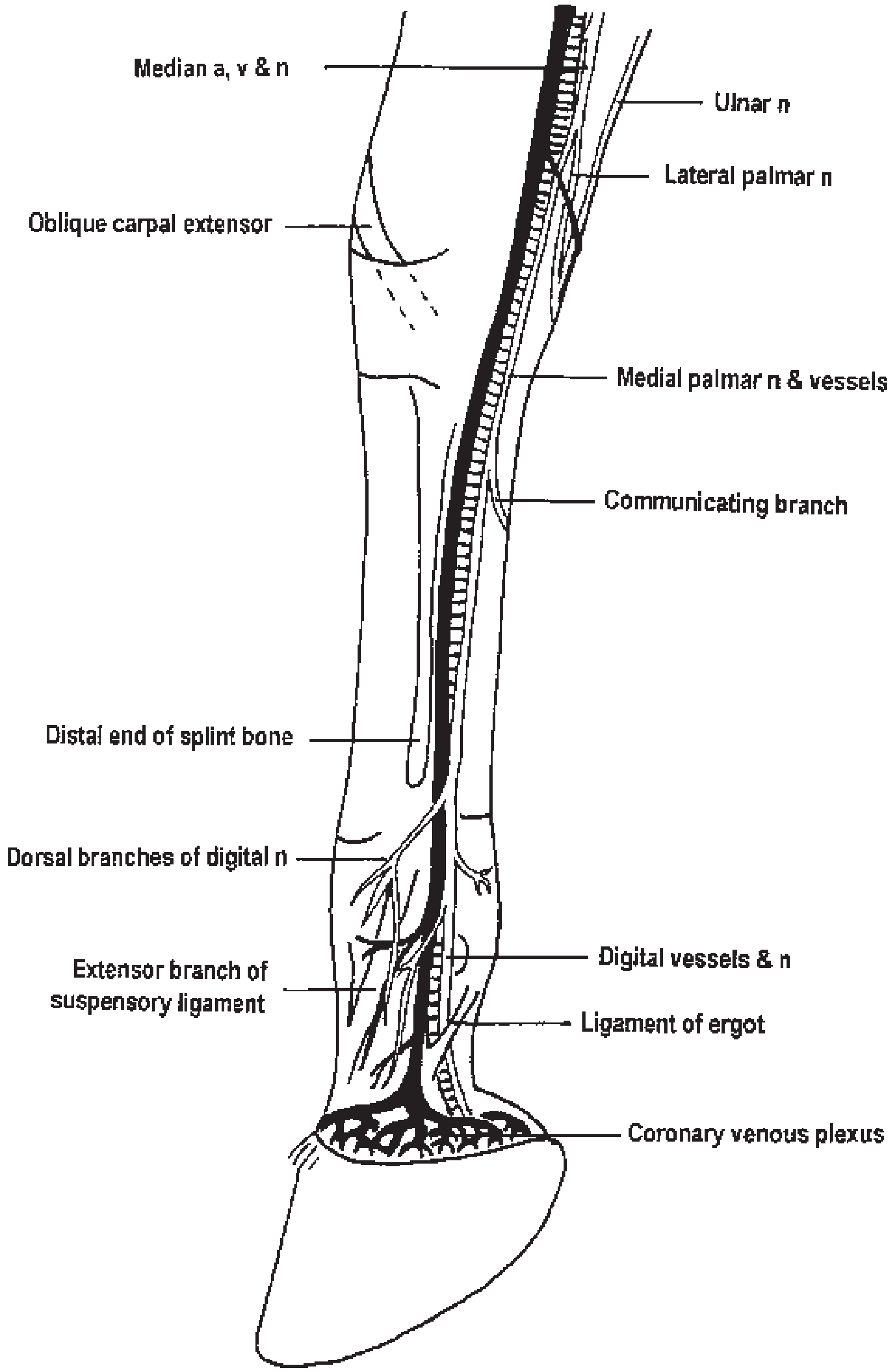


Figure 4-R: Vessels and nerves of medial fore limb

Venous plexuses of the hoof

i) Dorsal or laminar plexus

In laminar corium on dorsal surface of PIII. Drains into digital veins which emerge from the solar foramina of the distal phalanx.

ii) Coronary plexus (Fig 4.28)

Encircles foot at coronet, overlying extensor tendon and lateral cartilages. Drains into digital veins lying alongside the corresponding arteries.

iii) Palmar/plantar plexus

In solar corium. Anastomosing veins from this plexus join the coronary plexuses, via small foramina in lateral cartilages.

The venous plexuses are of major additional importance for two reasons:

- **Thermoregulation - arteriovenous anatomoses** are plentiful in the horse's foot, and during normal circumstances control loss of heat from the foot by shunting blood directly from arterioles to venules, bypassing the capillaries.

  They are also implicated in the cause of laminitis, when blood supply to the corium is severely compromised and laminar junctions can break down, with severe physiological and mechanical consequences.
- **Dissipation of concussive forces** (see later chapters)

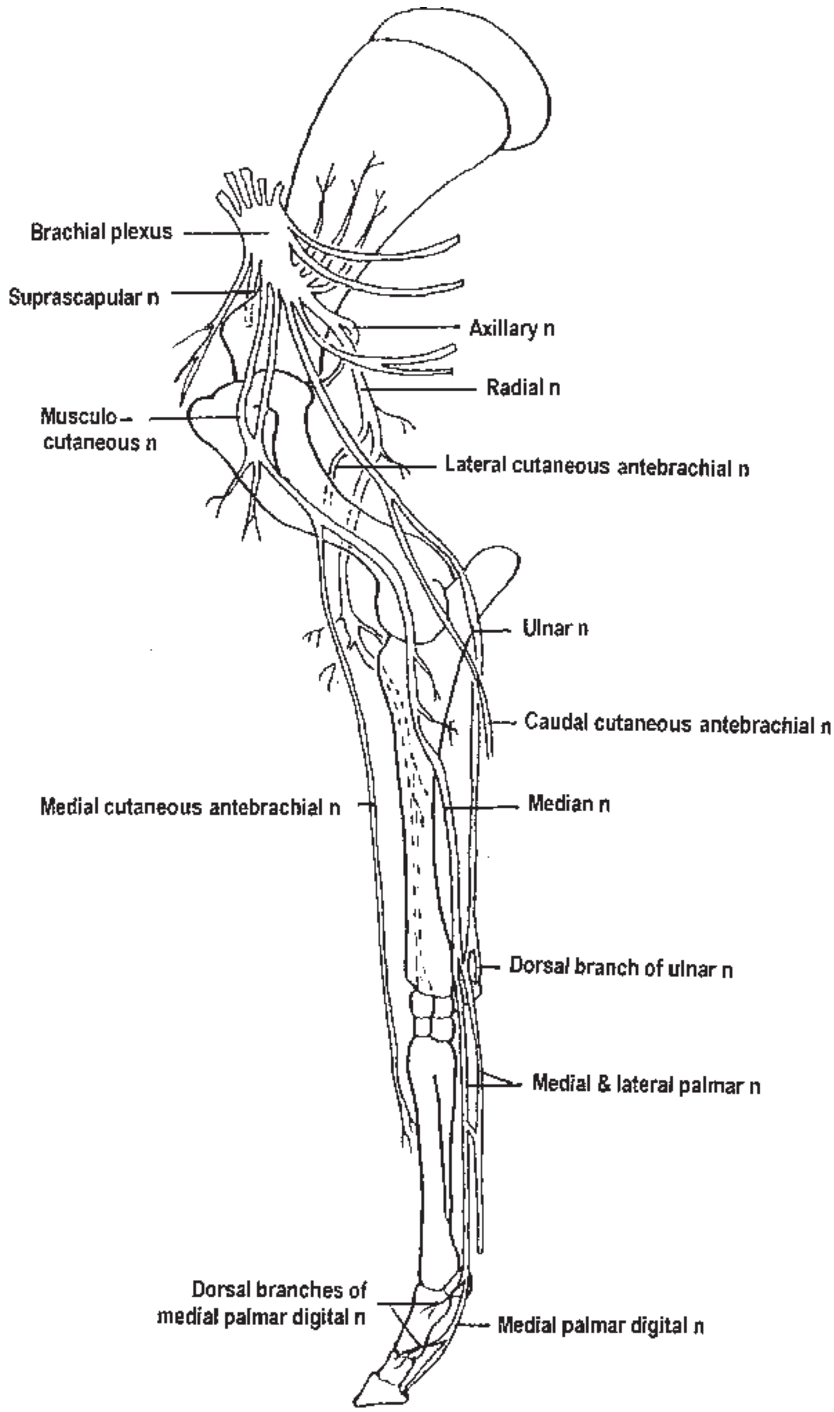


Figure 4-S: Innervation of the equine fore limb (medical aspect right forelimb)

Innervation of horse limbs

Clinically, it is important to understand innervation of the major muscle groups in order to assess nerve damage. In addition, local anaesthesia of sensory nerves supplying different regions of the lower limb is an established technique in diagnosing the site of lameness.

Innervation of forelimb (Fig 4.S)

Innervation of muscles is essentially similar to the dog:

a) Suprascapular nerve: (motor)

Mainly motor: crosses cranial edge of scapular neck to supply **supraspinatus and infraspinatus** muscles.

Damage: *flaccid paralysis of supraspinatus and infraspinatus - **shoulder slip.** Permanent damage results in atrophy (**sweeney**) in these muscles.*

b) Musculocutaneous nerve: (mixed)

i) Motor: Supplies **biceps, brachialis & coracobrachialis** muscles.

ii) Sensory branch (medial cutaneous antebrachial) leaves at distal forearm, (palpable across lacertus fibrosus), supplying **skin of medial forearm.**

Damage - *unusual, little effect.*

c) Radial nerve: (mixed)

Supplies **triceps** then runs to lateral surface in musculospiral groove to supply **all extensors of carpus and digit.**

Sensory (as lateral cutaneous antebrachial) to **skin of lateral forearm.**

Damage:

i) Whole nerve (e.g. avulsion injury in harness horse accidents) - limb cannot bear weight, dropped elbow, flexed knee and digit,

ii) Below triceps - no voluntary extension of foot, but may learn to compensate.

d) Axillary nerve: (mixed)

Motor: Supplies **flexors of shoulder**

Sensory: (as cranial cutaneous antebrachial) to **skin of cranial arm.**

Damage rare.

e) Median nerve: (mixed) Palpable on medial aspect of elbow under pectoral muscle.

Moto branches to **flexors of carpus and digit** leave at proximal forearm.

Main sensory supply to distal limb: continues on medial side, dividing above carpus to **medial and lateral palmar nerves** (see Fig 4.Q and 4.T).

Damage:

i) *little motor effect as functional overlap with ulnar nerve*

ii) *loss of sensation in the foot.*

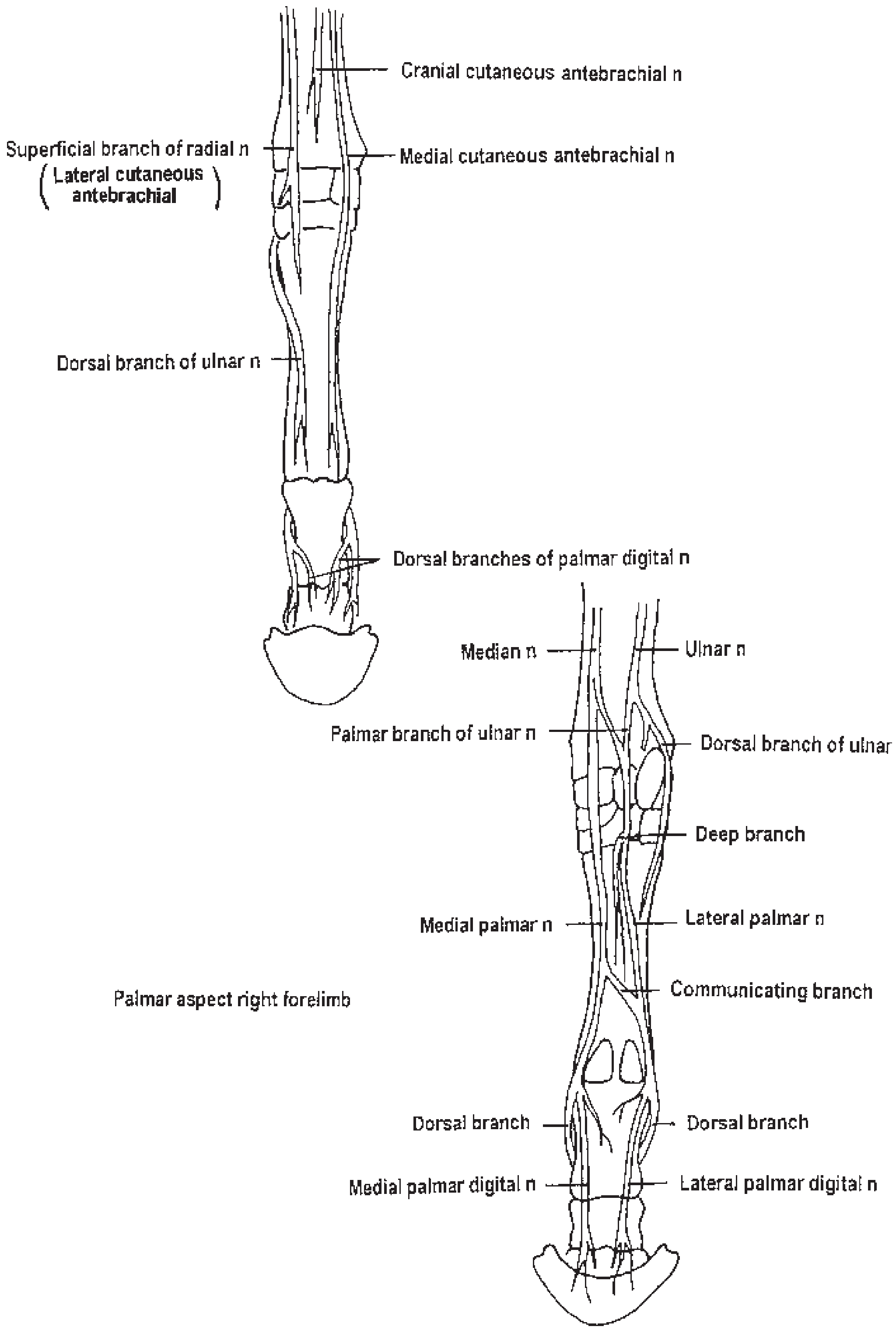


Figure 4-T: Innervation of the lower fore limb (Dorsal aspect right fore-limb)

f) Ulnar nerve: (mixed)

Passes caudal to medial epicondyle of humerus

Motor branches supply **flexors of carpus and digit**

Sensory:

– caudal cutaneous antebrachial, sensory to **skin of caudal forearm.**

– minor contribution to sensation in distal limb,

i) dorsal branch - supplies **skin of lateral metacarpus**

ii) palmar branch - contributes to lateral palmar nerve

Damage - *little effect as functional overlap -with median nerve.*

Innervation of forefoot (Fig 4.T)

Sensation in distal limb is supplied mainly by the terminal branches of the median nerve (medial and lateral palmar nerves).

a) Medial palmar nerve

Passes through carpal canal, and runs down metacarpus between DDFT and suspensory ligament with medial palmar artery and vein **Communicating branch** runs between medial and lateral palmar nerves, palpable over SDFT in mid-metacarpus. Above fetlock, becomes **medial palmar digital nerve.**

b) Lateral palmar nerve

Crosses carpus subcutaneously, joined by palmar branch of ulnar nerve. Deep branches **(palmar metacarpal nerves)** supply suspensory ligament and contribute to sensation in fetlock joint and skin of pastern.

Above fetlock, becomes **lateral palmar digital nerve.**

c) Medial and lateral palmar digital nerves

Each give off one or two **dorsal branches** - principal sensory supply to skin of pastern, coronary matrix and cranial third of foot.

Palmar branches continue over abaxial surface of proximal sesamoids, under ligament of ergot, into foot: supply sensation in caudal two-thirds of foot.

Clinical implications:

Local anaesthesia of foot (for therapeutic or diagnostic purposes) can only be achieved fully by anaesthesia of both palmar digital nerves before they give off the dorsal branch.

Anaesthesia of fetlock requires blockage of both palmar nerves and palmar metacarpal nerves at level of end of splint bones.

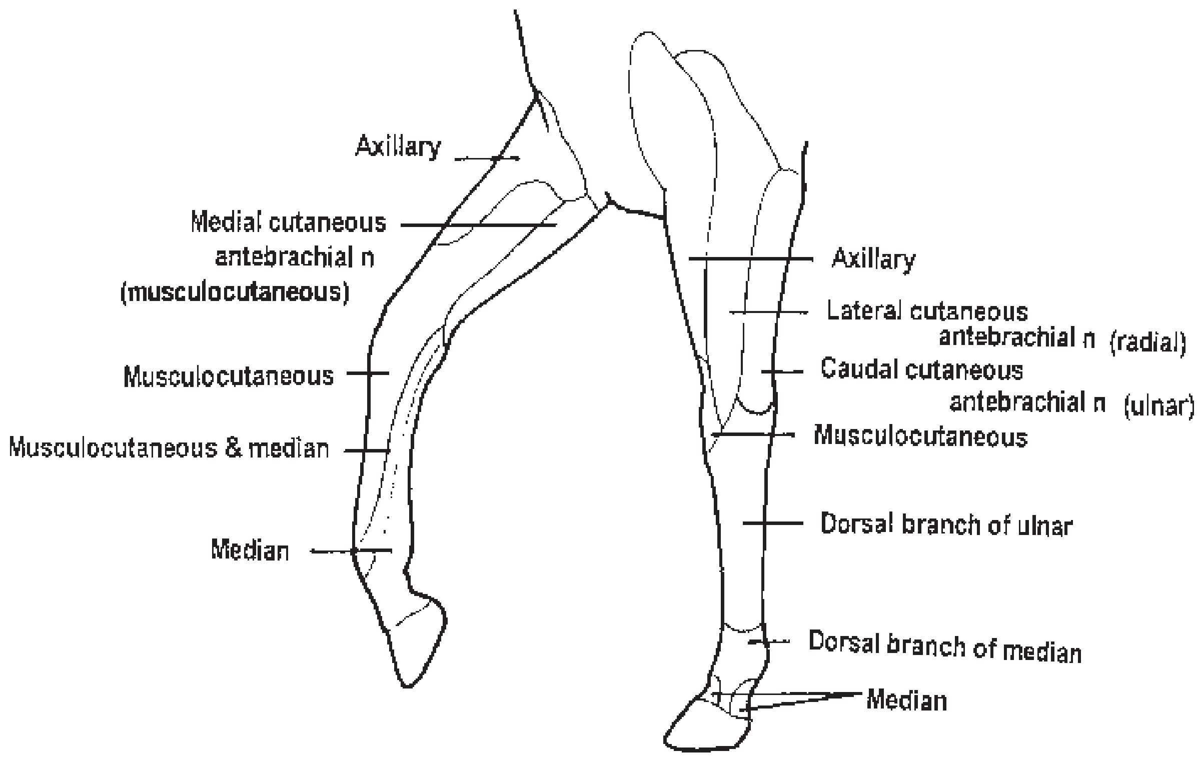


Figure 4-U: Cutaneous innervation of horse limbs

Chapter 5

Anatomy of the Pelvic Limb of the Dog

The hind limb of the dog

1. Bones and muscles

This chapter follows much the same format as the previous chapter. Once again, study the angles of the limb joints in Figure 5-A, and understand how the limb may be extended or withdrawn by extension or flexion of these joints. When you have a good understanding of the information in this Chapter, turn to Appendix 2 to relate underlying anatomical structures to topographical features in the live animal.

A. Muscles of the limb (See Fig. 5-A)

Muscles of the hindlimb are concerned entirely with moving the limb. Unlike the fore limb, the hind limb articulates with the trunk at the acetabulum.

An important difference in action when compared to the fore, is that in the hind limb:

– **extensors of digits flex the tarsus** (equivalent to dorsiflexion of the human ankle)
– **flexors of the digits extend the tarsus** (equivalent to ventriflexion of the human ankle)

NOTE: In the horse, the **reciprocal apparatus** link movement of the hock and stifle, so flexion and extension of the hock are dependent on muscles operating at the stifle rather than the digits.

As in the fore limb, muscles may have two or more functions.

Muscles, muscle groups and their actions

The following series of diagrams are presented as exercises for you to complete. By working through the diagrams and identifying muscles, their innervations and actions, you will gain a better understanding of the anatomy of the hind limb.

The origin and insertion of limb muscles are presented in Table 5-1. Use this table to identify the muscles in Figs 5-B to 5-H. From this information and your knowledge of the bony structure of the dog's limbs, WORK OUT THE ACTION OF EACH MUSCLE.

Usually, there is more than one muscle acting on any one joint, and so the muscles are grouped together according to their function (see Fig. 5-B to 5-H).

Innervation of muscle groups, and relationship to their actions

Frequently, all the muscles in a group are innervated by the same nerve. Use the information on the lumbosacral plexus and nerve supply to the hind limb, presented later in this chapter, to fill in the nerves for each muscle in Figs 5-B to 5-H.

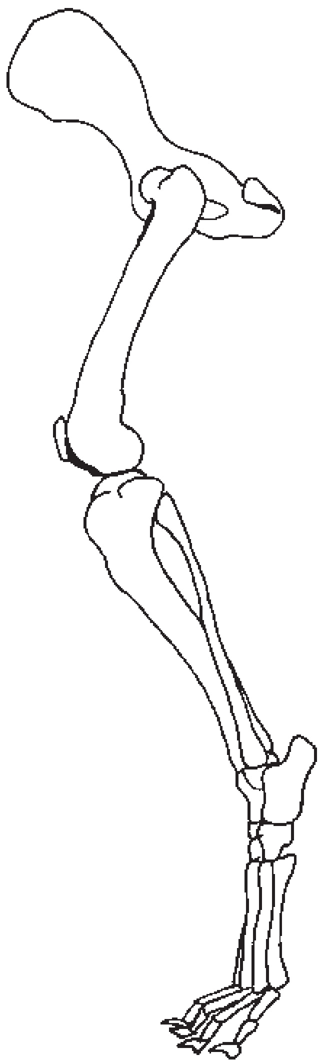


Figure 5-A: Flexion and extension in the hind limb

Consider which movements at each joint constitute flexion or extension.

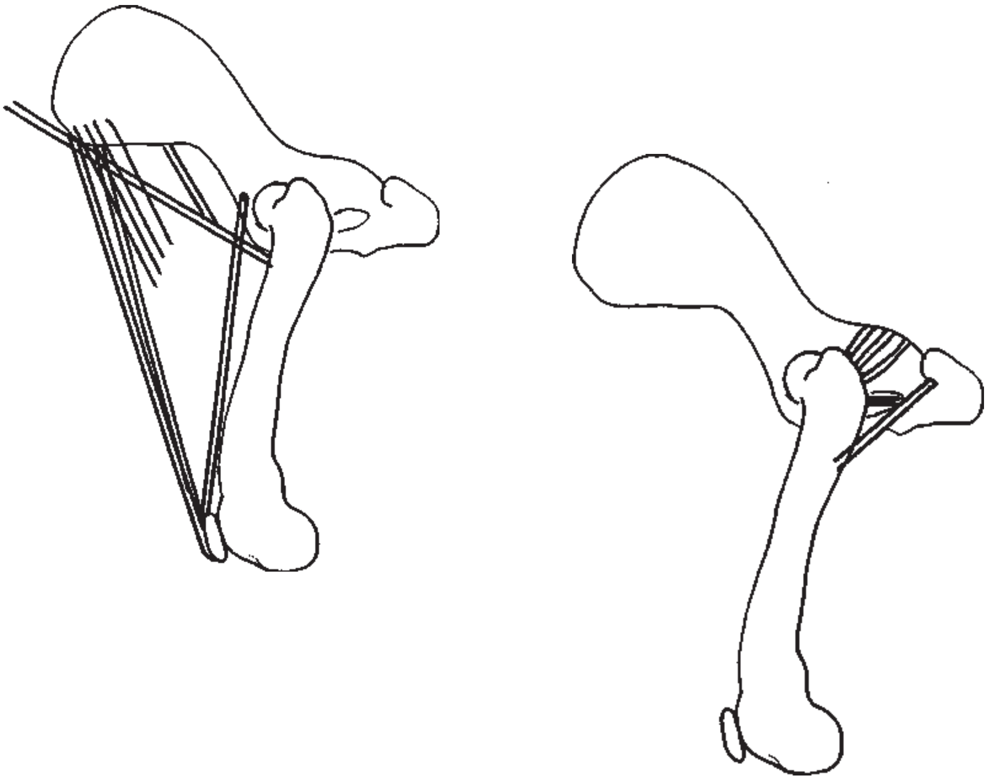


Figure 5-B

FLEXORS OF HIP	NERVE
1. Iliopsoas	______________
2. Rectus femoris	______________
3. Sartorius	______________
4. Tensor fasciae latae	______________

OUTWARD ROTATORS	NERVE
1. Internal obturator	______________
2. External obturator	______________
3. Gemellus	______________
4. Quadratus femoris	______________

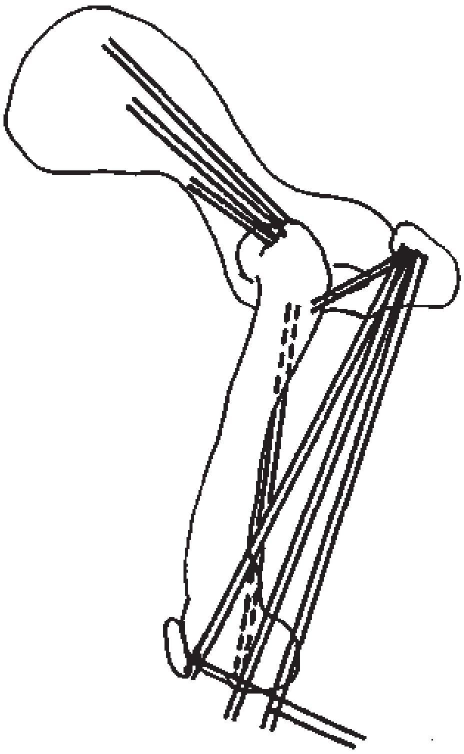


Figure 5-C

EXTENSORS OF HIP	**NERVE**
1. Biceps femoris	______________
2. Semitendinosus	______________
3. Semimembranosus	______________
4. Gluteals	
- superficial	______________
- middle	______________
- deep	______________
5. Quadratus femoris	______________
6. Gracilis	______________

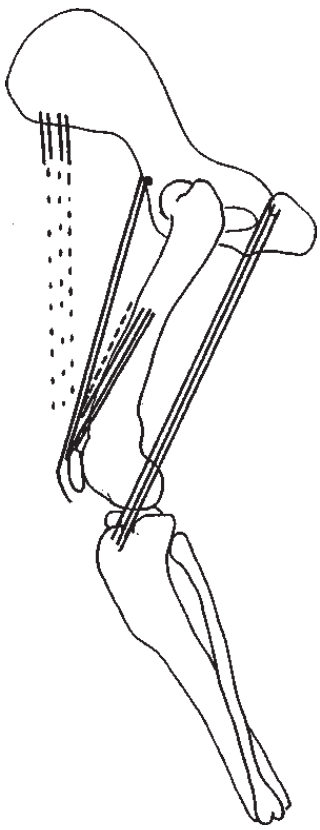


Figure 5-D

EXTENSORS OF STIFLE	**NERVE**
1. Biceps femoris	____________________
2. Semitendinosus	____________________
3. Semimembranosus	____________________
4. Quadriceps femoris	____________________
5. Tensor fasciae latae	____________________

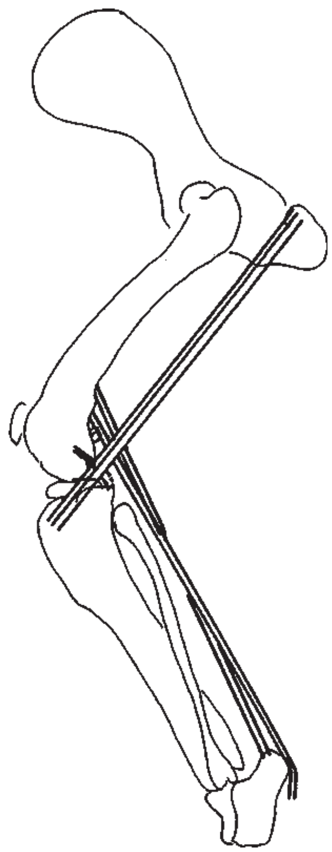


Figure 5-E

FLEXORS OF STIFLE	**NERVE**
1. Gastrocnemius	______________________
2. Popliteus	______________________
3. Superficial digital flexor	______________________
4. Hamstring mm.	______________________

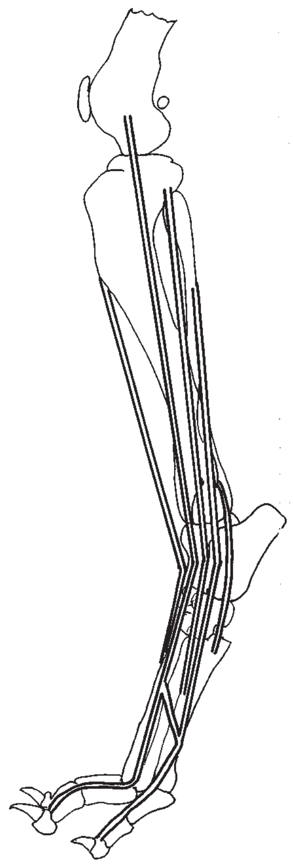


Figure 5-F

FLEXORS OF TARSUS	**NERVE**
1. Long digital extensor	______________________
2. Cranial tibial	______________________
3. Peroneus longus + brevis	______________________

EXTENSORS OF DIGITS	**NERVE**
1. Long digital extensor	______________________
2. Lateral digital extensor	______________________

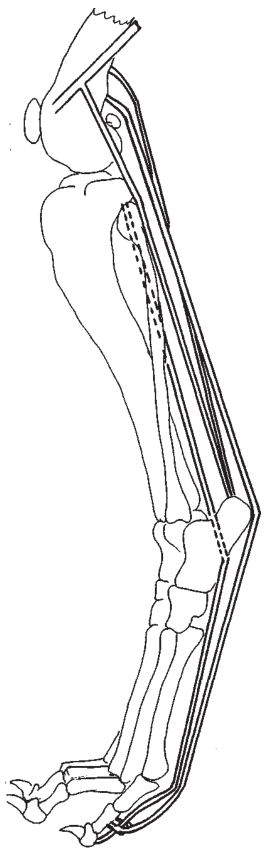


Figure 5-G

EXTENSORS OF TARSUS	NERVE
1. Biceps femoris	______________________
2. Semitendinosus	______________________
3. Gastrocnemius	______________________
4. (+ soleus in cat)	______________________
5. Superficial digital flexor	______________________

FLEXORS OF DIGITS	NERVE
1. Superficial digital flexor	______________________
2. Deep digital flexor	______________________
3. Interosseous mm.	______________________
4. Interflexorius	______________________
5. Lumbricales	______________________
6. Digital mm.	______________________

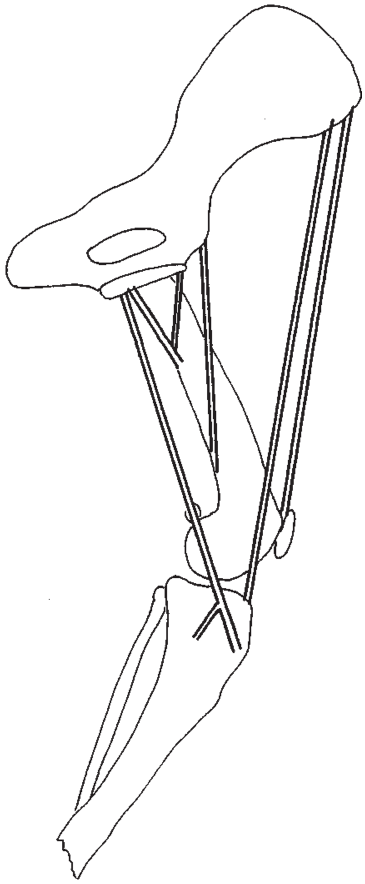


Figure 5-H

ADDUCTORS OF THE HIND LEG	**NERVE**
1. Sartorius	______________________
2. Gracilis	______________________
3. Adductor magnus et brevis	______________________
4. Adductor longus	______________________
5. Pectineus	______________________

TABLE 5-1**: Fill in the ACTION of each muscle. (All muscles listed here apply to the dog.)**

Muscles of the hindlimb

SUBLUMBAR MUSCLES	**Action**
Iliopsoas Origin - L2-L7; ventral surface of ilium Insertion - Lesser trochanter of femur	
FASCIAL TENSOR	**Action**
Tensor Fasciae Latae Origin - Coxal tuber of ilium Insertion - Fascia lata (fascia over quadriceps femoris)	
CLOSE MUSCLES OF HIP	**Action**
Superficial Gluteal Origin - Sacral tuberosity of ilium, sacrum, caudal vertebrae, and sacrotuberous ligament Insertion - Third trochanter of femur	
Middle Gluteal Origin - Lateral surface of ilium Insertion - Greater trochanter of femur	
Deep Gluteal Origin - Lateral surface of ilium Insertion - Greater trochanter of femur	
Piriformis Origin - Sacrotuberous ligament Insertion - Third trochanter of femur	
Internal Obturator Origin - Dorsal surfaces of ischium and pubis Insertion - Trochanteric fossa of femur	
External Obturator Origin - Ventral surface of pubis adjacent to the symphysis pubis Insertion - Trochanteric fossa of femur	

CLOSE MUSCLES OF HIP (continued)	Action
Gemellus Origin -Lateral surface of ischium Insertion - Trochanteric fossa of femur	
Quadratus Femoris Origin - Ischiatic tuberosity Insertion - Trochanteric fossa	
Pectineus Origin - Pecten of pubis Insertion - Lower caudal surface of femur	

MUSCLES OF THE THIGH	Action
Caudal muscles: the Great Extensors of the Hip **Biceps Femoris (a large muscle)** Origin - Ischial tuberosity Insertion - Tibial tuberosity; patella, tuber calcis of the calcaneus	
Semitendinosus (large) Origin - Ischial tuberosity Insertion - Medial surface of tibia, tuber calcis of the calcaneus	
Semimembranosus (shorter than semitendinosus) Origin - Ischiatic tuberosity Insertion - Medial surfaces of femur and tibia	
Caudal Crural Abductor (Tenuissimus: a thin strap-like muscle) Origin - Sacrotuberous ligament Insertion - Crural fascia	

MUSCLES OF THE THIGH (continued)	Action
Cranial Muscles of the Thigh **Quadriceps Femoris (consists of four heads)** Origins 1. Rectus femoris - Tuberosity of rectus femoris. 2. Vasti: - Medial Vastus - Medio-cranial surface of proximal femur - Lateral Vastus - Latero-cranial surface of proximal femur - Intermediate Vastus – Cranial surface of proximal femur. Insertions - All onto patella →distally onto tibial tuberosity.	
There are also two small muscles of the thigh. **Capsularis Coxae** Origin - Iliopubic eminence of ilium Insertion - Neck of femur	
Articularis Genus Origin - Cranial surface of distal femur Insertion - Tibial tuberosity	

ADDUCTOR MUSCLES	Action
MEDIAL **Sartorius** Origin - Tuber coxae of ilium Insertion - Cranial border of tibia	
Gracilis Origin - Pelvic symphysis Insertion - Cranial border of tibia, tuber calcis of calcaneus	
Adductors (two) 1. Adductor Magnus et Brevis (larger) Origin - Pelvic symphysis (mainly symphyseal tendon) 2. Adductor Longus (smaller - fusiform) Origin - Pubic tubercle Common Insertion - Close to the third trochanter extending down to origin of gastrocnemius (closely associated with Pectineus and insertion of Quadratus Femoris)	

EXTENSORS OF HINDLIMB	Action
Cranial Tibial Origin - Tibial crest Insertion - Proximal part of 2nd metatarsal II	
Long Digital Extensor Origin - Lateral epicondyle of femur Insertion - 3rd phalanx of digits II-V	
Peroneus Longus Origin - Upper extremity of tibia and fibula Insertion - Upper part of metatarsals I, II, V	
Peroneus Brevis Origin - Distal two-thirds of tibia and fibula Insertion - Proximal part of Vth metatarsal	
Lateral Digital Extensor Origin - Proximal third of fibula Insertion - Long digital extensor tendon of Vth digit	

CAUDAL MUSCLES	Action
Gastrocnemius (two heads) Origin - Just outside the popliteal surface of the femur Insertion - Tuber calcis	
Superficial Digital Flexor Origin - Popliteal surface of femur and lateral fabella (united with head of gastrocnemius) Insertion - Tuber calcis; 2nd phalanx of digits II-V	
Deep Digital Flexor (2 main heads: Lateral - Flexor Hallucis Longus; and Medial - Flexor Digitorum Longus) Origin - Upper part of fibula and upper caudo-lateral part of tibia Insertions - 3rd phalanx of digits II-V	
Tibialis Caudalis Origin - Upper medial part of fibula Insertion - Medial ligaments of tarsus	

CAUDAL MUSCLES (continued)	Action
Popliteus Origin - Lateral condyle of femur Insertion - Medial border of tibia	
MUSCLES OF THE PAW	
DORSAL	
Short Digital Extensor (Extensor Digitorum Brevis) Origin - Lower part of calcaneus Insertion - Upper part of digits II-IV	
PLANTAR	
Interflexorii (two muscles) Origin - Deep digital flexor tendon Insertion - 3rd and 4th branches of deep digital flexor	
Abductor Digiti Quinti Origin - Tuber calcis Insertion - Head of the Vth metatarsal The Interosseit Lumbricales, Adductor Digiti Secundi CH) and Adductor Digiti Quinti (V) are the same as the corresponding muscles in the forelimb.	

B. Bones of the hind limb

Again, this section is intended to extend your knowledge of the osteology of the dog, with respect to the locomotory apparatus.

Use the checklist of bones and labelled diagrams in Figures 5-I to 5-K, to familiarise yourself with the bones of the limbs. Extra features, included because they have importance in locomotion, are identified by an asterisk.

During the residential part of the course, make sure that you are also quite familiar with actual specimens of these bones .

Under the heading “Significance”, write in the importance of each feature to locomotion. In many cases, this will be a muscle attachment and the diagrams of origins and insertions of muscles in “Guide to the Dissection of the Dog” (Evans and Delahunta) and in “Miller’s Anatomy of the Dog” will be useful to identify them. In other cases, it may be an articular surface (consider the other articulating body) or the pathway for a tendon.

You are unlikely to be able to complete this initially, but as you acquire knowledge of the limb muscles, attempting this exercise will reinforce your knowledge of both the bones and muscles and increase your understanding of how they operate together.

Hind limb

OS COXAE	Significance
Ilium	____________________
Ilium - wing	____________________
Ilium - body	____________________
Tuber coxae	____________________
Tuber sacrale	____________________
*Iliopubic eminence	____________________
Tuberosity of Rectus Femoris (Iliopectineal eminence)	____________________
Pubis	
*Pecten of pubis	____________________
*Pubic tubercle	____________________
Pubic symphysis	____________________
Obturator foramen	____________________
Acetabular fossa	____________________
Acetabular notch	____________________
Ischium	
Ischiatic tuberosity	____________________
*Lesser sciatic (ischiatic) notch	____________________
*Ischiatic symphysis	____________________
*Sacrotuberous ligament	____________________

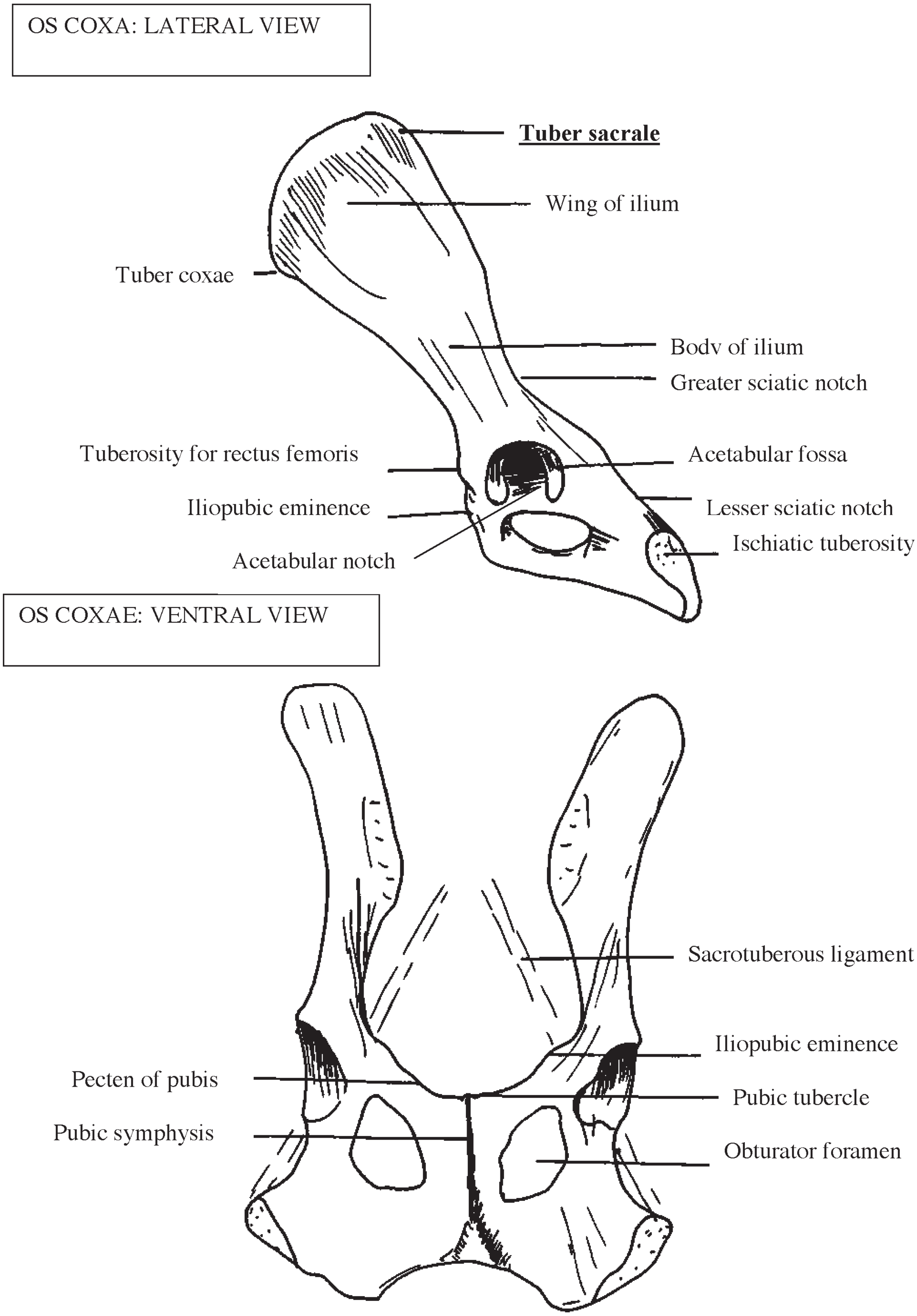

OS COXA: LATERAL VIEW
Tuber sacrale
Wing of ilium
Tuber coxae
Bodv of ilium
Greater sciatic notch
Tuberosity for rectus femoris
Acetabular fossa
Iliopubic eminence
Lesser sciatic notch
Ischiatic tuberosity
Acetabular notch
OS COXAE: VENTRAL VIEW
Sacrotuberous ligament
Iliopubic eminence
Pecten of pubis
Pubic tubercle
Pubic symphysis
Obturator foramen

Figure 5-1

FEMUR	**Significance**
Head	______________________
*Fovea	______________________
Neck	______________________
Greater trochanter	______________________
Lesser trochanter	______________________
*Third trochanter	______________________
*Intertrochanteric crest	______________________
*Trochanteric fossa	______________________
Shaft	______________________
*Popliteal surface	______________________
Lateral epicondyle	______________________
Medial epicondyle	______________________
Lateral condyle	______________________
Medial condyle	______________________
Trochlea	______________________
Patella	______________________
*Fabellae	______________________

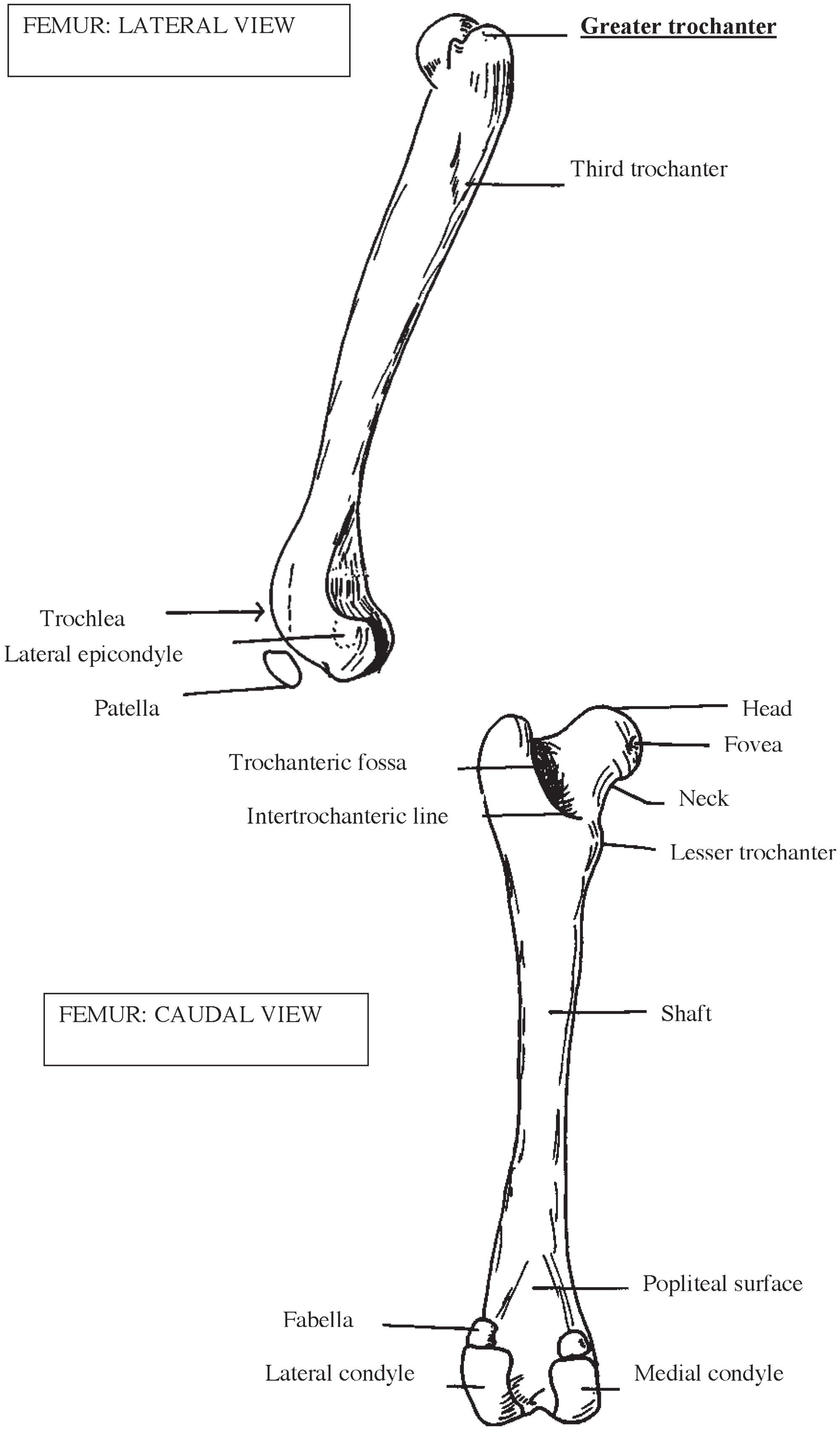

FEMUR: LATERAL VIEW
Greater trochanter
Third trochanter
Trochlea
Lateral epicondyle
Patella
Head
Fovea
Trochanteric fossa
Neck
Intertrochanteric line
Lesser trochanter
FEMUR: CAUDAL VIEW
Shaft
Popliteal surface
Fabella
Lateral condyle
Medial condyle

Figure 5-J

TIBIA and FIBULA	**Significance**
Lateral condyle	__________________________
Medial condyle	__________________________
*Intercondylar eminence	__________________________
*Popliteal notch	__________________________
Tibial tuberosity	__________________________
Cranial border	__________________________
Medial malleolus	__________________________
Lateral malleolus	__________________________
*Tibial cochlear	__________________________

TARSUS	
Calcaneus	__________________________
Tuber calcis	__________________________
Talus	
*Trochlea	__________________________
Central tarsal	__________________________
I-IV distal tarsals	__________________________

METATARSALS II-V	__________________________
DIGITS II-V	__________________________
Proximal, middle and distal phalanges	__________________________

A dew claw (digit I) is sometimes present and then variably developed.

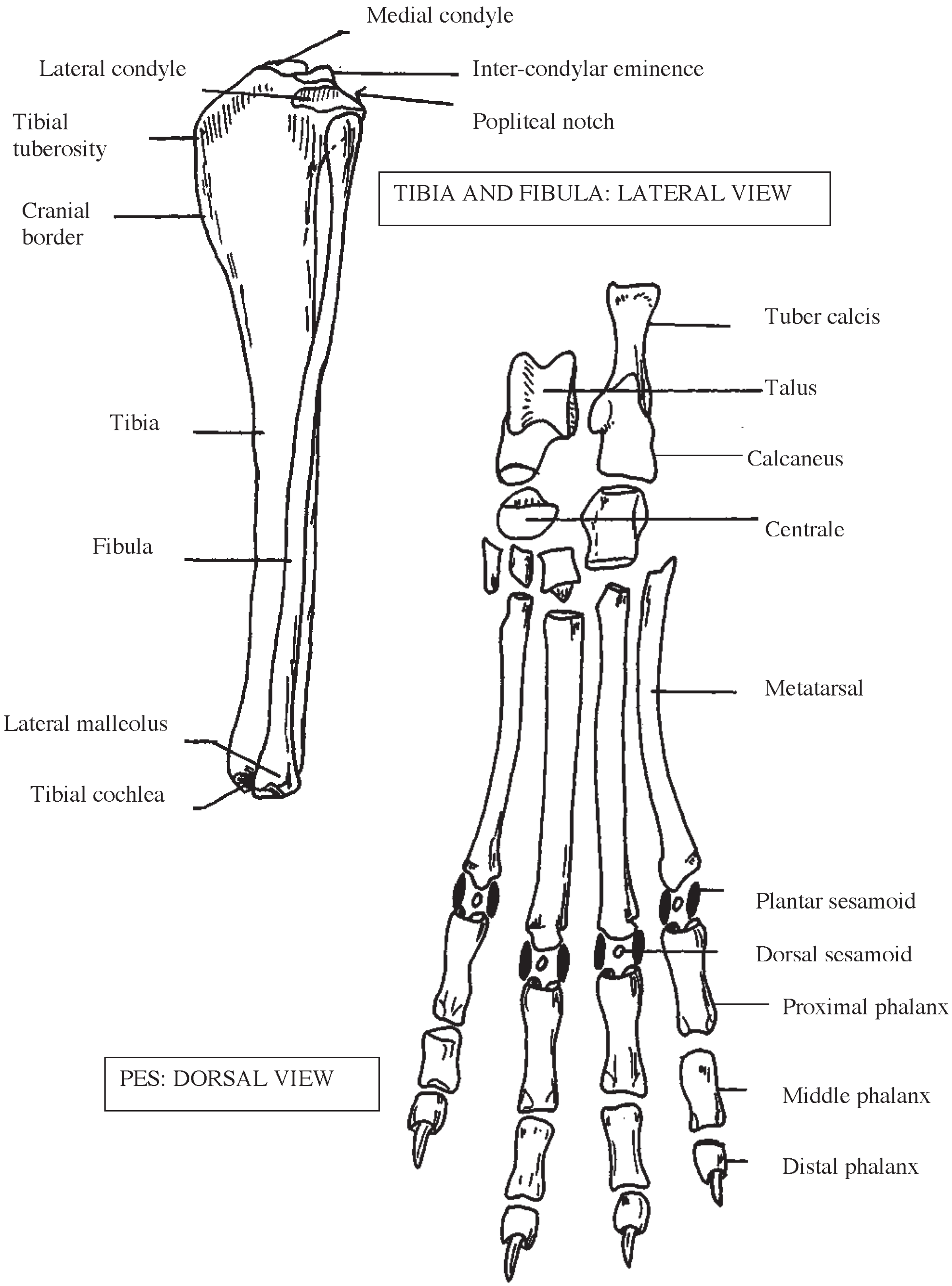

Medial condyle
Lateral condyle
Inter-condylar eminence
Tibial tuberosity
Popliteal notch
Cranial border
TIBIA AND FIBULA: LATERAL VIEW
Tibia
Fibula
Lateral malleolus
Tibial cochlea
Tuber calcis
Talus
Calcaneus
Centrale
Metatarsal
Plantar sesamoid
Dorsal sesamoid
Proximal phalanx
PES: DORSAL VIEW
Middle phalanx
Distal phalanx

Figure 5-K

The hind limbs of the dog

2. Nerves

Innervation of the limbs

It is recommended that you study carefully Fig 5-L, which illustrates the arrangement of nerves in the lumbosacral plexus.

IMPORTANT NOTE: Again, Dorsal Division Nerves and Ventral Division Nerves referred to in Fig. 5-L, do NOT refer to nerves supplying Dorsal and Ventral Muscle Masses respectively. They refer to the relative topographical position of the nerves in the plexuses. Although they roughly correspond to Dorsal and Ventral Muscle Mass Nerves, they are not the same, e.g. the Fibular (Peroneal) Nerve supplies the ventral muscle mass, but emerges dorsally in the lumbosacral plexus and is thus a dorsal division nerve.

Next, observe Fig. 5-M, which shows the nerves of the hind limb of the dog. Fill in the muscle groups which these nerves supply, as you did in Chapter 3 for the fore limb.

(When you have finished this exercise, you will then be in a position to fill in the nerve supplies to the different muscles and muscle groups in Figs 5-B to 5-H).

Cutaneous (sensory) innervation of the hind limb

Familiarize yourself with Fig. 5-N to 5-O which represent the cutaneous innervation of the limbs. This knowledge, together with understanding of innervation of muscles and muscle groups, can be important in identifying lesions in particular nerves.

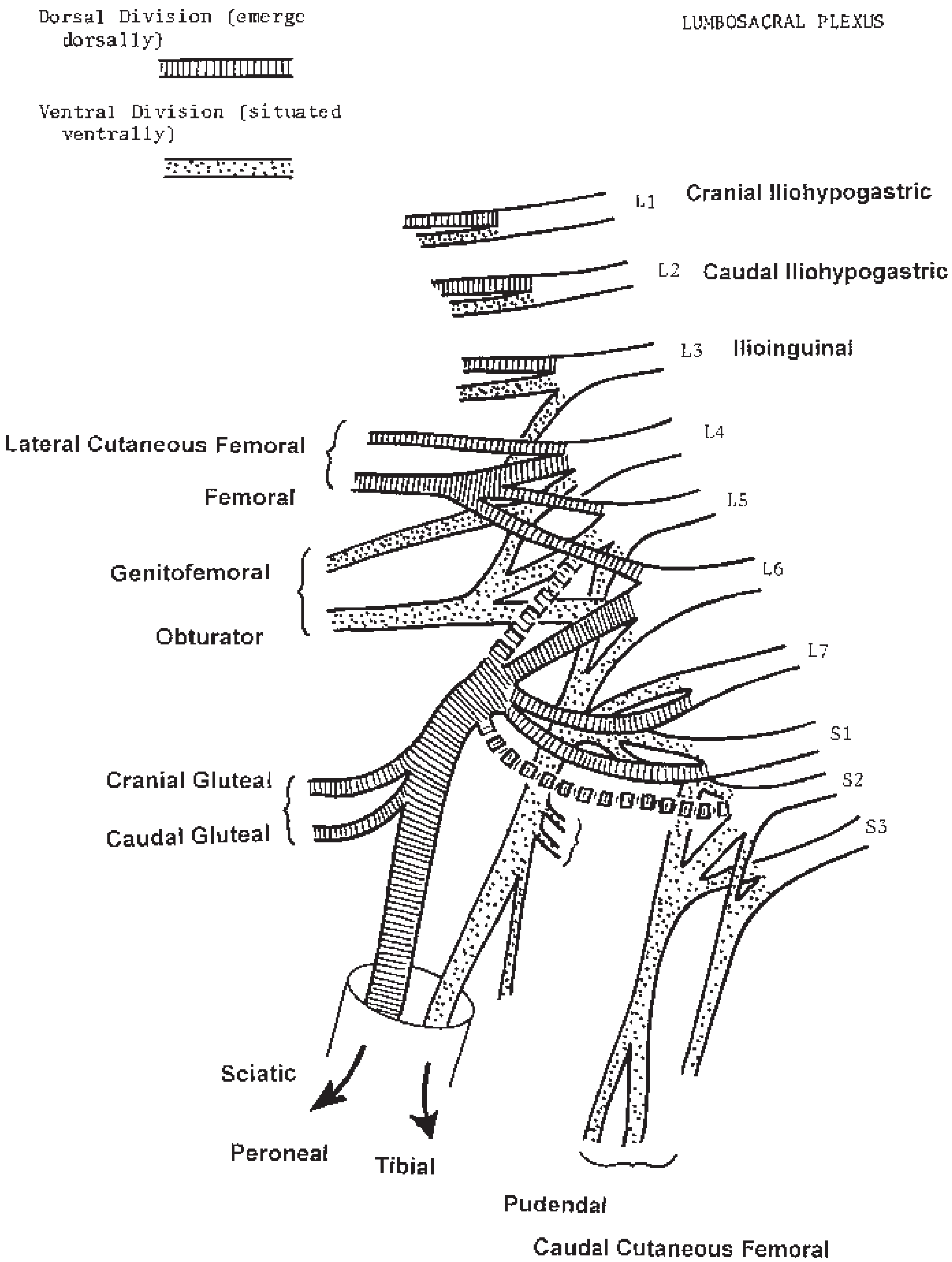


Figure 5-L: Lumbosacral plexus

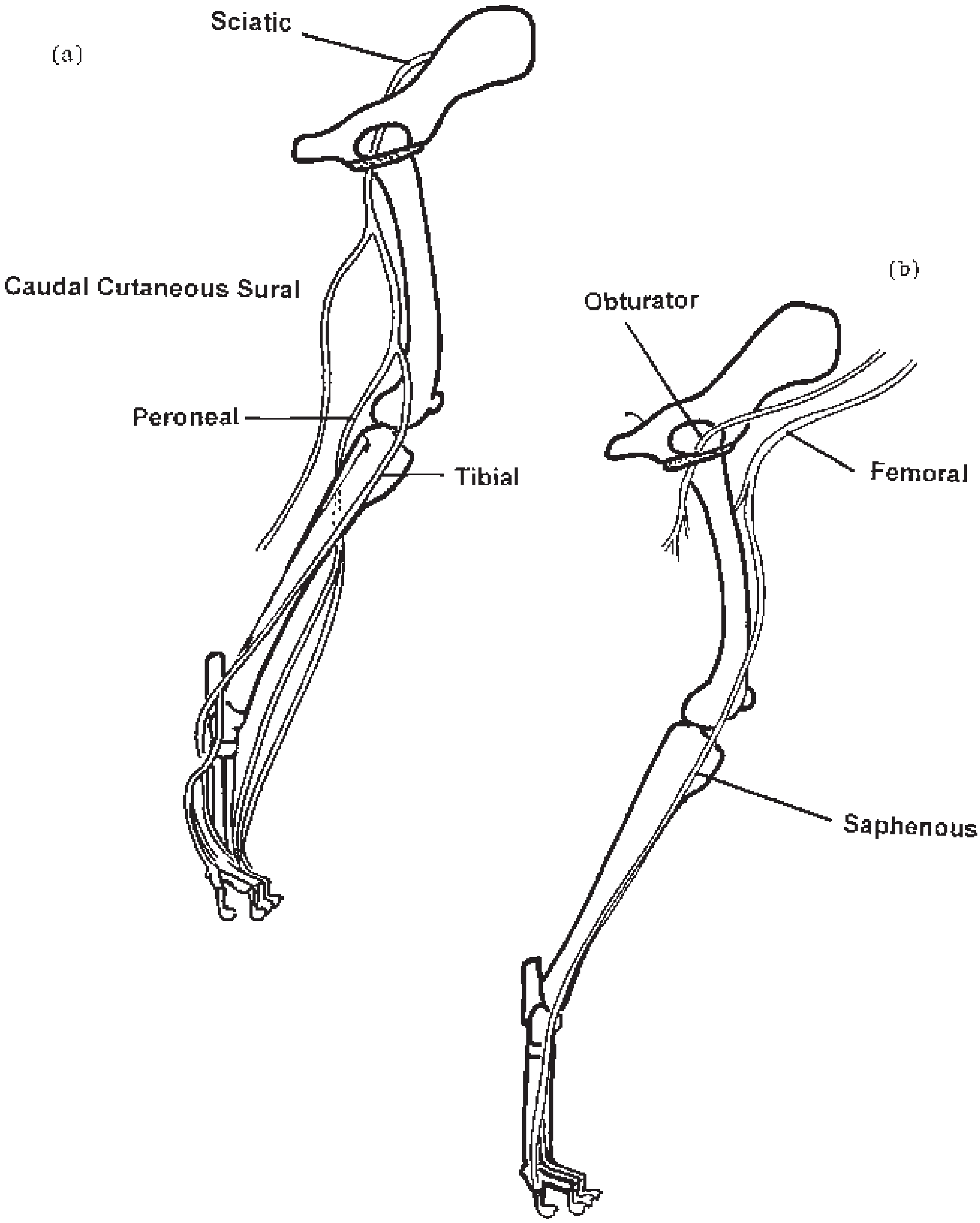


Figure 5-M: Innervation of the hind limb muscles

Fill in the muscle groups

Cutaneous (sensory) branches of the major nerves of the hindlimb

P - Peroneal
S - Saphenous
T - Tibia
LCF - Lateral cutaneous femoral
CCF - Caudal cutaneous femoral
LCS - Lateral cutaneous sural
CCS - Caudal cutaneous sural

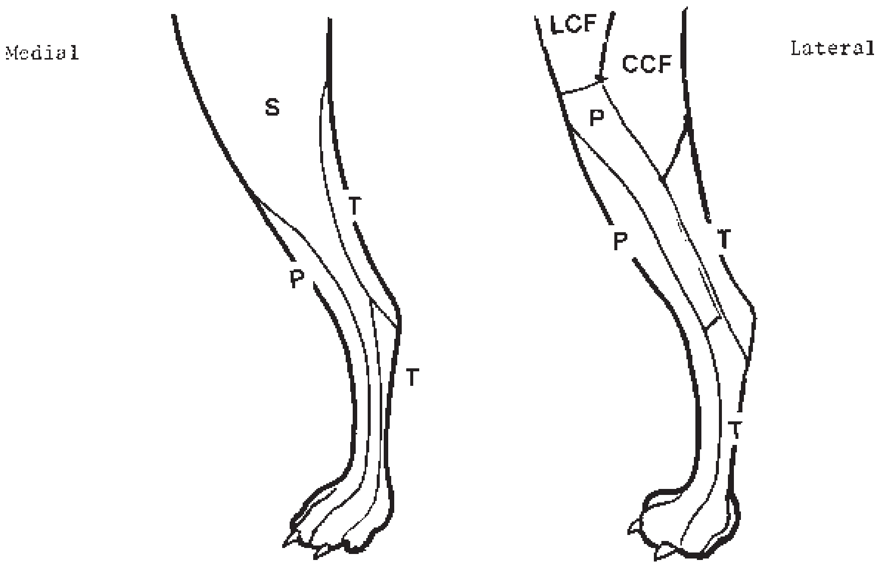


Figure 5-N

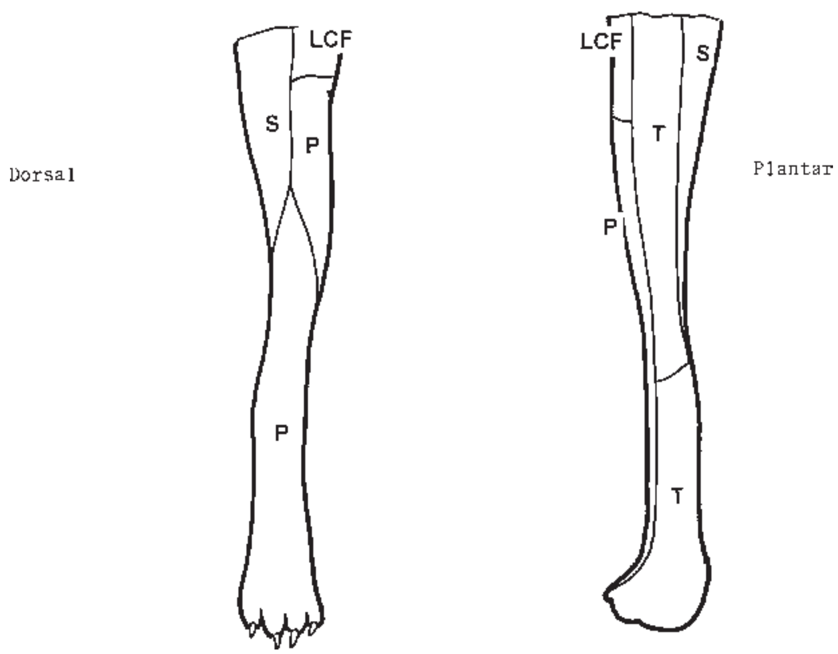


Figure 5-O

The hind limbs of the dog

3. Joints

Sacroiliac joint (Fig. 5-P)

(Usually included as a limb joint, as it affects hindlimb action.)

Type of Movement: This joint is designed for stability (arthrodia).

Joint Capsule: This is very thin and the auricular surfaces of the wings of ilium and sacrum have fibrocartilage interposed. It is more firmly attached to the sacrum and joins the two bones craniodorsally in relation to the synovial part of the joint.

Ligaments:

1. Dorsal and Ventral Sacroiliac Ligaments: Their position is obvious from their names.
2. Sacrotuberous Ligament - This ligament extends from the caudal extremity of the sacrum and the first two coccygeal vertebrae to the lateral surface of the tuber ischii. It is usually embedded in the superficial gluteal muscle.

Hip joint (Fig. 5-Pa and b)

(This is a much more important joint in locomotion.)

Type of Movement: Flexion and extension. Outward and inward rotation (enarthrosis).

Joint Capsule: Simple with fibrous thickenings, but no ligaments. It is extensive.

Ligaments:

1. The acetabulum is deepened by a peripheral fibrocartilaginous lip - Acetabular Lip. This continues across the acetabular notch as a free ligament - **Transverse Acetabular Ligament**.
2. **Ligament of the Head of the Femur**: (Ligamentum Capitis Femoris - older terms are **Round Ligament** or Ligamentum Teres) - This ligament extends from the **fovea capitis** to the **acetabular fossa**. It is covered by synovial membrane and may blend with the transverse acetabular ligament.

Stifle joint (Fig. 5-Q)

This is a complex joint which includes three articulations,

– one between the femur and the tibia - **Femorotibial Articulation**,
– one between the femur and the patella **- Femoropatella Articulation,** and
– one **between the tibia and fibula**.

Type of Movement: The main joint is the femorotibial. Here, flexion and extension are the main movements, although it would appear that a modicum of rotation of the tibia is possible (ginglymus).

The femoropatella joint is designed for limited dorsal and ventral movement of the patella over the trochlear of the femur (probably arthrodia).

Joint Capsule: The joint capsule has a number of diverticula or pouches.

1. Passes round the trochlea and under the patella and round the sides of the epicondyles.
2. Extends under the tendon of origin of the Long Digital Extensor.
3. Pouches caudally to the proximal articulation between the tibia and fibula.
4. Caudal pouch extending dorsally between the fabellae in the head of the Gastrocnemius and the proximal surface of the condyles of the femur.

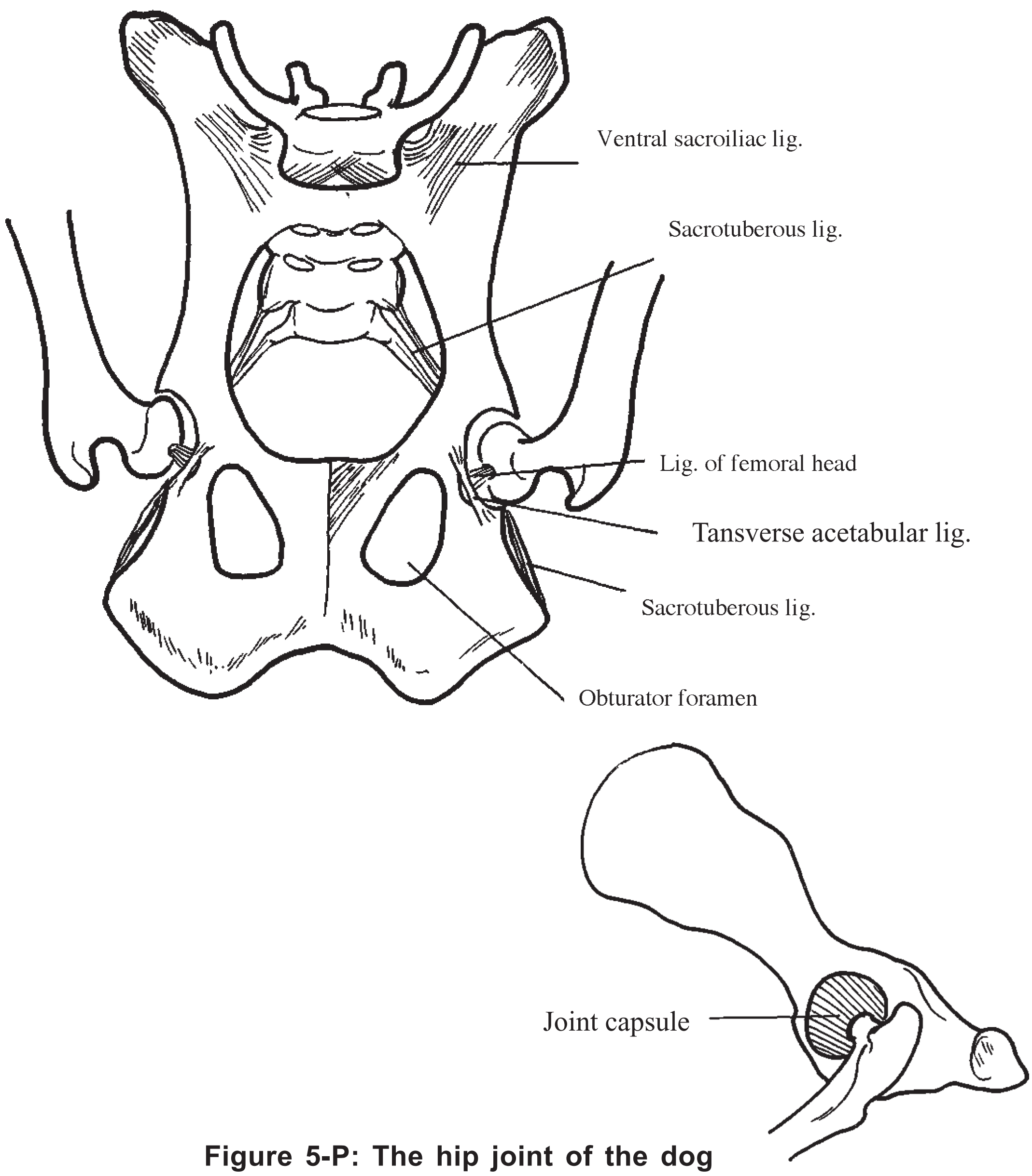


Figure 5-P: The hip joint of the dog

The joint is a compound joint with two cartilages [Menisci) intervening between the femur and the tibia. Between each meniscus, however, the articular surfaces of each bone are in contact.

Ligaments:

1. **Meniscal Ligaments** - Each meniscus is joined to its fellow cranially -Transverse Ligament, and is attached to the tibial spine by two ligaments.
2. The lateral Meniscus has an extra Ligament (**Meniscofemoral**) to the Intercondyloid Fossa of the Femur (so this meniscus has0 three meniscal ligaments, whilst the medial one has only two).

   In addition to the meniscal ligaments, there are seven other ligaments in the stifle joint. These are:

3&4. **Lateral and Medial Collateral Ligaments** (i.e. Fibular Collateral Ligament and Tibial Collateral respectively).

5&6. **Cranial and Caudal Cruciate Ligaments** (these lie entirely within the joint capsule).

7&8. **Lateral and Medial Femoropatellar Ligaments**.

9. A single **Distal Patellar Ligament**.

Tibial-fibular articulation

Type of Movement: Virtually none - there is no evidence of significant movement between the tibia and the fibula. The two bones form a syndesmosis although the cavities of the stifle joint capsule extend between them proximally. Distally, a pocket of the tarsal joint capsule extends between the lateral malleolus and the lateral surface of the fibula

Ligaments:

1. A small ligament of the fibula head is a fibrous thickening which lies under the distal part of the Lateral Collateral Ligament.
2. Distally, there is a **Cranial Tibiofibular Ligament** which runs from the lateral malleolus to the tibia, and a **Caudal Tibiofibular Ligament** which runs from the lateral malleolus to the lateral border of the calcaneus.

The tarsal joint (Fig. 5-R)

Type of Movement: Like the carpal joint, the overall movement involves extension and flexion. It is important to note, however, that the articular surfaces are not absolutely in a cranio-caudal direction. This turns the lower limb very slightly and thus permits it to pass on the outside of the forelimb when the animal is galloping.

The tibio-tarsal joint is a ginglymus whilst the intertarsal and tarsometatarsal -joints are arthrodia.

Joint Capsule: The principle of the joint capsule is the same as that of the carpus. But, the intertarsal joint has a proximal and distal compartment due to the shape and position of the central tarsal bone.

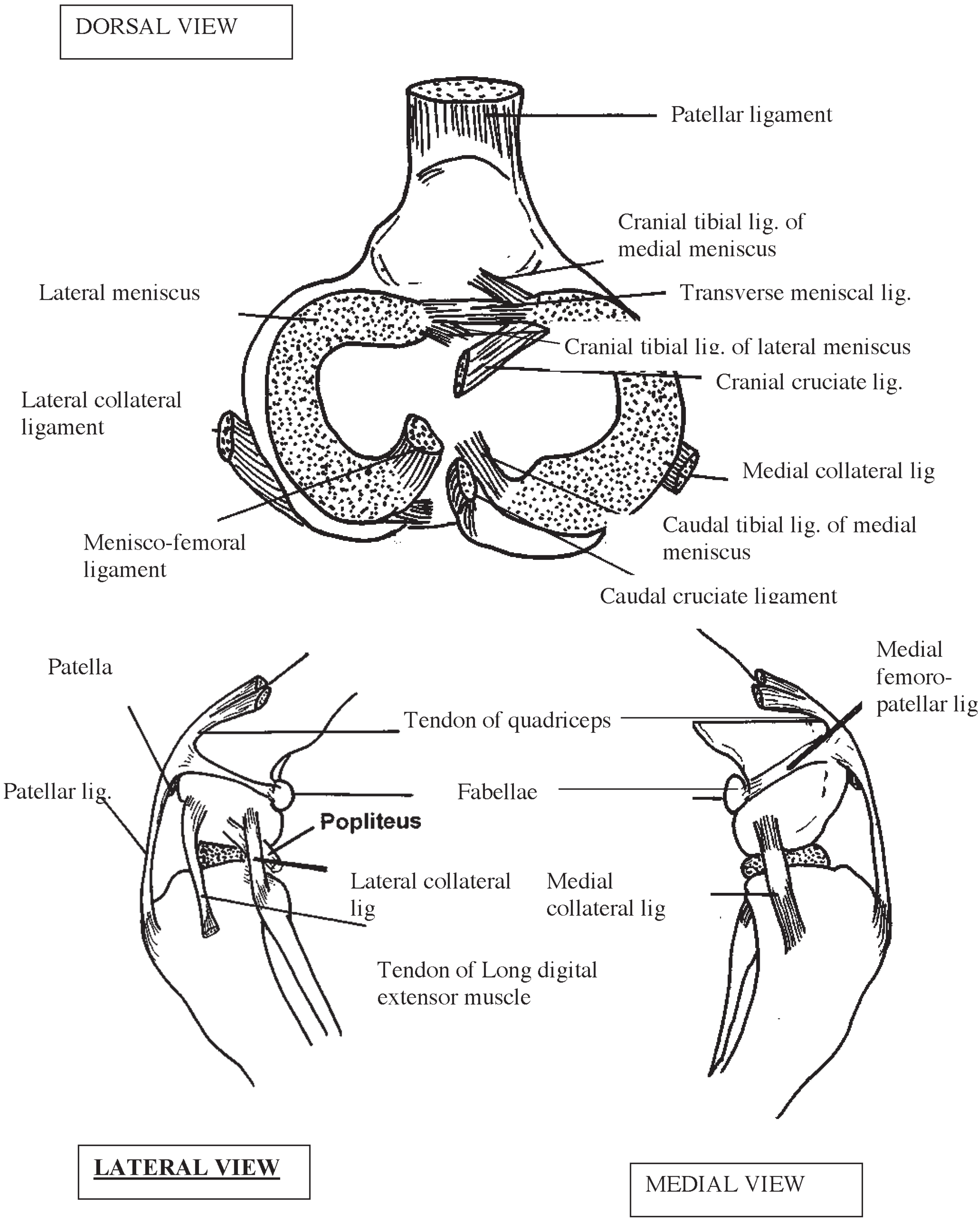


Figure 5-Q: Ligaments of the stifle joint of the dog

Ligaments: Principle is similar to that in the carpus, but two features are worth noting.

1. The **Medial and Lateral Collateral Ligaments** each have a long and a short part and this probably adds strength.
2. Also, a plantar thickening of the joint capsule (**Annular Ligament** – **Retinaculum**) completes the tarsal canal, and a distal ligament extends from the caudal surface of calcaneus to metatarsal V.

In brief, therefore, the tarsal joint has:

1. Collaterals.

2. Dorsal and Plantar Ligaments.

3. Intertarsal Ligaments.

Dorsally (cranially), there is a **Proximal and Distal Transverse Ligament** (**retinacula**).

Joints of the Pes

These essentially resemble those of the manus.

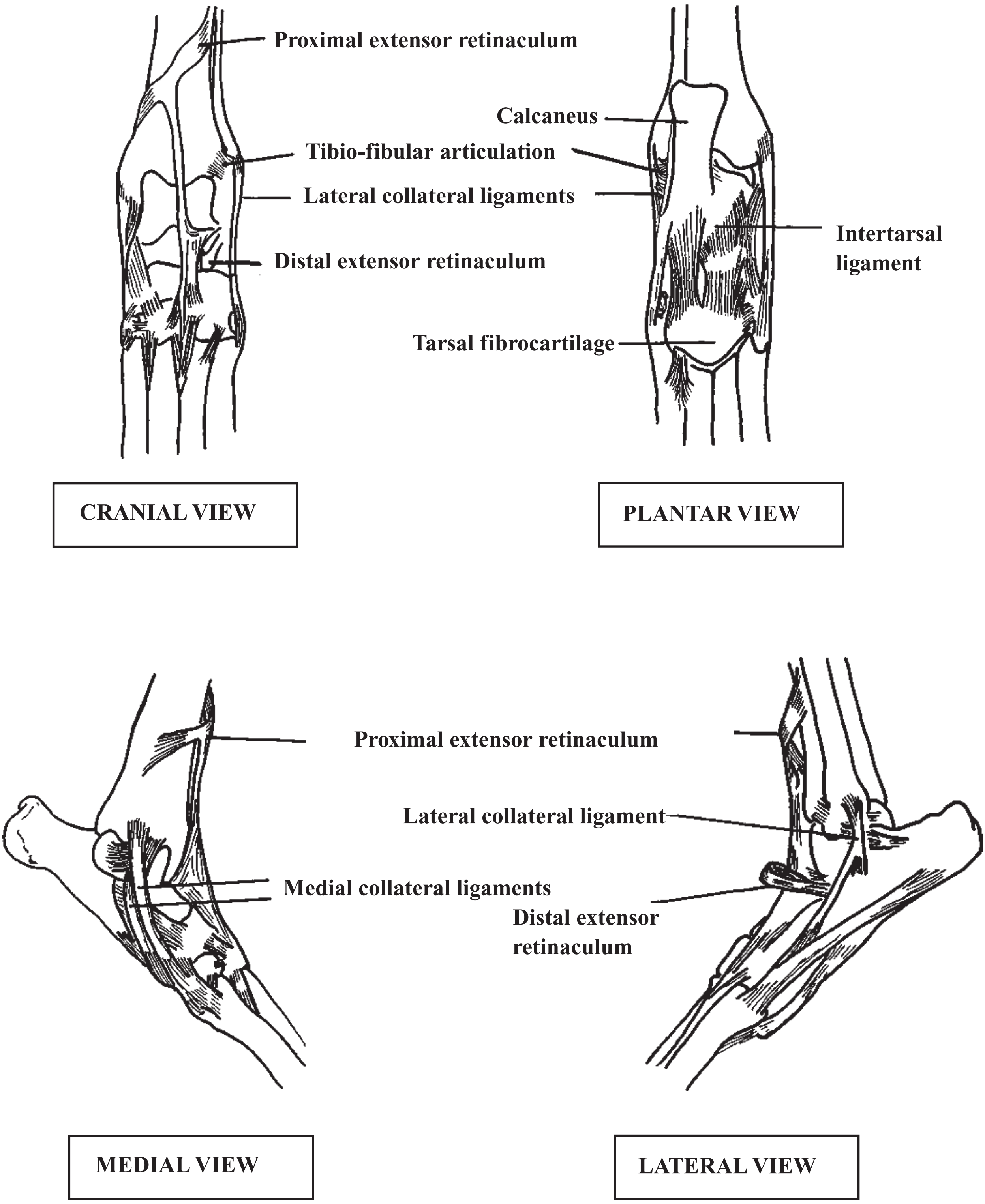


Figure 5-R: The tarsal joint of the dog

The hind limbs of the dog

4. Blood vessels

The distribution of the main vessels is illustrated in Figs. 5-S and 5-T. It is recommended that you study these diagrams in the practical classes during your dissection of the limbs.

A. Arteries (see Fig 5-S)

The main stem artery of the hind limb is the **External Iliac Artery**, arising from the termination of the Aorta at about the level of the last lumbar vertebra. It leaves the abdomen through the **femoral ring** (just behind the inguinal canal) and becomes the **Femoral Artery**.

The femoral artery runs down the medial surface of the limb between the sartorius and pectineus muscles, which together constitute the cranial and caudal walls of the **Femoral Triangle**. (The lateral wall is formed by the medial vastus and iliopsoas muscles).

Here, the artery is superficial and its pulsations are palpable – this is the most accessible site for taking the pulse in the dog.

Above the stifle, the stem artery continues as the **Popliteal Artery**, giving off a main branch: the **Saphenous Artery**. The Popliteal artery lies between the two heads of the gastrocnemius.

Distal to the popliteal region of the femur and tibia, the main trunk or stem artery (i.e. the Popliteal Artery) continues as the **Cranial Tibial Artery**.

Lower down the limb, this artery is rejoined by the cranial branch of the Saphenous artery, forming a loop. The paw is supplied with blood from both the Saphenous and the Cranial Tibial arteries.

B. Veins (see Fig 5-T)

Again, there are two divisions of venous drainage, a deep division (which basically follows the pattern of the arteries) and a superficial division.

The **Lateral Saphenous vein** represents the superficial drainage division, and is an important vein both in terms of venous drainage, and venipuncture in the hindlimb. The **Cranial Branch** of the Lateral Saphenous Vein runs upwards and backwards above the hock. It presents an excellent site for venipuncture.

The deep venous drainage system mirrors the arterial supply, with the **Medial saphenous vein** following a course which is similar (but retrograde) to the saphenous artery. The Medial Saphenous may be seen on the inside of the limb in smooth haired dogs. It too has cranial and caudal branches.

The **Cranial Tibial vein** arises above the hock and becomes the **Popliteal vein** at the stifle. It is joined by the Saphenous Veins above the stifle, to form the **Femoral Vein** (which lies next to the corresponding artery in the femoral triangle).

The Cranial Tibial and Saphenous veins receive blood from the **Digital Veins** which are arranged much as in the forelimb.

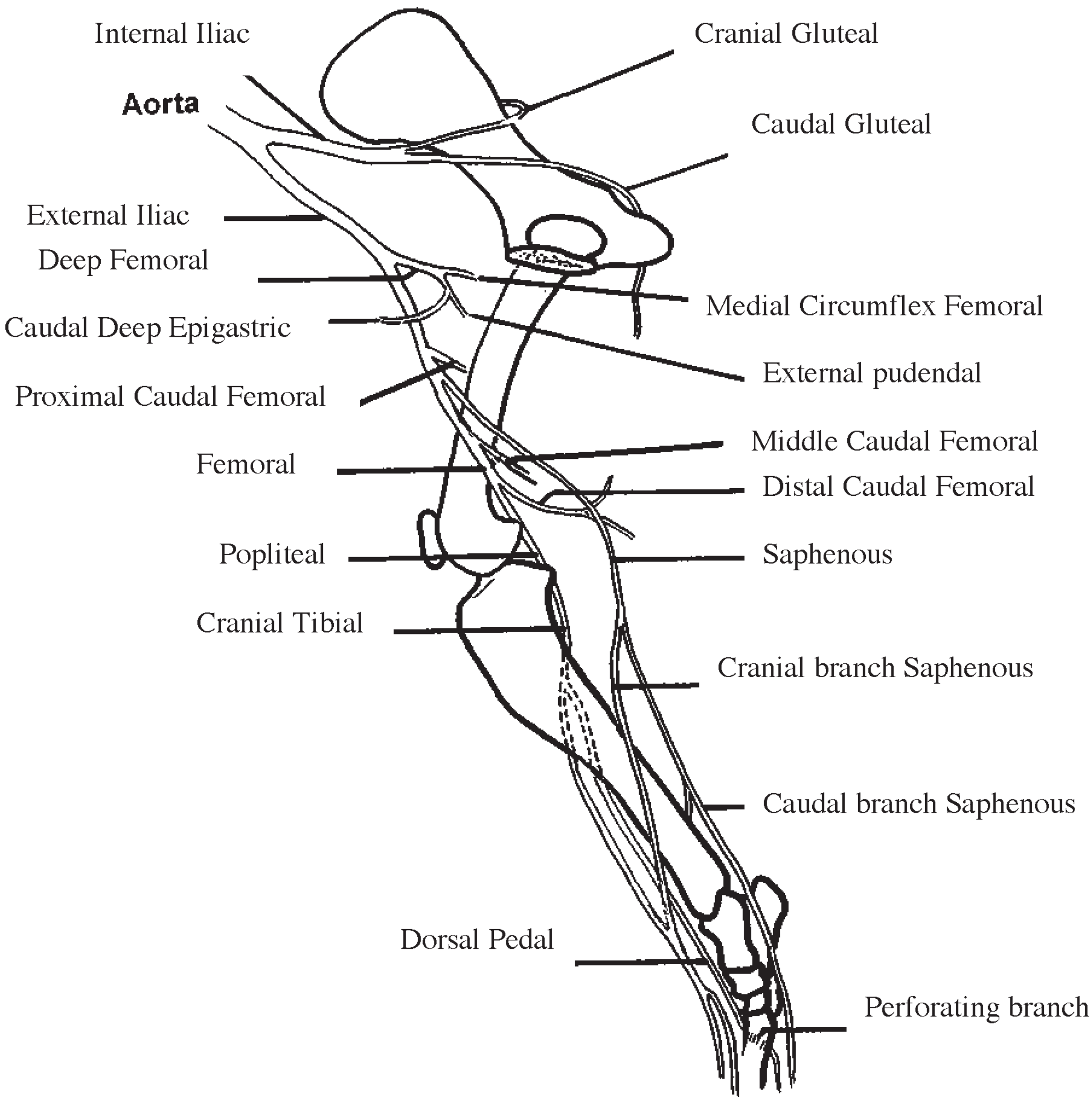


Figure 5-S: Arteries of the hind limb of the dog (medial view)

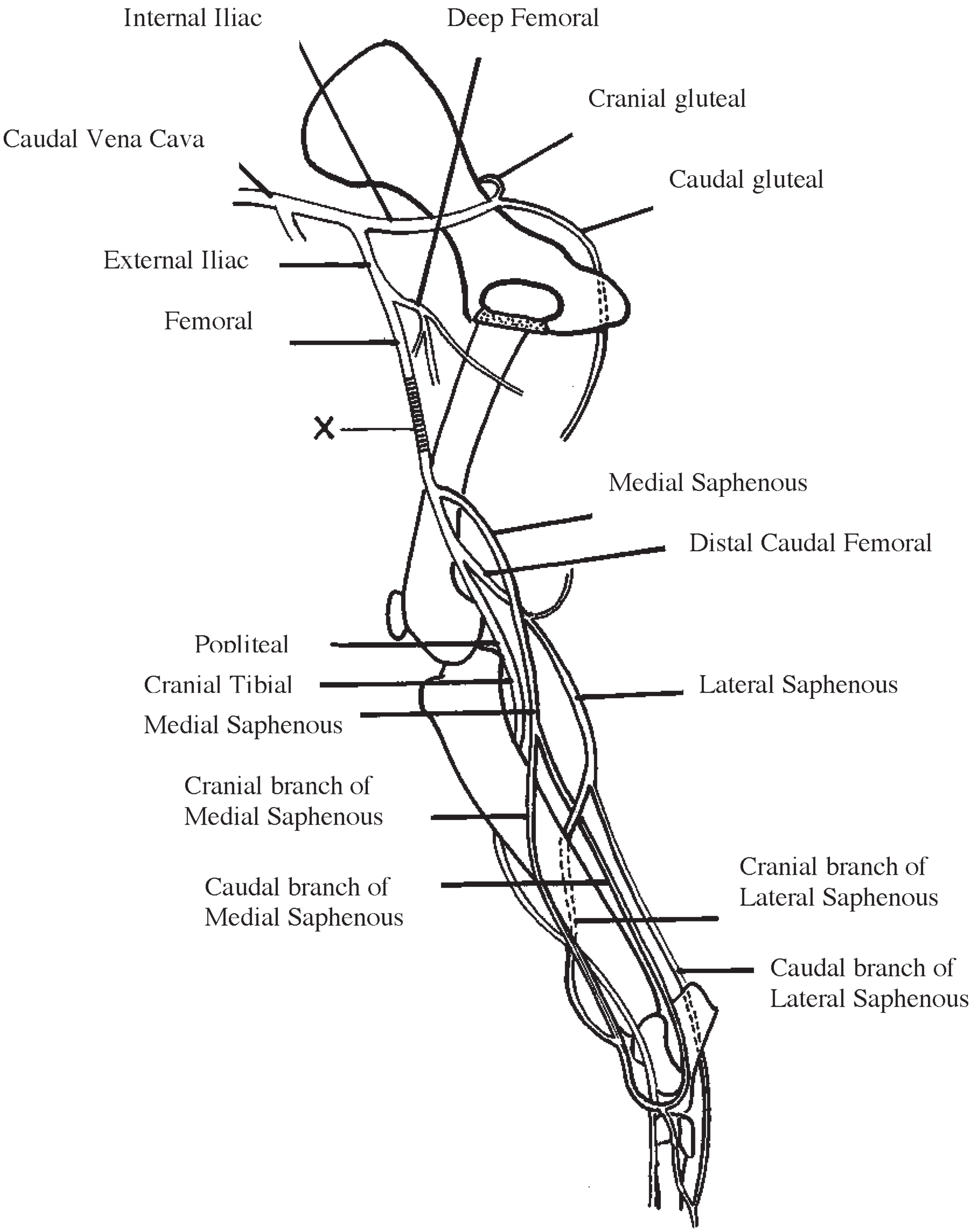


Figure 5-T: Veins of the hind limb of the dog (medial view)

The hind limbs of the dog

5. The paw

The hind paw is essentially similar to the fore paw.
Small variations have been considered in chapter 3.

Questions

The hip joint displays a variety of movements. How do the muscles associated with the joint achieve these movements?

How many ligaments are there associated with the stifle joint (including the femoropatellar joint)?

What types of joint are to be found in the hock? Classify them.

What part of the 'knee joint' is exposed to the greatest strain?

Chapter 6

Anatomy of the Pelvic Limb of the Horse

Abbreviations used in following text

Mc	Metacarpal
Mt	Metatarsal
P	Phalanx
DDFT	Deep digital flexor tendon
SDFT	Superficial digital flexor tendon

Suggested reading

*DYCEKM, SACK WO & WENSING CJC (1995) Textbook of Veterinary Anatomy.

SISSON & GROSSMAN'S (1975) The anatomy of the Domestic Animals Chapters 15, 16, 17.

*ADAM'S LAMENESS IN HORSES (1974) Ed. Ted S Stashak Chapters 1 and 2.
GRAY Sir J (1968) Animal Locomotion Pages 265-286

MUYBRIDGE E (1957) Animals in Motion Pages 29-57

* Highly recommended

Bones of pelvic limb (Fig 6-A)

The pelvic limb **bears 40-45% of the body weight,** but provides the **major component of thrust** in locomotion.

- **Os coxae:** Tuber coxae and tuber sacrale both palpable. Tuber ischii also large, but buried under mass of hamstring muscles.
- **Femur:**

  Greater trochanter is divided into separately palpable cranial (lower) and caudal (higher) parts for attachment of deep and middle gluteal muscles.

  Third trochanter is prominent laterally for attachment of superficial gluteals. **Medial ridge of trochlea** is enlarged.
- **Patella: parapatellar fibrocartilage** forms hook medially.
- **Fabellae - absent.**
- **Tibia:** large (longer than radius), and is only weight-bearing component of crus. Large **tibial tuberosity** for attachment of patellar ligaments. Medially the tibia is subcutaneous. The **cochlea is inclined craniolaterally** so lower limb moves laterally on flexion of the hock.
- **Fibula is greatly reduced:** distal part incorporated into tibia. Proximal part tightly articulated with tibia, with short shaft.

- **Tarsals (Fig 6-B):**

  Proximal row: calcaneus and talus

  - **Calcaneus** plantar, enlarged for muscle attachment. Distal process **sustentaculum tali** - forms **plantar groove.**
  - **Talus has oblique trochlea.**
    Middle row: central tarsal

  Distal row: 1st and 2nd fused (medial), 3rd wedge-shaped. 4th large and deep occupying middle and distal rows.

  Distal limb bones are similar to those of the fore limb. The IIIrd metatarsal is marginally longer than its fore limb equivalent, and the 3rd phalanx is more oval in outline, but otherwise, the osteology is identical.

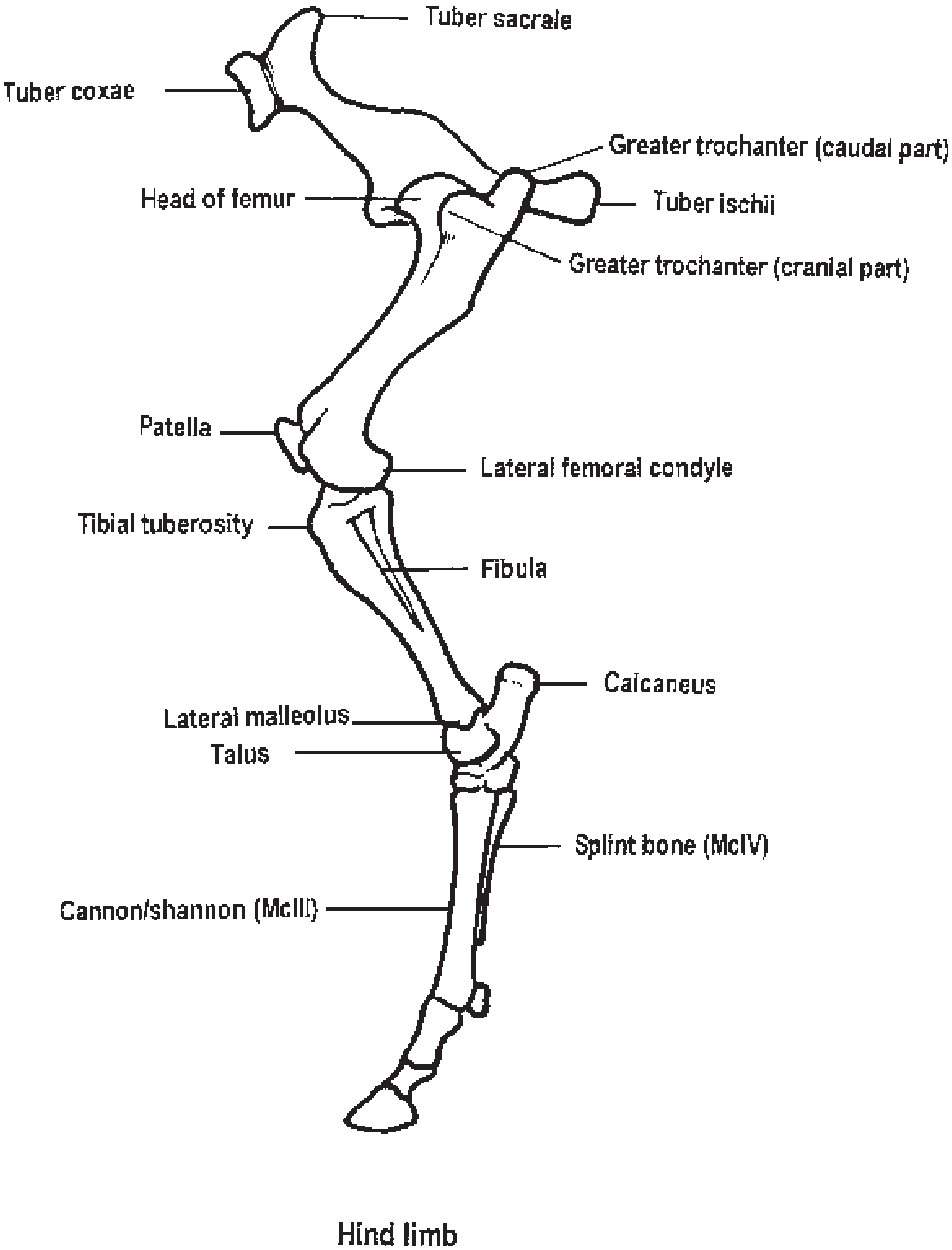


Figure 6-A: Bones of pelvic limb

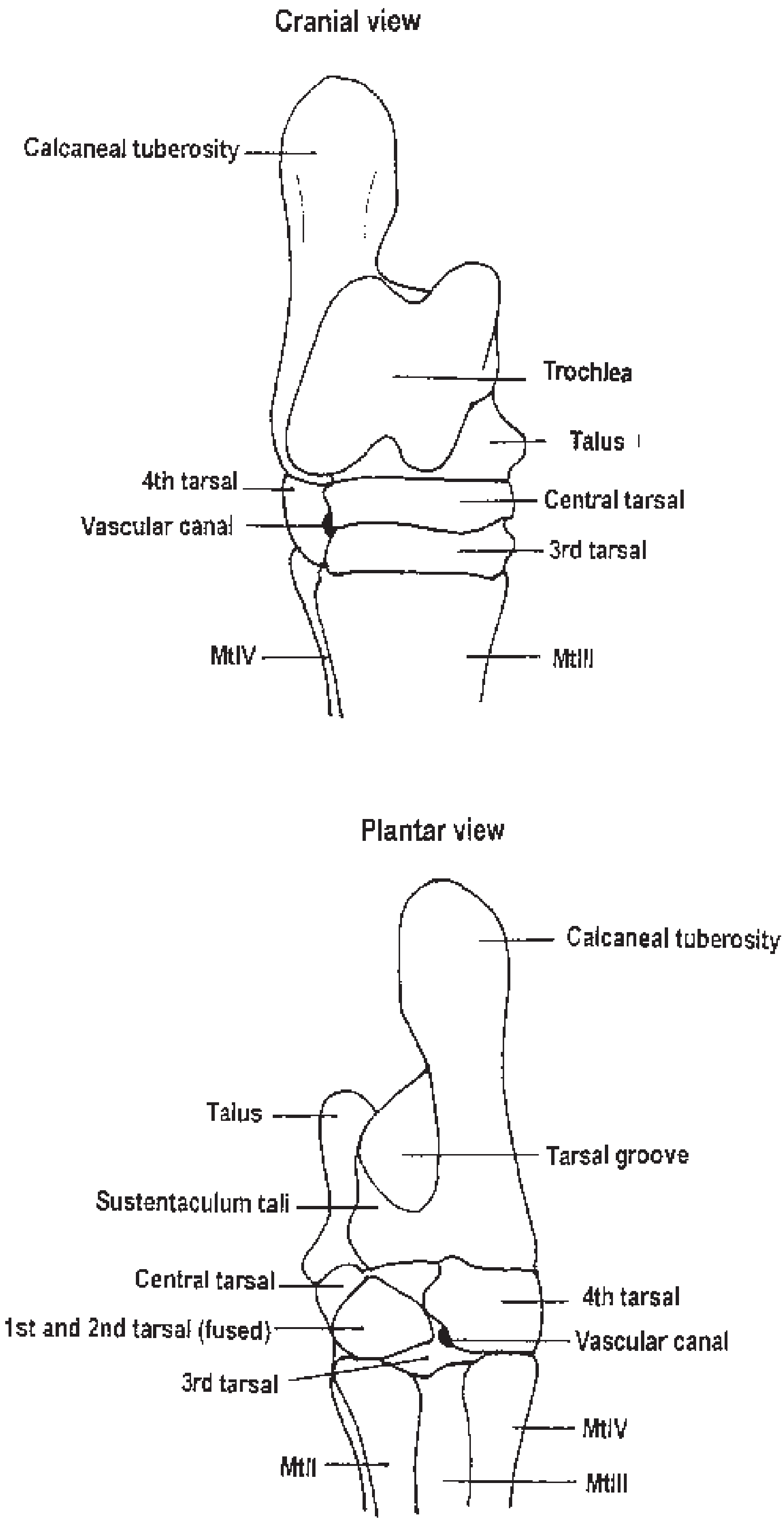


Figure 6-B: Hock joint

Synovial joints of the pelvic limb

Sacroiliac joint

Ligaments of sacroiliac joint:

- **sacroiliac:** dorsal and ventral parts, incorporated into fibrous component of joint
- **sacrosciatic:** forms broad sheet, leaving **greater and lesser ischiatic foramina** over respective ischiatic notches.

Coxofemoral (hip) joint (Fig 6-C)

Ligaments of hip joint:

a) **Cotyloid ligament: fibrocartilaginous** extends round rim of acetabulum to deepen and stabilise joint.

b) **Accessory (femoropubic) ligament:** unique to Equidae. A detachment of prepubic tendon enters hip joint via acetabular notch and inserts on head of femur, markedly restricting abduction of hind limb. (However, a horse can still aim a remarkably accurate kick to the side by tilting its pelvis, so do not be fooled by the old adage that a horse cannot cow-kick).

c) **Ligament of femoral head (round ligament):** short and stout, similar to other species.

d) **Transverse acetabular ligament: completes** acetabulum across acetabular notch, and holds accessory ligament in place.

Joint capsule can be accessed deep between cranial and caudal parts of greater femoral trochanter.

Stifle joint (Fig 6-I)

Similar arrangement of ligaments as in dog (collaterals, cruciates, meniscal ligaments etc), except that horse has three **(medial, middle and lateral)** distal **patellar ligaments,** all inserting on tibial tuberosity. The medial patellar ligament is involved in the locking mechanism of the stifle (see section on Stay Apparatus).

Joint divided into:

a) **Femoropatellar joint:** *accessible caudal to lateral collateral ligament.* Communicates with medial femorotibial joint in ≈75% of horses, **and with** lateral femorotibial in ≈25%.

b) **Medial and lateral femorotibial joints** very rarely communicate. *They are accessible for aspiration at cranial border of medial and lateral collateral ligaments respectively.*

Tarsal (hock) joint (Fig 6-B)

Compound joint consisting of four levels:

a) Tibiotarsal (talocrural/tarsocrural)

b) proximal intertarsal joints

c) distal intertarsal joint

d) tarsometatarsal joint

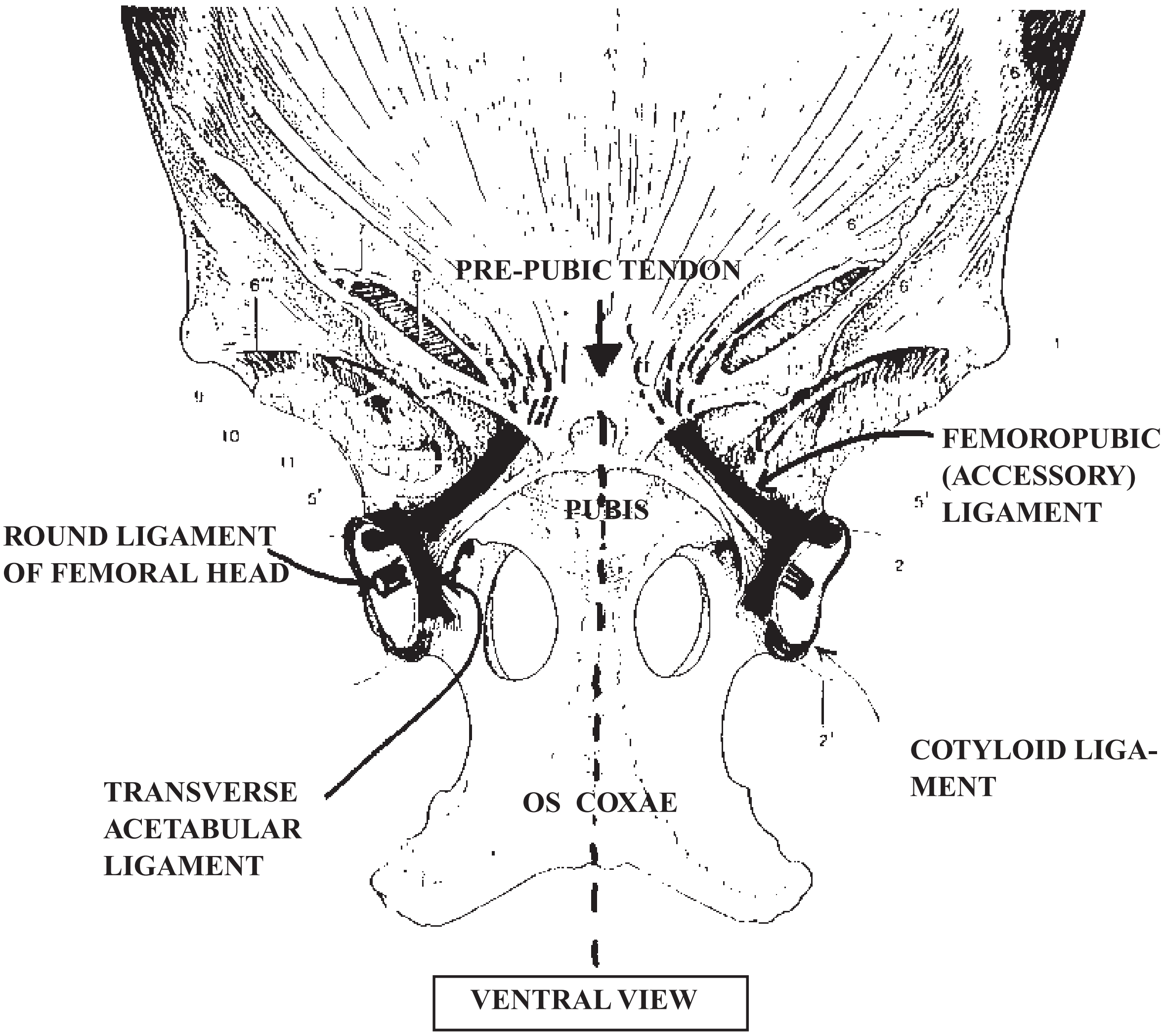


Figure 6-C: Ligaments of coxofemoral (hip) joint (Redrawn from Dyce, Sack and Wensing)

Tibiotarsal joint forms weight-bearing articulation, calcaneus forms lever for muscle attachment. All **movement is at tibiotarsal joint,** very little at intertarsal or tarsometatarsal joints.

Fibrous joint capsule extends from tibia to metatarsus, attached to tarsal bones in places, free at others. Tibiotarsal and proximal intertarsal joints share a synovial compartment, others separate.

*The tibiotarsal joint is accessible for aspiration dorsomedially. Inflammation of the hock joint is known as **spavin**. Chronic distension of the tibiotarsal joint is referred to as **bog spavin.** Bony changes are referred to as **bone spavin.***

Ligaments of hock joint Fig 6-D):

a) **Collateral ligaments** intact, extending from tibia to metatarsus.

b) **Long plantar ligament** runs from calcaneus to proximal metatarsus - *prone to conformation-related strain or "**curb** "*. Forms deep wall of tarsal canal.

c) **Plantar annular ligament (retinaculum** – broken line in Fig 6-D): forms outer wall **of tarsal canal** by running from to medial border of talus, enclosing deep digital flexor tendon in plantar groove, en route to distal limb.

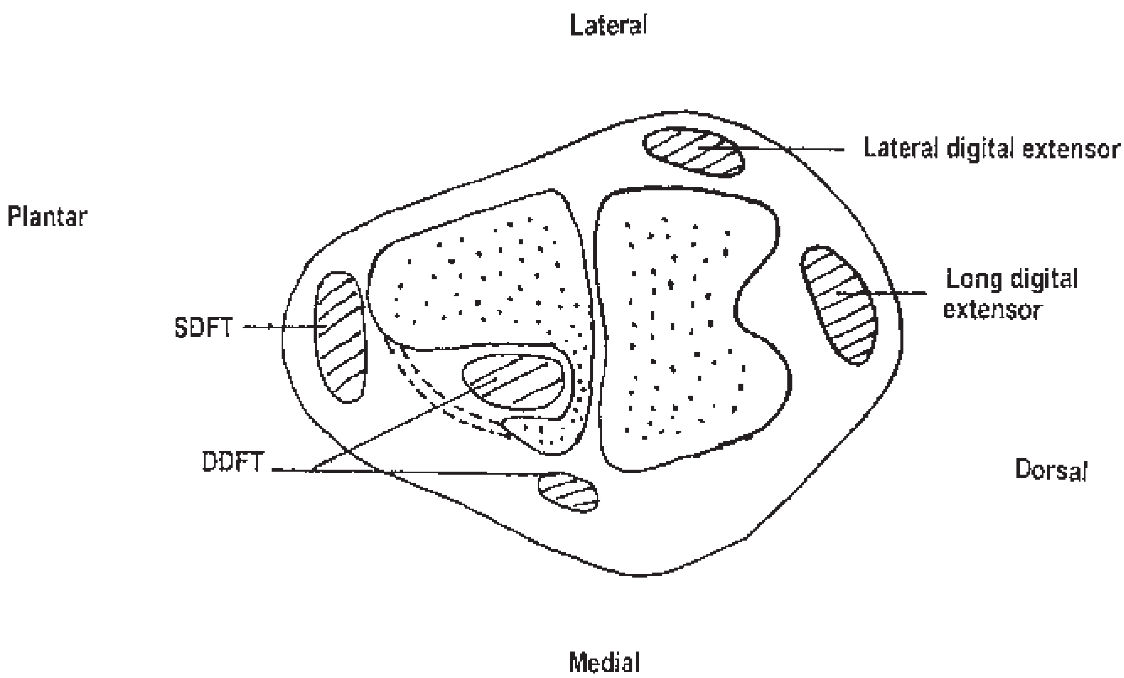


Figure 6-D: Tendons in region of tarsal canal of left hind limb

Joints of the pes are covered in chapter 4, as they are essentially similar to those of the manus.

Muscles of pelvic limb

1. Muscles of rump and cranial thigh (Fig 4-J)

a) Gluteals

Superficial gluteal - Inserts on 3rd trochanter, flexes and abducts hip

Middle gluteal - Inserts on caudal part of greater trochanter; extends hip as in rearing. **Accessory -** (deep part of middle) Inserts on intertrochanteric line; underlying **bursa** where it passes over trochanter; extends hip.

Deep - Inserts on cranial part of greater trochanter; extends hip and abducts thigh.

b) Tensor fasciae latae: as dog

c) Quadriceps femoris as dog, but shorter, fatter bellies. When stifle is in resting position, no active tension is required by this muscle to maintain position of joint.

2. Muscles of medial thigh

a) Gracilis, pectineus and small muscles of hip: as dog.

b) Sartorius: has single belly, adducts and flexes hip.

c) Adductor small, not clearly divided. Primary function is adduction, also extends hip.

3. Muscles of caudal thigh (hamstrings)

All similar to dog but with **well developed vertebral attachments** resulting in the smooth contours of the rump compared with dogs, as vertebral heads cover ischiatic tuberosity.

a) Biceps femoris: bursae present over greater and third trochanter, and at tendon of insertion at patella.

Three insertion sites:

i) fasciae latae and patella

ii) patellar ligaments

iii) calcaneus (via **tarsal tendon**)

b) Semitendinosus: has tarsal tendon to calcaneus. **Bursae** present under tendons of origin (tuber ischii) and insertion (medial tibial crest).

c) Semimembranosus.

4. Dorsolateral muscles of crus

In the horse, **flexion and extension of the hock is locked in parallel with the stifle by the reciprocal apparatus (Fig 6-E).** Essentially, there are no active flexors or extensors of the hock, which follows the movements of the stifle. Therefore, the terms flexion and extension are used here to refer to the digit only.
Note: the peroneus longus is replaced by the peroneus tertius in the horse.

a) **Long digital extensor:** origin lateral stifle region, **joined by lateral digital extensor tendon at level of proximal MtIII.** Inserts on extensor process of PHI, (also PI and PII).

b) **Lateral digital extensor:** arises lateral collateral ligaments of stifle, **joins tendon of long digital extensor at proximal MtIII.** *Implicated in some cases of stringhalt.*

c) **Peroneus tertius:** deep to Long DE, entirely tendinous, a main **component of the reciprocal apparatus** (Fig 6-E).

Origin: lateral distal femur Insertions: Mt III and lateral hock

d) **Cranial tibial:** lies under peroneus tertius, tendon of which divides around it. **Bursa** is interposed between tendons at this point.

Divides at insertion:

i) Dorsal branch to Mt III

ii) Medial hock. This branch **(cunean tendon)** has underlying **bursa.**

e) **Short digital extensor:** small and functionally insignificant muscle, notable for being the only muscle belly located below the hock.

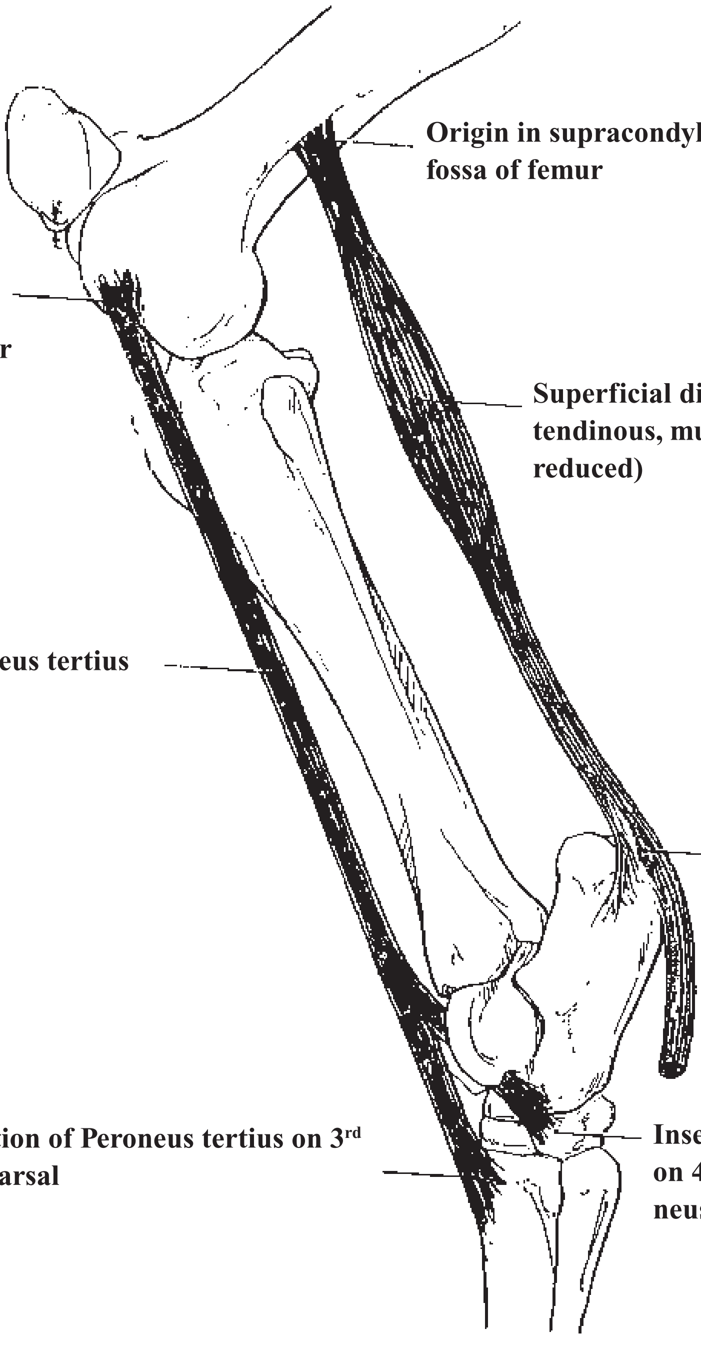


Figure 6-E: Reciprocal apparatus of the horse's hindlimb (Redrawn from Adam's Lameness in Horses)

5. Caudal muscles of crus

a) **Gastrocnemius:** Tendon of gastrocnemius combines with SDFT and tarsal tendons of hamstrings to form **common calcaneal** (Achilles) **tendon.**

Paradoxical action of gastrocnemius - attachments suggest that it both flexes stifle and extends hock, but reciprocal apparatus prevents these actions occurring simultaneously. Probably acts to adjust tension in peroneus tertius, and loading on tibia.

b) **Soleus:** insignificant (absent in dog, well-developed in cat and human)

c) **Popliteus:** as dog.

d) **Superficial digital flexor:** almost entirely tendinous, other **main component of reciprocal apparatus.**

Attached medially and laterally to calcaneus, then continues distally. Insertions as for fore limb.

e) **Deep digital flexor:** three heads

- **Medial head -** Tendon **runs in groove over medial malleolus,** and joins common DDFT tendon in proximal third of Mt III.
- **Superficial and Deep** heads have a common tendon which **passes through tarsal canal.** Insertions as in fore limb.

Accessory (tarsal) check ligament is sometimes present as a ligamentous slip from the fibrous hock joint capsule, but is poorly developed or absent.

LATERAL ASPECT

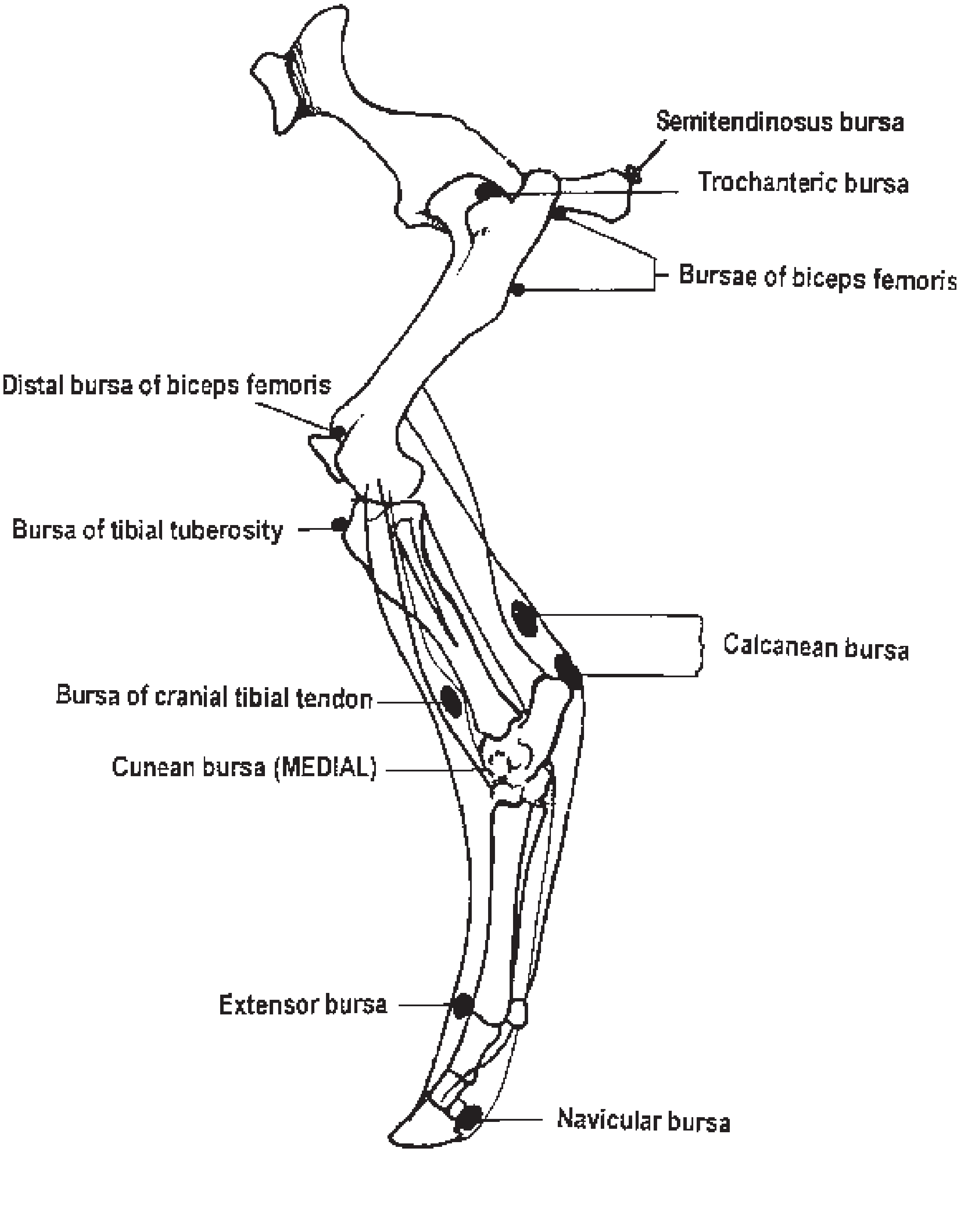


Figure 6-F: Synovial bursae of the hind limb

Synovial bursae and tendon sheaths

Synovial bursae of the hind limb (Fig 6-F)

i) **Trochanteric bursa**

Between accessory gluteal muscle and cranial part of greater trochanter of femur.

ii) **Bursae of biceps femoris**

At three sites

- greater trochanter
- third trochanter
- patellar insertion

iii) **Semitendinosus:** at tuber ischii

iv) **Bursa of long digital extensor**

Beneath common origin with peroneus tertius and over lateral tibial crest.

Communicates with lateral femoropatellar joint.

v) **Calcanean bursa**

Large, between SDFT and calcaneus, extending between tendon of gastrocnemius and SDFT. Communicates with small bursa between gastrocnemius tendon and calcaneus. *Adventitious bursa common at hock - capped hock.*

vi) **Bursa of cranial tibial tendon**

Between tendons of cranial tibial and peroneus tertius.

vii) **Bursa of cunean tendon**

Medially, between cunean tendon and tarsal bones. *Bursitis causes pain which can be alleviated by sectioning the cunean tendon. Sometimes erroneously diagnosed as spavin.*

viii) **Navicular and extensor bursae**

As fore limb.

Tendon sheaths of the hind limb

The principal tendon sheaths of the hind limb are the tarsal sheath at the hock, and the digital sheath which is similar to the fore limb.

a) **Tarsal sheath (Fig 6-G):**

Extends through the tarsal canal, enclosing common tendon of deep and superficial heads of DDFT, until they unite with the tendon of the medial head.

*Distension more noticeable medially, above hock -**tendinous thoroughpin.***

b) **Digital sheath:** as fore limb.

Again, distension noticeable above fetlock - **tendinous windgalls**; commoner in hind limb than fore limb**.**

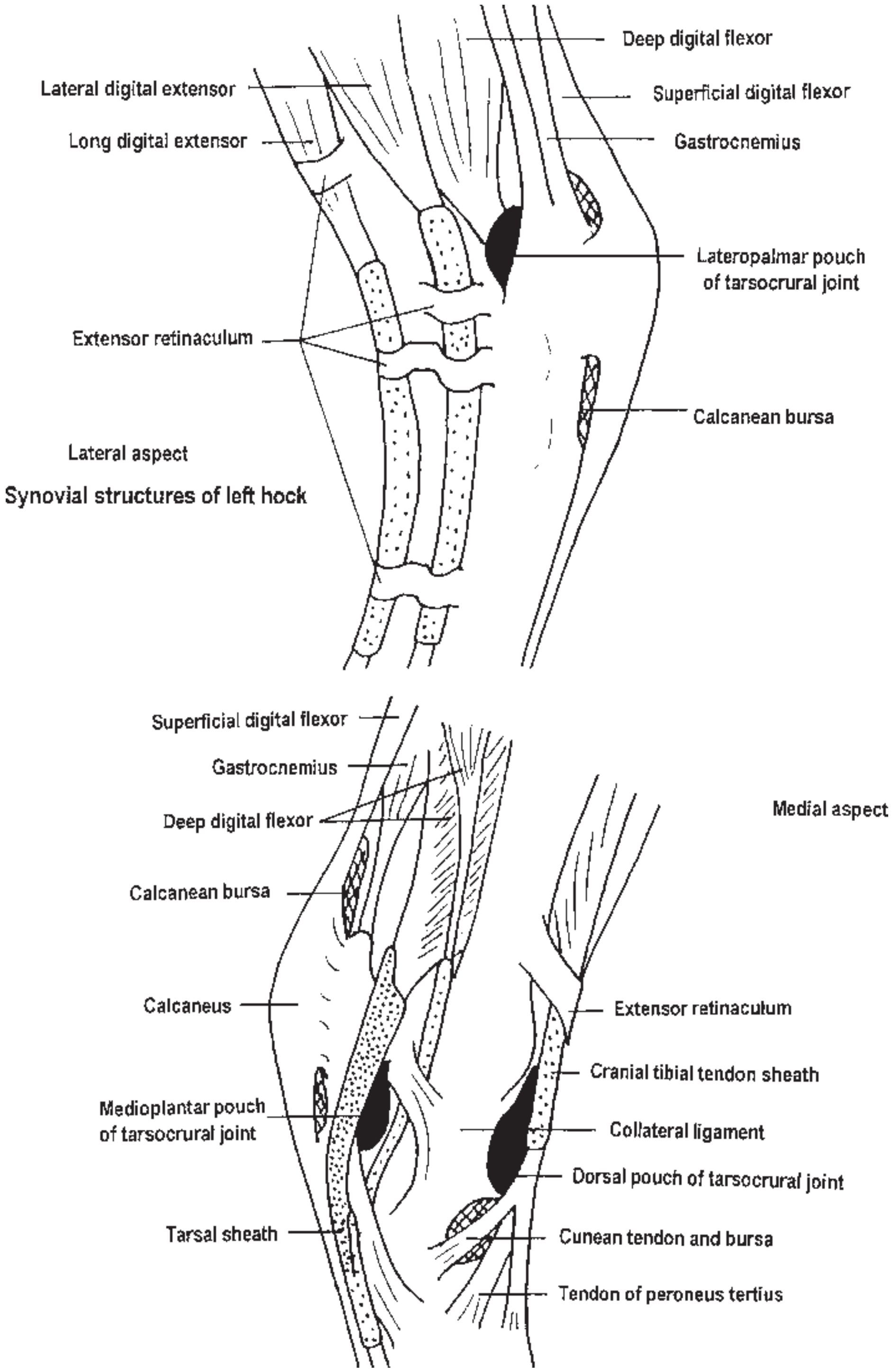


Figure 6-G: Synovial structures of the hock

The stay apparatus of the hind limb (Fig 6-H)

a) Support of hock:

Collapse of the hock joint is prevented by linking its movement with that of the stifle by the **reciprocal apparatus.** This consists of

i) **Peroneus tertius** cranially, connecting femur with hock and Mt III.

ii) **Superficial digital flexor** caudally, connecting femur with calcaneus. (Having given off medial and lateral slips attaching to the calcaneus, it continues distally to insert around the pastern joint, as in the fore limb).

This mechanism synchronises movements of hock and stifle. When stifle is locked, hock is also fixed.

b) Support of stifle (Fig 6-I):

Can be fixed in extension by **patellar locking mechanism,** allowing large part of body weight to be supported on one hind limb while other is rested. Allows animal to doze while standing, although lies down for true sleep.

Anatomical features facilitating this mechanism are

- **medial trochlear ridge** of femur enlarged and prolonged proximally forming resting "shelf
- patella extended medially by parapatellar **fibrocartilage**
- **three patellar ligaments,** all inserting on tibial tuberosity.

During locomotion, patella slides up and down trochlear groove, reaching the resting shelf when stifle is extended, but without locking.

Locking requires a conscious decision by the horse, and is effected by **extending stifle, and rotating patella medially by about 15°** (by vastus medialis). This **hooks medial patella r ligament over medial trochlear ridge,** from which it firmly resists displacement. Weight can then be lowered onto locked joint.

Unlocking is achieved by elevating patella (action of rectus femoris) and rotating it laterally (action of biceps femoris and tensor fasciae latae).

Inability to unlock stifle sometimes occurs transiently in young horses with poor muscle development. Persistent problems relating to poor conformation can be alleviated by improving muscular development; occasionally, the condition is so persistent that transection of the medial patellar ligament is required.

c) **Support of hip:**

Tonic activity of **biceps femoris and semitendinosus** prevents flexion of hip joint.

The Suspensory Apparatus of the hind limb is identical to that of the fore limb. The check ligament of the DDFT is less well developed than in the fore limb, and may even be absent. The attachments in the hind limb of the SDFT to the calcaneus, as it passes over the calcaneal tuberosity, are analogous to the accessory check ligament of the SDFT.

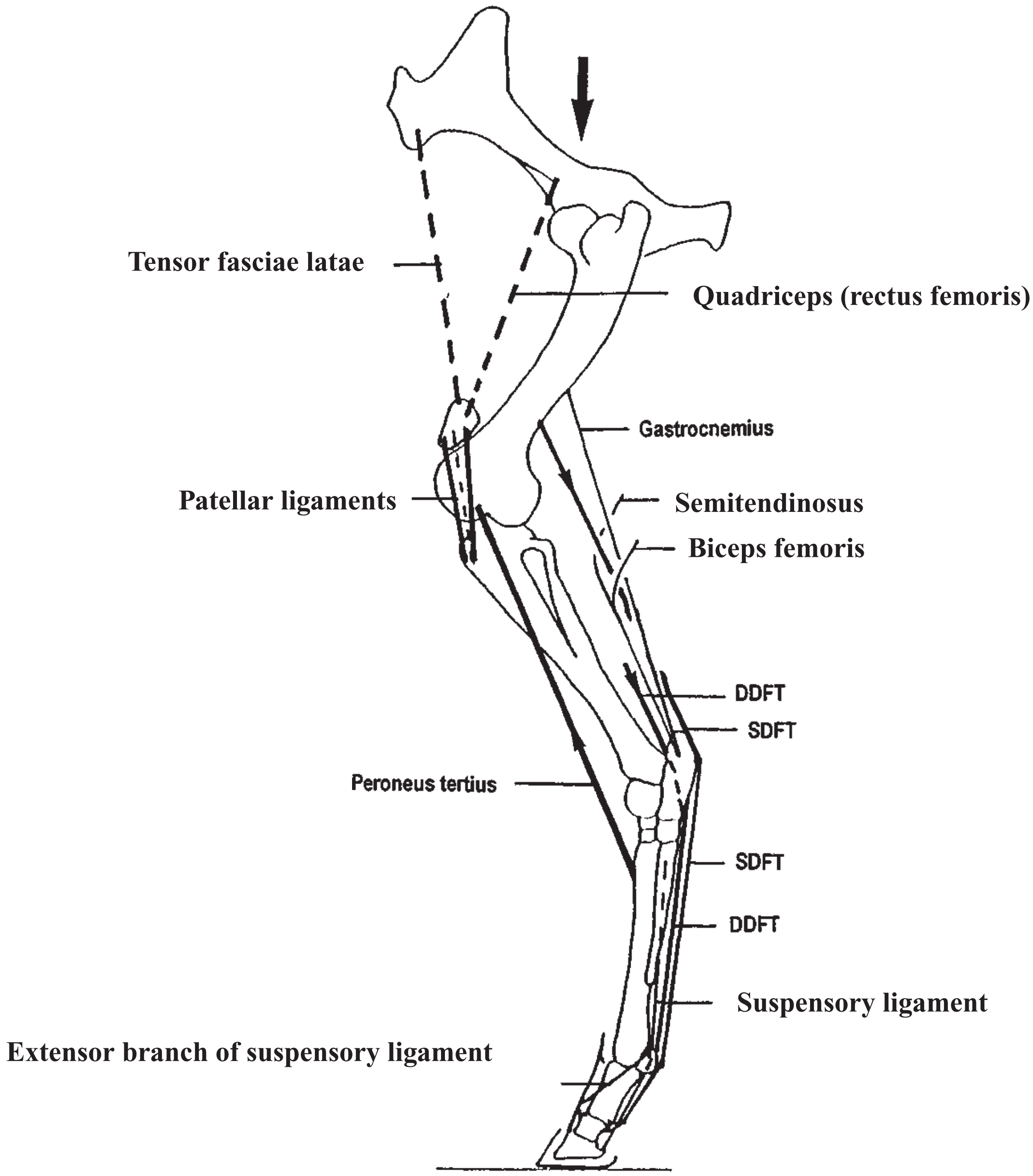


Figure 6-H: Stay apparatus of hind limb

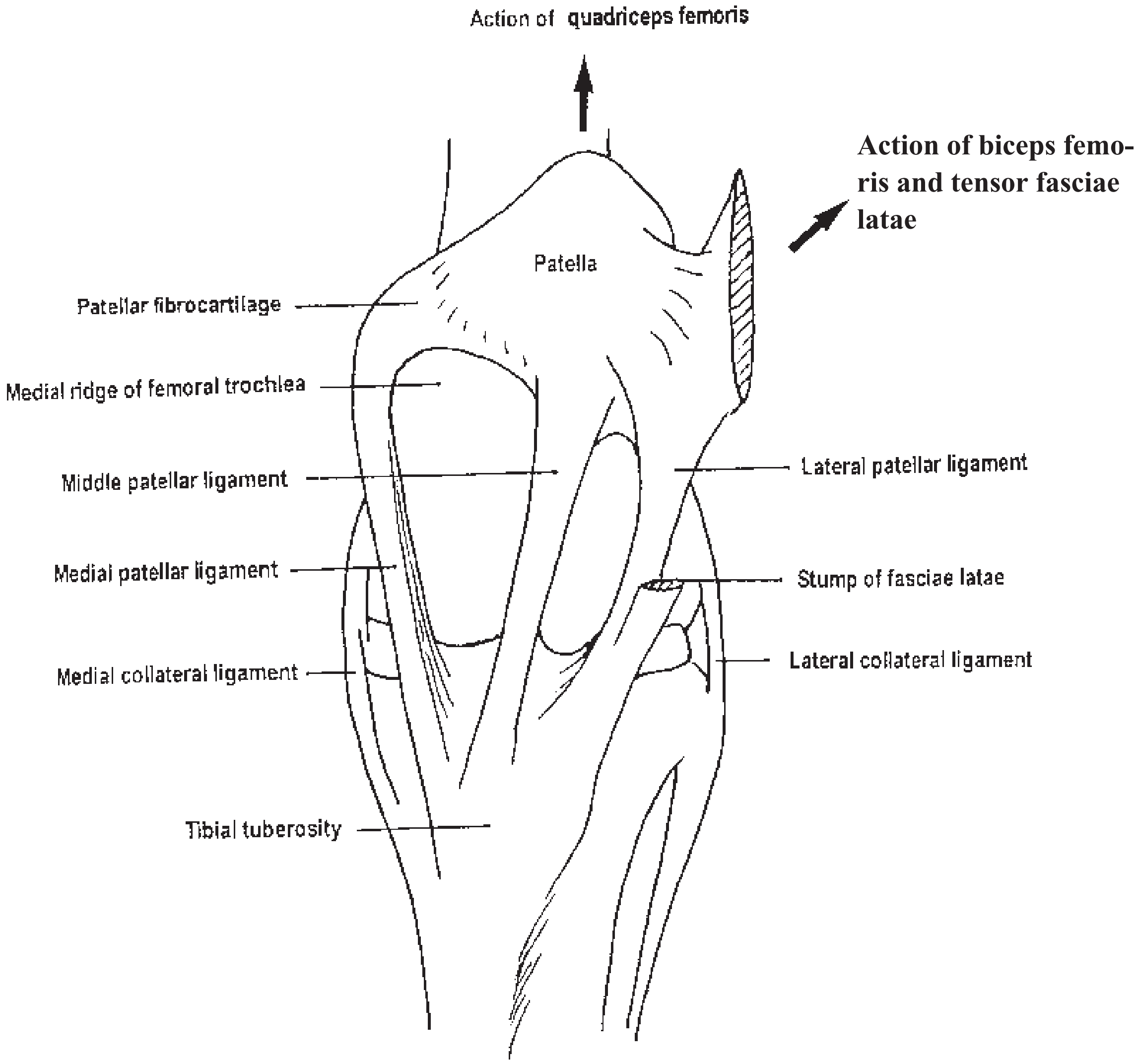


Figure 6-I: Cranial view of patellar ligaments of left hind limb

Blood supply to the hind limbs

The principal arteries of the hind limb are similar to the dog.

Arteries of hind limb (Figs 6-J and 6-K)

Main trunk is the **cranial tibial artery,** arising from the **popliteal artery.** Runs over dorsal surface of hock, and crosses to lateral side, protected by extensor tendons, and continues as:

- **dorsal metatarsal artery -** main supply to foot, running in the **vascular groove** between cannon bone and lateral splint bone. Passes under distal end of lateral splint bone and then gives rise to **plantar digital arteries.**
- The smaller **plantar and plantar metacarpal arteries** arise from the **saphenous and caudal tibial arteries.**

The supply to the digit follows the same pattern as in the fore limb, but obviously vessels are terms plantar rather than palmar.

Veins of hind limb

Follow a similar pattern to those of the dog, except that the medial saphenous vein is more prominent than the lateral in the horse.

Veins which lie subcutaneously are vulnerable to laceration. Most important are:

- **medial saphenous** - over dorsal surface of hock
- **digital veins** at fetlock and pastern
- **lateral saphenous –** prominent medially before crossing to outer thigh

Venous return from the hoof and distal limb has the same limitations, and contributes in the same way to absorption of concussive force, as in the fore limb.

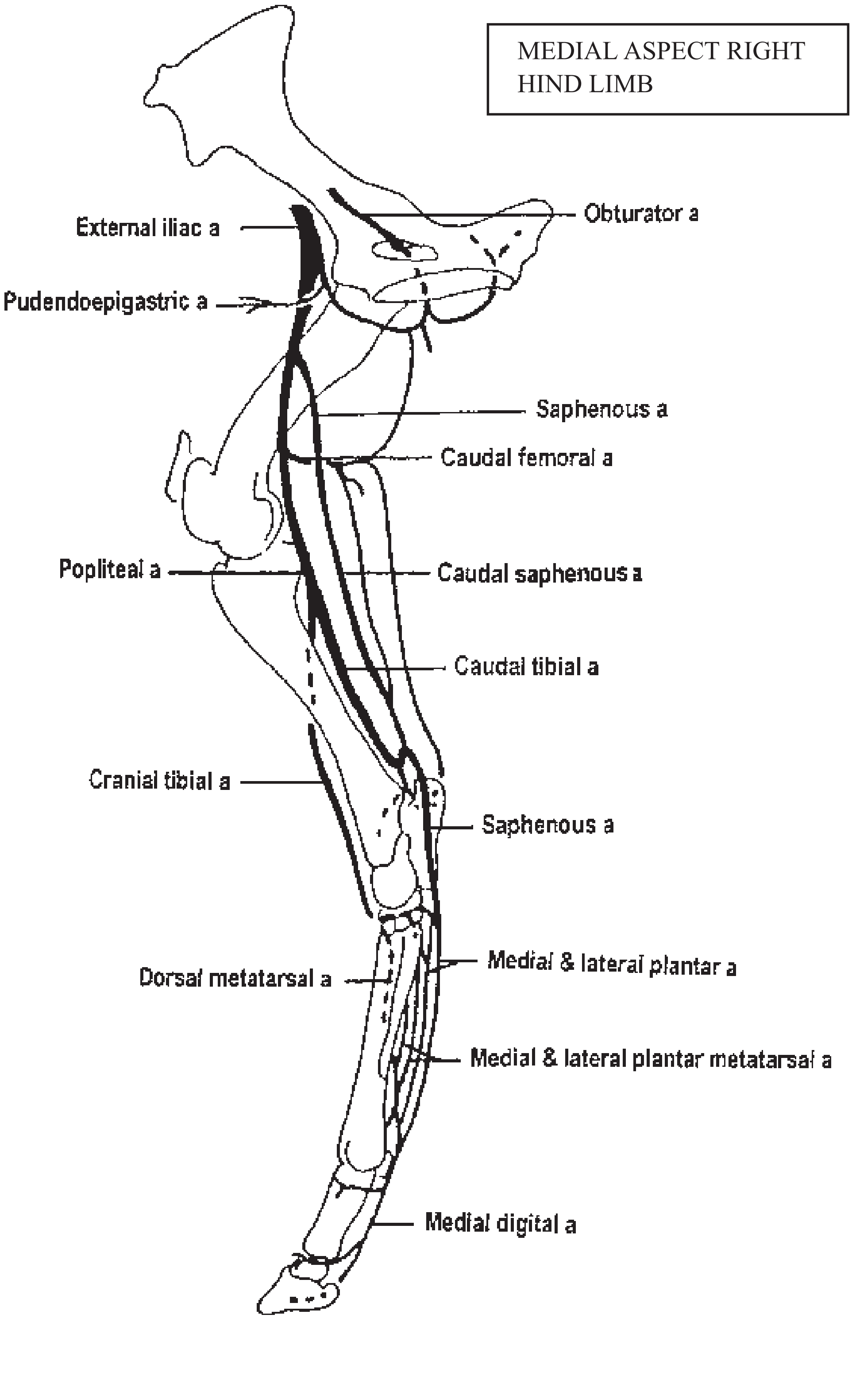


Figure 6-J: Arterial supply to hind limb

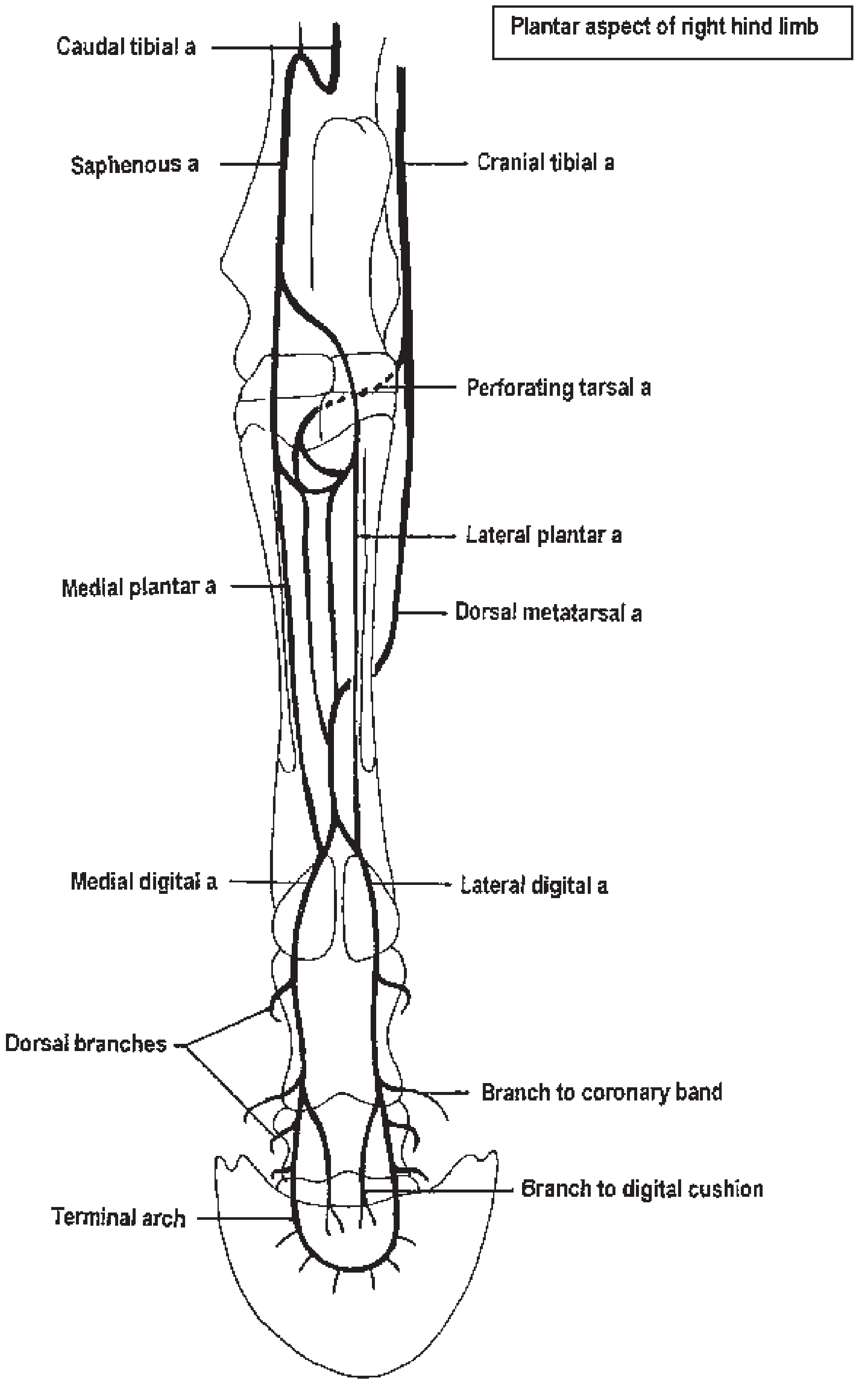


Figure 6-K Arterial suppy to lower hind limb

Innervation of hind limb (Fig 6-L)

a) **Femoral nerve: (mixed)**

Supplies **sublumbar muscles and quadriceps.**

Saphenous branch - supplies **sartorius** and sensation in skin of medial limb.

Damage: *uncommon, but severe. Cannot fix or extend stifle, so cannot bear weight.*

b) **Obturator nerve: (motor)**

Supplies **adductor, gracilis, pectineus and external obturator.**

Damage: *usually following foaling or pelvic fracture. Unable to adduct limb, so unable to get up.*

c) **Sciatic nerve: (mixed)**

Leaves pelvis via greater ischiatic foramen, passes behind acetabulum. Supplies **gluteals** and **hamstring group.**

Divides at level of hip joint into **tibial nerve and common peroneal nerve.**

Damage:

i) catastrophic if whole nerve affected.

ii) Unable to back if only branches to hamstrings involved.

d) **Tibial nerve: (mixed)**

Largest branch of sciatic - supplies **gastrocnemius and flexors of digit.**

Sensory part continues, palpable between DDF and common calcanean tendon, supplying skin on plantar surface of distal limb. At calcaneus divides into **medial and lateral plantar nerves** which are **main sensory supply to foot.**

Damage:

i) *Inability to extend hock and flex digit. Remarkably little effect on gait due to action of reciprocal apparatus.*

ii) *Loss of most sensation in hind foot.*

e) **Common peroneal nerve: (mixed)**

Divides into deep and superficial branches.

i) Superficial peroneal:

Motor to **lateral digital extensor** and sensory to skin of lateral **leg.**

ii) Deep peroneal:

Motor to **all other extensors of digit.**

Sensory part continues, dividing at hock into **medial and lateral dorsal metatarsal nerves,** supplying sensation from skin on metatarsus, fetlock **and pastern.**

Damage: *usually as a result of fibular fracture, where nerve is superficial. Inability to extend digit - may learn to compensate.*

Innervation of hind foot (Fig 6-M)

Sensation in the distal hind limb is supplied mainly by the terminal branches of the tibial nerve (medial and lateral plantar nerves).

Distribution of nerves is similar to fore limb, except that the communicating branch is reduced or absent. Lateral plantar nerve gives rise to **medial and lateral plantar metatarsal.**

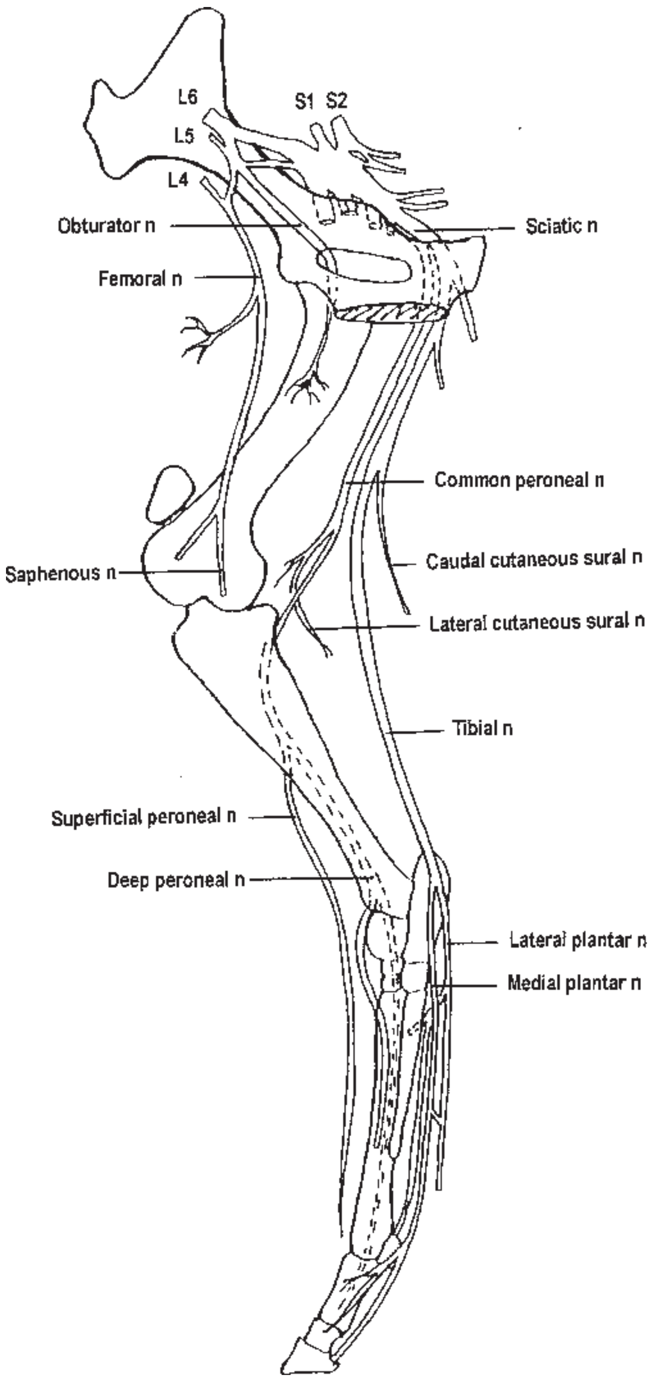


Figure 6-L: Innervation of hind limb (medial aspect right hind limb)

Nerves, which supply the suspensory ligament, palmar pouch of fetlock joint and some deep structures of the foot.

Clinically, most important differences between fore and hind limb innervation are:

a) ***dorsal metatarsal nerves (from deep peroneal) reach as far as coronary band***

b) ***plantar metatarsal nerves contribute to sensation in deep structures within hoof.***

Full local anaesthesia of the foot is, therefore, more difficult to achieve, requiring blocking of not only of plantar nerves, but also the plantar metatarsal nerves (tibial nerve), and dorsal metatarsal nerves (deep peroneal).

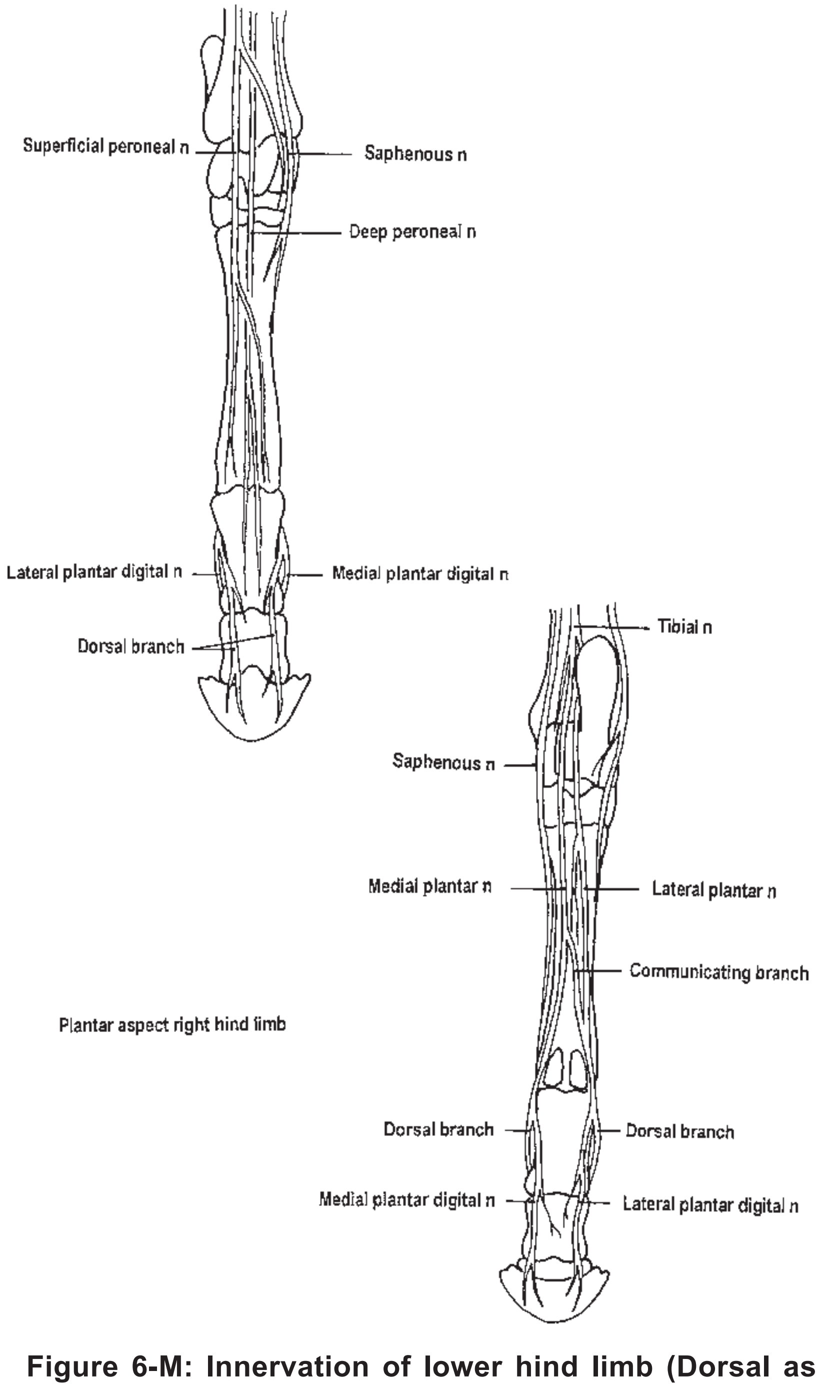


Figure 6-M: Innervation of lower hind limb (Dorsal aspect right hind)

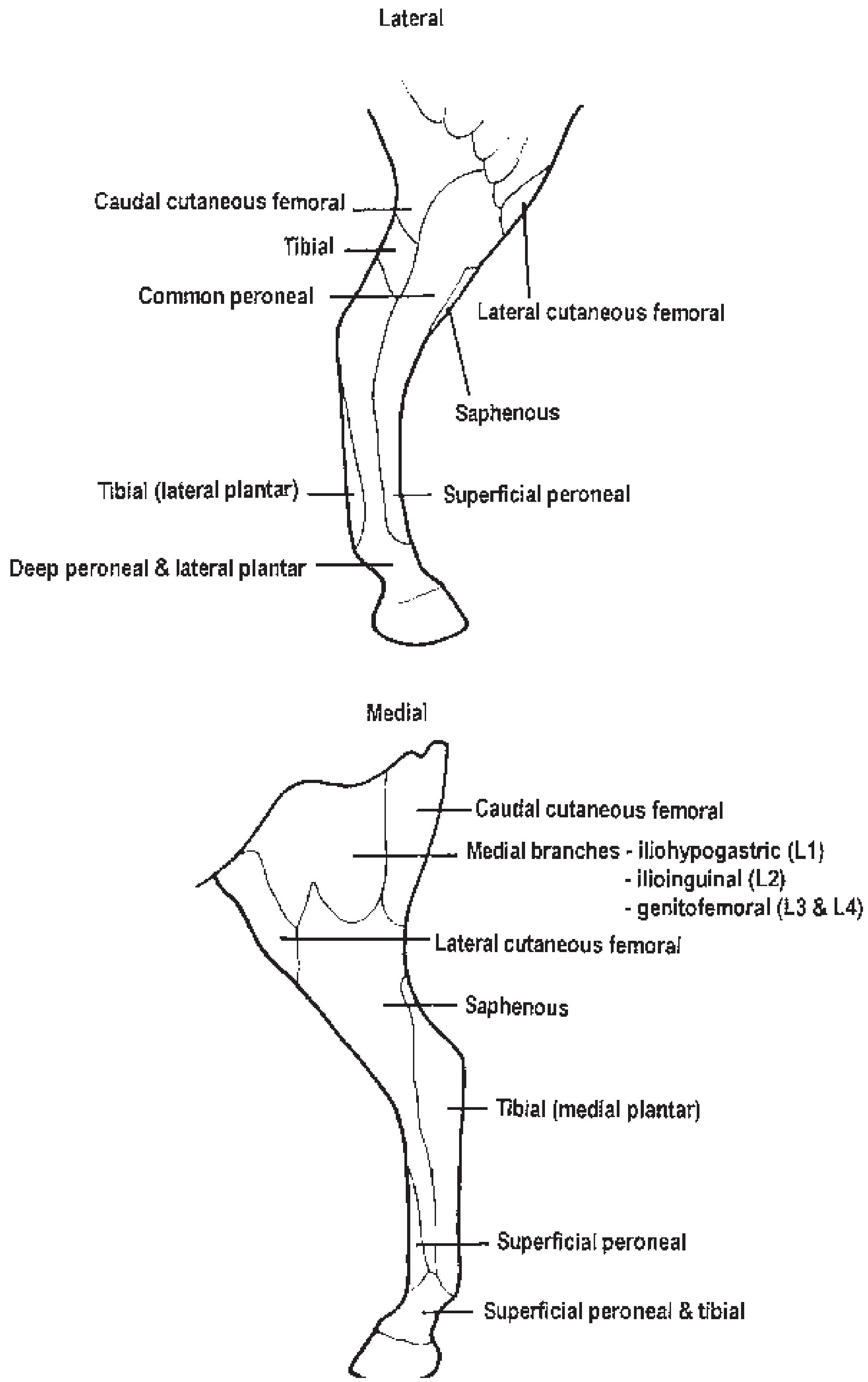


Figure 6-N: Hind limb cutaneous innervation

Chapter 7

Anatomy of the Head, Neck and Trunk

The back and neck in locomotion

General considerations

Many disorders and traumas in the locomotory system have a mechanical basis so a basic knowledge of the mechanical processes in locomotion is of considerable value. An understanding of the mechanics involved in locomotion will also add to your appreciation of the action of the muscles and ligaments involved.

For example, the Centre of Gravity of a horse is nearer the front of the animal with 55% of weight on the fore limb and 45% on the hind limb (see Fig. 7-A). If the head is raised, the centre of gravity is shifted backward and the front legs can be raised. If the head is lowered, the centre of gravity shifts forward and a hind; leg can be raised.

This also has important practical consequences: -

– to stop a horse kicking with its hind legs, keep its head high. This transfers the centre of gravity caudally and places more weight on the hind limbs.
– when a lame forelimb takes weight, the head is raised to reduce the weight on it.

Mechanical models of the back and neck

(a) Bending (in a vertical plane)

In terrestrial vertebrates the body axis has to bear the body weight and transmit the locomotory power -mainly from the hind legs. Early work suggested that the body could be compared with a table or a bridge (see Fig. 7-B}, but these static models do not represent a living, moving animal very well. In particular, they showed poor agreement with the structures actually found in animals.

The “String and Bow” Model

Modern theories suggest that the body can be likened to a “string and bow”. The body axis consists of a series of rigid elements (vertebrae) with intervertebral discs providing flexibility, to form a “bow” of variable curvature (see Fig. 7-C).

Stability of the "bow" is provided by the axial muscles, the supraspinous, dorsal and ventral ligaments, and the shape of articular processes between vertebrae. This results in compressive stress within the vertebral bodies and the trabeculae are aligned longitudinally to resist this stress.

Intervertebral joints allow flexibility in the "bow" and the soft nucleus pulposus of the intervertebral discs hydrostatically distributes the compressive forces evenly.

The curvature is stabilised by the ligaments and muscle bridges:

1. Dorsal - epaxial muscles which tend to straighten the "bow".
2. Ventral - hypaxial muscles in the thoracic and lumbar regions.
3. The "string" - consisting of abdominal muscles between the thoracic cage and the pelvic girdle caudally, and the scalenus muscle cranially.

The advantage of this system is that it is delicately balanced so that slight muscle contraction will compensate for changes in strain, e.g. a horse's back does not sag under the rider due to increased tension in the abdominal muscles.

However, young pups and cubs do have a sag in their back until their abdominal muscles are fully developed.

Unlike the early static models mentioned above, this is a dynamic system which can rapidly adjust to changing needs of the animal.

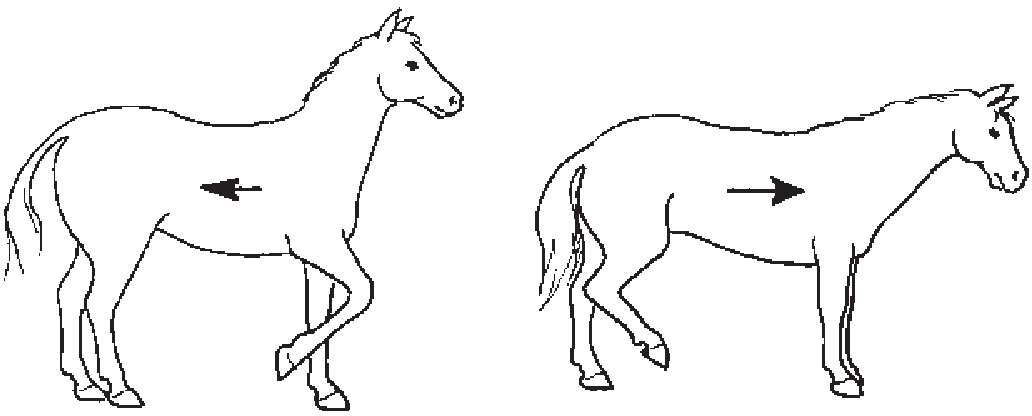


Figure 7-A: Changes in the centre of gravity associated with movements of the head

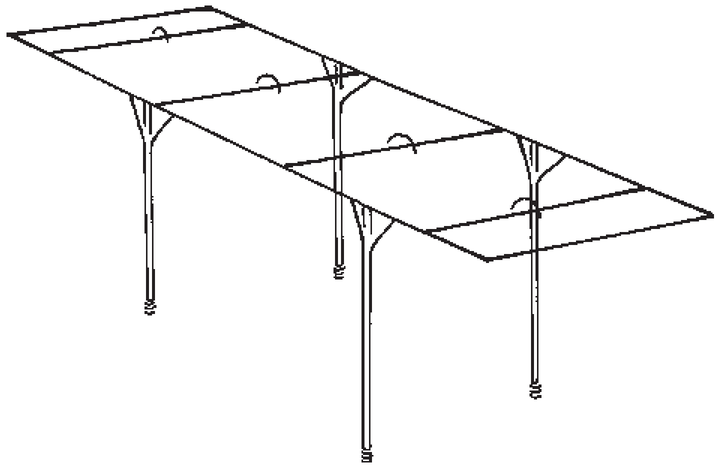


Figure 7-B: "Table" model for structure of the back

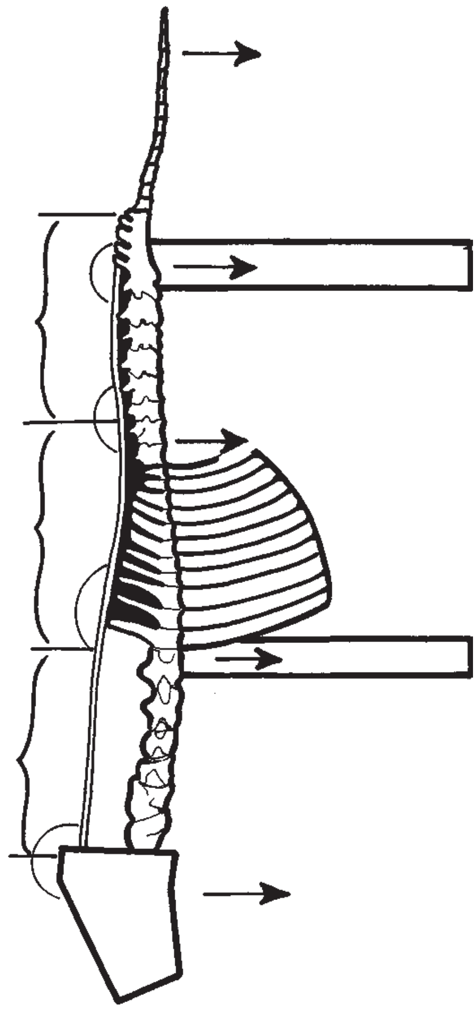


Figure 7-C: The "string and bow" model

Propulsion

Muscles, acting to retract the limbs, propel the animal forwards. Friction between the limb and the ground is essential for propulsion to occur. This is easily seen when watching an animal trying to run on a slippery floor.

In animals which bend their back when running, the propulsive force acts about a pivot near the thoraco-lumbar junction. Propulsion is produced by the action of axial muscles and extrinsic limb muscles.

Hindlimb

Retraction of the hindlimb is produced by the extensors of the back (longissimus muscles) and the extensors of the hip (middle gluteal and hamstring muscles) (see Fig. 7-D).

Forelimb

Retraction of the forelimb is produced by the flexors of the vertebral column (ext. abdominal oblique and rectus abdominis) and retractors of the forelimb (latissimus dorsi and deep pectoral muscles) (see Fig. 7-E).

The Head and Neck

As body size increases, scaling effects have important consequences on the structure and movement of animals.

- length increases by a factor x
- muscle strength increases by x^2
- weight increases by x^3
- moment increases by x^4

Thus as animals get larger, increasing power is needed to raise the head. In small animals the strength of the epaxial muscles is sufficient to keep the head up but in larger animals there is a distinct nuchal ligament.

Animals with long necks and heavy heads, such as the Artiodactyla, have highly developed nuchal ligaments extending from the head onto the back. As the neck is lowered, elastic fibres in the nuchal ligament will stretch, storing energy, which can be later utilised when the animal raises its head, thus reducing the strain on the muscles. Wild grazing animals must frequently raise their heads to detect approaching predators and so it is important to reduce the energy costs of this action.

These animals also have tall spinous processes on the thoracic vertebrae (withers). These provide a relatively large attachment area for the muscles of the back and the neck which are required for raising and lowering a heavy head.

(b) Horizontal (side to side) bending

A bend in this direction may take place when an animal suddenly changes direction and in dogs it often accompanies vigorous wagging of the tail.

The movement is restricted in horses due mainly to the prominent transverse processes of the lumbar vertebrae compared with that in the dog.

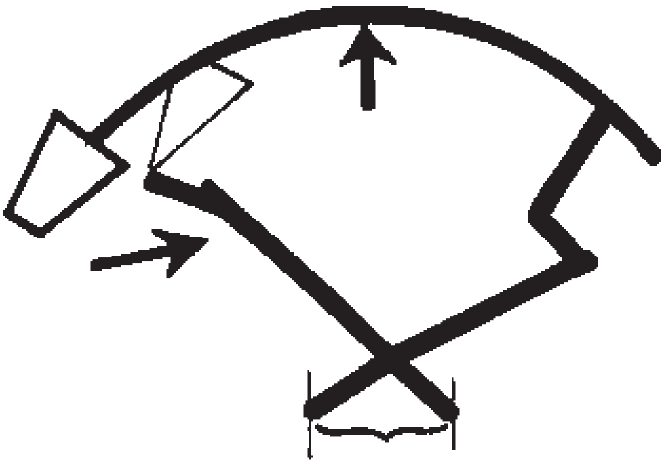


Figure 7-D: Retraction of the hind limb

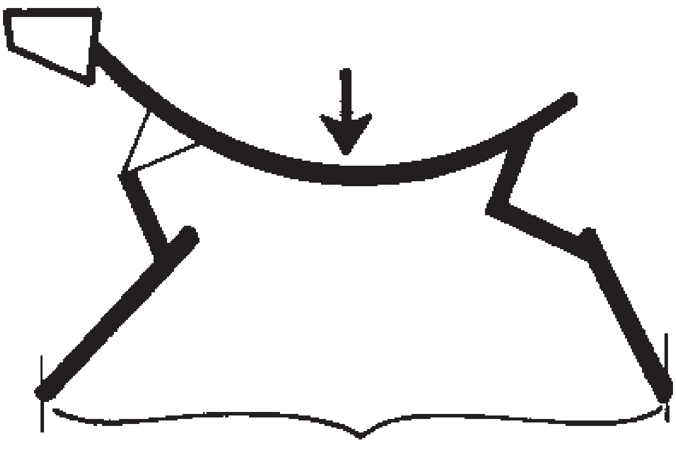


Figure 7-E: Retraction of the fore limb

(c) Rotation (torsion or twisting about a long axis)

This frequently occurs in animals when they are trying to get their legs over an obstacle during a jump. A rolling action of the back is also seen in the horse in pacing and might well occur in a dog taking a sharp bend. Thus, the essence of the relationship between the head, the neck, the back and the limbs is that the system represents a series of checks and balances.

The ligaments, the particular structure of the vertebrae, and especially the interaction between the epaxial and hypaxial musculature (particularly at high speeds) are all important, not only in assisting forward movement itself, but also in resisting undue distortion of the back and providing resilience against bending forces.

The limbs, for instance, are obviously vital in avoiding vertical distortion by virtue of their upward thrust, but each limb must thrust equally, if vertical distortion is to be avoided. Thus, all these structures must exert their correct force at the right time.

Major anatomical features of relevance

Bones (see chapter 1)

Cervical Vertebrae

Typically, low spinous processes and huge articular surfaces. Movement here is limited except rostro-caudally and for some lateral movement.

Atlas and Axis

Limited dorso-ventral movement because of the attachment of the dens, but rotation is permitted. Some lateral movement in this joint is seen in turning and shaking the head.

Atlas and Skull

Permits most vertical movement of the head and neck, e.g. nodding and tossing of the head. The joint also operates when the ‘chin’ is drawn in during a ‘collected’ walk or canter (arched neck).

Thoracic Vertebrae

Tall spinous processes. These vertebrae also articulate with the ribs.

Dog - 1st spine is the tallest. Spines point backwards to the 11th (anticlinal vertebral, then point forwards.

Horse - 1st spine is small, then increase in size to the 3rd, 4th and 5th.

Lumbar Vertebrae

Dog - The transverse processes point downwards and forwards.

Horse - The transverse processes are horizontal and the 4th, 5th and 6th articulate with each other. The 6th also articulates with the sacrum.

Sacrum

A series of fused vertebrae. Rigidity appears to be needed at this level of the spine.

Dog - 3 small spines.

Horse - 5 separate spines (fused in the ox and absent in the pig).

Caudal Vertebrae

The first few have spinous processes and transverse processes, but these are absent in the more caudal vertebrae.

Joints

1. Between the bodies of the vertebrae: (Amphiarthroses)

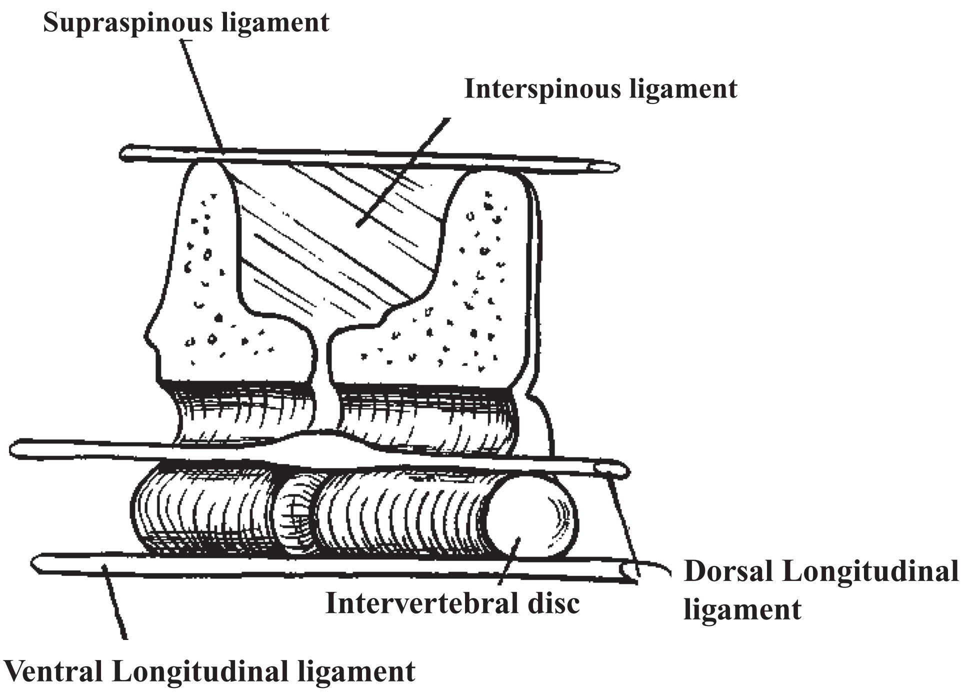
Characterised by intervertebral discs. Usually the annulus fibrosus of these discs is thicker ventrally.

Ligaments:

– Ventral Longitudinal ligament: Extends from the thoracic region to the sacrum and widens caudally. It is strongest in the lumbar region.

– Dorsal Longitudinal Ligament: Runs on the floor of the vertebral canal. Extends from the axis to the sacrum. It is wider over the intervertebral discs, but is less robust than the ventral ligament.

Most support is, therefore, on the ventral surface of the vertebrae.



2. Between the articular processes of the vertebrae (diarthroses)

Articular Surfaces

Cervical - flat and large - Arthrodia

Thoracic - flat

Lumbar - concave/convex - Trochoid

In the cervical region, the joint capsules are large but they become smaller caudally in the vertebral column.

Associated either directly or indirectly with these joints are:

(i) Supraspinous ligament;

(ii) Interspinous ligaments;

(iii) Intertransverse ligaments.

Supraspinous Ligament

Extends from the occipital bone or axis to the sacrum. It is modified in the neck and withers the nuchal ligament (ligamentum nuchae) (see Fig. 7-Fb.).

Dog - Extends from the spine of the axis to the spinous process of the first thoracic vertebra. It is simply a paired fibrous band of yellow elastic fibres,

Horse - Extends from the occipital bone to the first few thoracic spines, after which it continues caudally as the thoraco-lumbar part of the ligament, which is fibrous and not elastic. In the horse, the ligament consists of two parts:

i) Funicular Part: Extending onto the first thoracic spines, it changes from being a cord-like structure of roughly spherical diameter to a flattened wide strap-like structure over the thoracic spines. The changeover at the withers from elastic to fibrous tissue is imperceptible. Note:

The Atlantal Bursa, between the atlas and the Funicular part of the ligament is the seat (site) of Poll Evil, an infection of the bursa which is now relatively rare.

The Supraspinous Bursa, between the spinous processes of the 2nd and 3rd thoracic vertebrae and the ligament is the seat of a similar condition called Fistulous Withers,.

(ii) Lamellar Part: Two elastic lamellae separated by a layer of connective tissue. It is formed by ‘digitations’ extending from the 2nd and 3rd thoracic spines to the cervical spines (except for the first and the last). The 1st digitation going to the axis is very strong, and then each decreases in strength caudally, so that the last one is flimsy. The lamellar part of the nuchal ligament is:

– present in the ox
– less well developed in the pig
– absent in the dog (Fig. 7-Fa)

Interspinous Ligaments

Consist of fibrous strands passing downwards and forwards between the spinous processes of the thoracic and lumbar vertebrae. In the horse, the ligament is elastic between the last cervical and first thoracic vertebrae.

Intertransverse Ligaments

Between the transverse processes of lumbar vertebrae.

Yellow Ligaments (Ligamenta Flava)

Thin elastic sheets between arches of adjacent vertebrae.

3. Articulation between the skull and the atlas (ginglymus)

Articular Surfaces
Cavities of the atlas
Convex condyles of the occipital bone

Joint Capsule

Two, which may communicate ventrally.

Ligaments

2 small Lateral Ligaments extend from the atlas to the paracondylar process of the occipital bone.

Dorsal Atlanto-Occipital Membrane / Ventral Atlanta-Occipital Membrane: Both these membranes are fused to the joint capsule and extend from the atlas to the Foramen Magnum.

4. Articulation between the atlas and axis

Articular Surfaces

Saddle-shaped facets with wide notch above and narrow below.

Joint Capsule

Loose and ample laterally

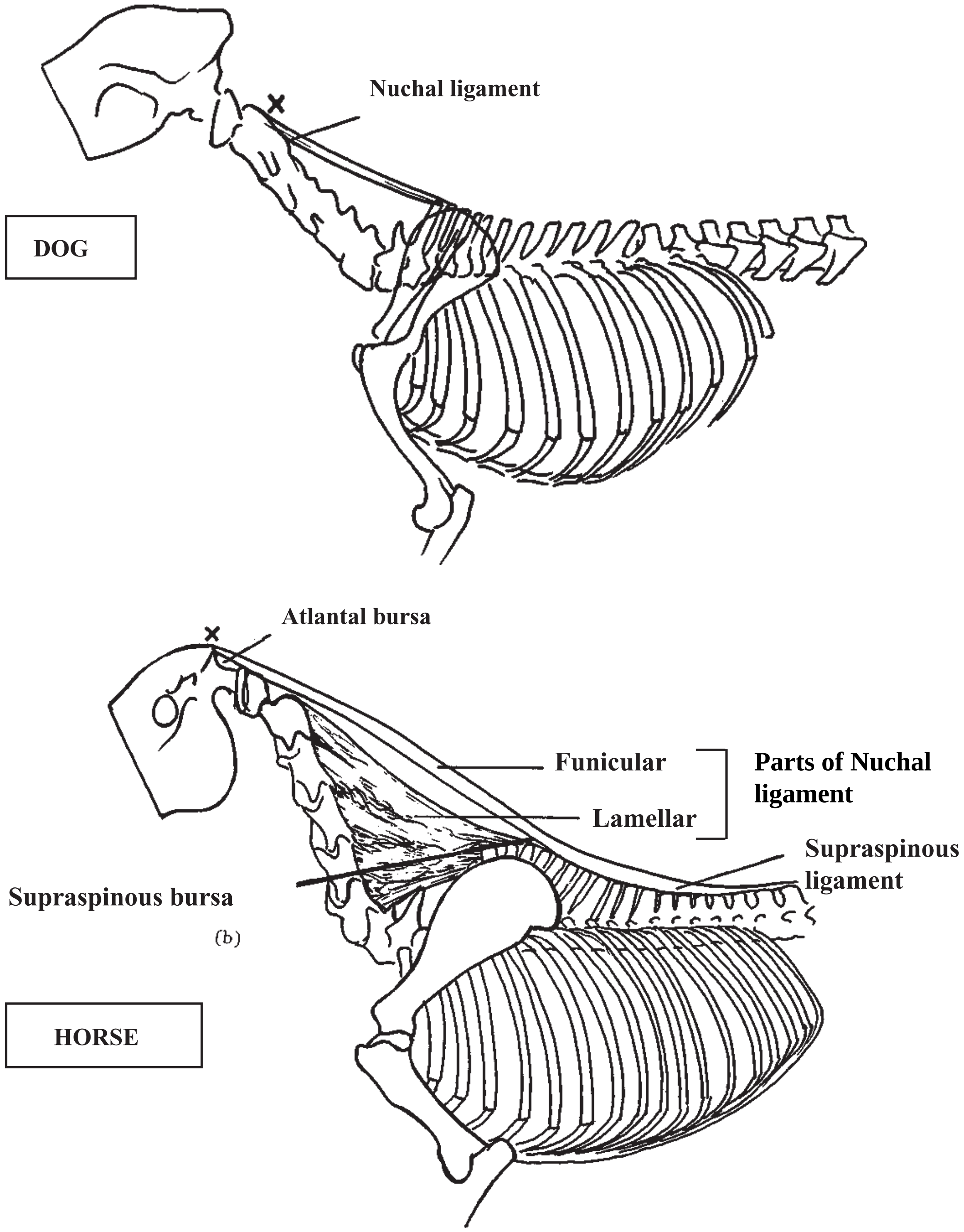
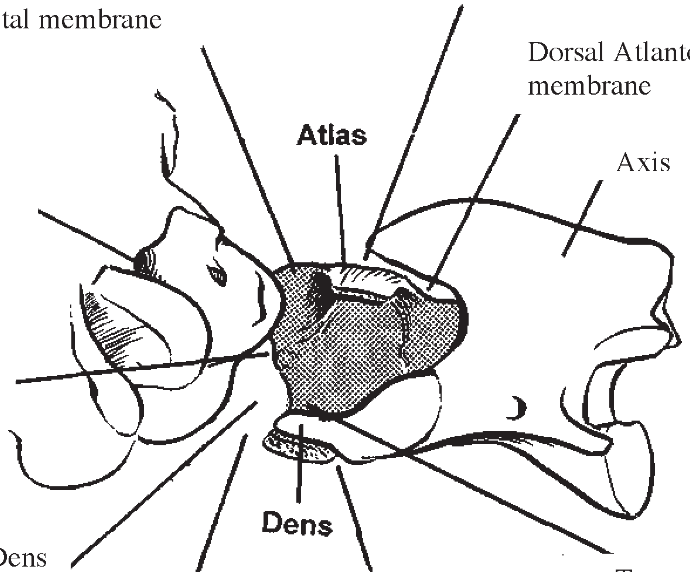


Figure 7-F: Ligamentum Nuchae



Ligaments

Dorsal Atlanto-Axial Membrane:

Reinforces the capsule dorsally. This ligament is membranous (tectorial membrane).

Interspinous Ligament:

Dorsal to the above ligament, this one passes from the arch of the atlas to the spine of the axis.

Ventral Atlanto Axial Membrane:

Runs ventrally between the ventral tubercles of each bone.

Ligament of the Dens:

Dog - An apical ligament of the dens. Consists of 3 parts:

Lateral Parts (Alar Ligaments) -Arise on lateral surface of dens and diverge to the occipital condyles at the side of the foramen magnum.

Central Part - Extends from the end of the dens to the floor of the foramen magnum.

Horse - Longitudinal ligament (of the dens) is short and strong and extends from the dorsal surface of the dens to the lateral part of the floor of the atlas.

Transverse Atlantal Ligament:

This ligament extends across the floor of the atlas over the top of the dens. It therefore, serves to hold down the dens onto the floor of the atlas. It is present in both the dog and the horse, and rupture of this ligament can occur in either species and is usually followed by sudden paralysis or death.

Muscles

Movements of the neck and back are produced by epaxial and hypaxial muscles.

a. Flexion of the back – hypaxials (assisted by abdominal muscles)
b. Extension of the back - epaxials
c. Lateral bending of the back – epaxials and hypaxials contracting unilaterally.
d. Rotation of the back - simultaneous unilateral contraction of epaxials and contralateral hypaxials in the lumbar region; thoracic region also uses the small rotator muscles.

Because some of the attachments of these muscles are difficult to locate in dissection, their major areas of attachment are presented here in Tables 7:1 to 7:5.

Hypaxial muscles

These are the muscles which lie immediately below the transverse processes of the vertebrae operating as ventral fixers of the spine but primarily as flexors of the spine. They have a close association with the action of the hindlimb in locomotion.

Perhaps the most conspicuous mass in this group is provided by the sublumbar muscles iliopsoas, psoas minor, quadratus lumborum. Their attachments are given in Table 7:1.

Epaxial muscles

Two characteristics:

a. Apart from some small special muscles, this musculature consists of 3 main columns of muscle which represent individual muscular systems.
b. The columns run along the dorsal surface of the back (above the "transverse processes of the vertebrae! and extend a variable distance up the neck, reaching, in one case, the head.

The distribution and attachments of the musculature in each system is described in Table 7:2 and illustrated in Figs. 7-Ga and b.

Extrinsic neck muscles

These muscles are attached entirely to cervical vertebrae and the skull. They are thus concerned primarily with movements of the head. By and large, they are situated dorsal to the cervical vertebrae. See Fig 7-H.

Lateral neck muscles

These muscles are associated with the trunk and the pectoral girdle, but extend into the neck and may reach the head.

Small muscles of the back

1. **Rotatory Muscles (Rotators)**

   Occurring in the dog, these small muscles are confined to the cranial end of the thoracic region and consist of two parts:

   (i) Long bundles - These are lateral to the other parts and extend forward from the transverse processes to the preceding spinous process.

   (ii) Short bundles - These are deep to the above and extend dorsally up to corresponding transverse processes.

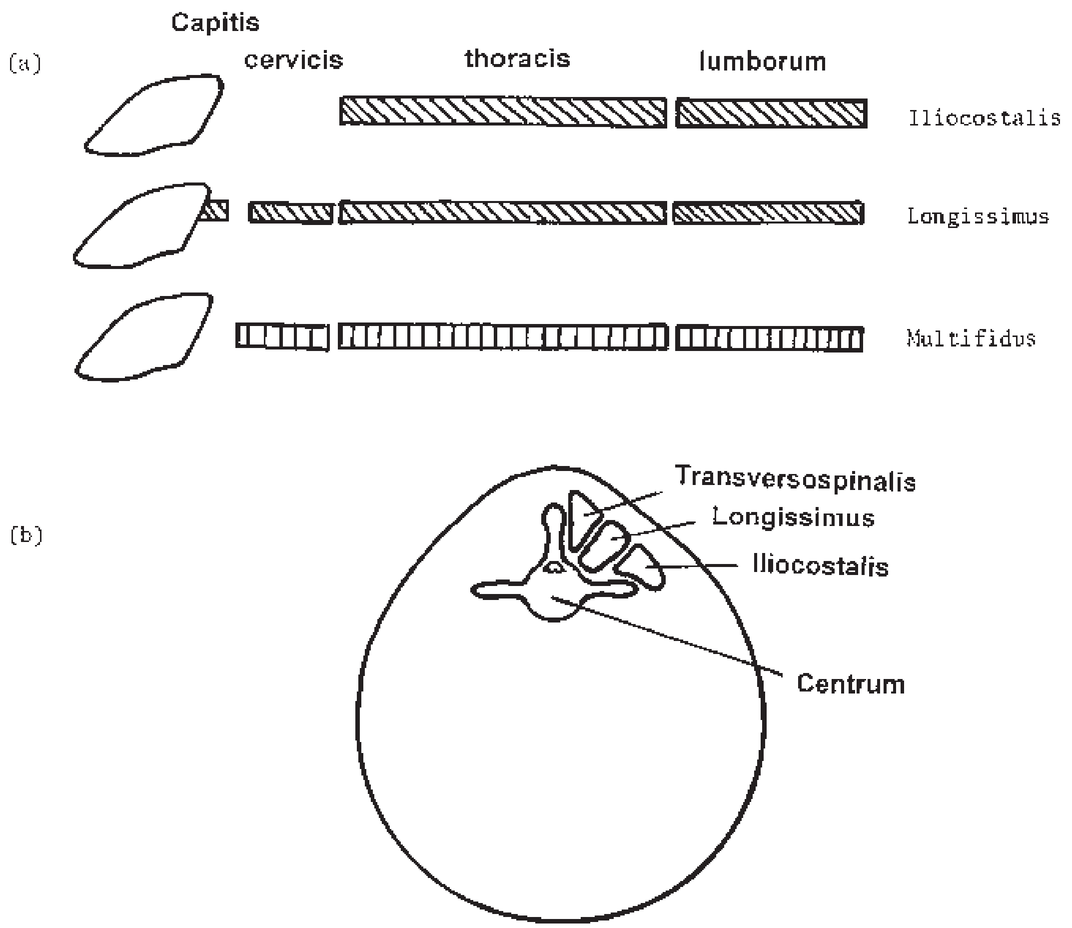


Figure 7-G: Epaxial muscles

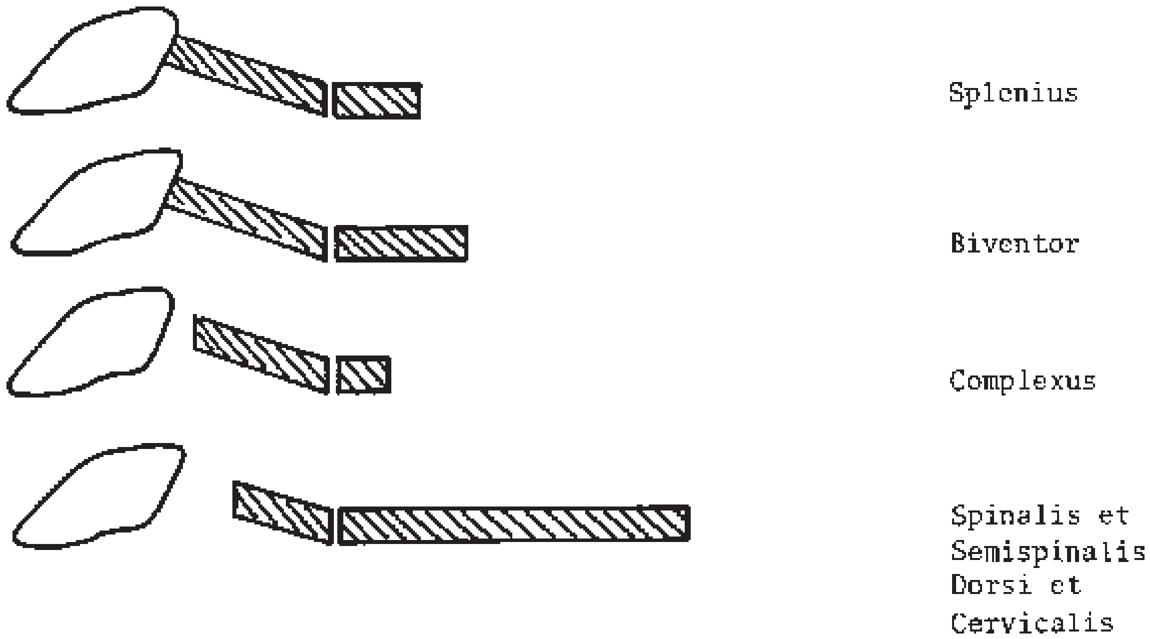


Figure 7-H: Extrinsic neck muscles

2. Interspinales

These muscles, distinctly divisible into lumbar, thoracic and cervical portions, are essentially between the spinous processes of the vertebrae. They must assist in fixing the vertebral column.

3. Intertransversarii

These are small muscle bundles extending more or less throughout the length of the spine. Thus, there are caudal, thoracolumbar and cervical groups. The cervical group consists of the largest bundles. The caudal group is referred to in the anatomy of the tail (see Teaching Guide on "Reproductive System").

These muscles are really epaxial muscles and serve to fix the back or to bend it if acting unilaterally.

Note:

You are asked to read over the contents of Tables 7-1 to 7-5. It will be in your interests to learn the details provided in Tables 7-1 and 7-5 but information given in the remaining tables need not be memorized in detail.

Table 7-1: Hypaxial muscles

Muscle	Attachments
Iliopsoas	Consists of the psoas major arising on the ventral surface of the last 3 or 4 lumbar vertebrae and the iliacus arising on the ventral surface of the ilium. Together the two parts pass under the middle gluteal and insert onto the lesser trochanter of the femur.
Psoas Minor	Arising from the last 3 or 4 thoracic and 1st 3 or 4 lumbar vertebrae, this muscle inserts onto the iliopectineal line.
Quadratus Lumborum	This is the most dorsal of the sublumbar muscles and is more extensive in the dog than in the horse. Dog - Has thoracic and lumbar portions. The former consists of muscle bundles which may become tendinous and extend to the last two or three thoracic vertebrae. The latter, associated in origin with psoas minor, runs under the transverse processes of the lumbar vertebrae to reach the medial surface of the wing of the ilium. Horse - A thin muscle, it extends from the level of the last two ribs, lies under the transverse processes of the lumbar vertebrae, to reach the wing of the sacrum and the ventral sacroiliac ligament.
Intertransversarii Lumborum (absent in the dog)	Between the transverse processes of the lumbar vertebrae except for 5 and 6.
	These muscles are assisted in dorsiflexion by the ABDOMINAL MUSCLES.
External Abdominal Oblique	Arising from the ribs (from about the 4th backwards) and the lumbodorsal fascia, this inserts onto the linea alba and caudally onto the prepubic tendon.
Internal Abdominal Oblique	Passing from the coxal tuber and the inguinal ligament, it passes to the linea alba and the last four or five ribs.
Transversus Abdominis	From the transverse processes of the lumbar vertebrae and the asternal ribs, this muscle runs to the linea alba and attaches to the xiphoid cartilage of the sternum.

Table 7-2: Epaxial muscles

Muscle	Attachments
Lateral Column (Lateral System)	
Iliocostalis	
- Lumborum	Wing of the ilium to transverse processes of all 7 lumbar vertebrae and last 4 or 5 ribs.
- Thoracis (Dorsi)	From the 12th to the 3rd ribs to transverse process of the last cervical vertebra.
Middle Column (Intermediate System)	
Longissimus	
- Thoracis (Dorsi) and Lumborum	Wing of the ilium to lumbar vertebrae, last 7 thoracics and last few ribs.
- Cervicis	Four fascicles from 2nd to 5th thoracics up to 3rd to 6th cervicals.
- Capitis	From 1st 3 thoracics, passing over the cervicals to the mastoid process of the temporal bone.
Medial Column (Medial System)	
Multifidus	
- Lumborum	This group has a lumbar, thoracic and cervical component and consists of little bundles of muscles. It is perhaps best
- Thoracis (Dorsi)	developed in the lumbar portion where it extends from the sacrum.
- Cervicis	In the neck it lies deep to the complexus and in the thoracic and lumbar regions it is associated with the rotator muscles, the interspinales and intertransversales.
Transversospinalis group	The multifidus muscles make up a major part of the medial column, but there are a number of other small, epaxial muscles which are all included in the Transversospinalis Group. These include: (a) Multifidus (b) Spinalis (c) Semispinalis (d) Rotatores (e) Interspinales (f) Intertransversarii

Table 7-3: Extrinsic neck muscles

Muscle	Attachments
Splenius	From the lumbodorsal fascia to the nuchal crest and mastoid processes of the temporal bone (in conjunction with the longissimus capitis).
Semispinalis Capitis	
- Biventor	
- Complexus	This is the dorsal part of this muscle mass and extends from the 2nd to the 4th thoracic vertebrae to the caudal part of the skull on the occipital bone. (It is slightly below the splenius.) From the 1st thoracic and last 4 cervical vertebrae to the nuchal crest. (It thus arises further forward than the biventor.)
Spinalis et Semispinalis	
Dorsi et Cervicis	Arising from the 10th rib as part of the aponeurosis of the longissimus dorsi, this complex extends forward from the 6th and 7th thoracic vertebrae onto the last 6 cervical vertebrae.

Table 7-4: Intrinsic neck muscles (Fig 7-l)

Muscle	Attachments
Longus Capitis	Extending from the cervical transverse processes to the tympanic bullae of the skull, this muscle lies ventral to the intertransversales and lateral to the longus colli. It pulls the head down.
Obliquus Capitis Caudalis	Extends obliquely from the spine of the axis to the wing of the atlas. It rotates the head or fixes it by bilateral action.
Obliquus Capitis cranialis	It has two parts: (a) Extends from the wing of the atlas to the mastoid process of the temporal bone. (It attaches with the cleidomastoid and sternomastoid.) (b) A superficial part goes to the nuchal crest. The whole muscle is concerned with extension of the atlanto-occipital joint (pushing the head forward).
Rectus Capitis Dorsalis Major	Extends from the spine of the axis to the nuchal crest. It also extends the atlanto-occipital joint (it has another portion which is considered by some to be a separate muscle - the Rectus Capitis Dorsalis Intermedius).
Rectus Capitis Dorsalis Minor	Extends from the arch of the atlas to the occipital bone at the foramen magnum. It also extends the atlanto-occipital joint.
Rectus Capitis Ventralis	Extends from the ventral arch of the atlas to the basi occipital bone. It flexes the atlanto-occipital joint (draws the chin in).
Rectus Capitis Lateralis	Extends from the caudal half of the wing of the atlas to the occipital bone. This is also a flexor of the atlanto-occipital joint, but may also assist in turning the head laterally.

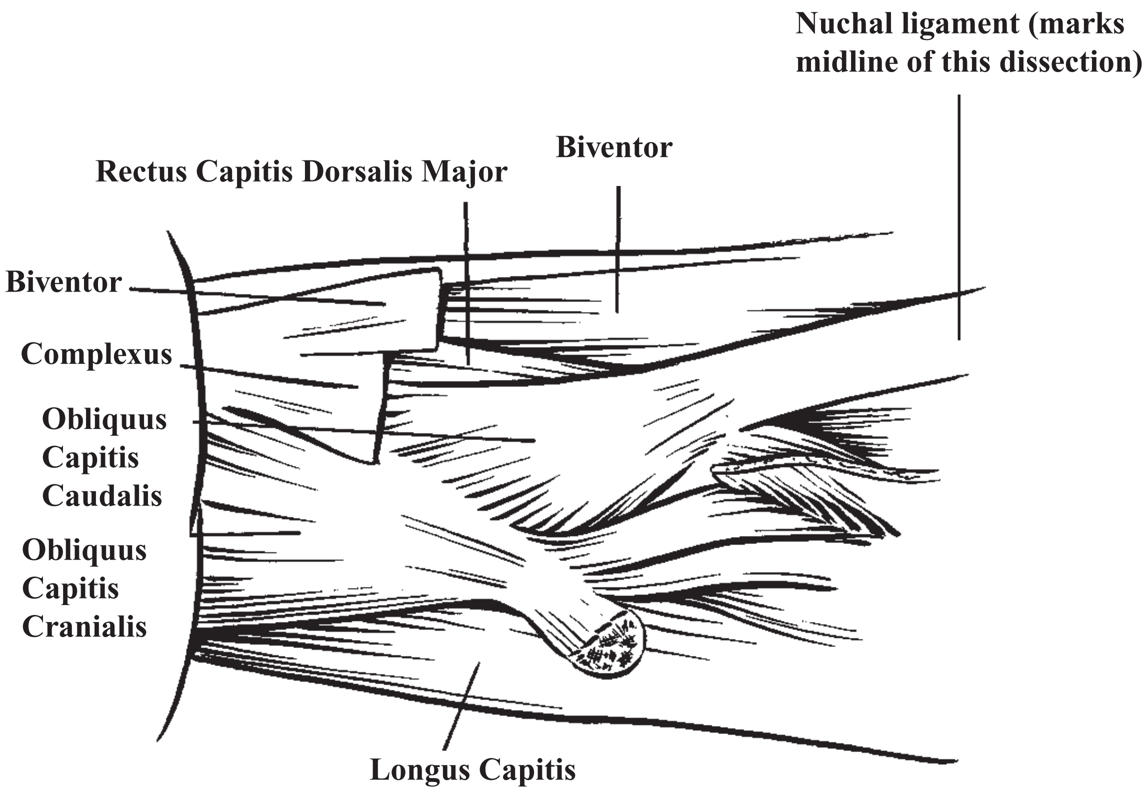


Figure 7- I: Intrinsic neck muscles

Table 7-5: Lateral neck muscles

Muscle	Attachments
Brachiocephalic	Extends between the upper cranial border of the humerus and axillary fascia to the median raphe of the neck and the mastoid process of the temporal bone. It is the prime protractor of the forelimb or turns the head and neck if the forelimb is fixed.
Sternocephalic	It extends from the sternum (cariniform cartilage) to the ramus of the mandible. It flexes the head and when acting singularly, it inclines the head. NOTE: Innervated by the spinal accessory (Cranial Nerve XI).
Omohyoid (absent in the dog)	Extends from the subscapula fascia close to the shoulder joint to the lingual process of the hyoid bone. It retracts the root of the tongue.
Omotransversarius (absent in the horse)	Extends from the spine of the scapula to the caudal end of the wing of the atlas. It flexes the neck laterally if the leg is fixed.
Scalenus	A strangely complex muscle, it consists of two major parts. (a) A deep part - Scalenus Primae Costae. This part is again divided into two: (i) Dorsal part - Extending from the 1st rib to the 7th cervical vertebra. (ii) Ventral part - Extending from the 1st rib to the 6th, 5th and 4th cervical vertebrae. (b) A superficial part - Scalenus Supracostalis, which goes back to the 7th or 8th rib. This muscle may flex the neck laterally, but may also assist (through the scalenus primae costae) in inspiration.
Serratus Ventralis	Its cervical part extends from the scapula to the 4th and 5th cervical vertebrae (it also has a thoracic part which goes to the 8th and 9th ribs), This muscle exerts a stabilizing action and has little effect on movement of the neck

Thoracic and abdominal anatomy

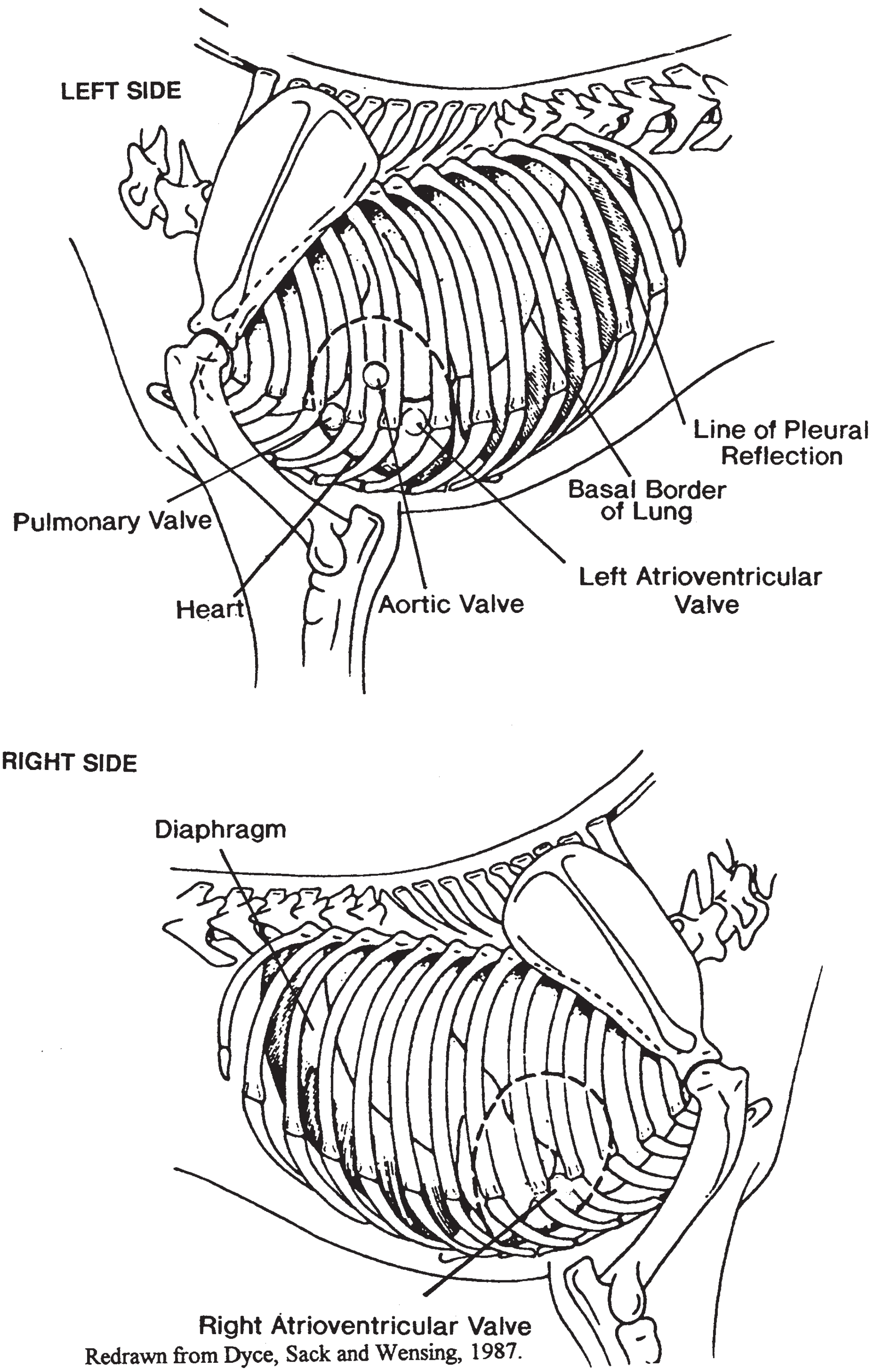
It is beyond the scope of this manual to cover detailed anatomy of the thorax and abdomen. From the point of view of locomotion, the significant species differences in trunk anatomy arise not only from differing roles as prey and predator, but also because of the necessity to house differing digestive systems.

The canine digestive system is very similar to the human design, with a simple stomach, long small intestine for digestion and absorption, a small redundant caecum, and a relatively short large intestine for further absorption. The pattern of feeding of carnivores such as dogs (although they are omnivorous both in the wild and when domesticated), it catching and eating food, resting while food is digested, then hunting again when hungry.

By contrast, the horse is herbivorous, and like all herbivores it must find a way to circumvent the inability of mammalian digestive processes to break down cellulose. They achieve this by housing vast numbers of bacteria in the digestive tract that can perform this digestive role, but this requires them to carry enormous volumes of fermenting cellulose in a soup of digestive secretions for hours while fermentation is achieved. This process occurs in the forestomach of ruminants, and in the caecum of the horse. The horse's large intestine is also elaborated into vast coils, so most of the volume of digestive material lies in the caudal portion of the digestive tract.

It is apparent that the comparatively short thorax, slender abdomen and flexible spine of the dog could not support the enormous weight of the caudal digestive tract of the horse, hence the extended thorax (and 18 ribs), relatively rigid back and the heavy elastic tunic of the equine abdominal wall.

It is not necessary to know the detailed anatomy of the thoracic and abdominal contents, but their general topography in the dog and the horse are illustrated in Figures 7-K to 7-O.



Redrawn from Dyce, Sack and Wensing, 1987.

Figure 7-K: Topographical anatomy of the canine thorax

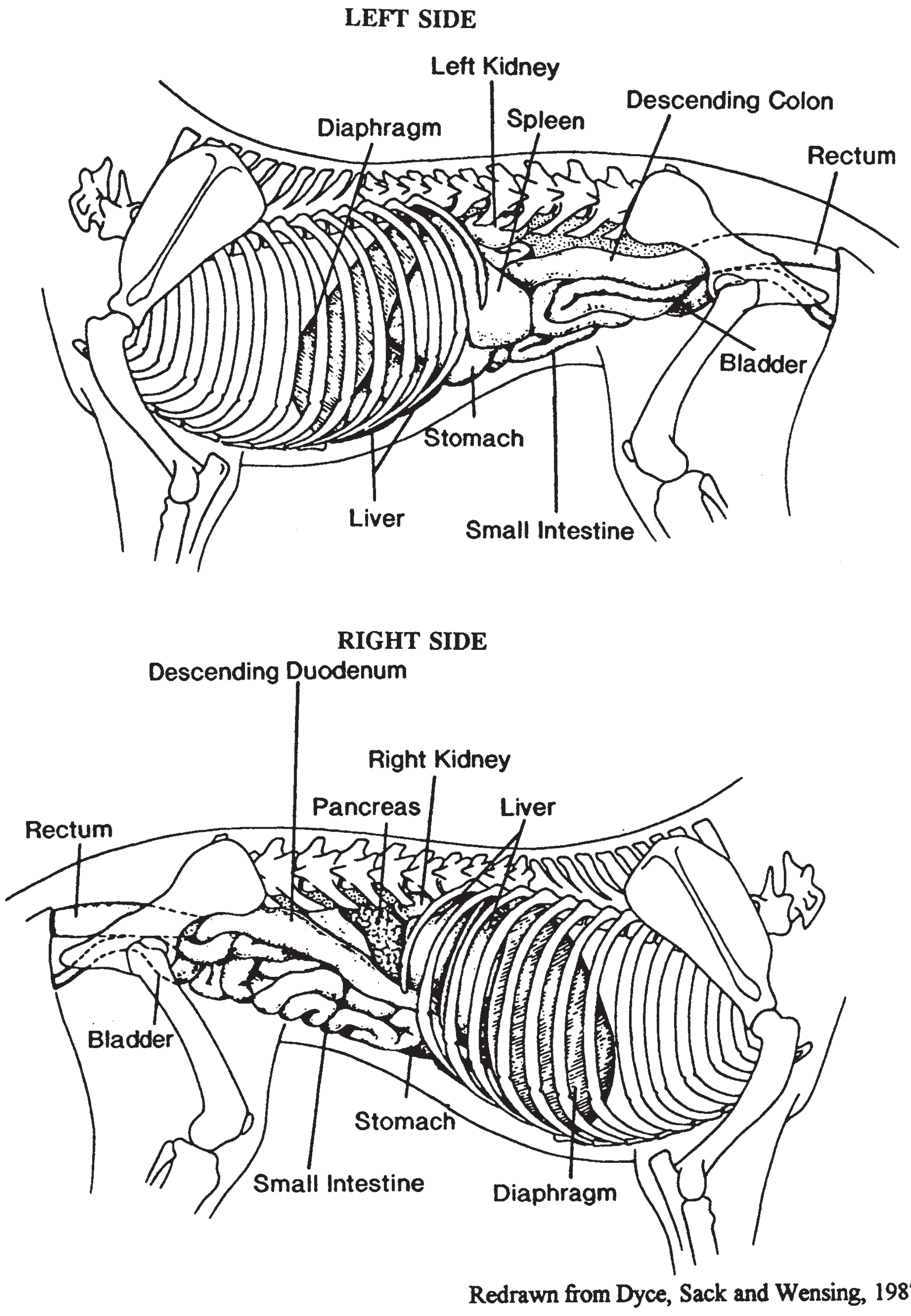


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Figure 7-L: Topographical anatomy of the canine abdomen

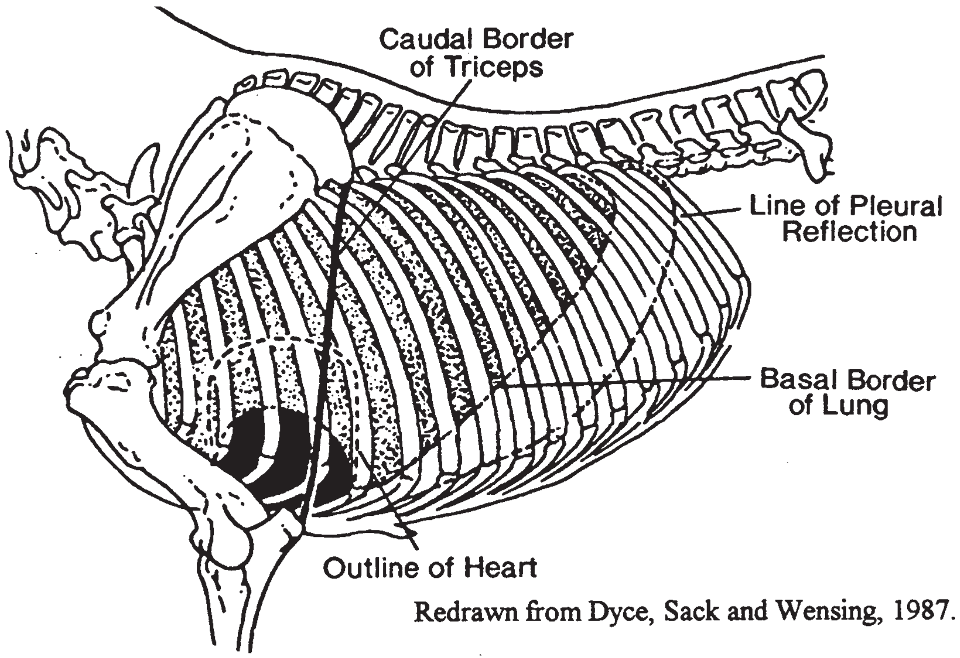


Figure 7-M: Topographical anatomy of the equine thorax

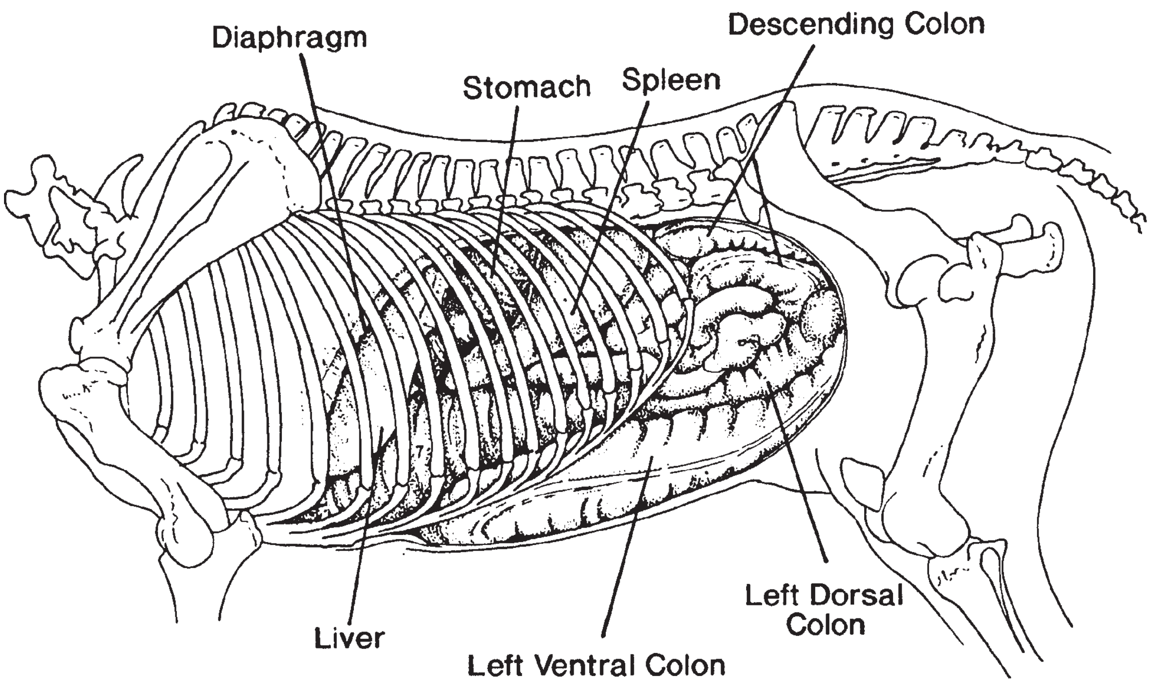


Figure 7-N: Topographical anatomy of the left side of the equine abdomen (Redrawn from Dyce, Sack and Wensing, 1987)

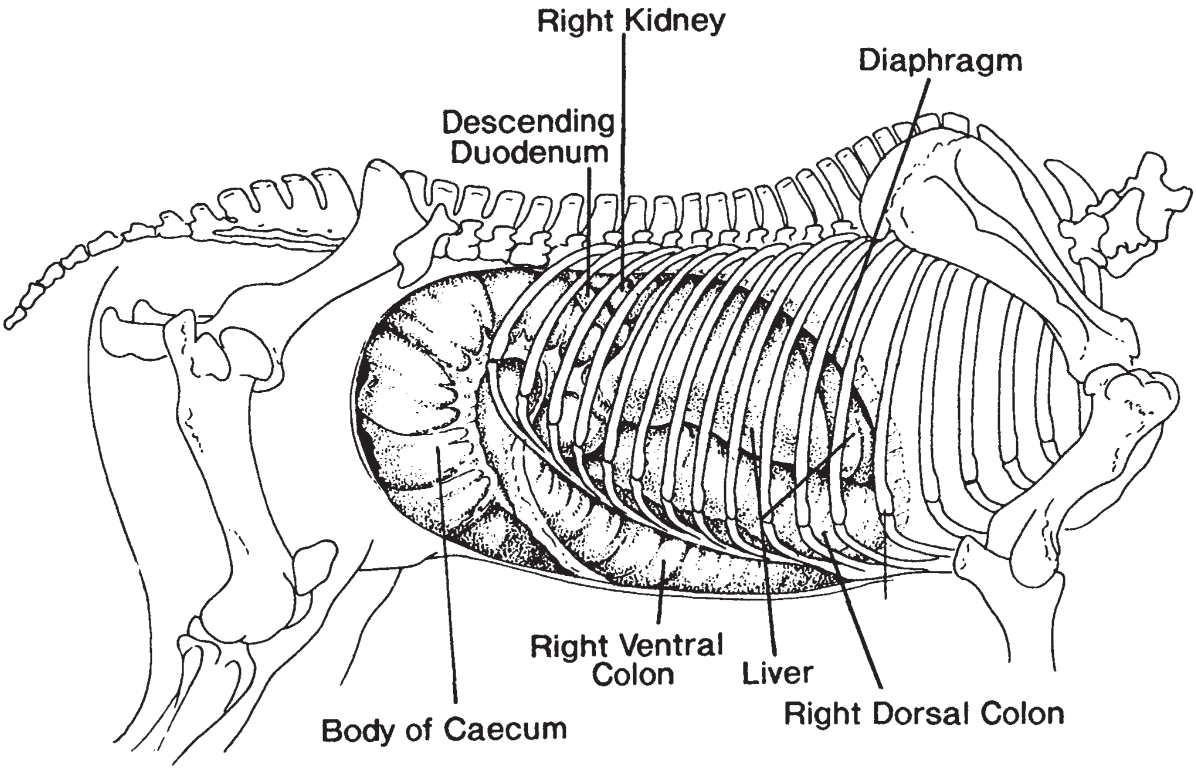


Figure 7-O: Topographical anatomy of the right side of the equine abdomen (Redrawn from Dyce, Sack and Wensing, 1987)

Dentition

The head acts as a balance arm in locomotion of the quadruped, so some understanding of the differing anatomy of the head is required. The profoundly different head shape in dogs and horses results largely from the dentition: the teeth of dogs are adapted for an omnivorous (though largely carnivorous) diet requiring tearing and shearing, while those of the horse are adapted for a purely herbivorous diet requiring cutting and grinding.

Teeth originated in vertebrates as simple, conical structures, derived from dermal scales. They were readily disposable as they became worn, as is seen in sharks and a number of other vertebrates to this day.

In mammals, teeth are much more permanent structures and the types, number and arrangement of teeth is different in each species. Each tooth has a root embedded in a socket or alveolus, and a crown protruding above the gingiva. They are all comprised of three mineralized tissues (see Fig 7-J):

– **Dentine:** similar to bone, is formed by odontoblasts at base of dentine layer; these remain alive for life of tooth.
– **Enamel:** the hardest substance in the body, is formed of hexagonal prisms of hydroxyapatite. Formed by ameloblasts, which disintegrate after enamel is formed; thus it cannot undergo repair.
– **Cement:** similar to bone, contains collagen fibres "which extend into bony socket (alveolus); they form periodontal membrane which holds tooth in place.

These tissues vary somewhat in their arrangement in the two main types of tooth. (Note: not all teeth can be classified into these types).

Brachydont teeth, which have deep roots in relation to the crown; the crown is covered in enamel, and in general the teeth stop growing once they have reached adult size (Fig 7P-a). This is the kind of tooth found in dogs

Hypsodont teeth, which have high crowns in relation to the roots; the crown is covered in cementum as well as enamel, and enamel also extends into the root. The teeth may retain the potential for growth throughout life (Fig 7-Pb, c). As the surface wears down (by about 2-3mm per year), the pulp cavity may become exposed, but this is sealed off by secondary dentine formed as result of odontoblast activity. This is the kind of tooth found in herbivores, including the horse.

The teeth in mammals have different functions in different parts of the oral cavity:

Incisors: which are brachydont in dogs, but hypsodont in horses, are used for cutting off pieces of food (mainly in herbivores). Normally three on each side, upper and lower.

Canines: are used for grasping food (carnivores) and for offence. Are absent in ruminants, and most mares. An interdental space or diastema separates canines from cheek teeth.

Cheek teeth: (**premolars**, **molars**) which are more complex, may be brachydont (dog,) or hypsodont (horse).

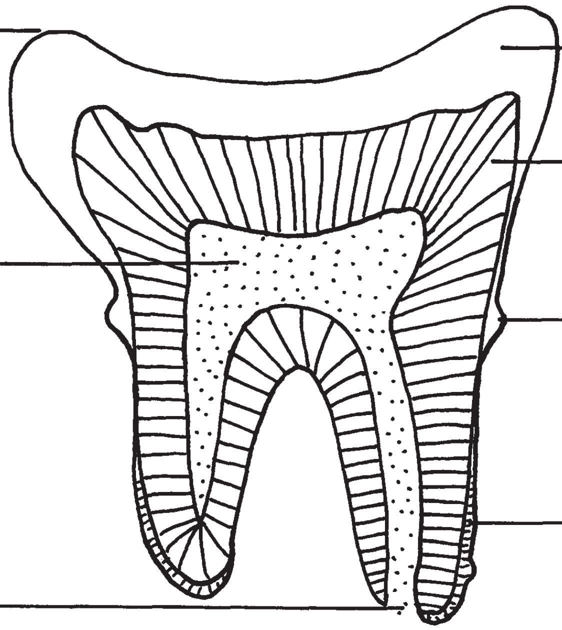


Figure 7-Pa: Frontal section of a human molar

Cheek teeth in herbivores have a complex pattern on the surface due to invagination of enamel layer. As the surface wears down, hard enamel crests occur on surface (Figs 3B, C). Because of hardness of enamel, these help in grinding of food. This grinding action is helped by sloping surface of teeth, and by lateral jaw movements. Sharp edges may develop, which require rasping if they irritate the mucosa of the cheek or interfere with eating.

Cheek teeth in carnivores are very effective in crushing and cutting food. Main cutting action is by **carnassial teeth**, which are P4/M1 in dog.

The number of teeth of each type is often described by the **dental formula,** which tells the number of incisors, canines, premolars and molars. In young animals, deciduous teeth appear first. Because of smaller size of jaws, these are smaller than permanent teeth, they do not all erupt together, and they are fewer in number even when all present (eg. there are no deciduous molars).

Deciduous teeth are replaced in fixed sequence, and some deciduous, and some permanent teeth may be present together. Replacement occurs as a developing permanent tooth grows and occludes blood supply to the deciduous tooth. This dies, and falls out, then the permanent tooth erupts into the corresponding socket.

Thus the dental formula for deciduous teeth of the dog is:

$$\frac{I3 - C1 - P3}{I3 - C1 - P3} = 28$$

while the adult dental formula is:

$$\frac{I3 - C1 - P4 - M2}{I3 - C1 - P4 - M3} = 42$$

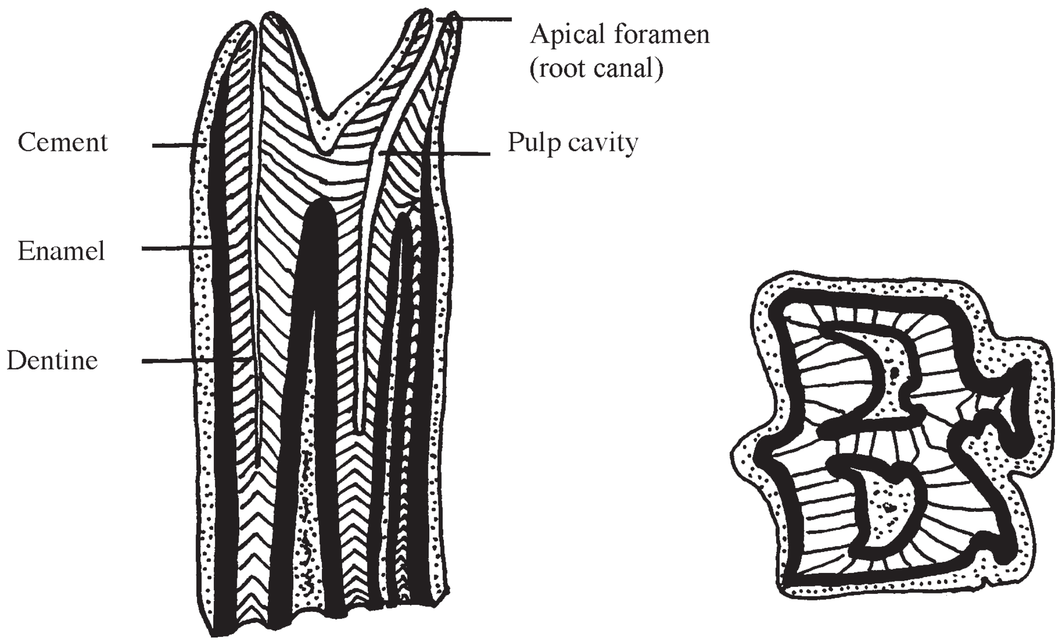


Figure 7-Pb: Upper cheek tooth of horse: frontal and transverse sections

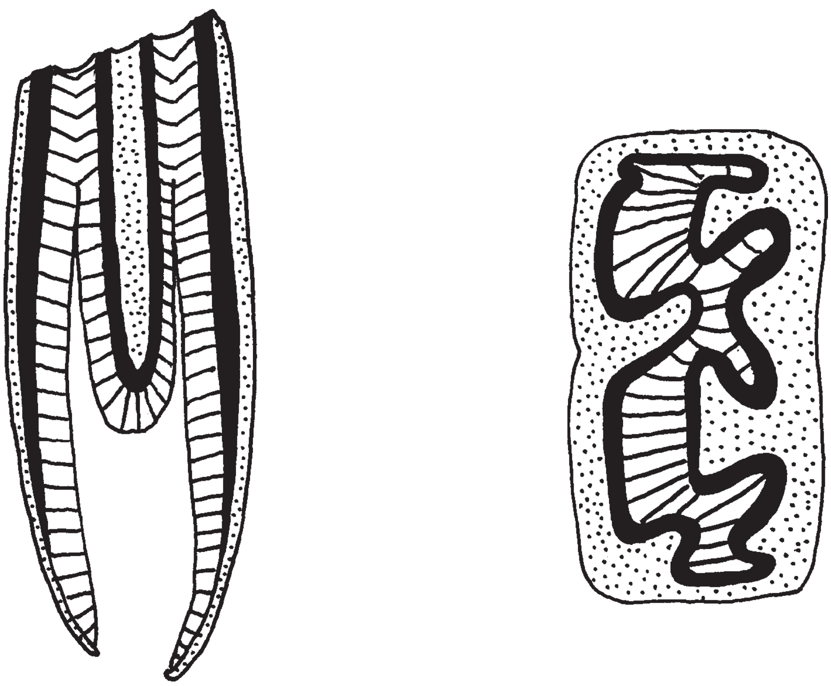


Figure 7-Pc: Lower cheek toot of horse: frontal and transverse sections

In horses, the deciduous dental formula is

I3 – C0 – P3
I3 – C0 – P3

The adult formula is

I3 – C1 – P3(4).-.M3
I3 – C1 – P3 – M3

Canines are generally absent in mares, though not always; the fourth upper premolar may interfere with comfortable bit placement and may require removal.

The teeth may be used as a guide for estimation of age in the horse, but different individuals wear their teeth at different rates, particularly if subject to vices such as crib-biting. Once all permanent teeth are in wear at 5 years, aging horses from their teeth becomes unreliable, and beyond about 8 years of age, it is a largely speculative process based on knowledge of averages. Tables describing the process of aging a horse from its teeth are available in numerous textbooks, including Textbook of Veterinary Anatomy (Dyce, Sack and Wensing).

One important aspect of the upper cheek teeth is their relationship with the maxillary sinuses of the skull (Figure 7-Q). The roots of the molars are separated from the sinus only by thin alveolar bone, so infection may spread to the sinus from tooth root abscesses. As the animal ages, the volume of the sinus enlarges as extrusion of the tooth gradually lowers the alveolar floor, and as the teeth migrate rostrally to some degree. Removal of an upper cheek tooth is sometimes required, and this is achieved by opening the sinus and applying retropulsion to the tooth.

Relationship of the teeth to the jaws

The upper incisors are embedded in the **incisive** bone (premaxilla), and the canines and premolars and molars in the **maxilla**. In young horses, the molars and occasionally last premolar project into the **maxillary sinus**, but as the horse ages and the teeth grow the amount of tooth in the sinus decreases. All lower teeth are embedded in the **mandible**.

The mandible is free to move in all three planes. However, movement in the frontal and transverse planes is freer in herbivores than carnivores.

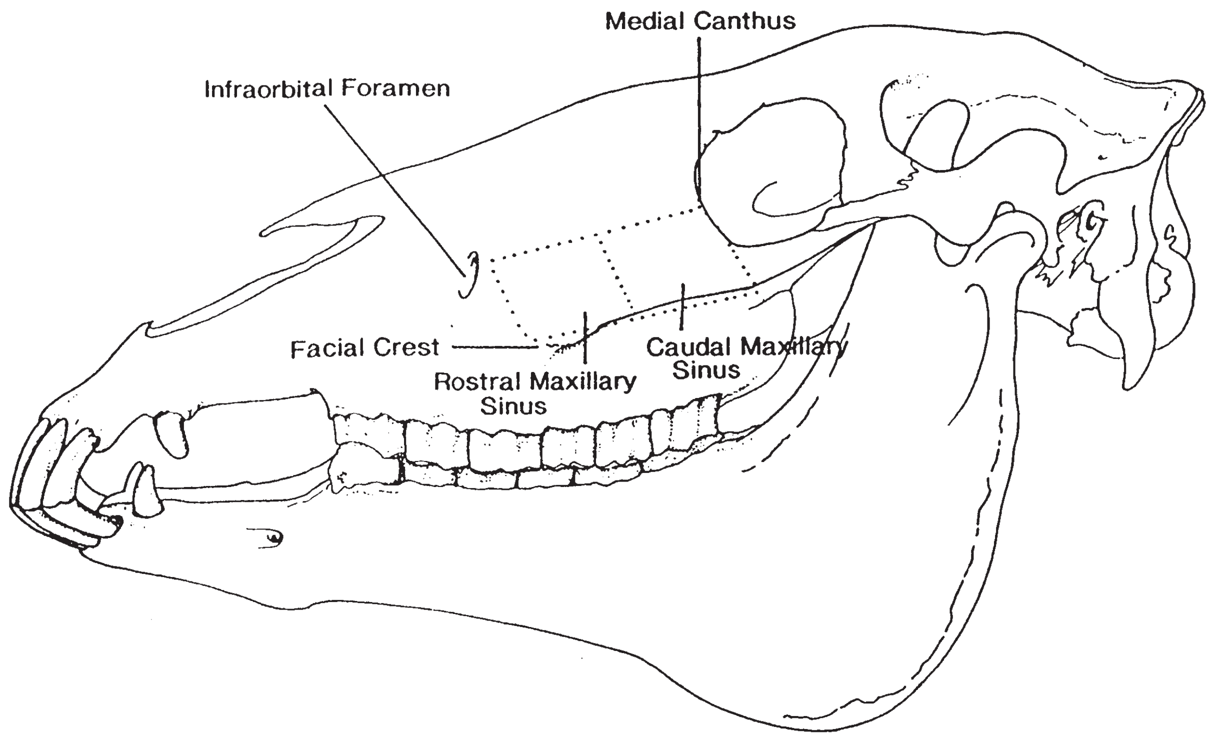


Figure 7-Q: Relationship of upper cheek teeth of horse to maxillary sinus (redrawn from Dyce, Sack and Wensing, 1987)

Questions

Back injury, particularly muscular damage, commonly results from sudden sprinting in dogs, for example, chasing a ball or a Frisbee. Why do you think injury of this kind occurs more readily in dogs than in horses?

Why do you think the Nuchal ligament of a dog is poorly developed relative to that of a horse?

Why is dorsiflexion of the spine especially dangerous to health in older animals?

Chapter 8

Gait and Conformation

Gait

Gait is the manner in which an animal progresses in locomotion. These notes concern quadrupedal gait only, with special emphasis on the gait of the horse.

Each gait is described pictorially, and by footfall formula, which illustrates which feet are on the ground during each phase of the gait. Footfall timing (hoof beat) is also described.

Note: Near = left Off = right

Natural gaits

1.	Walk	3.	Canter
2.	Trot	4.	Gallop
		5.	(Backing)

Walk and trot are referred to as **equal gaits** because the limbs on either side of the body provide equal thrust. Canter and gallop are **unequal gaits** in that one limb (lead limb) exerts more thrust than its opposite number.

Artificial gaits

These are gaits for which the horse is trained. The most commonly encountered in Australia is the Pace, used in some harness racing. Others are used in American breeds such as the Saddlebred and Tennessee Walking Horse, and include the Flat-foot and Running walk, Rack, Fox Trot, Amble.

Walk (Fig 8-A)

A four beat diagonal gait in eight phases, where the second half of the cycle is a mirror image of the first half. It is an equal gait, with no moment of suspension.

At a brisk walk, the hind limb footfall lands in the same place as the fore limb of the same side (tracking up), or slightly in front (over tracking).

Footfall formula:

LH	LH	LH LF	LH LF	LH LF	LF	LF	
RH RF	RF	RF		RH	RF	RH RF	

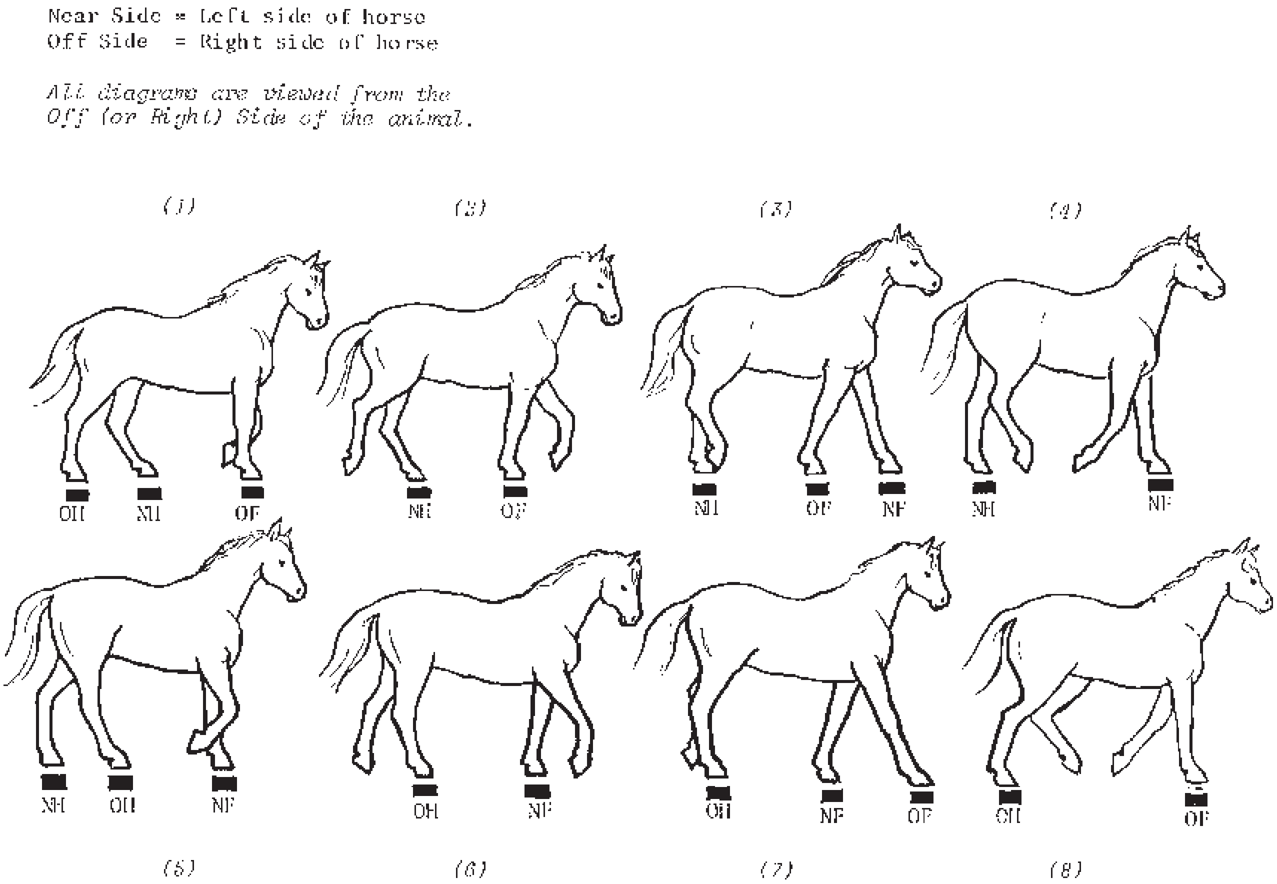


Figure 8-A: The walk

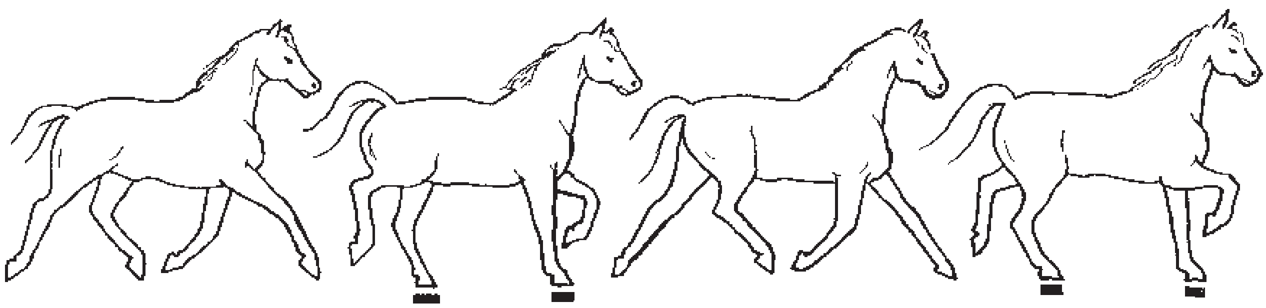


Figure 8-B: The trot

Trot (Fig 8-B)

A two beat diagonal gait with two moments of suspension per cycle.

The head of the horse does not normally nod in trot because diagonal balance is maintained throughout the cycle, so this is a good gait for assessing lameness. The **head nods downward on the sound forelimb**.

Footfall formula:

LH		LF	
RF		RH	

Pace (Fig 8-C)

An artificial two beat lateral gait. Support is by ipsilateral limbs, with two moments of suspension per cycle.

Some animals do this naturally (camel, some large dogs); pacers have been bred for this gait and some foals will adopt this gait naturally from birth. Most, however, must be trained with hobbles.

It is a fast gait (although no faster than a fast trot), but it avoids collision between fore and hind limbs resulting in overreach injuries, which may occur at a fast trot. At speed, pacing causes a considerable "rolling" of the back, which can be most disconcerting when ex-pacers are used for riding after retirement from racing.

Footfall formula:

		LH LF	
RH RF			

Canter (Fig 8-D)

A three beat unequal gait, with one moment of suspension at the end of the cycle.

The leading limb is usually the inside limb while the horse is on a circle, but may be either. If the outside limb is leading on a circle, it is referred to as counter-canter. In sustained cantering, lead limbs are changed intermittently to prevent fatigue.

Footfall formula (left leg leading):

		LH	LH	LH LF	LF	LF	
RH	RH	RH RF	RF	RF	RF		

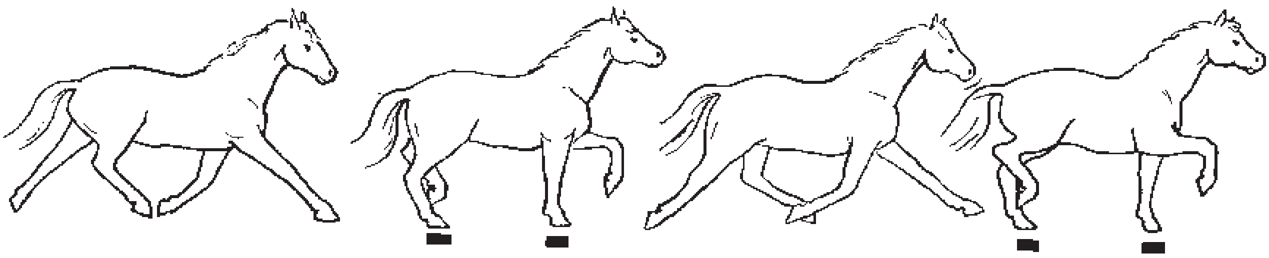
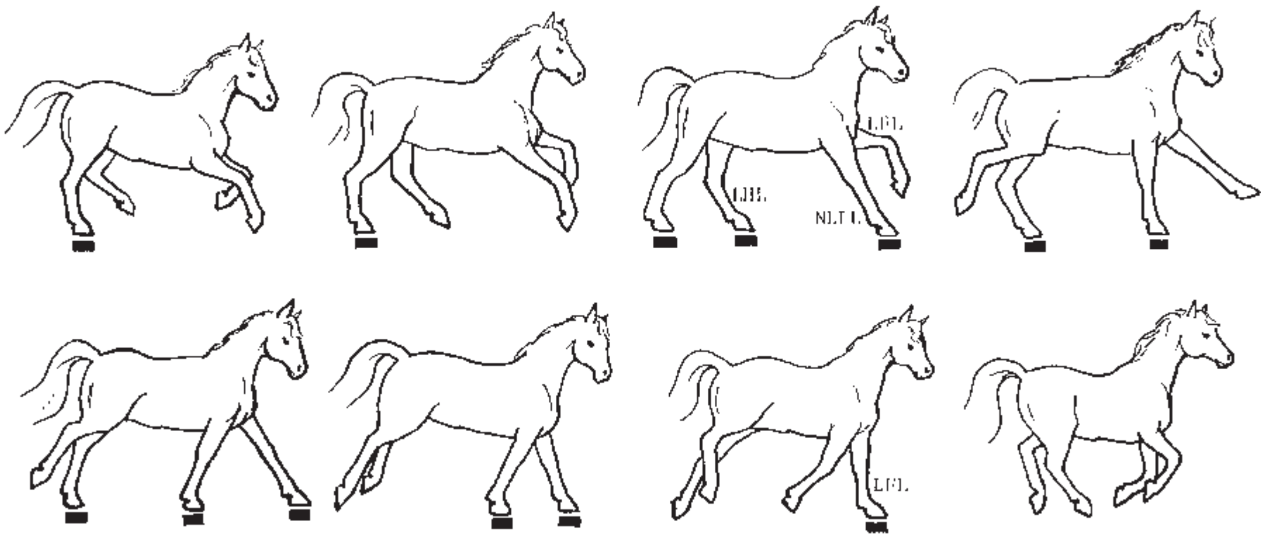


Figure 8-C: The pace



LFL : Leading Forelimb (NF)
NLFL : Non-leading Forelimb (OF)
LHL : Leading Hindlimb (NH)

Figure 8-D: The canter

Gallop

There are two modes of galloping employed by animals:

1) Transverse gallop: used by animals with rigid backs allowing little dorsi- and ventriflexion eg horse, camel, buffalo, rhinoceros.
2) Rotary gallop: used by animals with more flexible backs, eg dog, cheetah, deer and various antelope. See Fig 8-E

Transverse gallop (Figure 8-F)

Faster than the canter, this is a four beat unequal gait with one moment of suspension at the end of the cycle.

As the speed and stride length increase, the diagonal pair which strike the ground together in canter separate, due to the longer arc of flight of the forelimb. The hind limb thus strikes before the fore, and a three beat gait becomes a four beat gait. The lead limbs strike the ground just after their opposite numbers.

Both canter and gallop are linked with respiration. After the lead limb leaves the ground there is a moment of suspension, during which inspiration takes place. Expiration occurs during the footfall phase. This link between gait and breathing can be heard clearly when listening to a horse cantering or galloping.

Footfall formula (left leg leading):

______	LH	LH	LH	______	LF	LF	______
RH	RH		RF	RF	RF		

Rotatory gallop (Fig 8-H)

This gait is also a four beat unequal gait, but it is characterised by two moments of suspension. The sequence of limbs touching the ground rotates around the animal, instead of crossing over (as in the transverse gallop).

Footfall formula (left leg leading):

LH	LH	______	______	______	LF	LF	______
	RH	RH		RF	RF		

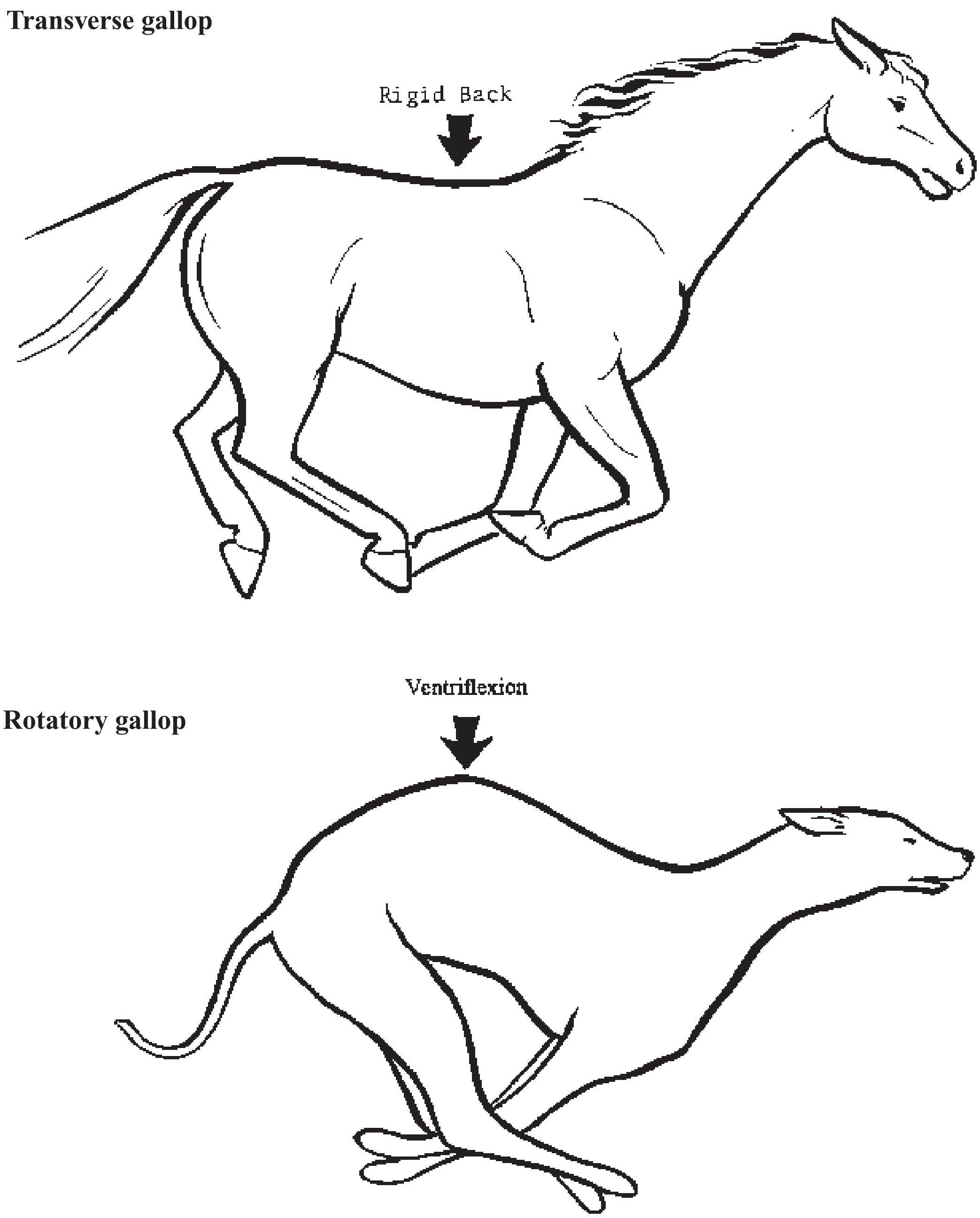
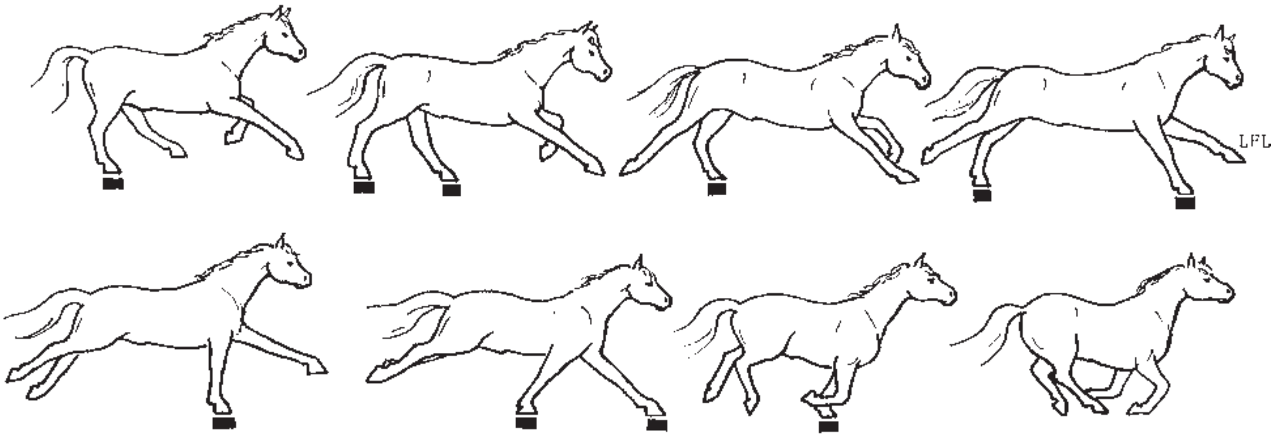


Figure 8-E: Gallop



LFL : Leading Forelimb (NF)

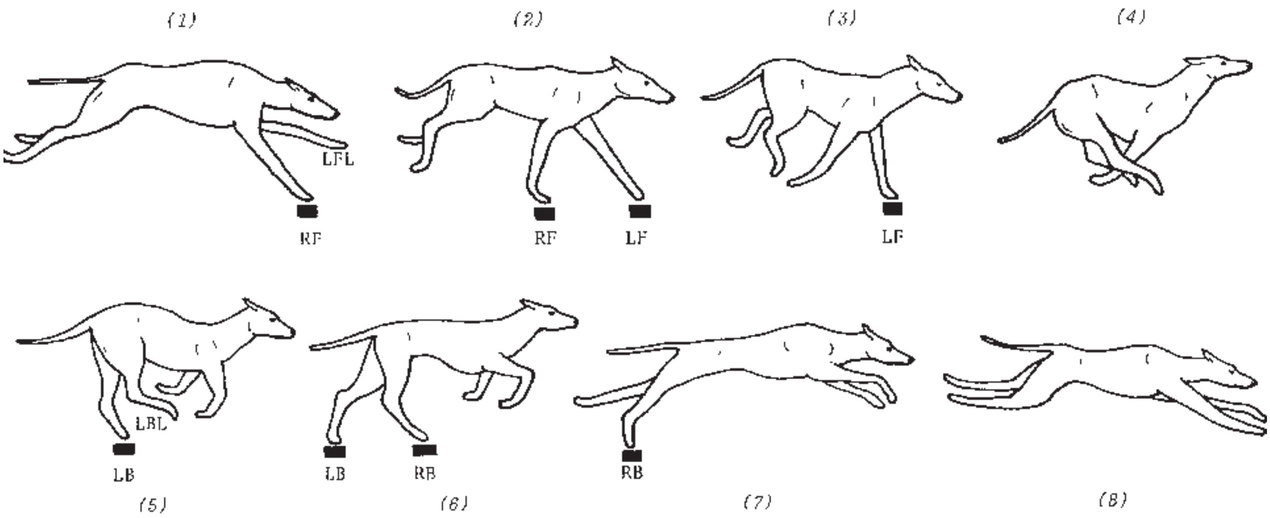
Figure 8-F: Transverse gallop

LF = NF
OF = RF

LB = NH
RB = OH

ROTATORY GALLOP

(of a Whippet)



LFL : Leading Front Limb (LF)
LBL : Leading Back Limb (RB)

NOTE: Stages (4) and perhaps (5) are modified in the Lateral Gallop of the Deer.

Figure 8-G: Rotatory gallop

Jumping (Fig 8-H)

This is sometimes used as a gait by cats, but is most commonly used by domestic animals for jumping obstacles. Both hind limbs are used to spring, but the animal lands on one forelimb, followed quickly by the other. The strain on the landing forelimb is considerable, especially in a tiring animal.

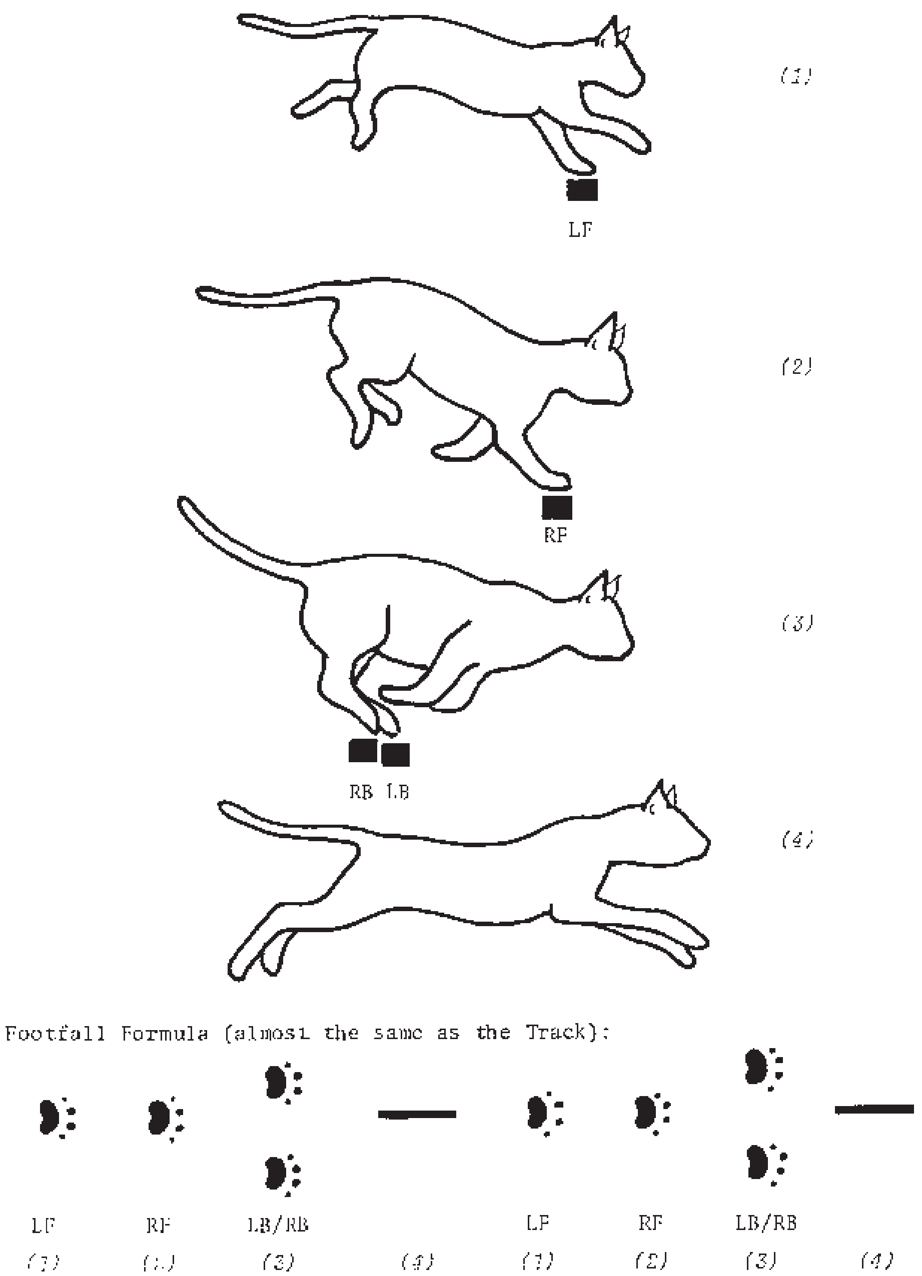


Figure 8-H: Cat bounding along

Conformation and gait

The usefulness and, therefore, value of a horse is determined largely by the soundness of feet and limbs during locomotion. Many variables influence soundness, including general health, nutrition, training, fitness and conformation. Of these factors, only conformation cannot be altered, but it plays a key role in both short and long term maintenance of soundness.

Conformation of foot

This is of paramount importance in avoiding injury and lameness, and can be improved by good farriery. Equally, poor farriery or foot neglect can have serious deleterious effects. Many causes of lameness in the forelimb of the horse originate in the foot, so a good understanding of anatomy and normal conformation of the horse's foot is essential in equine practice. Revise the anatomy of the hoof from the Teaching Guide to the Integument.

Foot and pastern axis (Fig 8.1) and foot level

a) **Foot axis:** the angle of hoof wall with ground (≈45°–50° in front foot and ≈50°–55° in hind foot). A vertical line through centre of toe should form 90° with **foot level** (line across ground surface of wall at quarters).

b) **Pastern axis:** line through centre of pastern should bisect proximal and middle phalanges.

Viewed laterally, **foot and pastern axis should be at same angle** (see Fig 8.1). Individual variation, but provided foot and pastern axis are same angle, foot axis should not be altered by trimming. When foot and pastern axis have different angles **(broken axis),** (Fig 8.2), abnormal strain is placed on distal limb, and may cause foot pathology.

c) **Foot level:** the medial and lateral walls of the foot should be the same length, such that the longitudinal axis of the cannon, fetlock and pastern is at 90º to a line joining the ground surface of each heel. A level foot indicates that the horse is landing evenly on both heels, thus wearing the foot evenly. *If an unlevel foot is not corrected by farriery, there will be disproportionate use of one heel, so structural damage and lameness may ensue (sheared heels).*

Effect of foot on gait

The foot undergoes three phases of locomotion

- **landing**
- **break over**
- **foot flight**

a) **Landing**

Heels should land evenly, striking ground just before rest of foot, then transferring weight to frog and digital cushion.

- **base narrow** animal lands on **outside** of foot
- **base wide** animal lands on **inside** of foot

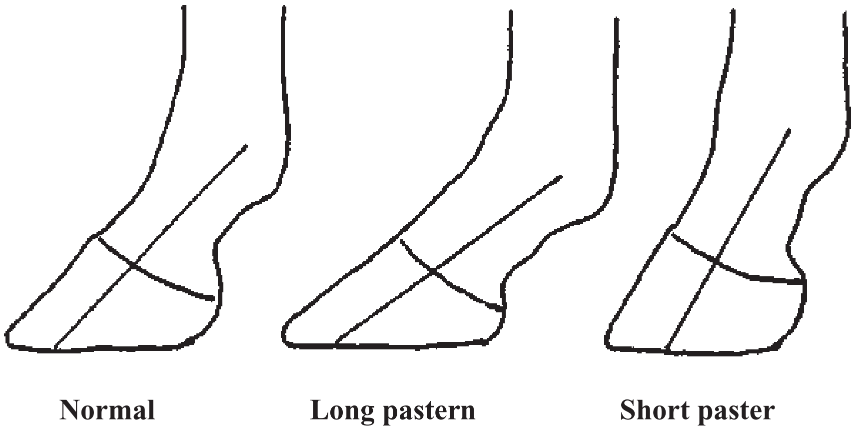


Figure 8-1: Foot and pastern axis

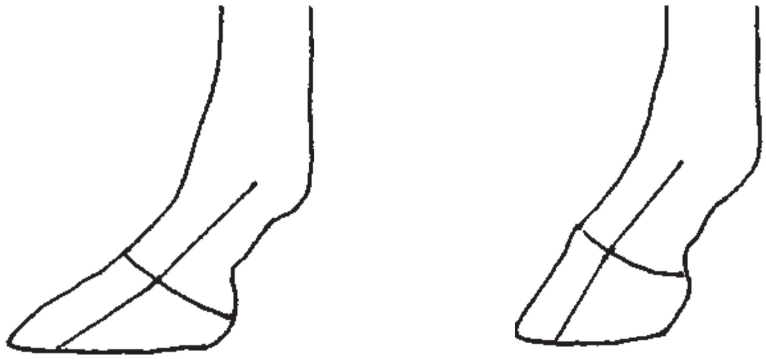


Figure 8-2: Broken axis

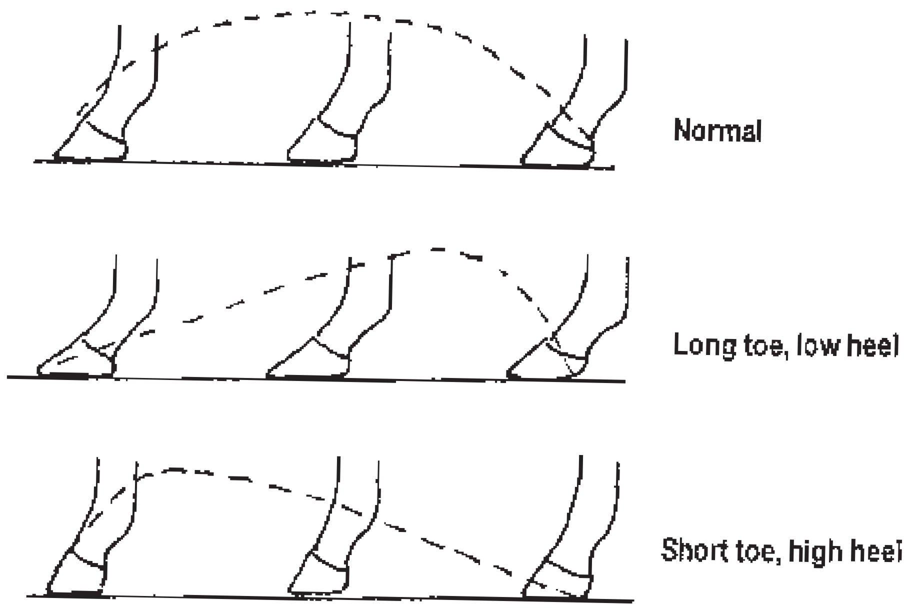


Figure 8-3:Arc of fight

Small drop in fetlock is normal part of shock absorption mechanism. Marked drop in fetlock often accompanies over-extension of carpus, predisposing to:

- strained tendons or suspensory ligament
- carpal or proximal sesamoid fracture
- periosteitis dorsal surface Mc/MtHI and PI

b) Break over

Should break squarely over toe. Problems occur if

- break over **outside - base narrow**
- break over **inside - base wide**

Early break over *is usually caused by* ***pain*** *in palmar part of foot or fetlock eg navicular disease, sidebone, pain in proximal sesamoid region. May also be associated with standing camped in front, or holding fetlocks in abnormally upright position.*

c) Foot flight (see Fig 8.12)

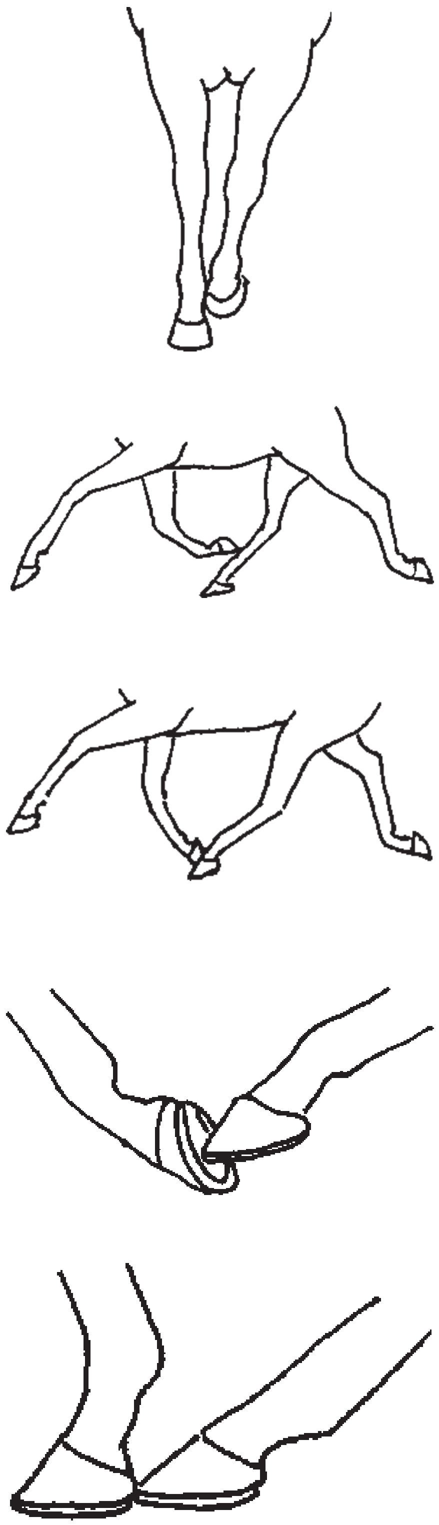
Normal foot has even arc of flight, reaching peak as it passes opposite limb.

Low foot flight usually due to pain inflexion eg navicular disease, conditions of phalangeal, fetlock and carpal joints.

Uneven arc of flight:

i) Peak of flight before passing opposite limb - low heel, long toe acts as lever and delays break over. *Increases strain on palmar aspect of limb*.

ii) Peak of flight after passing opposite limb - short toe, high heel. *Increases concussive forces*.



Brushing

Scalping / speedy cutting

Cross-firing

Forging

Over-reaching

Figure 8-4: Forms of interference between limbs

Conformation of limbs

Poor limb conformation affects **progression of the limb** during locomotion. It increases risk of injury from **interference** between limbs, and may contribute to strain of ligaments or tendons due to abnormal loading. Conformation of limbs also affects shape, wear and flight of feet. Limbs should not be too fine for the weight of the body (heavy-topped).

Remember, forelimbs bear a greater proportion of weight, while hind limbs provide greater proportion of thrust. Many of the causes of lameness encountered in the hind limb occur in the hock joint, so an understanding of the hock joint anatomy and conformation is essential.

Forms of limb interference (Fig 8.4)

During locomotion, the limbs may contact one another, particularly if the horse is unfit, fatigued, immature or unbalanced. Poor conformation is a major factor predisposing the limbs to interference injury.

Brushing:	Contact, usually light, between inner surfaces of limbs.
Scalping:	Toe of forefoot strikes at or above level of coronary band of hind limb on the same side. Mainly occurs in trotters.
Cross-firing:	Inside of hind foot strikes inside quarter of opposite forefoot. Mainly in pacers.
Forging:	Toe of hind foot strikes sole of forefoot on same side. Name arises from sound made as a result of this contact.
Overreaching:	Toe of hind foot catches forelimb on same side. May result in a number of problems, from pulling shoe off, to laceration of heel, fetlock or flexor tendons.
Speedy-cutting:	Loose term for any kind of limb contact at speed.
Elbow-hitting:	Shoe hits elbow during flexion of knee. Usually horsed with artificial gaits (eg Hackney, Tennessee Walking Horse), or while jumping.

Faults in gait (Fig 8.5)

Winging:	Hoof swings in, close to opposite limb during flight.
Paddling (Dishing):	Hoof swings out, away from opposite limb during flight.
Plaiting:	Each forefoot is placed directly in front of the other.

A. Fore limb conformation

a) **Fig 8.6** In cranial view, perpendicular from point of shoulder should bisect limb. Feet should be same distance apart as limbs are at origin, and toes should not be turned inward or outward.

- **Base narrow** - increased stress on outside of foot.
- **Base wide -** increased stress on inside of foot.

b) Look at slope of shoulder and pastern:

- excessively **upright** conformation leads to a shorter stride and increases concussive forces on distal limb

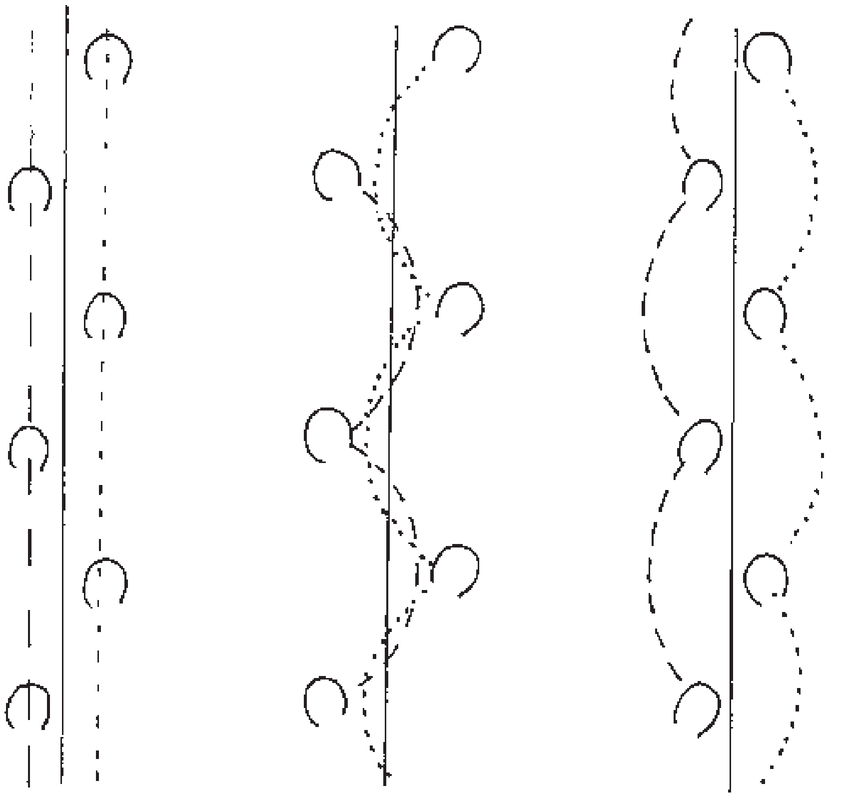


Figure 8-5: Faults in gait

- excessively **long sloping** pastern predisposes to injury of flexor tendons, suspensory ligament and proximal sesamoids

c) Carpus should not deviate (**Figs 8.7 and 8.8**)

- Inwards: **carpal valgus,** knock knees
- Outwards: **carpal varus,** bow legs
- Offset laterally: **bench knees**
- Forwards or backwards

d) **Fig 8.8** From lateral aspect, knee should not be

- Tied-in below palmar surface
- Cut out under cranial surface

e) In lateral view, perpendicular dropped from scapular tuberosity should bisect limb at fetlock. Horse should not

- **stand under** (fore limb caudal to perpendicular) - predisposes to stumbling.
- stand **camped** (fore limb cranial to perpendicular) - *usually a sign of bilateral pain eg laminitis, navicular disease*

B. Hind limb conformation

a) In caudal view a perpendicular dropped from tuber ischii should bisect limb (Fig 8.9).

- **Base wide** (Fig 8.10)
- **Base narrow** (Fig 8.11) - leads to limb interference

b) Observe hock conformation. In lateral view, perpendicular from tuber ischii follows caudal aspect of metatarsus. Should not have

- **sickle hocks** (Fig 8.12) *Predisposes to curb.*
- **straight hocks** - excessively upright hind limbs *predispose to spavin, upward fixation of patella.*
- **cow hocks** (Fig 8.10): hocks close, base wide below hock. *Increases strain on medial aspect of hock - spavin.*

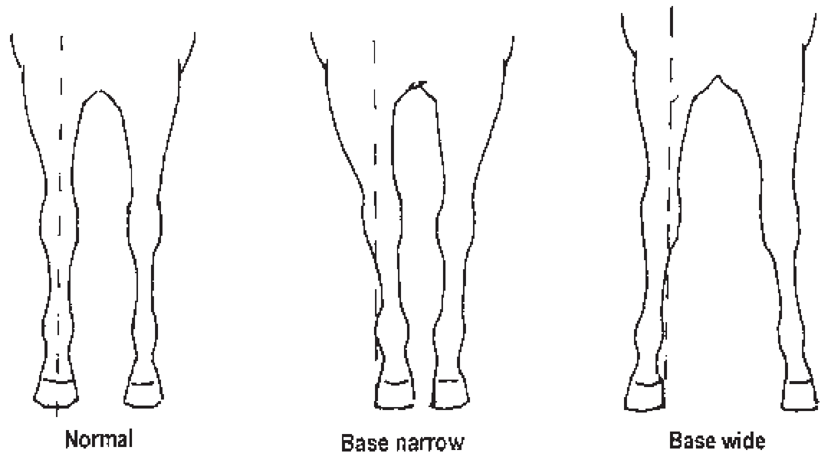


Figure 8-6

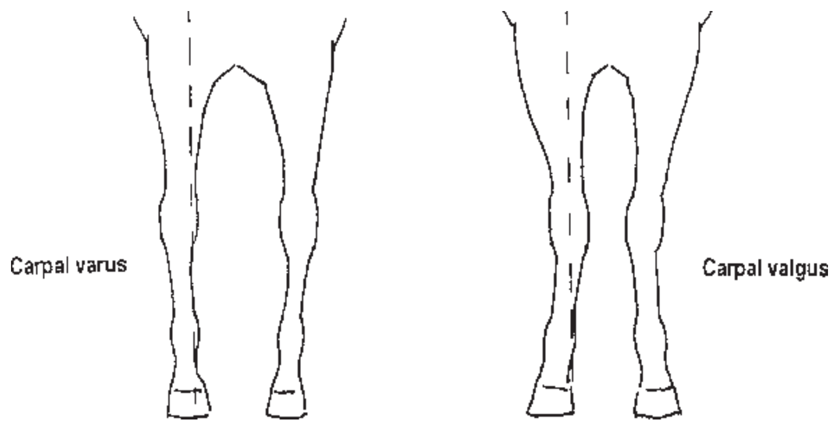


Figure 8-7

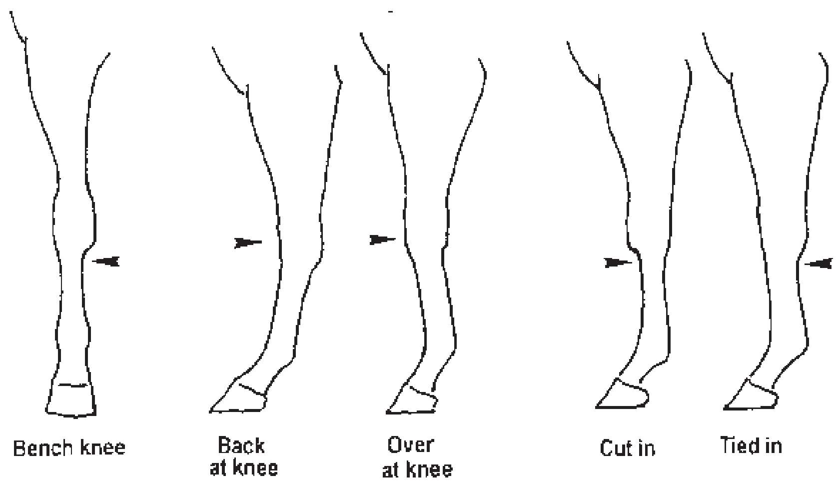
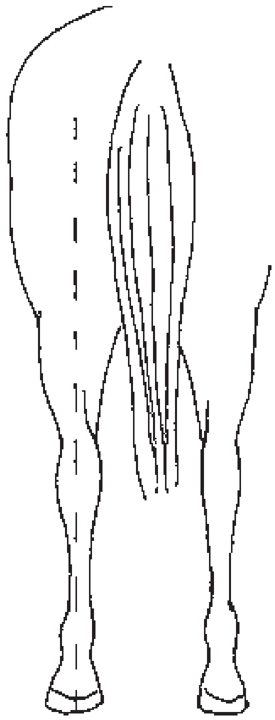
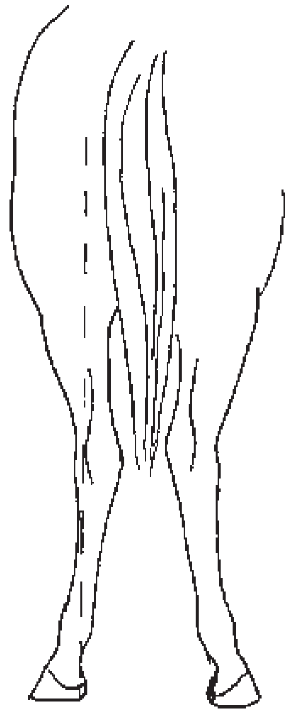


Figure 8.8



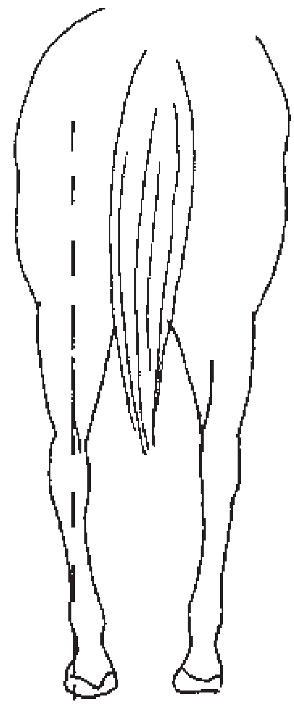
Normal

Figure 8.9



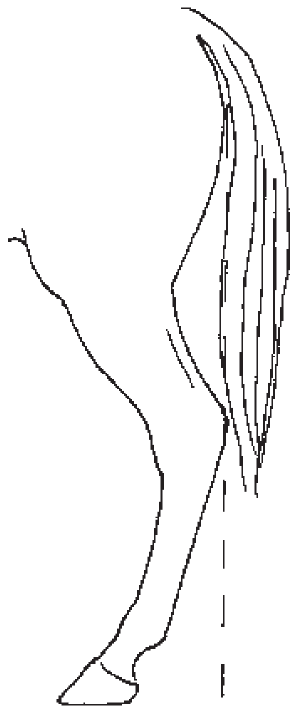
Cow hocks (Base wide)

Figure 8.10



Bow legs (Base narrow)

Figure 8.11



Sickle hocks

Figure 8.12

Conformation of body

Although less influence on lameness, body conformation affects **centre of gravity** and, therefore, balance. The centre of gravity is normally in the centre of the rib cage, just caudal to a perpendicular dropped through withers and olecranon. Alteration of the centre of gravity, particularly forwards, due to poor conformation, predisposed to limb interference and injury. Much of the training of a horse involves teaching it to compensate for the alteration of centre of gravity imposed by loading the horse with a rider.

a) Perpendiculars dropped from withers through elbow, and from tuber coxae through stifle, should divide the body into three roughly equal parts.

   Excessively long or short back predisposes to back problems and limb interference.

b) A line from point of shoulder to stifle should be parallel with ground (a **high rump** throws centre of gravity forward, predisposing to overreaching).

c) A line down centre of back should divide body into two halves.

d) Head acts as balance-arm for adjusting centre of gravity, and is useful marker for detecting lameness. *At trot, head normally carried evenly when each fore limb strikes the ground. If there is fore limb lameness, the horse raises the head as that limb strikes the ground to reduce the limb loading. The head appears to nod down with the other limb:* ***sinks on sound side.*** *In hind limb lameness, usually the hip is held higher on the lame side, so equally, the hip appears to* ***sink on the sound side.***

Questions

Which gait is most useful for assessing lameness, and why?

Explain why the fore limb of the horse is particularly vulnerable to injury while landing from a jump. What sort of leg and foot conformation might predispose to such an injury?

Describe the abnormalities in conformation which might predispose to

– Medial splint formation
– Curbs in the hind limbs
– Upward fixation of the patella
– Navicular disease

Chapter 9

Anatomy of the Foot and Integument of Horse and Dog

Dissipation of concussive forces in the foot

The anatomy of the feet of dogs and horses has been covered in earlier chapters, in terms of osteology, joints and muscles. Essentially, the dog has all five of the digits of the basic mammalian manus, but weight bears only on digits II-V. The horse shows one extreme on the scale of cursorial adaptation, and has reduced its weight-bearing to the distal phalanx of a single digit (III), with only vestigial remnants of II and IV remaining. This species difference in the arrangement of the digits results in very different systems of shock absorption during weight bearing. The anti-concussive mechanisms rely heavily on the keratinised skin appendages at the distal end of the limb.

The dog

The dog uses the simplest kind of skin appendage, the torus or pad. The torus is developed by the skin on the contact surface of the extremities. The primitive arrangement is shown in Figure 9-A. The torus consists of

– A subcutaneous cushion (pulvinus) which contains a considerable amount of fatty tissue and glands
– Dermis (or corium) with a high papillary layer
– Epidermis with and extensive stratum corneum ie thick keratinised skin

The primitive pattern has been modified somewhat in the dog in that the intermediate interdigital metacarpal and metatarsal tori have fused, leaving a single metacarpal or metatarsal pad. The digital pads remain discrete, although some dogs may show a degree of fusion between the pads on digits III and IV. Carpal pads are well developed. The position of the tori on the ground surface of the feet of different species is shown in Figure 9-B.

With the limited weight-bearing necessary in a relatively small animal like the dog, the tori are effective anti-concussive devices protecting the joints and small bones of the manus.

The tip of each digit is protected by the claw (Fig 9-C). Carnivore claws are hard keratin structures produced by epidermis over the terminal part of the IIIrd phalanx. The epidermis is supported by a thick corium, continuous on its deep face with the periosteum. Each claw consists of two walls, joined at a high dorsal ridge, and a sole.

The proximal rim of the wall fits under the ungual crest of the IIIrd phalanx, concealed by a fold of skin, the claw fold.

The hard horny claw plate is composed of flat cornified cells, strongly joined and often deeply pigmented. It is the stratum corneum of the epidermis over the whole wall, but it is produced more actively by the proximal coronary band and dorsal ridge, so it is thick dorsally and decreases laterally . Sole epidermis produces a thick cornified layer which is slightly softer than the wall. The wall plate usually grows forward beyond the sole to form the hard tip to the claw .

The claw fold covers the proximal part of the horny claw plate. The dorsal surface of the fold is hairy skin, but the underside is fused to the horn of the claw and forms a thin covering (stratum externum or stratum tectorium) of the wall. This fold corresponds to the periople in the hoof (see below). A similar fold (the limiting furrow) separates the sole epidermis from the digital pad.

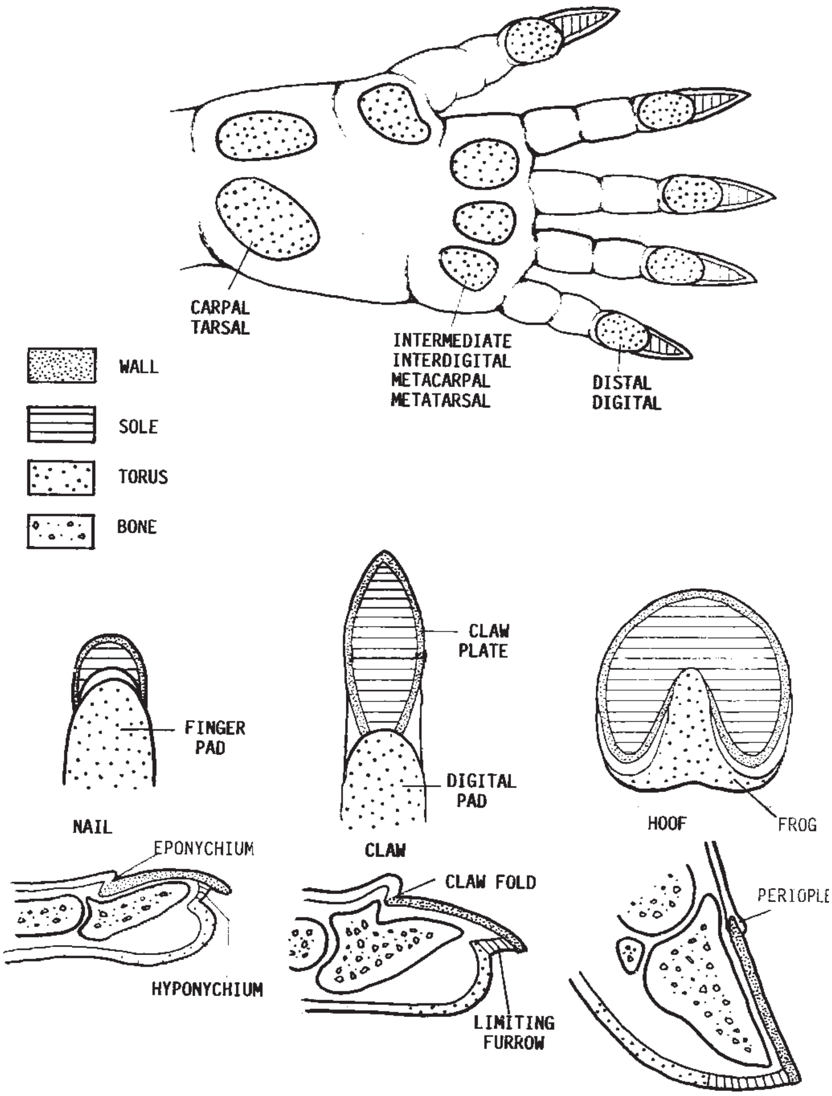


Figure 9-A: Pattern of torus distribution

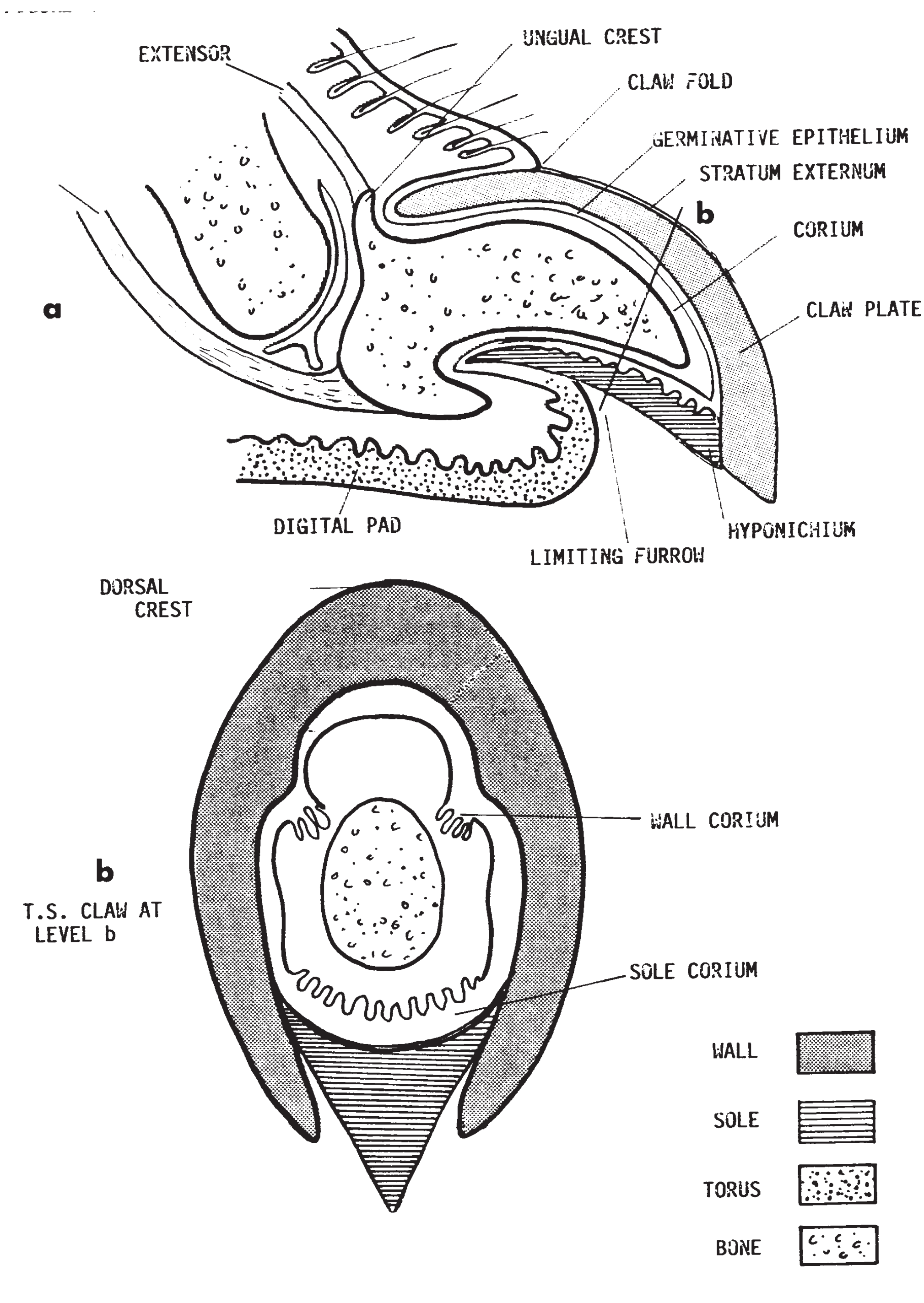


Figure 9-B: The claw of the dog

The horse

Anatomy of the hoof

Like the claw , the ungulate hoof is a hard keratin structure produced by the epithelium over the terminal part of the phalanges. The hoof simultaneously provides a hard wearing contact surface, and a suspensory and shock absorbing mechanism for digitigrade locomotion. Figure 9-C shows the distribution of tori in the horse, and the topographical anatomy of the hoof.

The equine hoof consists of a wall, sole and frog. The wall is the part visible when the foot is on the ground, and consists of several regions: toe, medial and lateral quarters, and sharply inflected bars. The curve of the wall is wider laterally , and the slope is steepest medially . The wall is produced by the periople, coronary and laminar (lamellar) epithelium. Figure 9-D shows the cross-sectional anatomy of the hoof, and an enlarged view of the wall of the hoof, showing the lamellar arrangement. In cross section, three layers of horny substance can be seen:

- Stratum externum (tectorium), produced by perioplic corium
- Stratum medium, the major component, produced by the coronary corium
- Stratum internum (lamellatum): fine leaves of keratin running parallel with the wall surface, produced by the lamellar corium.

The sole covers the ground surface between the wall and the frog. It is slightly concave with respect to the ground, crescent shaped with the angles fitting the inflection of the wall at the bars. It is produced by the solar epidermis. The frog (cuneus) is triangular in shape, with an apex and a base, which is expanded and covered by periople to form the bulbs of the heels. There is a central groove on the ground surface, and a corresponding frog spin internally . The frog is separated from the bars by the collateral grooves. Its horn is somewhat softer than solar keratin.

The keratin of the hoof has special features which help it to withstand the forces generated on contact with the ground. A transverse section examined microscopically shows a pattern of tubules cemented together by amorphous intertubular horn. Cortical and medullary areas can be seen within each tubule, similar to the structure of hair . Tubular horn owes its structure to epidermal and dermal specializations in the area in which it is produced.

The corium (dermis) of the hoof varies in thickness, but is generally a strong fibroelastic connective tissue with an abundant blood supply .

The regions of the hoof are shown in Fig 9-D. The periople is a skin fold forming the junction with normal hairy skin, and overlies the epithelium of the coronary region. Perioplic epithelium, supported by perioplic corium, produces the flaky horn of the thin stratum externum, which extends only a short distance down the wall. The coronet is a raised band of coronary corium and epidermis over the proximal border of the horny wall. Coronary corium is very important, as it is responsible for production of the stratum medium, which is the main component of the hoof wall. Damage to the coronary band can result in defects in growth of the wall of the hoof.

In the laminar region, the corium is shaped into many long parallel folds, extending from the coronet to the ground surface, each with microscopic secondary folds on its lateral surfaces.

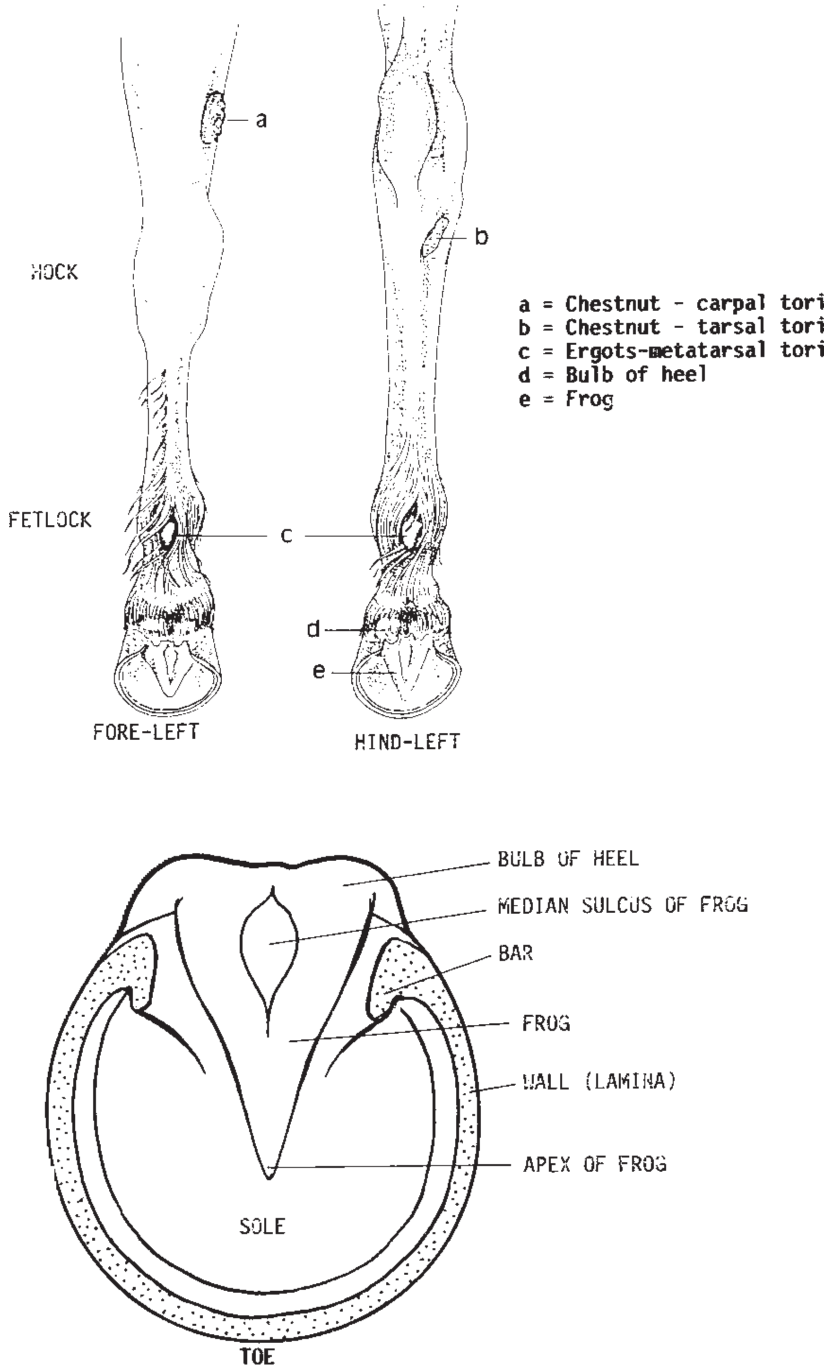
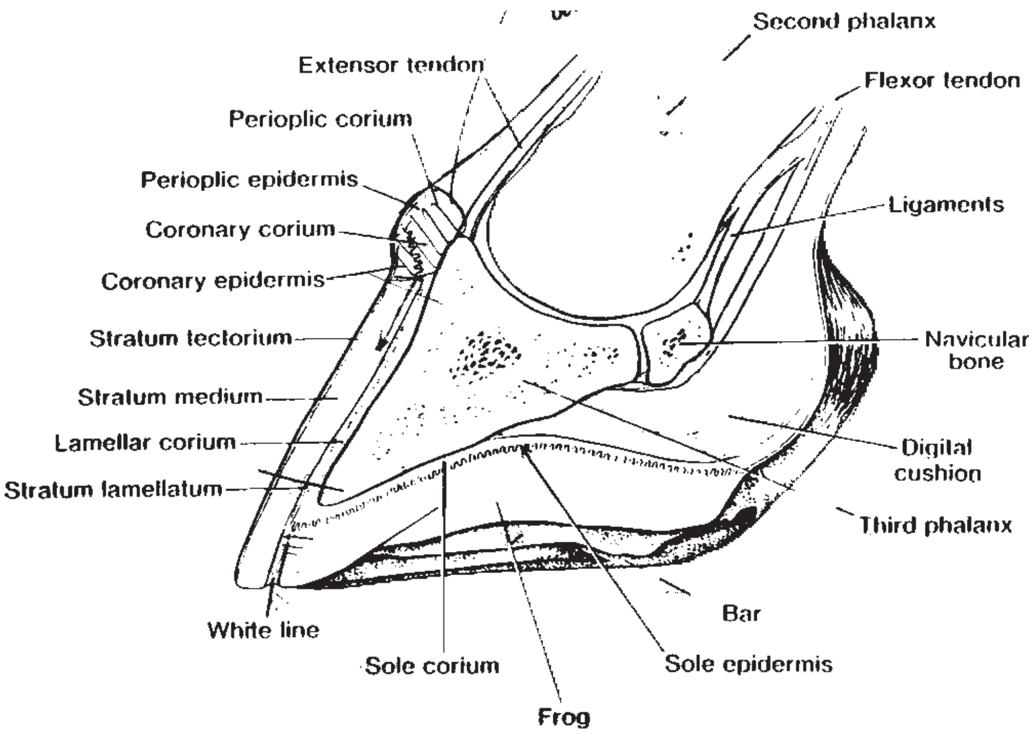


Figure 9-C: Distribution of the tori in the horse and topographical anatomy of the hoof



These diagrams are taken from "Applied Veterinary Histology" by W.J. Banks.

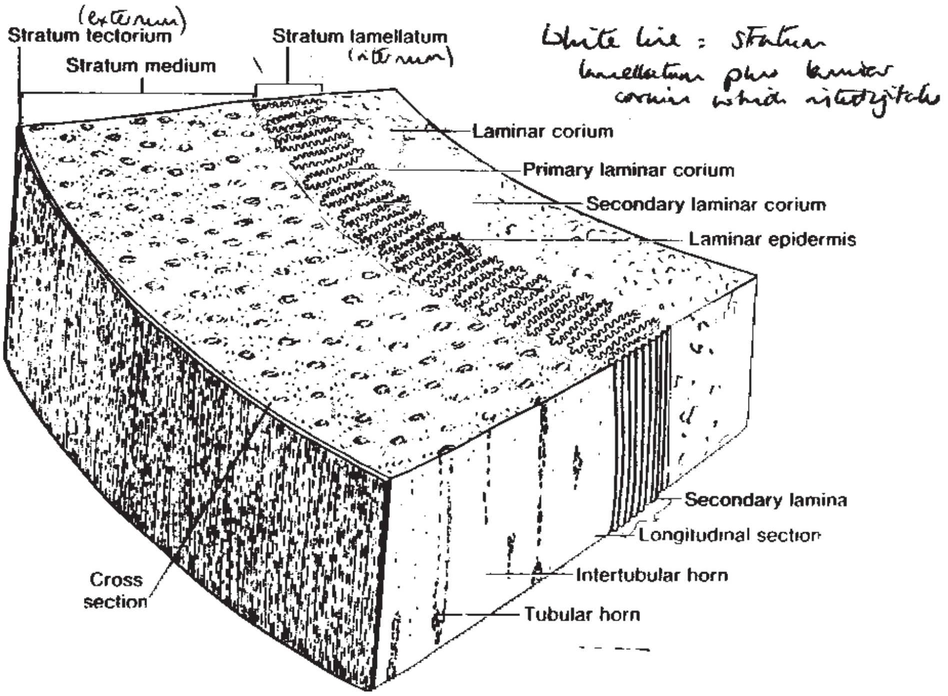


Figure 9-D: Anatomy of the hoof

The epithelium over the lamellae forms a much softer unpigmented keratin, which is produced at the same rate as the stratum medium growing down over it, so it anchors the hard

substance of the wall to the underlying structures while still allowing growth longitudinally. See in transverse section (Fig 9-D), the soft lamellae and interlocking inner edge of the hard keratin from the coronary band form the stratum internum (lamellatum).

Solar germinal epithelium covers a papillary solar corium pointing towards the ground surface, and produces tubular and intertubular horn.

It is the contrast between the unpigmented laminar horn and the pigmented, hard horn produced by the coronary band and sole which produces the white line on the ground surface of the hoof. The position of the white line is used to indicate the junction of the sensitive and non-sensitive structures of the hoof.

The frog corresponds to the digital pad of other species. Epidermis over the papillary layer of the frog corium produces pigmented, slightly softer tubular and intertubular horn. The deep layer of the corium merges with a hypodermis containing fibrofatty tissue and some merocrine glands. This is the digital cushion, analogous to the pulvinus of the digital pad.

The metacarpal and metatarsal pads are reduced to the tiny ergots on the caudal surface of the fetlock joints, and the chestnuts represent the carpal and tarsal pads (Fig 9-C).

Anti-concussive mechanisms in the horse

A single digit bearing weight for the entire limb must have efficient mechanisms for shock absorption, especially at its distal extremities. In addition, a single digit encased in a keratin hoof at the end of a limb which is largely devoid of large muscles presents unique problems in venous return, as the muscular pump is effectively absent distally. The horse circumvents both of these problems by employing venous return as a form of hydraulic shock absorption.

In the horse shock absorption is achieved by three means:

1) **Elasticity of the hoof:**

Despite its apparent rigidity, the hoof is sufficiently elastic to absorb much of the concussion associated with locomotion. This elasticity is conferred by

- **the frog** which has relatively soft horn
- **the digital cushion**, which is displaced dorsally to lie above the frog
- **the lateral cartilages** which is perforated and surrounded by venous plexuses
- **horn thinner at heel than toe**

When the hoof strikes the ground, upward pressure on the frog compresses the digital cushion, causing outwards pressure on the lateral cartilages and bars of the hoof. This causes the heel to spread slightly.

Bad foot trimming can restrict frog contact with the ground and placement of nails too far caudally can limit the spread of the heels.

2) **Hydraulic shock absorption:**

External occlusion of the palmar/plantar digital arteries by the navicular bone occurs when the cof fin joint is extended, i.e. during the compression phase when the foot strikes the ground and weight is transferred to that limb. This prevents forced backflow up the artery and ensures that blood in the foot during the stance phase of the stride is delivered to the venous plexuses.

Spreading of heels causes the lateral cartilages to compress the venous plexuses so blood is delivered to the digital veins. **Valves** in these veins prevent backflow as the foot leaves the ground and pressure within the hoof drops.

3) **Elasticity of suspensory apparatus**

As the hoof strikes the ground, tension in the suspensory apparatus prevents over-extension. However , to dissipate concussion, some degree of elasticity is present in this system and a small drop in the fetlock is a normal part of the gait. This is particularly evident at faster gaits and landing from a jump, when the palmar aspect of the fetlock comes very close to the ground.

Note that if poor farriery restricts the mechanisms outlined in 1 and 2, the suspensory apparatus bears most of the shock-absorbing role, and if this is further compromised by poor conformation, overloading or fatigue, injury is likely to occur.

Many of the equine injuries for which veterinary attention is sought are sustained as a result of failure of the mechanisms by which the horse dissipated concussive forces. The factors which contribute to this failure are numerous, and include:

- *Increasing the load on the limbs with a rider*
- *Inappropriate or poor shoeing*
- *Jumping, fast work, artificial gaits*
- *Working on unsuitable surfaces (hard, soft, slippery)*
- *Poor foot or limb conformation*
- *Fatigue, overload or unfitness*

Use of nerve blocks in the distal limb of the horse

The foot and distal limb is the site of much of the lameness for which veterinary attention is sought. Regional perineural anaesthesia can be a very useful tool diagnostically in identifying the precise site of lameness by anaesthetising the limb in stages working distal to proximal, until lameness is abolished. It is also at times useful therapeutically in providing anaesthesia for suturing lacerations, or for corrective shoeing in painful feet. The following diagrams (Figures 9-E to 9-H) show the topographical locations of the nerves of the distal limb, and the sites at which they are accessed by the veterinarian for regional anaesthesia.

1. Palmar digital block A = distal B = proximal
2. Abaxial sesamoid block
3A and 3B. Low 4-point block

NB All blocks are performed on both medial and lateral sides

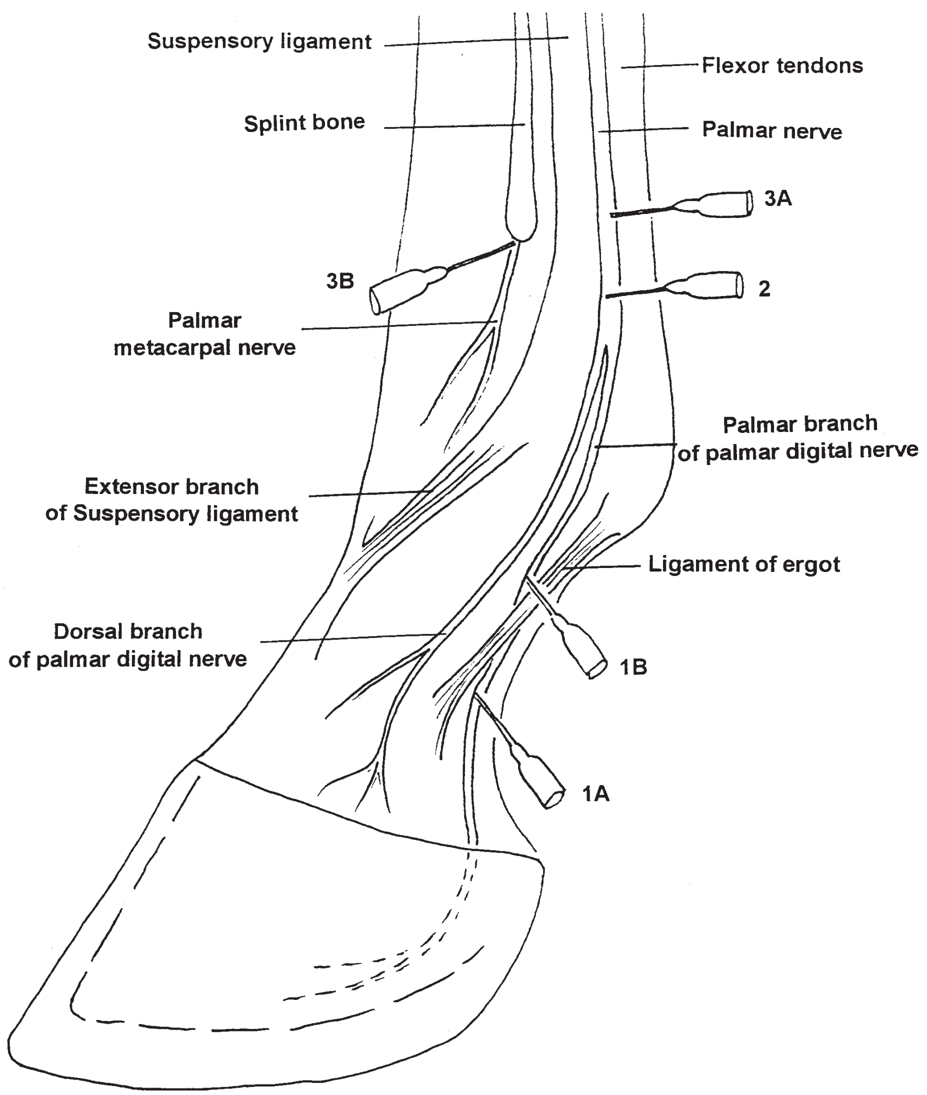


Figure 9-E: Nerve block sites of the distal fore limb of the horse

4. High 4-point block A = palmar nerve B = palmar metacarpal nerve
This is carried out medially and laterally
5. Lateral palmar block (unilateral)

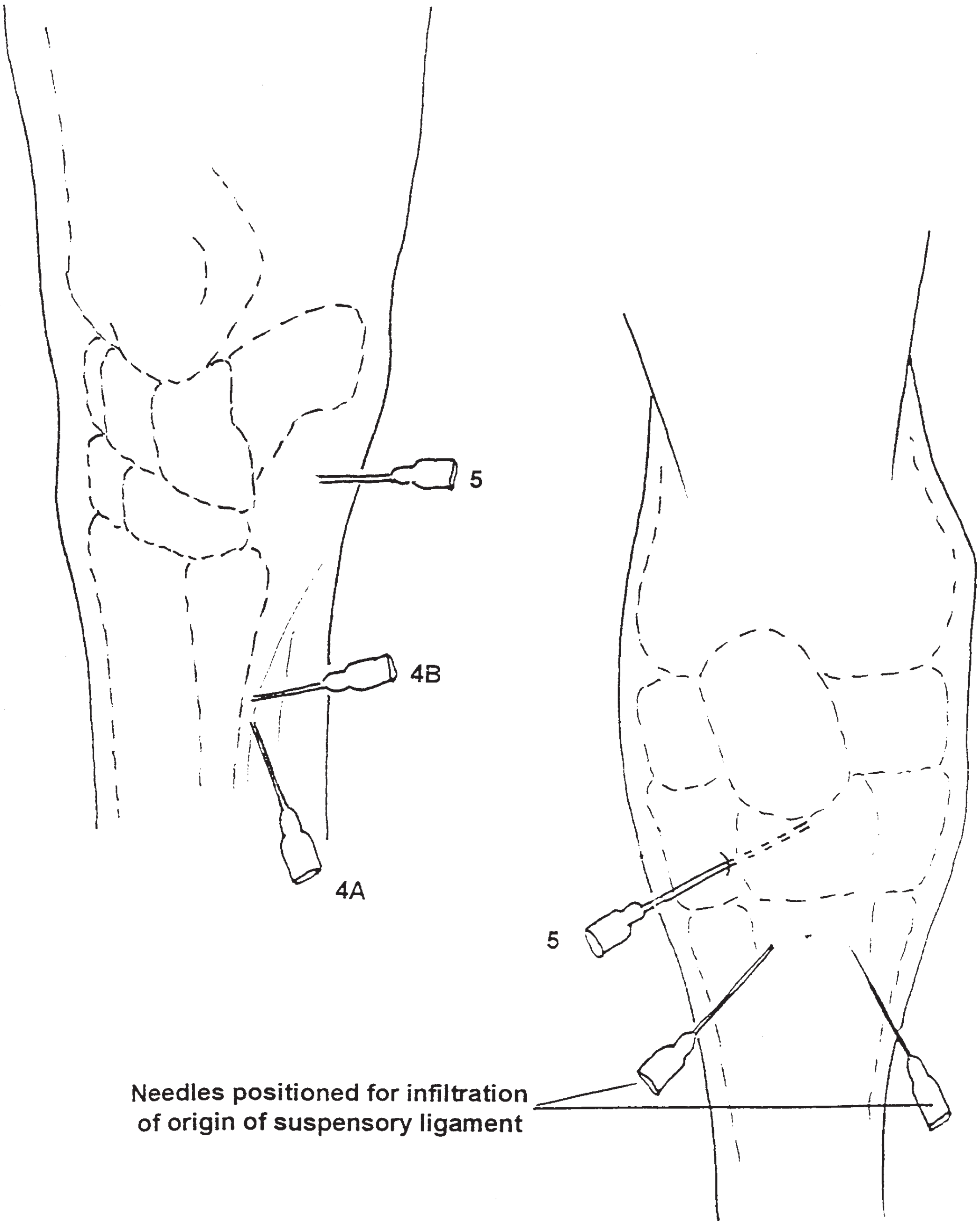


Figure 9-F: High four-point and lateral palmar nerve block sites

Blocking the dorsal metatarsal nerves (branches of deep peroneal)
(must be blocked both medially and laterally)

A In conjunction with plantar digital block

B In conjunction with abaxial sesamoid block

C In conjunction with 4-point block (ie for 6-point block)

NB The **plantar metatarsal nerve** also contributes to sensation in the coffin joint

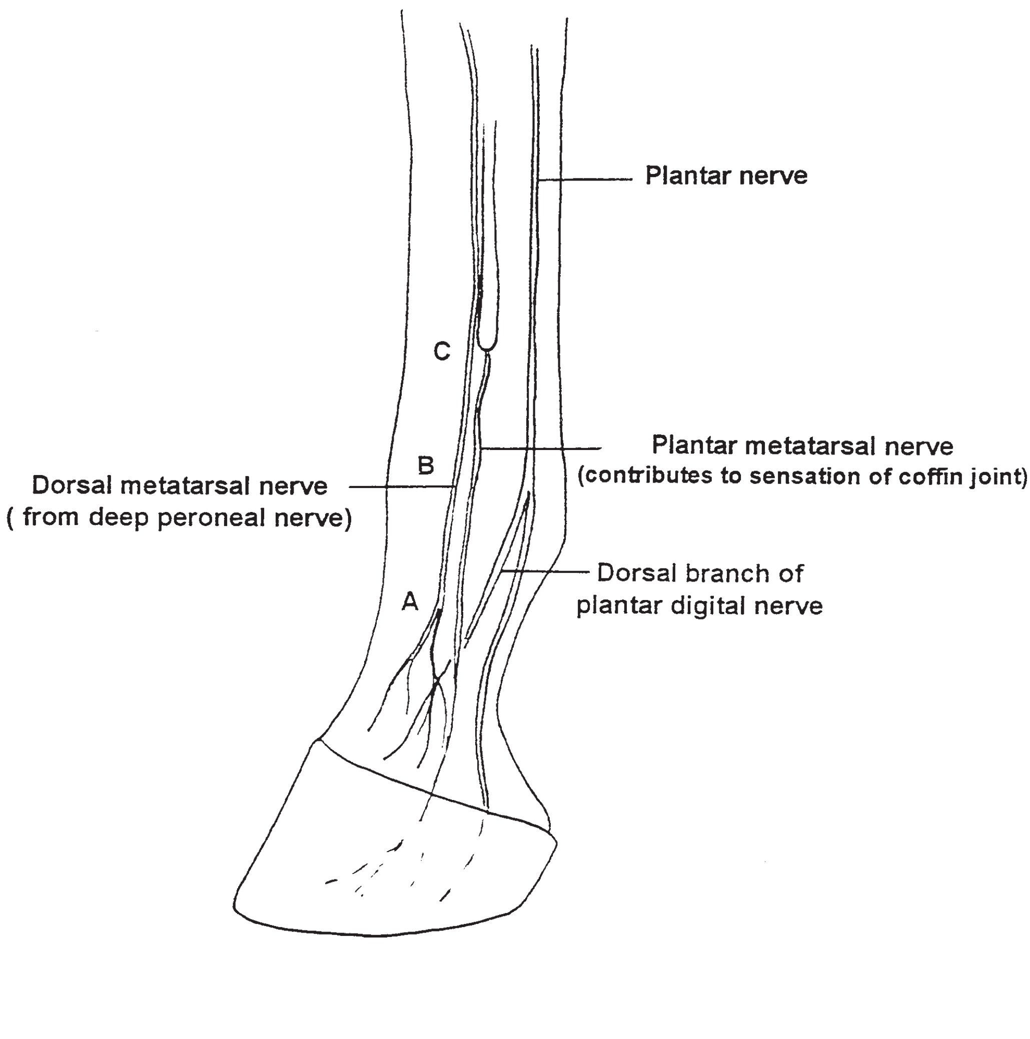


Figure 9-G: Dorsal metatarsal nerve block sites

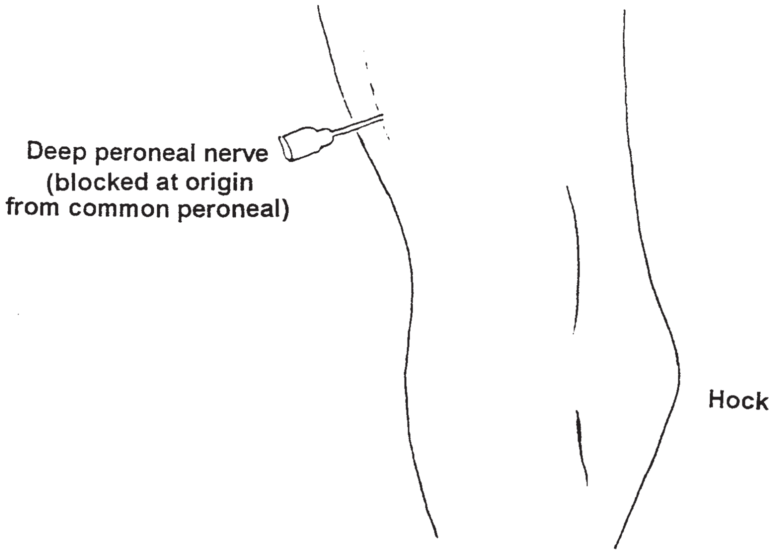


Figure 9-H: Caudolateral view of hock and tigh proximal blockade of deep peroneal nerve

Hair and associated structures

The structure of hair

Hair is a flexible fibre, composed of fully keratinised (and therefore dead) epithelial cells. It is produced by a cone of living epithelium over a dermal papilla. The hair bulb formed by these two structures lies at the bottom of the hair follicle, an epithelial invagination into the dermis (Figure 9-I).

The free part of the hair is the shaft; the part within the canal is the root. Towards the surface of the follicle, the hair shaft lies free in the pilo-sebaceous canal. Deeper, it is surrounded by the inner and outer root sheath. In an active follicle, rapidly dividing epithelial cells at its base and over the dermal papilla form the hair matrix. Upward movement and differentiation of these cells produces the hair shaft and inner root sheath. Epidermal cells lining the sides of the follicle produce the outer root sheath.

A transverse section across a hair shaft (Fig 9-J) shows three concentric zones:

– Medulla

– Cortex

– Cuticle

Medullary cells are produced by matrix over the tip of the papilla. They are usually cuboidal, loosely arranged, or interrupted by cortical cell projections or air-filled spaces. The cortex contains densely packed elongated cells. They contain melanin pigment, nuclear remnants, fibrillar keratin in an amorphous matrix. Melanin is transferred to the cortical cells by melanocytes in the matrix. Cortical cells are produced by matrix over the sides of the papilla.

The cuticle is a single layer of overlapping flat cells with pointed tips aligned in the direction of growth of the hair .

The relative width of medulla and cortex, the shape of their cells, and the degree of pigmentation all dif fer widely between species and individuals. Shape and size of cuticle cells is species distinctive and may be used for identification, especially when combined with medulla/cortex ratio.

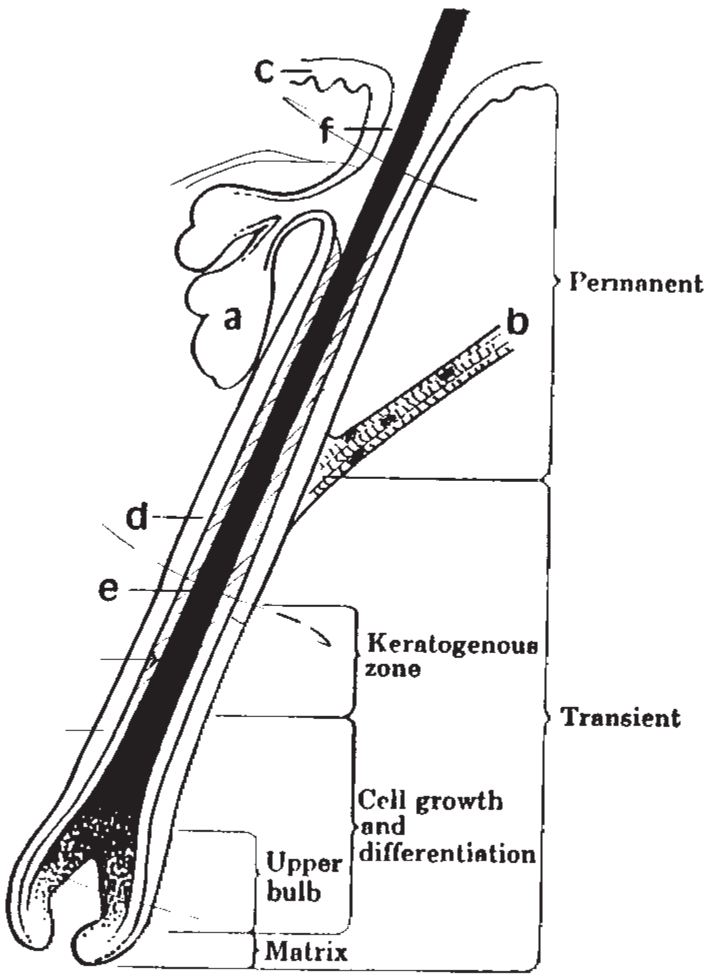
The transverse section of the hair also shows the shaft surrounded by an inner and outer epidermal root sheath. The inner root sheath has three concentric layers:

- Root sheath cuticle: resembles hair cuticle, but pointing downwards
- Huxley's layer (epithelial granular layer): cells contain deeply staining granules of trichohyalin
- Henle' s layer (epithelial pale layer): one cell thick

All the cells of the inner root sheath are produced by matrix around the periphery of the bulb. In most domestic species, the sheath is thrown into several corrugated folds before it disintegrates below the opening of the pilosebaceous canal. The outer root sheath consists of a number of rows of cells resembling stratum spinosum cells. It is separated from the dermis by a thick, hyaline glassy membrane.

The fibres and cells of the dermis around the follicle are organised to form an inconspicuous dermal root sheath. In sinus hairs (Figure 9-K), which are large hairs modified for sensory function, this dermal sheath is divided into an inner and outer dermal sheath, separated by a blood-filled sinus.

The arrector pili muscle is a small band of smooth muscle cells which is attached to the dermal sheath. It slopes upward to be inserted into the upper layer of the dermis by and elastic ligament.



a = Sebaceous Gland
b = Arrector Pili Muscle
c = Epidermis
d = Outer Hair Root Sheath
e = Hair Shaft
f = Pilosebaceous Canal

Figure 9-I: Longitudinal section of a hair

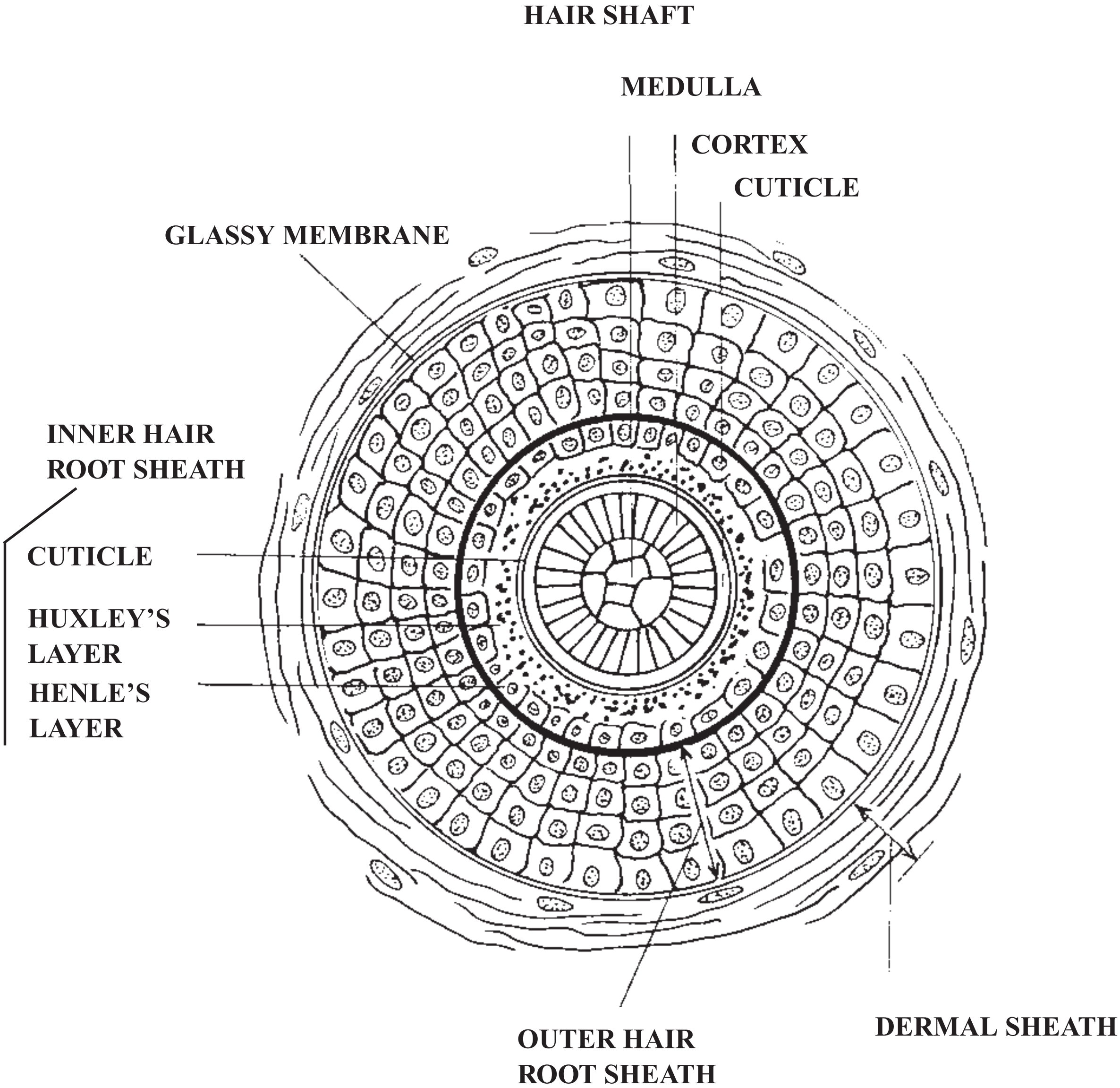


Figure 9-J: Transverse section through a hair follicle

Associated glands

Two types of glands are associated with hair follicles. Both are developed from follicle epithelium, and both open into the pilo-sebaceous canal.

a) Sebaceous glands:

These develop from the outer root sheath, and may be simple or compound, with a duct opening towards the surface of the hair follicle. They may be absent in tertiary follicles, and some secondary follicles. The cells of the glands become larger and pale staining as they accumulate lipid, then finally disintegrate to release sebum in a holocrine fashion. Sebum acts as a waterproof coating over hair and skin surface, and has antibacterial and antifungal properties.

b) Apocrine sweat glands:

These are the main thermoregulatory glands in domestic animals, but are poorly developed in most. As a result many animals do not appear to sweat, for example, the dog. However, they are well developed in the horse and produce a watery secretion for thermoregulation. They are loosely coiled glands, located in the dermis, with myoepithelial cells forming a layer between the secretory cells and the basal lamina. The ducts of these glands open into the follicle, usually just above the sebaceous gland duct.

A third kind of gland, the eccrine or merocrine sweat gland, is also present in the skin, but is not associated with the hair follicles. These are the common thermoregulatory glands of human skin, but in domestic animals they are limited to some areas of thick non-hairy skin, eg digital torus. This is why a hot or anxious dog will leave moist foot prints. They are highly coiled simple tubular glands, surrounded by myoepithelial cells. The secretory part is deep in the dermis, and the duct opens onto the skin independent of hair follicles. In animals, they serve to moisten certain skin areas, and probably contribute to scent marking.

Hair growth and distribution

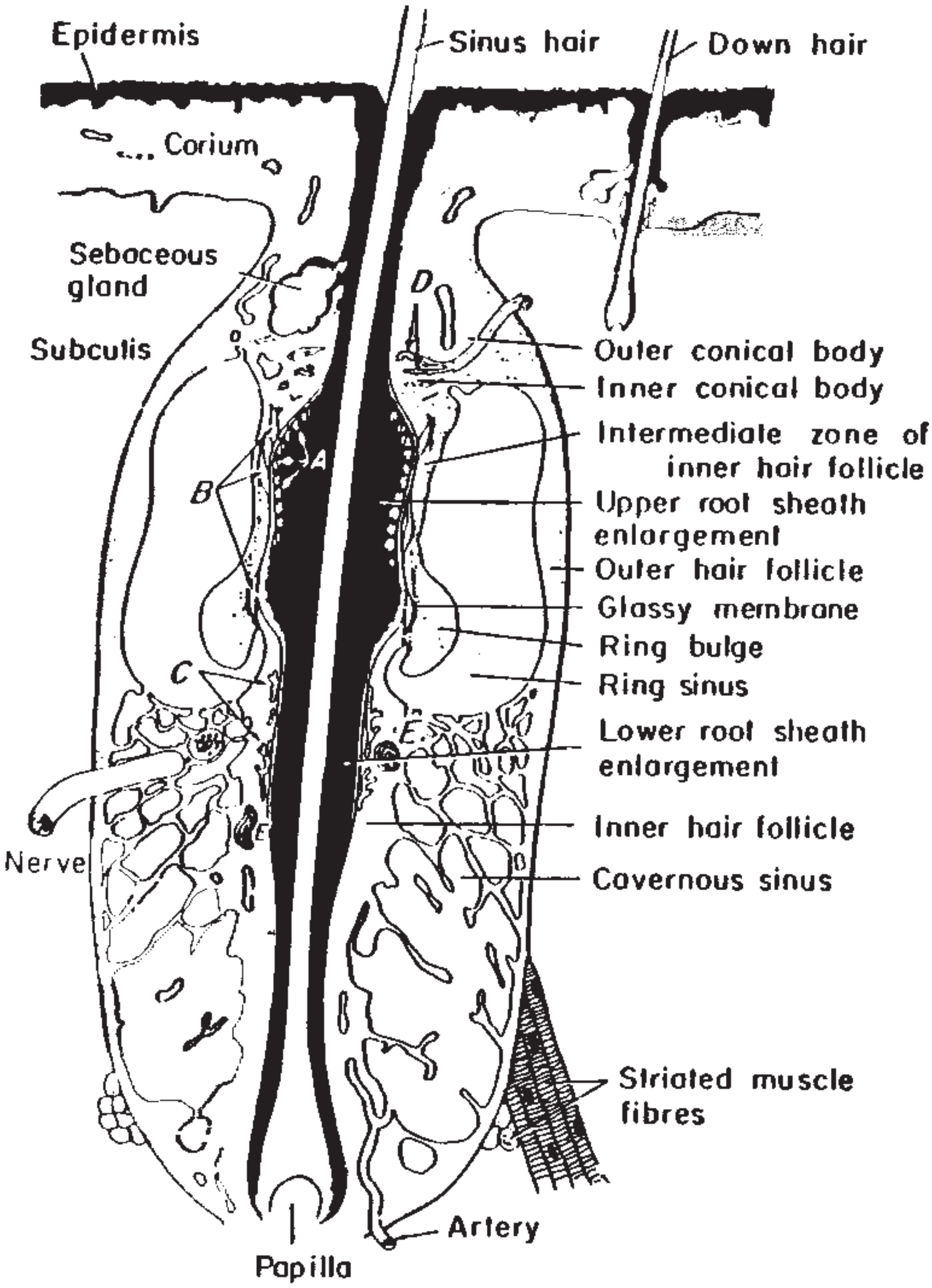
The coats of domestic animals contains hairs which vary in diameter, texture, crimp etc.

Down hair: these are the finest hairs, which usually lack a medulla. Other names include wool, fur and lanugo.

Guard hairs are long, strong and have a cortex and medulla; these make up most of the surface hairs of both dog and horse.

Very long, strong hairs without other specialisations are named according to the area in which they develop eg mane, tail, whisker

Tactile hairs (sinus hairs) with follicular modifications for touch sensitivity are also named according to their distribution eg supra- and infraorbital, zygomatic, buccal, maxillary, mandibular, mental, carpal.



SECTION CUT THROUGH A CAT'S WHISKER OR SINUS HAIR

A = Merkel cells; B = Lanceolate nerve endings;

C = Myelinated axons; D = Peripheral nerve;

E = Pacinian corpuscles

Figure 9-K: Longitudinal section through a sinus hair

Hair follicles are classified as

- Primary: deep set, with sebaceous and apocrine glands and arrector pili muscles
- Secondary: smaller, more superficial; may have a sebaceous gland, but lacks apocrine gland and muscle

Follicles are also classified as:

- Single: a single hair leaves the pilosebaceous canal
- Compound: more than one hair emerges. Each hair has its own root and bulb, but not necessarily its own sebaceous and apocrine glands

Hair distribution may vary between species

- In the horse, single follicles are evenly distributed over the surface
- In the dog, compound follicles occur in clusters of three, one of which is larger than the others. The compound follicles contain one guard hair and numerous smaller others.

Hair density is also species specific, and varies on different body areas; the axillae and groin of both horse and dog have a more sparse coat than elsewhere on the body.

Hair growth cycles

Hair growth is not a continuous process. A hair in the active growth phase is in anagen; after a variable length of time the bulb undergoes a regressive change (catagen) towards a dormant or resting phase (telogen).

During catagen, melanogensis ceases, cell division in the matrix decreases then ceases, and the follicle shrinks to about one third of its initial length. The final part of the hair shaft consists of unpigmented cortical cells only. The dermal papilla shrinks and becomes separated from hair germ cells.

In telogen, the resting hair has a clubbed base, surrounded by a layer of germ cells, and anchored to the papilla by a thin filament. Redevelopment of the follicle is dependent on the presence of the germ cells. Resting (club) hairs remain in the follicle until pushed out by new hair growth.

Hair growth rate is usually constant for a particular area, but varies on different parts of the body. It may vary between males and females, and in many animals in cold climates, hair growth rate may vary seasonally. Duration of the growth phase controls hair length and shedding cycles. Shedding occurs during anagen, when club hairs are pushed out by new follicle activity. Shedding may be intermittent, or it may be synchronised and wave like, producing a moult. Moult cycles are usually seasonal, under hormonal control and related to photoperiod and sexual cycles.

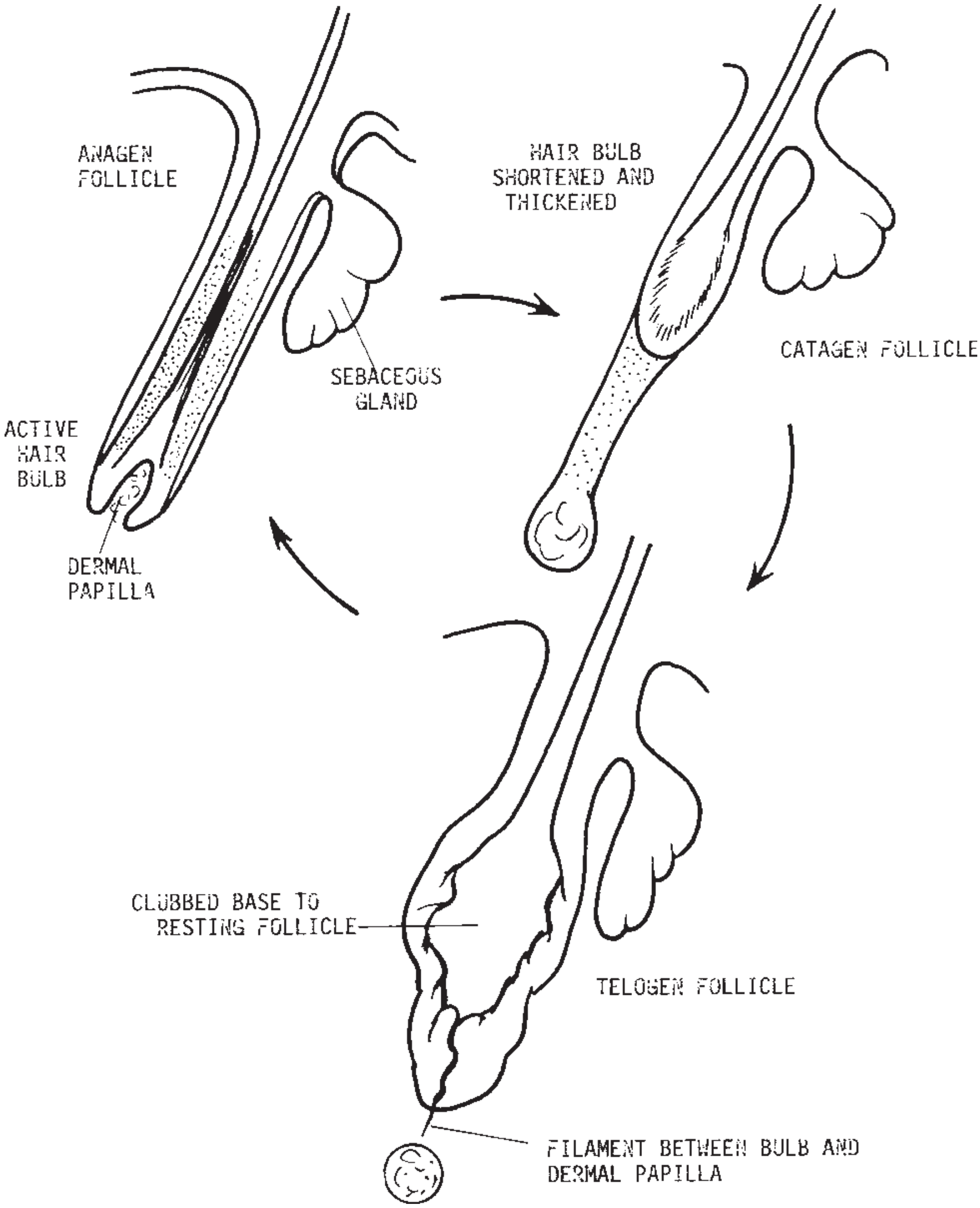


Figure 9-L: Growth cycles in hair follicles

Appendix 1

Topographical Anatomy of the Dog

Use the topographical diagrams to understand the underlying anatomical structures that correspond to topographical features on the thoracic limb of the living animal.

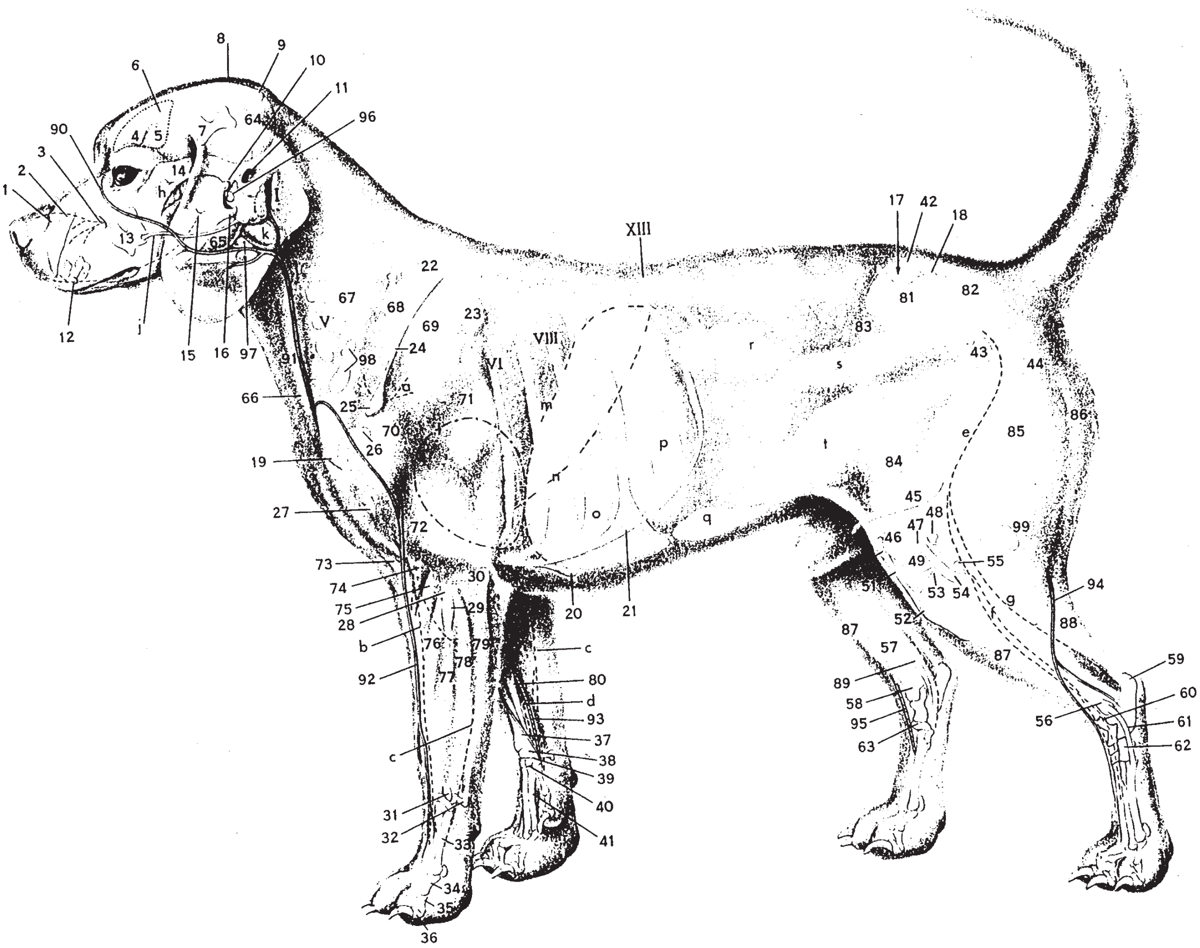


Figure 1: **Surface anatomy of the dog**

Skeleton, joints and ligaments

Head

1. Incisive bone
2. Root of canine tooth
3. Infraorbital foramen and nerve
4. Zygomatic process
5. Frontal sinus
6. Temporal line
7. Scutiform cartilage
8. Sagittal crest
9. Occipital protuberance
10. Temporomandibular joint
11. External acoustic meatus
12. Mental foramen
13. Camacial tooth - P4
14. Zygomatic arch
15. Mandibular foramen
16. Mandible

Neck and trunk

I. Wing of atlas
V. C5
VI. Rib 6
VIII. Rib 8
XIII. Spine of T13
17. Lumbosacral space
18. Sacrum
19. Manubrium stemi
20. Ziphoid
21. Costal arch

Forelimb

22. Cranial angle of scapula
23. Caudal angle of scapula
24. Spine of scapula
25. Acromion
26. Greater tubercle of humerus
27. Deltoid process
28. Lat. epicondyle of humerus
29. Lat. collateral lig. of elbow
30. Olecranon
31. Styloid process of ulna
32. Accessary carpal bone
33. 5th metacarpal bone
34. PI
35. P2
36. Pill
37. Subcutaneous surface of radius
38. Radiocarpal bone
39. Midcarpal joint
40. Carpometacarpal joint
41. 2nd. metacarpal bone

Hind limb

42. Tuber sacral e
43. Greater trochanter of femur
44. Tuber ischium
45. Os penis
46. Femoral trochlea
47. Epicondyle of femur
48. Gastrocnemius sesamoids
49. Lat. condyle of femur
50. Patellar
51. Patellar ligament
52. Tibial tuberosity
53. Lat. condyle of tibia
54. Lat. collateral of stifle
55. Head of fibula
56. Lat. malleolus
57. Subcut. surface of tibia
58. Med. malleolus
59. Tuber calcaneus
60. Talus
61. Lat. collateral lig. of hock
62. 4th tarsal bone
63. Central tarsal bone

Muscles and tendons

64. Temporalis
65. Masseter
66. Stemocephalic
67. Brachiocephalic
68. Supraspinatus
69. Infraspinatus
70. Deltoid
71. Triceps, long head
72. Triceps, lat. head
73. Biceps brachii
74. Brachialis
75. Ext. carpi radialis
76. Common digital extensor
77. Lat. digital extensor
78. Ulnaris lateralis
79. Flex. carpi ulnaris
80. Flex. carpi radialis
81. Medial gluteal
82. Superficial gluteal
83. Sartorius
84. Quadriceps femoris
85. Biceps femoris
86. Semitendinosus
87. Cranial tibial
88. Gastrocnemius
89. Deep digital flexor tendon

Blood vessels and lymph nodes

90. Angularis oculi vein
91. External jugular vein
92. Cephalic vein
93. Median artey
94. Lat. saphenous vein
95. Dorsal pedal artery
96. Parotid lymph node
97. Mandibular lymph node
98. Superficial cervical In.
99. Popliteal In.

Nerves

a. Suprascapular
b. Supf. br. of radial
c. Ulnar
d. Median
e. Sciatic
f. Peroneal
g. Tibial

Internal organs

h. Zygomatic sal. gland
i. Parotid sal. gland
j. Parotid duct
k. Mandibular sal. gland
l. Heart
m. Diaphragm
n. Basal border of lung
o. Liver
p. Stomach
q. Spleen
r. Left kidney
s. Descending colon
t. Bladder

Appendix 2

Topographical Anatomy of the Horse

Use the topographical diagrams to understand the underlying anatomical structures that correspond to topographical features on the thoracic limb of the living animal.

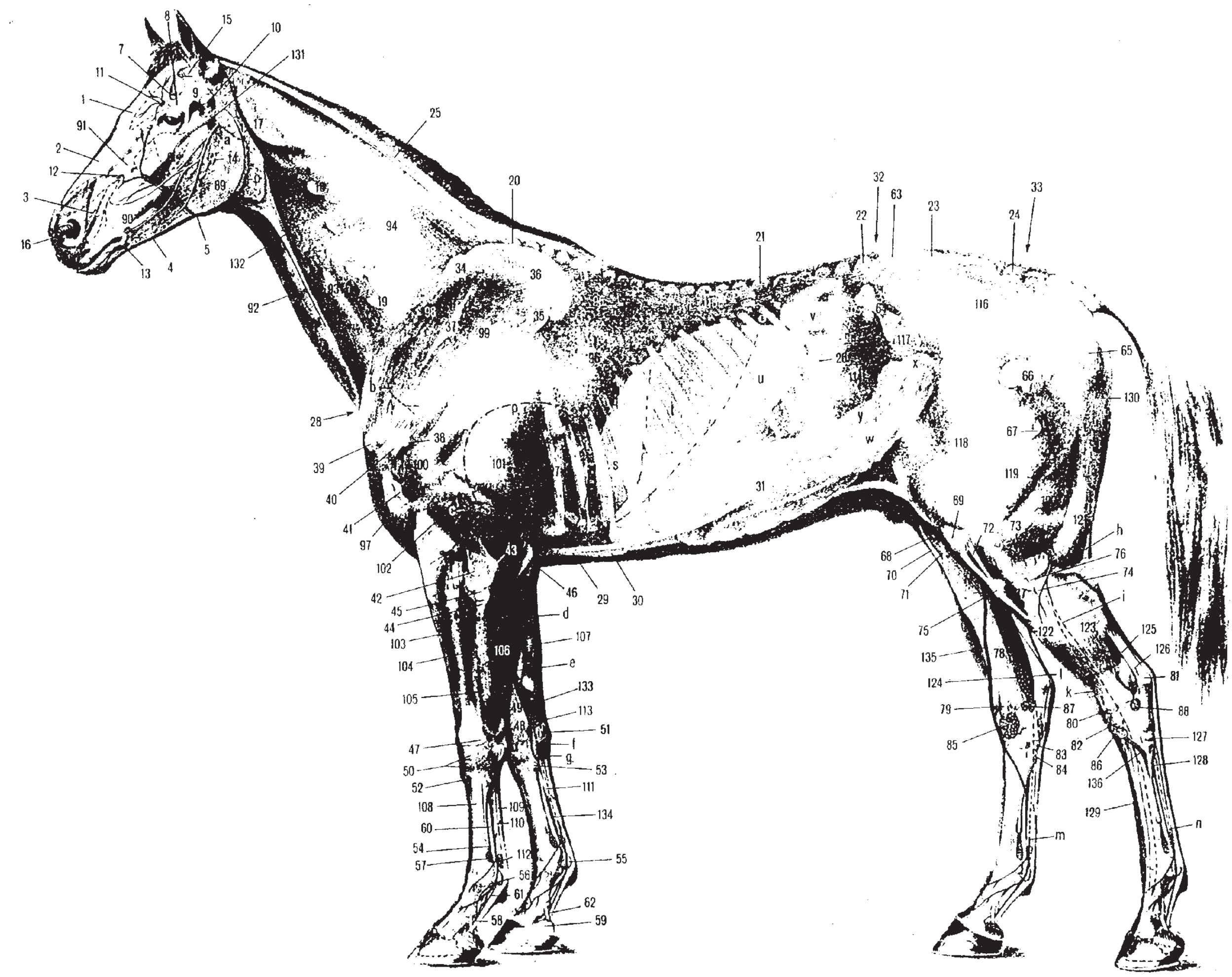


Figure 2: Surface anatomy of the horse

Skeleton, joints and ligaments

Head

1. Frontal sinus
2. Nasal bone
3. Incisive bone
4. Mandible
5. Facial artery and vein
6. Facial crest and maxillary sinus
7. Temporal line
8. Zygomatic process
9. Zygomatic arch
10. Temperomandibular joint
11. Supraorbital foramen & nerve
12. Infraorbital foramen & nerve
13. Mental foramen & nerve
14. Mandibular foramen
15. Scutiform cartilage
16. Alar cartilage

Neck and trunk

17. Wing of atlas
18. Transverse proc. of C3
19. Transverse process of C6
20. Spine of T4
21. Spine of LI
22. Spine of L6
23. Spines of sacrum
24. Spine of Cd 1
25. Ligamentum nuchae
26. Rib 18
27. Rib 5
28. Manubrium
29. Sternum
30. Xiphoid process
31. Costal arch
32. Lumbosacral space
33. Space between Cdl & Cd2

Forelimb

34. Cranial angle of Scapula

35 Caudal angle of Scapula

37. Scapular spine
36. Scapular cartilage
38. Cranial part of greater tubercle of humerus
39. Caudal part of greater tubercle of humerus
40. Tendon of infraspinatous
41. Deltoid tuberosity
42. Lateral supracondylar crest
43. Lateral epicondyle
44. Head of radius
45. Lat. collateral lig. of elbow
46. Olecranon
47. Styloid process of ulna
48. Styloid process of radius
49. Subcututaneous surface of radius
50. Pox. & distal rows of carpals
51. Accessory carpal
52. Metacarpal tuberosity
53. Proximal extremity of splint bones
54. Distal extremity of splint bones
55. Proximal sesamoid bones
56. Prox. collateral tubercle of PI
57. Pouch of fetlock joint
58. Prox. collateral tubercle ofP2
59. Cartilage of hoof
60. Interosseus
61. Oblique sesamoid ligament
62. Lig. from PI to cartilage of hoof

Hindlimb

63. Tuber sacrale
64. Tuber coxae
65. Tuber ischii
66. Greater trochanter
67. Third trochanter
68. Med. ridge of femoral trochlea
69. Trochlea
70. Intermediate patella lig.
71. Medial patella lig.
72. Lat. patella lig.
73. Lat. epicondyle of femur
74. Lat. condyle of tibia & head of fibula
75. Tibial tuberosity
76. Lat. collateral lig. of stifle
77. Extensor groove of tibia
78. Subcut. surface of tibia
79. Medial malleolus
80. Lateral malleolus
81. Tuber calcanei
82. Lat. ridge of trochlea of talus
83. 2nd tarsal bone
84. Splint bone

85. 86, 87, 88. Pouches of tarsocrural joint capsule

Muscles, tendons, and tendon sheaths

89. Masseter
90. Buccinator
91. Levator labii
92. Stemocephalic
93. Brachiocephalic
94. Splenius
95. Trapezius
96. Latissimus dorsi
97. Super, pec. & biceps brachii
98. Supraspinatus
99. Infraspinatus
100. Deltoid
101. Triceps
102. Lat. head of triceps
103. Ext. carpi radialis
104. CDE
105. Lat. dig. ext.
106. Ulnaris lateralis
107. Flexor carpi ulnaris tendons
108. CDE & LDE
109. SDF tendon
110. DDF tendon
111. Deep flexor accessory tendon
112. Prox. pouch of digital sheath
113. Prox. pouch of carpal sheath of flexor tendons
114. Flank
115. Longissimus thoracis
116. Middle gluteal
117. Tensor fasciae latae
118. Quadriceps femoris

119-121. Cranial middle and caudal parts of biceps femoris

122. Long dig. ext.
123. DDF
124. Deep flexor sheath
125. Gastrocnemius tendon
126. SDF tendon

127, 128. SDF and DDF tendons

129. LDE & LDE common tendon
130. Semitendinosus

Blood vessels

131. Transverse facial a.
132. External jugular v.
133. Cephalic v.
134. Med. palmar a.
135. Med. saphenous v.
136. Dorsal metatarsal a.

Nerves

a. Facial
b. Suprascapular
c. Radial
d. Ulnar
e. Median
f. Lat. palmar
g. Med. **palmar**
h. Common peroneal
i. Deep peroneal
k. Superf. peroneal
l. Tibial
m. Med. plantar
n. Lat. plantar

Internal organs

o. Parotid gland
p. Heart
q. Dome of diaphragm
r. Basal border of lung
s. Left lobe of liver
t. Stomach
u. Spleen
v. Left kidney
w. Left ventral colon
x. Pelvic flexure
y. Left dorsal colon

Appendix 3

Radiographic Anatomy of Bones of the Dog

The forelimb

Scapula (Fig. A3–A)

Being such a thin bone, only those parts viewed 'end-on' are conspicuous. There is a single epiphysis for the supraglenoid tuberosity .

In the cat, the small bony **clavicle** located at the base of the scapula may be mistaken for a foreign body .

Humerus (Fig. A3–B)

A nutrient canal is present on the caudal surface. A single proximal epiphysis is present. Distally there are separate epiphyses for:

i) Lateral and medial condyles.

ii) Medial epicondyle.

The cat has a supracondylar foramen medially , which may be misdiagnosed as a fracture.

Radius and ulna (Fig. A3–C)

Radius

Separate proximal and distal epiphyses.

Ulna

Separate epiphysis for olecranon. A separate ossification centre for the anconeal process has only been seen in large dogs, for a short period at about 3 months of age. If seen at a later stage, it usually indicates failure of fusion, an ununited anconeal process.

The distal epiphysis is very large, to correspond to growth of both radial epiphyses. Chondrodystrophic breeds (e.g. Basset Hound) have bowed forelimbs due to early closure of the distal ulnar epiphysis. The radius is forced to bow as it continues to lengthen. This can happen in other dogs if trauma to the growing plate causes premature closure of the distal ulnar epiphysis.

Carpus and paw (Fig. A3–D)

Complicated to interpret. The accessary carpal bone has a separate epiphysis, and the sesamoid in the abductor pollicis longus can be mistaken for a chip fracture.

In the digits, note the normal sesamoids – 2 ventral and 1 dorsal to the metacarpophalangeal joint.

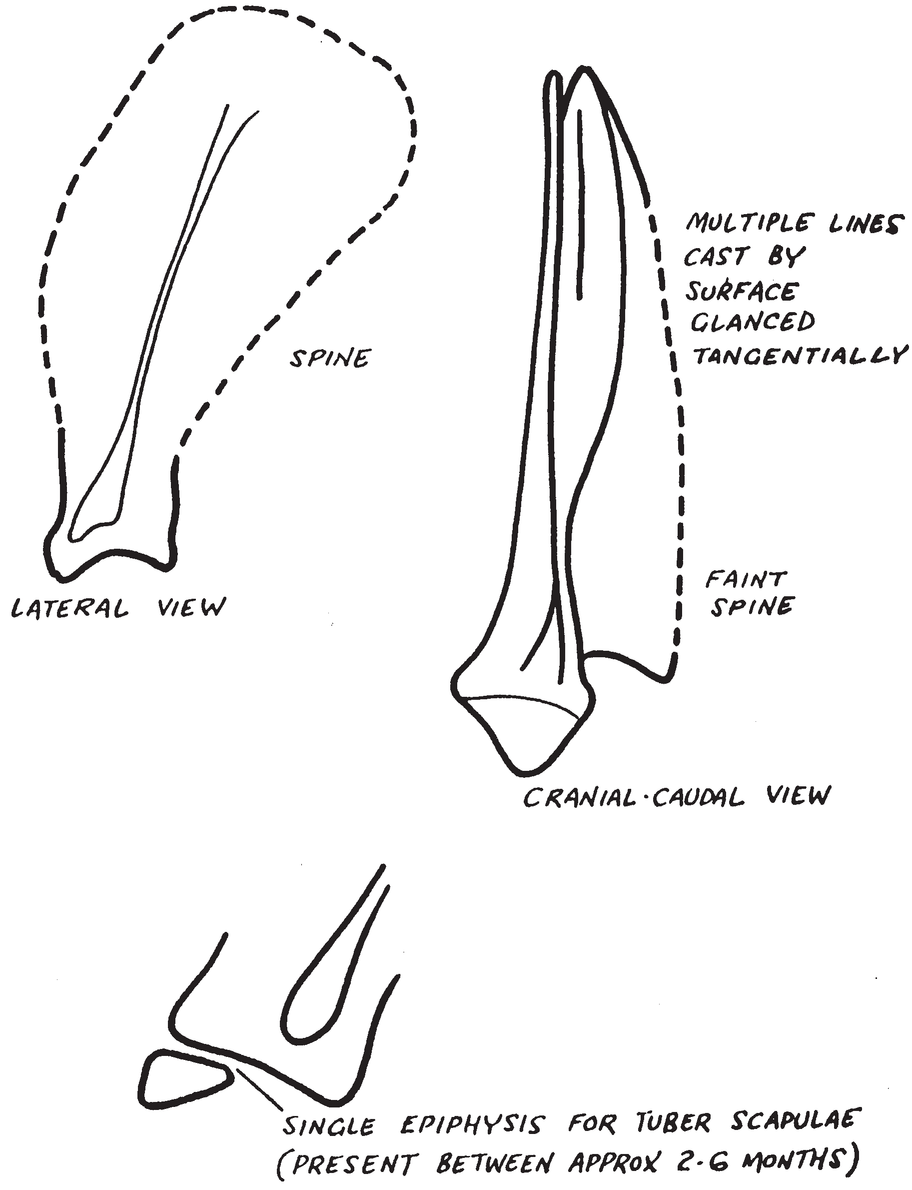


Figure A3–A: Radiographic appearance of the scapula

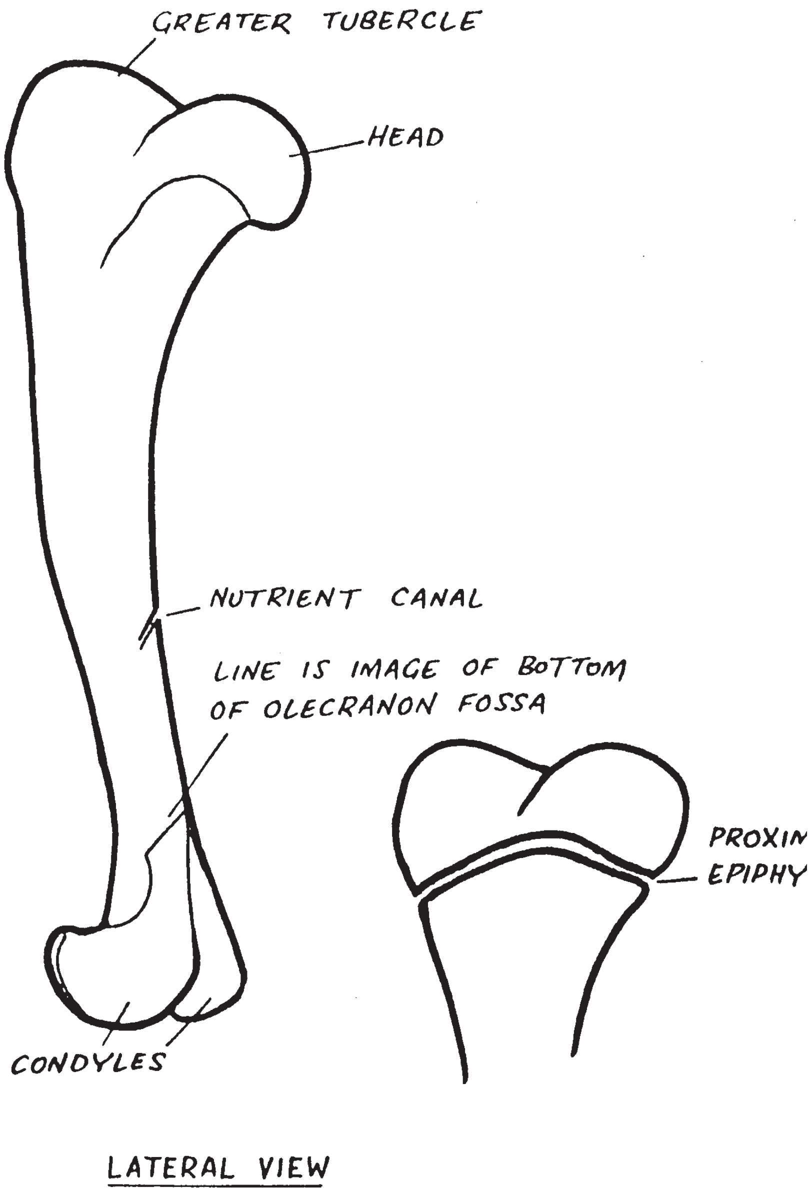


Figure A3–B: Radiographic appearance of the humerus

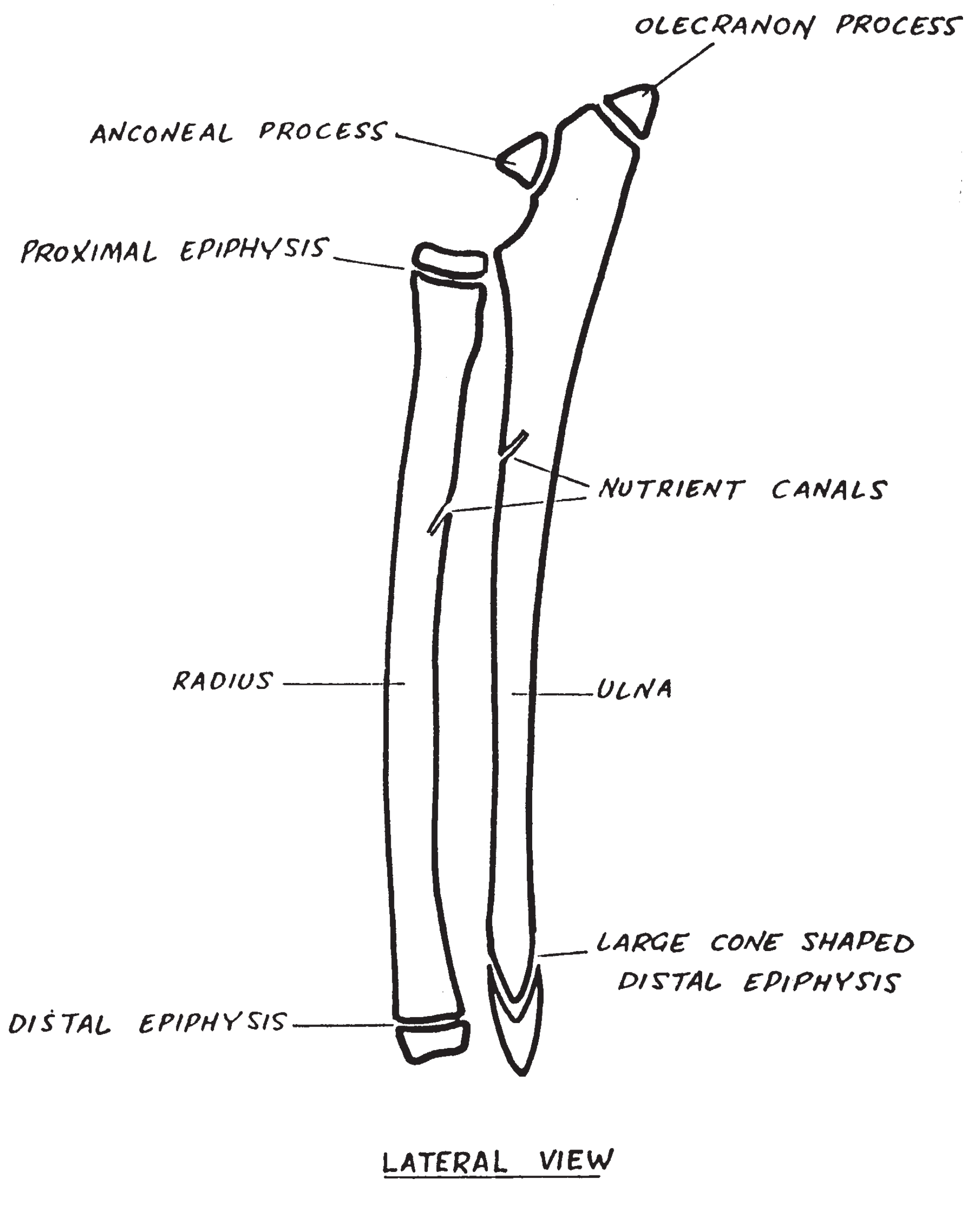


Figure A3–C: Radiographic appearance of the radius and ulna

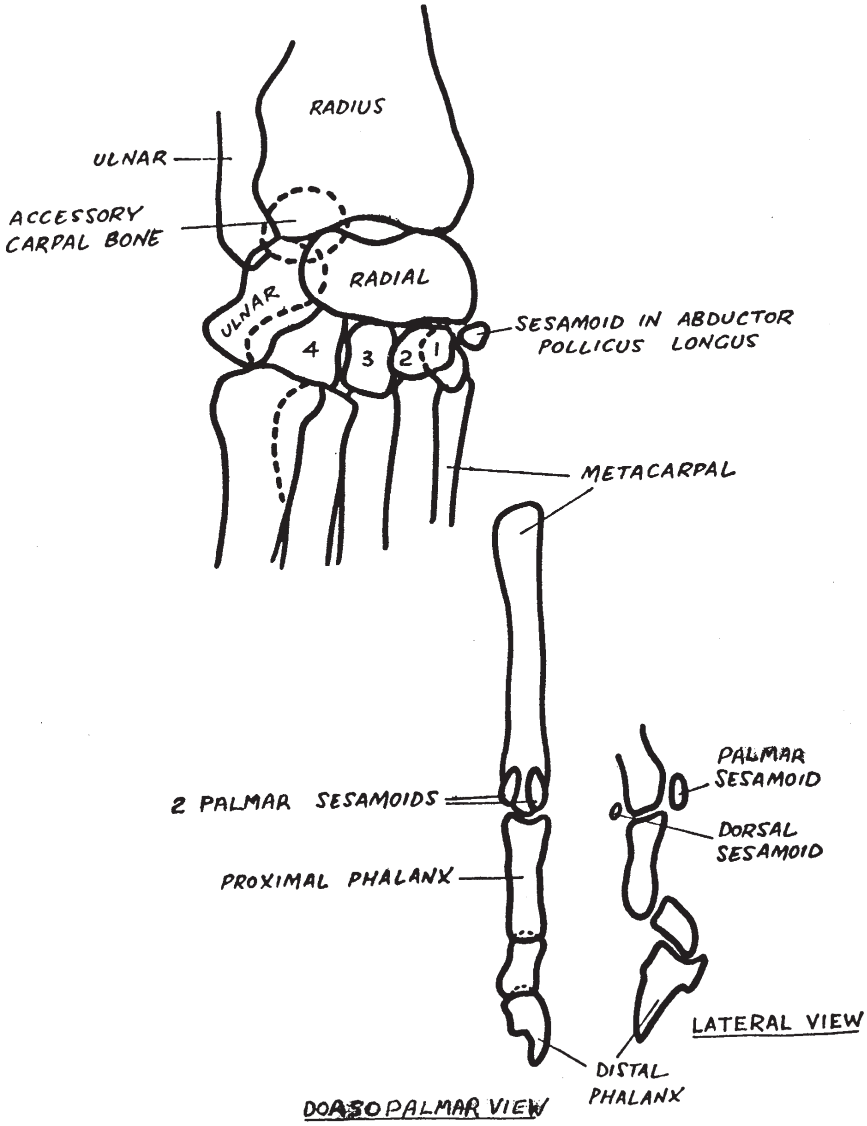


Figure A3–D: Radiographic appearance of carpus and digits

The hindlimb

Pelvis (Fig. A3–E)

This bone has several epiphyses, and the symphysis may take years to fuse entirely .

The radiological features of the acetabulum are of particular importance in interpreting hip dysplasia. In normal hip joints, the acetabulum should be deep enough to accommodate at least half of the femoral head. The diagnosis of hip dysplasia requires accurate assessment of these features, especially the relationship of the head of the femur to the radiographic borders of the acetabulum - Fig 13.

- Cranial ef fective acetabular rim
- Cranial acetabular edge
- Dorsal acetabular edge
- Caudal acetabular edge (not usually visible in the dorso-ventral view)

Femur (Fig. A3–G)

Proximally, there are separate epiphyses for the head and greater and lesser trochanters. Distally, a four-pronged diaphysis interlocks with the growth plate and a clear delineated epiphysis is rarely seen.

The cat has a relatively large fossa for the origin of the popliteus muscle, which may be mistaken for a pathological lesion.

Stifle joint (Fig. A3–F)

This joint is frequently involved in lameness, and a thorough radiographic knowledge is important. There are 4 sesamoids:

- patella
- 2 fabellae
- popliteal sesamoid

The infrapatella fat pad outlines the distal patellar ligament and the origin of the cranial cruciate ligament.

Tibia and fibula (Fig. A3–H)

Proximally there are separate epiphyses for the condyles and tibial tuberosity . The tibial tuberosity is a **traction epiphysis** (i.e. under great tension) and it develops as a fibrocartilaginous growth plate, instead of the more typical hyaline cartilage. This presents an unusual radiographic appearance, with ragged comb-like edges to the epiphyseal line.

The medial malleolus also has a separate epiphysis, and the nutrient canal is often especially conspicuous. In chondrodystrophic breeds, the fibula bows caudally .

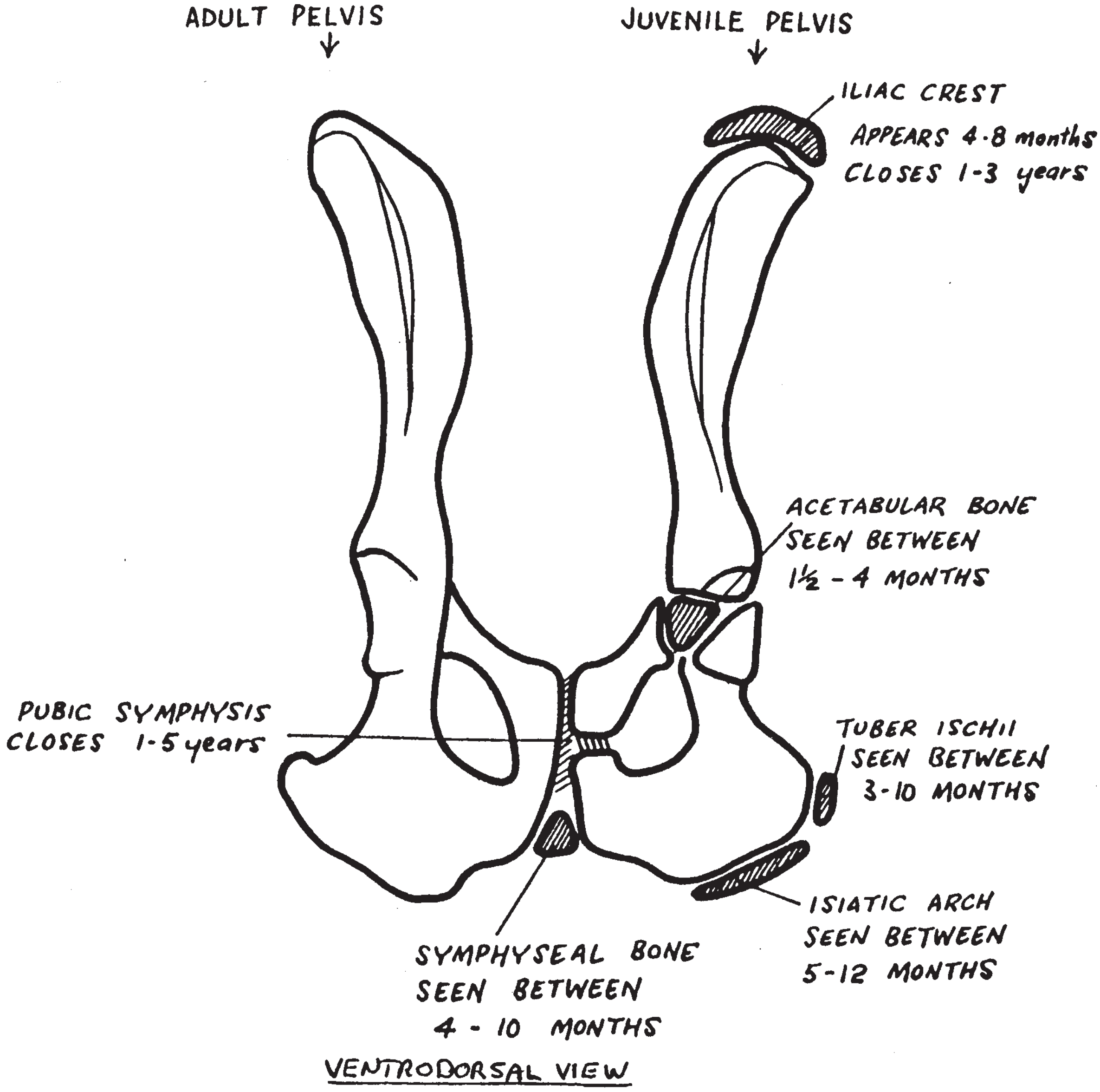


Figure a3–E: Radiographic appearance of adult and immature pelvis

Tarsus (Hock) (Fig. A3–I)

This is not easy to interpret. It is useful to have a skeleton beside you to remind you what is normal. The calcaneal tuber has a separate epiphysis.

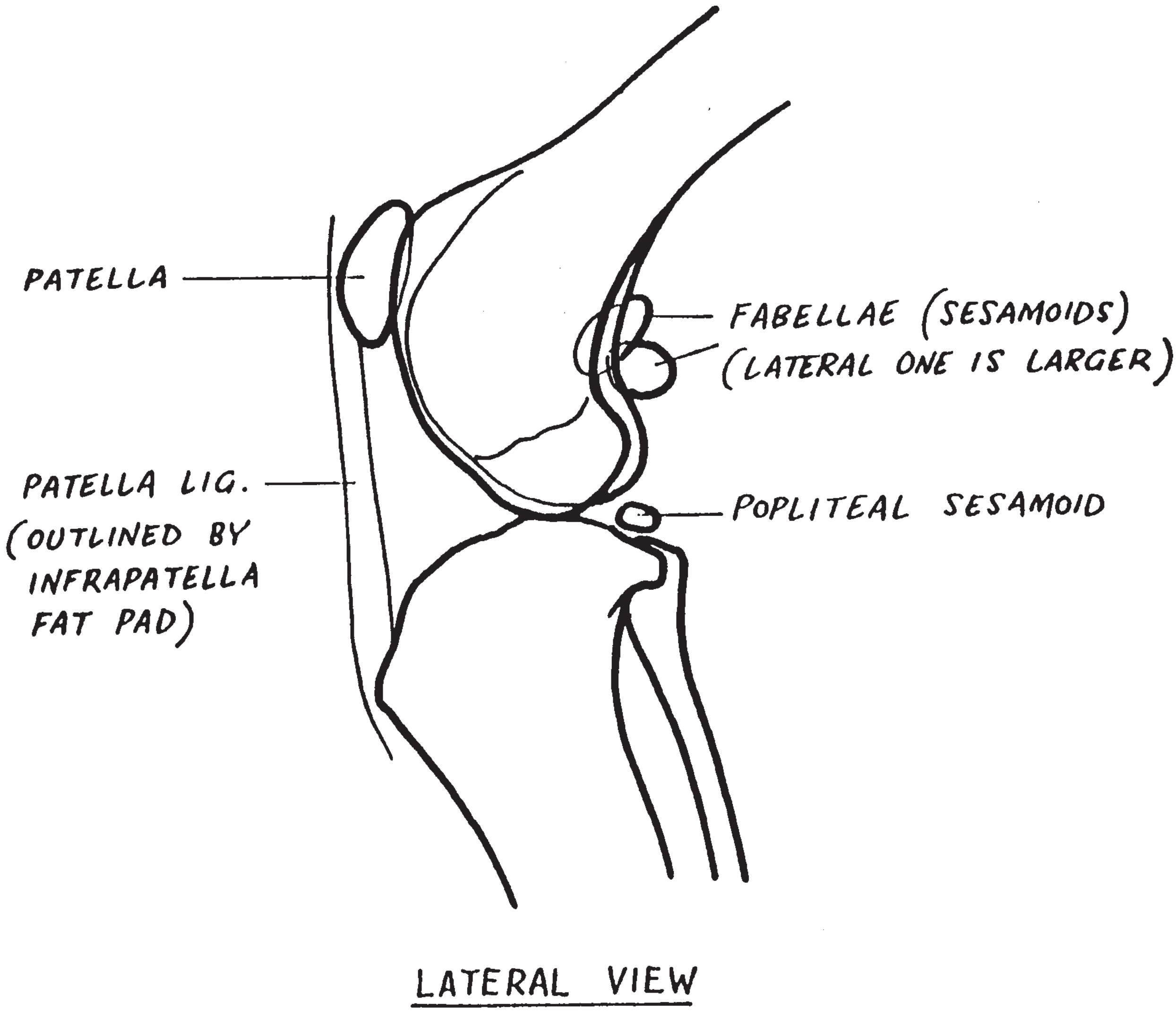


Figure A3–F: Radiographic appearance of the stifle joint

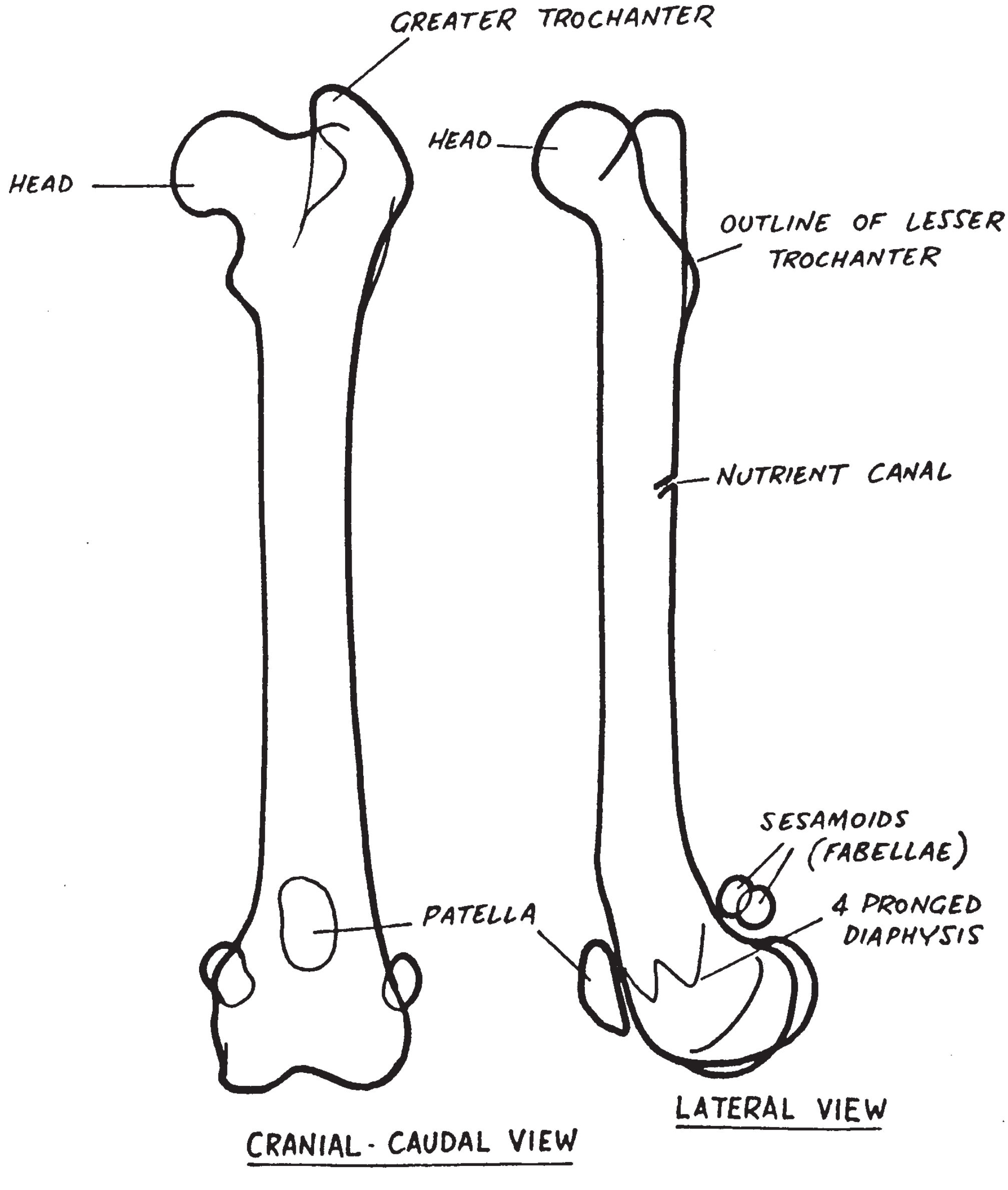


Figure A3–G: Radiographic appearance of the femur

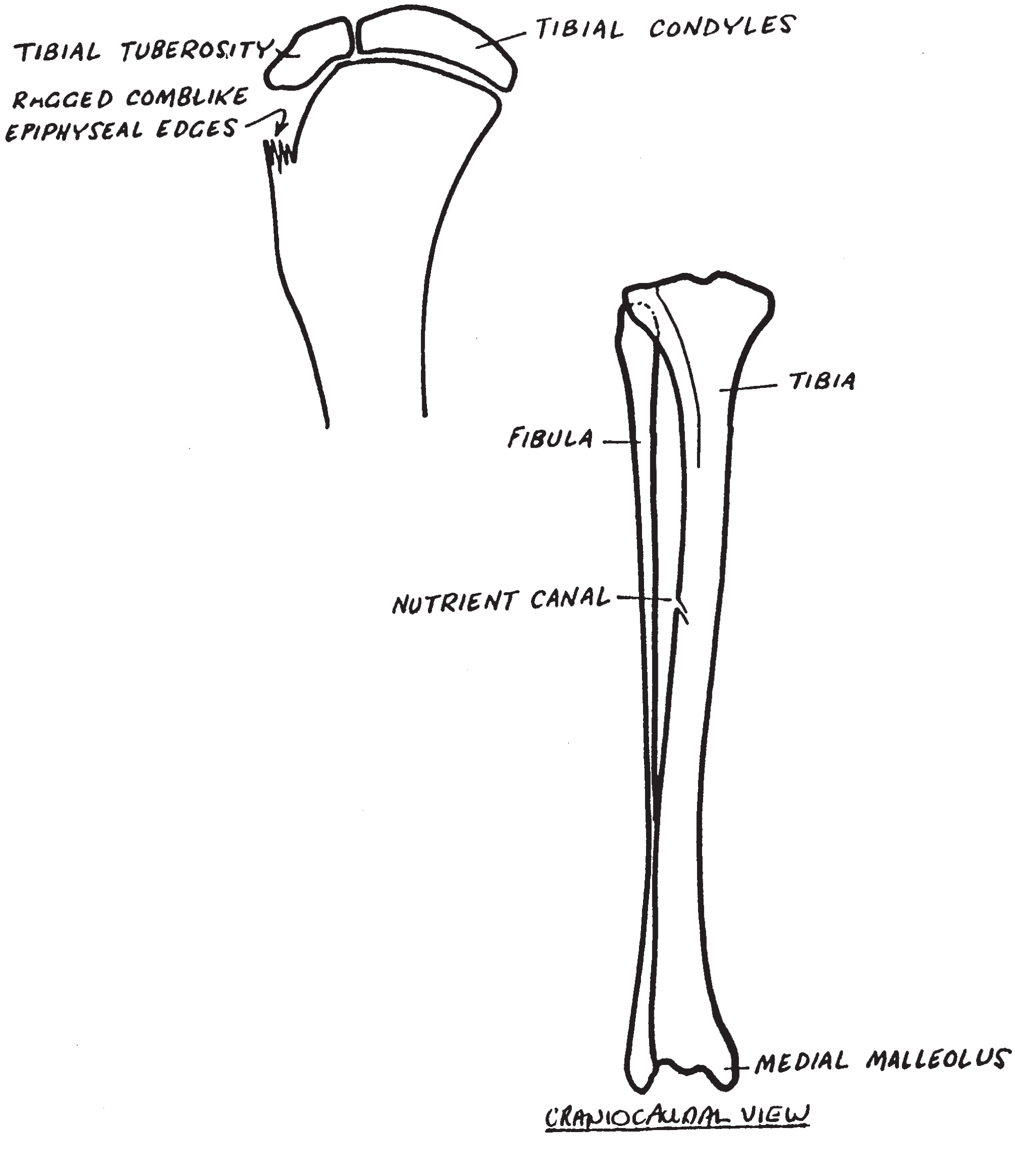


Figure A3–H: Radiographic appearance of the tibia and fibula

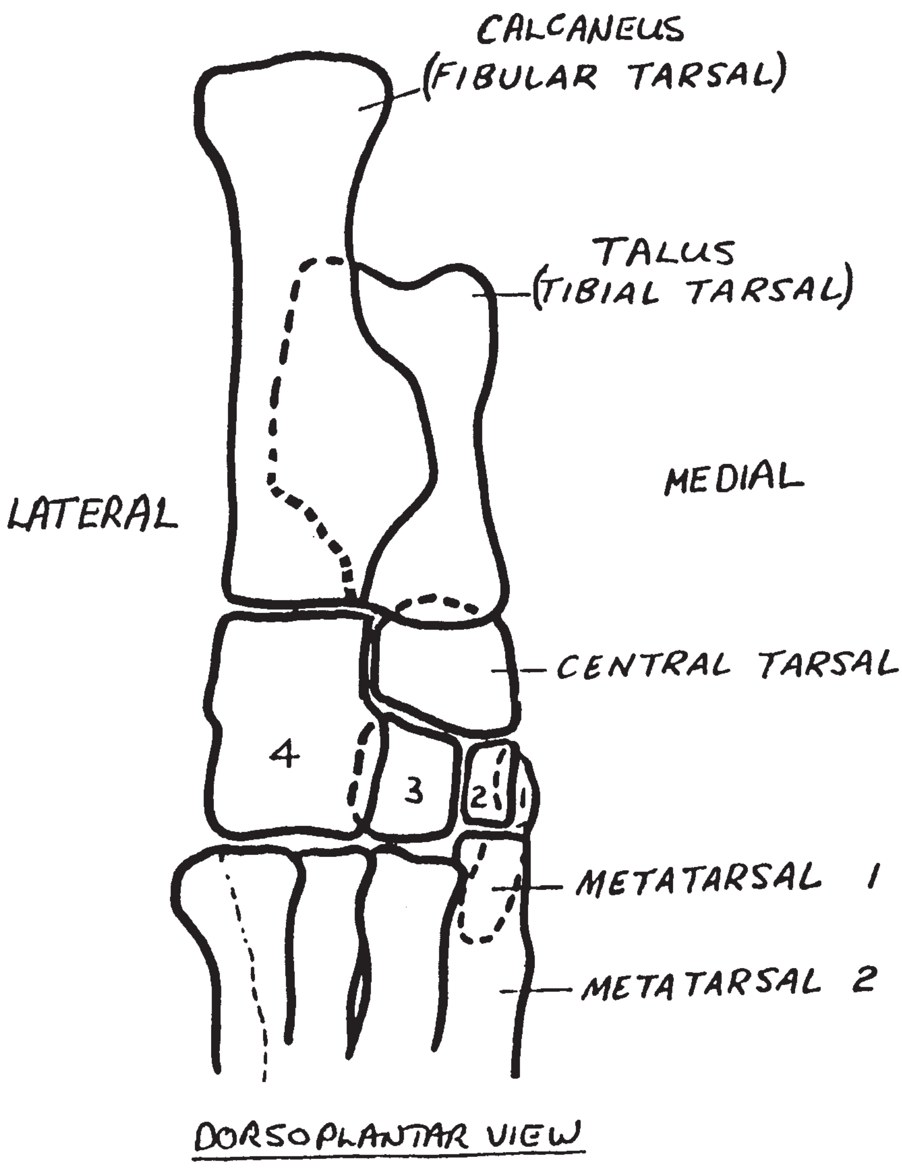


Figure A3–I: Radiographic appearance of the tarsus

Vertebral column

Interpretation is very dependent upon a good knowledge of anatomy. The effects of parallax and posture distortion necessitate good positioning and several sequential views for accurate interpretation.

General features (Fig A3–J):

- intervertebral foramina have a typical horse-head shape.
- transverse process crossing the intervertebral disc may simulate a calcified disc.
- to interpret the lines on the DV views, work through in a sequential fashion.

Cervical vertebral column (Fig. A3–K)

This is an important but difficult region to radiograph satisfactorily, and accurate positioning is essential. Notable features in a lateral view:

- intervertebral foramina are obscured by the large oblique articular processes.
- large flange-like transverse processes of C6
- oblique disposition of the vertebral bodies.
- laminae of the neural arches obscure the roof of the vertebral canal.
- wing of the atlas obscures the dens.
- transverse foramina (canal) confuses interpretation.
- the right and left lateral vertebral foramina are superimposed.

Sacro-iliac joint

Synchondrosis craniodorsally and diarthrosis caudoventrally. The synchondrosis will appear as a radiolucent line which can be mistaken for a disarticulated pelvis.

Head (Fig. A3–L)

Interpretation of the head also needs a detailed knowledge of anatomy. At this stage, you are only expected to recognize the main features. Note:

- the walls of the cranium, including ethmoidal fossa.
- the orbit is relatively inconspicuous.
- the fronto-parietal (coronal) suture in growing dogs - may remain open in some toy breeds.
- temporo-zygomatic line: a synchondrosis which remains open in the adult.
- frontal sinus is greatly reduced in the very young and in brachycephalic toy breeds (eg Pekingese).
- nasal chambers are very complicated due to the turbinate bones and nasal canals. The hard palate is separated from the vomer by the nasal air space.

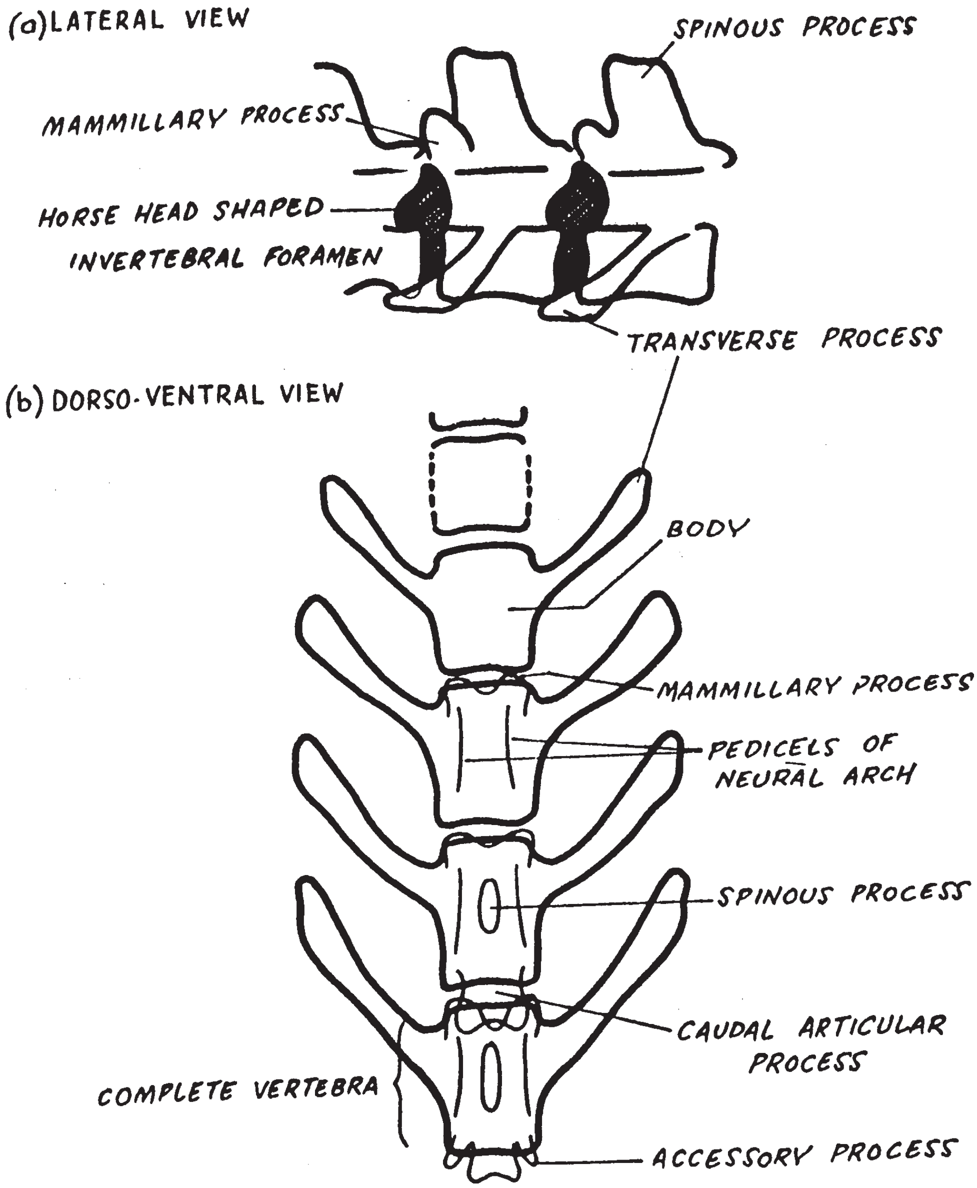


Figure A3–J: General radiographic appearance of the vertebral column

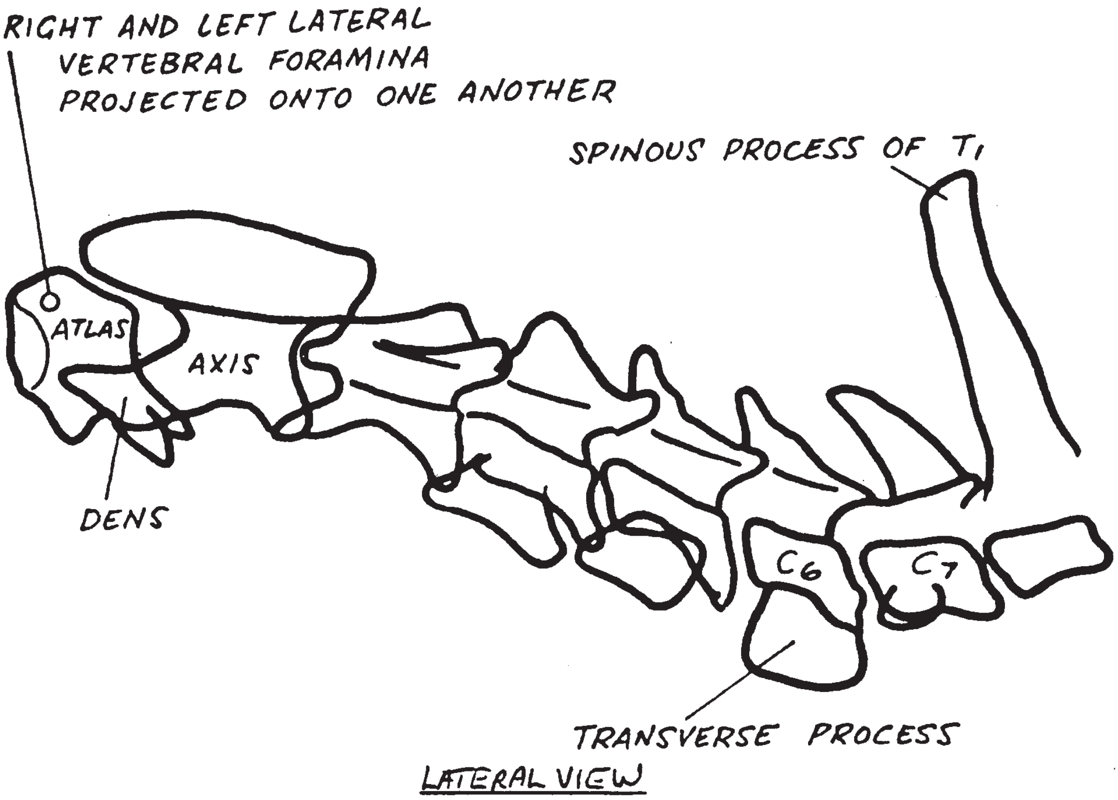


Figure A3–K: Radiographic appearance of the cervical spine

Teeth

- Enamel, dentine and pulp can all be distinguished.
- The pulp cavity narrows with age.
- The **periodontal membrane** is visible as a radiolucent line between the tooth and the alveolus.

Hyoid

The hyoid apparatus shows on underexposed x-rays. In a lateral view, the single basihyoid bone is seen 'end-on' and appears as a dense osseus structure. The stylohyoid appears separated from the temporal bone, because it is attached by the tympanohyoid cartilage.

Larynx

The laryngeal cartilages are radiolucent in the young animal but may begin to calcify by 1 year of age. This gives the region a mottled appearance.

The dorsal aspect of the cricoid can easily be mistaken for a foreign body when it is calcified.

Sternum and ribs

There are often incidental variations and deformities of the sternum and ribs.

There is a tendency to regard the ribs as an impediment to viewing the thoracic contents. Thoracic radiographs should be systematically viewed from the periphery inwards, to avoid missing rib pathology .

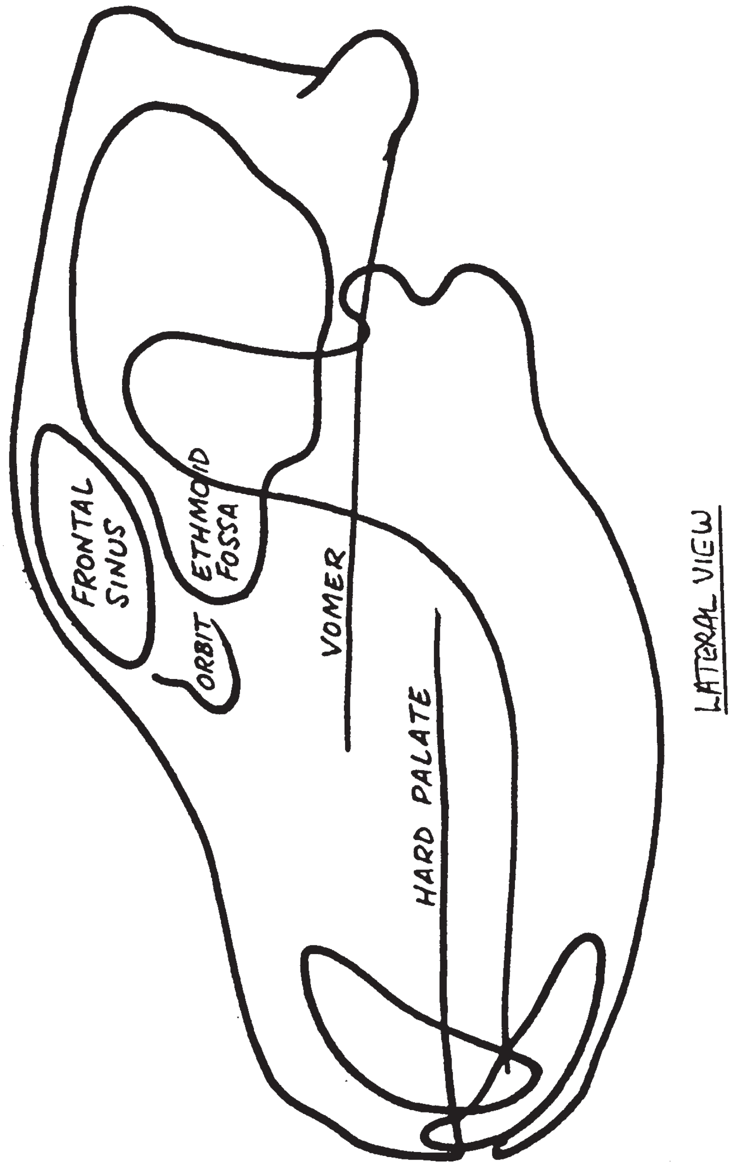


Figure A3–L: Radiographic appearance of the skull

Appendix 4

Radiographic Anatomy of the Bones of the Horse

Radiographic anatomy of the horse

Radiography is especially helpful in the diagnosis of equine lameness. The carpus and digits are the regions most frequently radiographed.

Carpus

Anatomically complex region, requiring views from a variety of different positions, so that all the bones may be thoroughly evaluated (Fig. A4-A). Accurate positioning is important since joint spaces may be artifactually narrowed and misinterpreted.

There is only one ossification centre for each carpal bone.

Dorsopalmar (DPa) View– (Fig. A4–B)

Useful for evaluation of the distal radius, the medial and lateral aspects of the carpal joints and the alignment of the carpal bones.

Lateromedial (LM) view – (Fig. A4–C)

Useful for evaluation of the cranial margins of the distal radius, radial, intermediate and 3rd carpal bones and the proximal 3rd metacarpal bone. The accessory carpal bone is also well visualized in this view.

Flexed LM view – (Fig. A4–C)

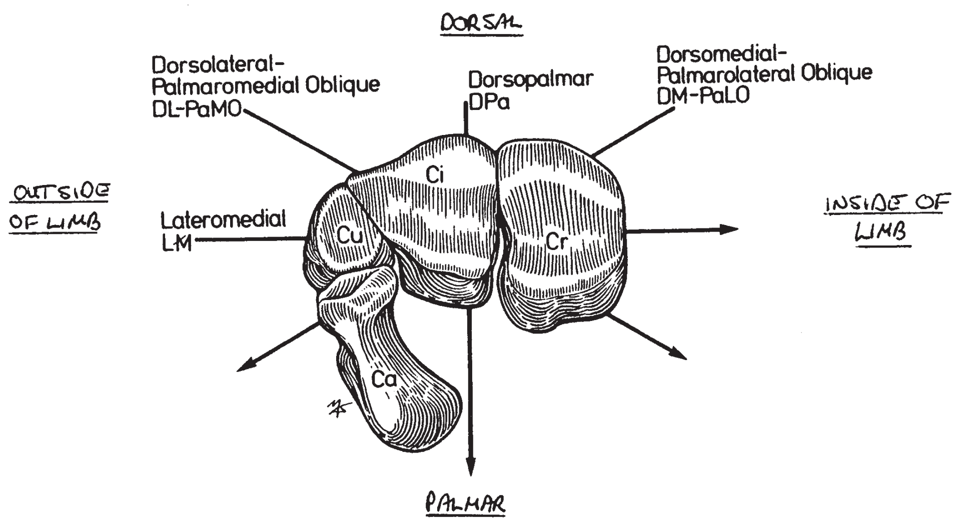
Useful for evaluation of joint spaces and articular surfaces of the carpal bones. This view demonstrates the extensive mobility of the radiocarpal (largest opening) and intercarpal joints and the relative immobility of the carpometacarpal joint.

Oblique views can also be used for assessment of specific carpal bones, and **skyline views** for localising chip or slab fractures on the cranial aspect of the carpus.

Digit

Epiphyseal plates are present at the distal end of the third metacarpal bone and at the proximal ends of the proximal and middle phalanges, closing at about 18 months. The epiphyseal plates at the opposite end of the bones close before, or very soon after birth.

The distal phalanx and sesamoid bones each develop from one centre of ossification.



Redrawn from Thrall, 1986.

Figure A4–A: Positioning for radiographic views of the lower limb

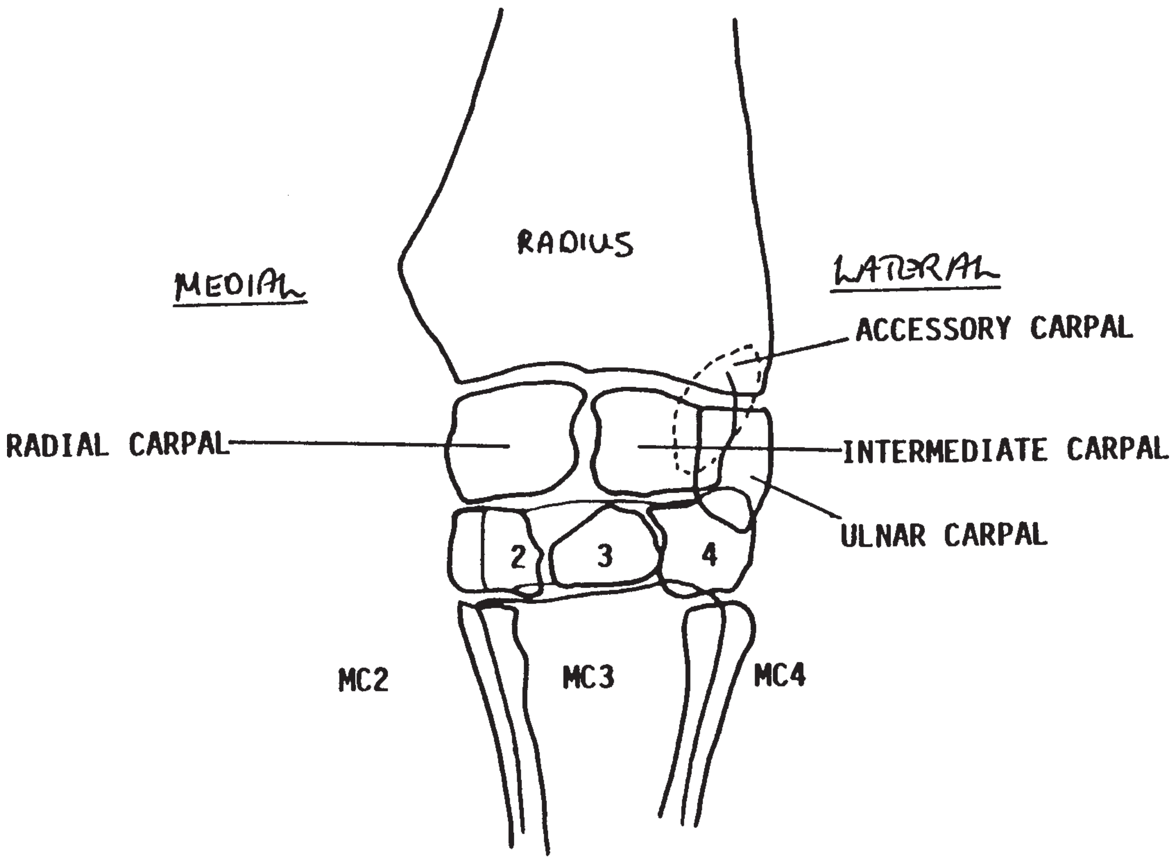


Figure A4–B: Radiographic dorsopalmar view of the carpus

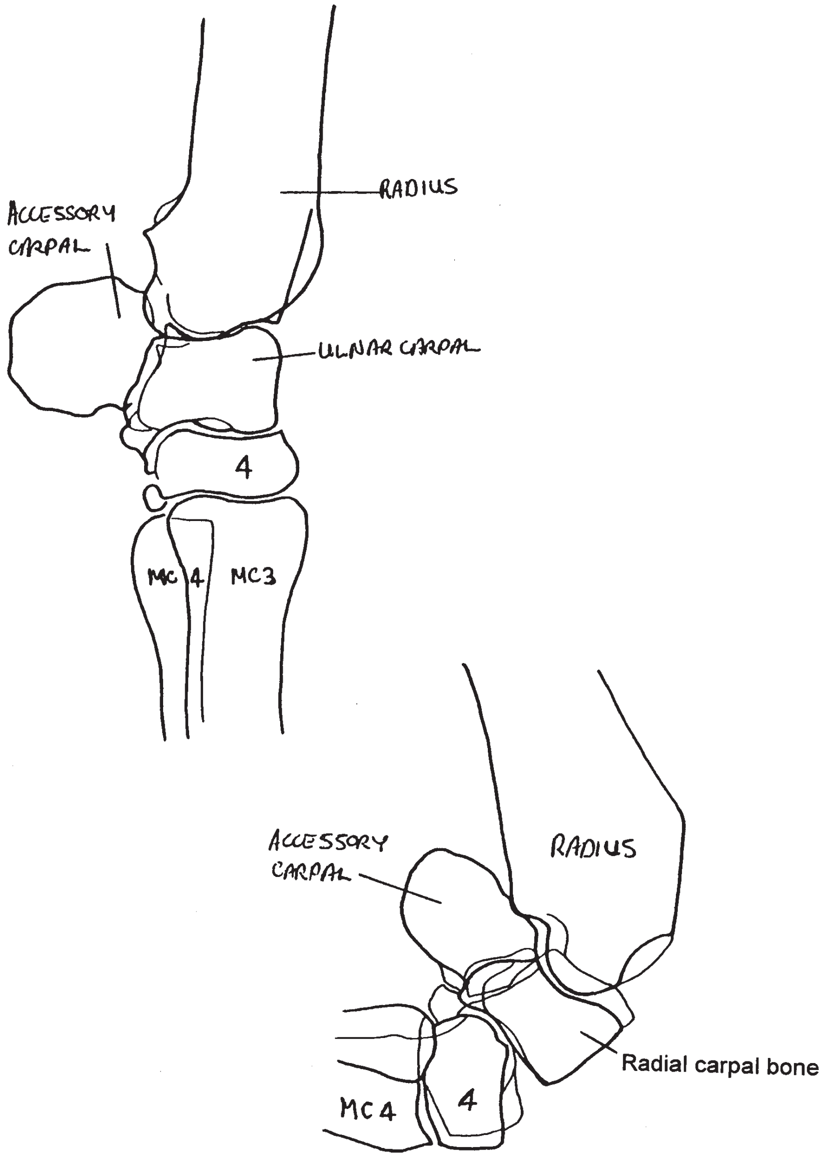


Figure A4–C: Radiographic lateromedial and flexed lateromedial views of the carpus

Lateromedial view – (Fig. A4–D)

Useful for assessing the dorsal and palmar/plantar surfaces of the digit. The dorsal aspect of the proximal and middle phalanges bear an eminence for the attachment of the extensor tendons. The extensor process on the coronary border of the distal phalanx is well developed.

Tangential views of the convexities and concavities at the ends of the phalanges produce superimposed shadows at the interphalangeal joints.

The dorsal surface of the distal phalanx should be parallel to the hoof wall. An area of radiolucency is caused by an 'end on' view of the solar (semilunar) canal. The medial and lateral palmar processes (angles) of the distal phalanx vary considerably in their development among different individuals, and are superimposed on lateral radiographs. The medial palmar process is usually shorter.

Dorsopalmar view of proximal digit (Fig. A4–E)

It is usually possible to distinguish medial from lateral even if not marked as the lateral proximal sesamoid boneappears to have a deeper concavity on the lateral (abaxial) surface. The articular surface medial to the sagittal ridge of the third metacarpal is slightly wider than on the lateral side. The sagittal ridge fits into the intermediate groove on the proximal end of the first phalanx, increasing stability of the joint.

There are eminences on the lateral and medial aspects of the ends of the phalanges where collateral ligaments attach. The caudal edges of proximal and middle phalanges cast shadows just above the interphalangeal joint spaces.

The ergot casts a faint shadow on the proximal phalanx. The ridges for the attachment of the oblique (middle) sesamoidean ligaments can be seen on the proximal phalanx.

Dorsopalmar view of the distal phalanx (Fig. A4–F)

The distal phalanx has numerous vascular foramina and canals, giving this it a very porous appearance. Numerous vascular canals open onto the solar (distal) border; positioning alters their appearance.

Parts of the solar (semilunar) canal can be distinguished and the medial and lateral solar foramina are sometimes visible.

Note: The distal sesamoid (**navicular**) bone is superimposed upon the middle phalanx. A skyline view of the hyperextended coffin joint is required to view the navicular in isolation.

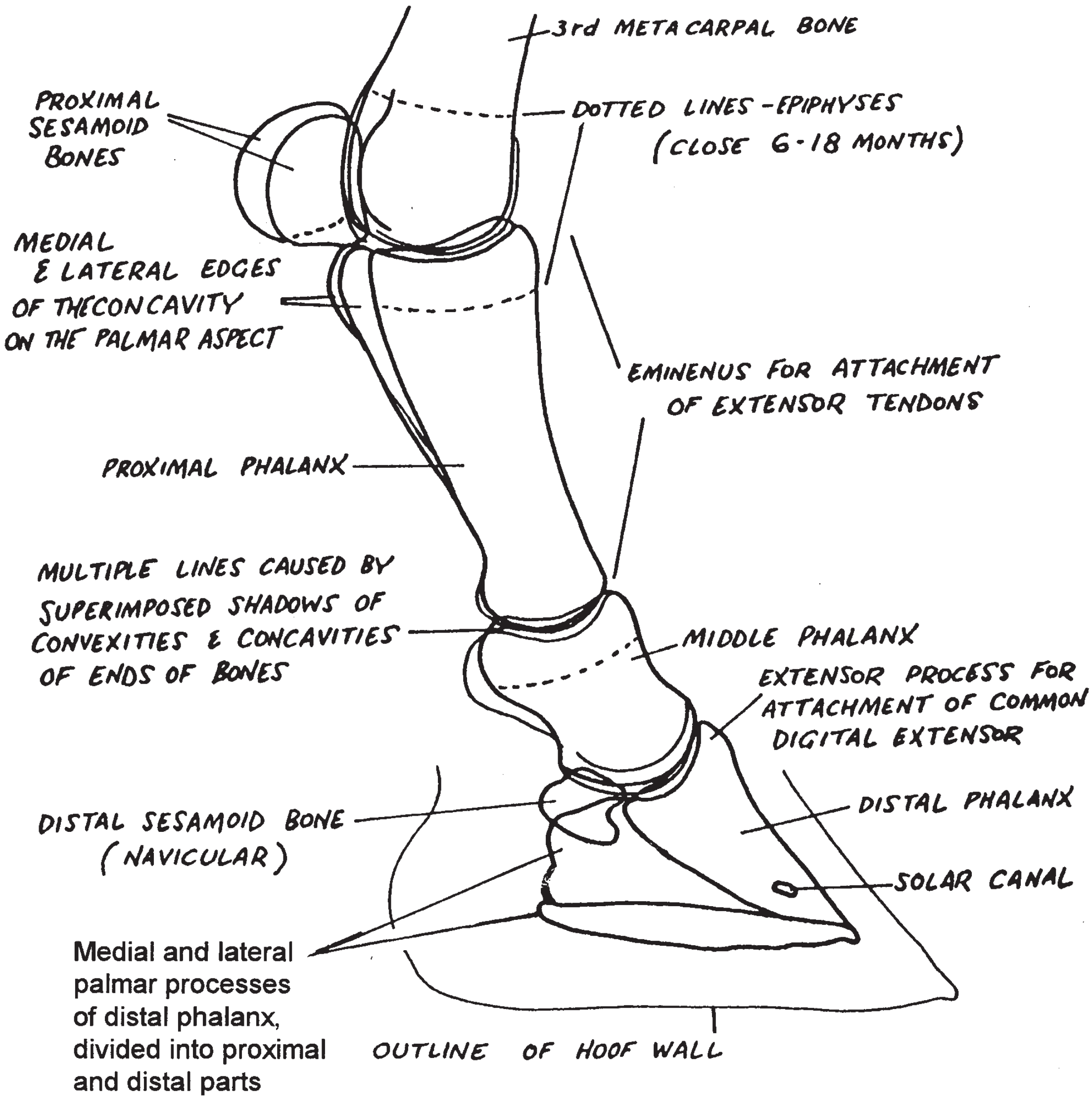


Figure A4–D: Radiographic lateromedial view of the digit

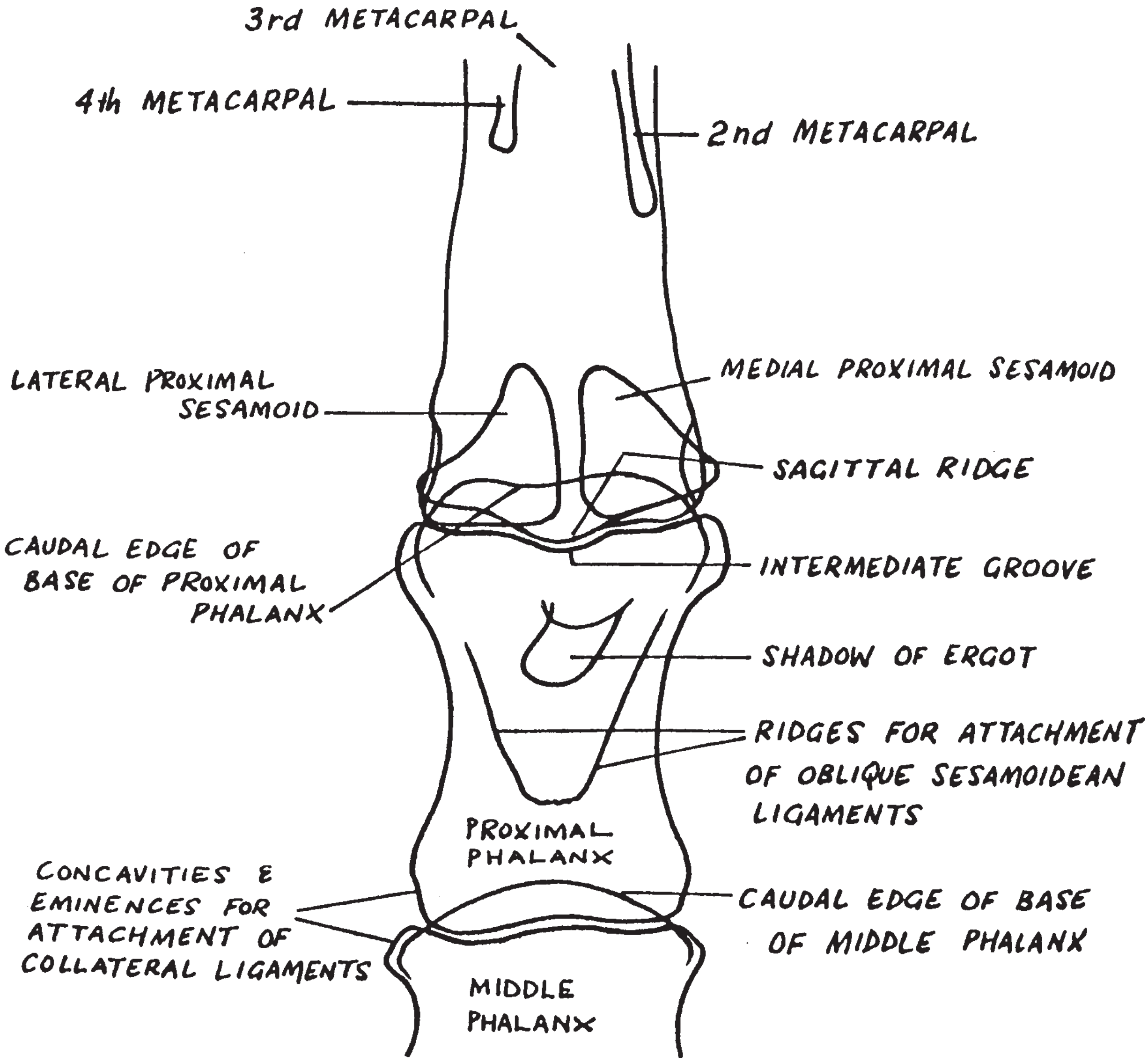


Figure A4–E: Radiographic dorsopalmar view of proximal part of digit

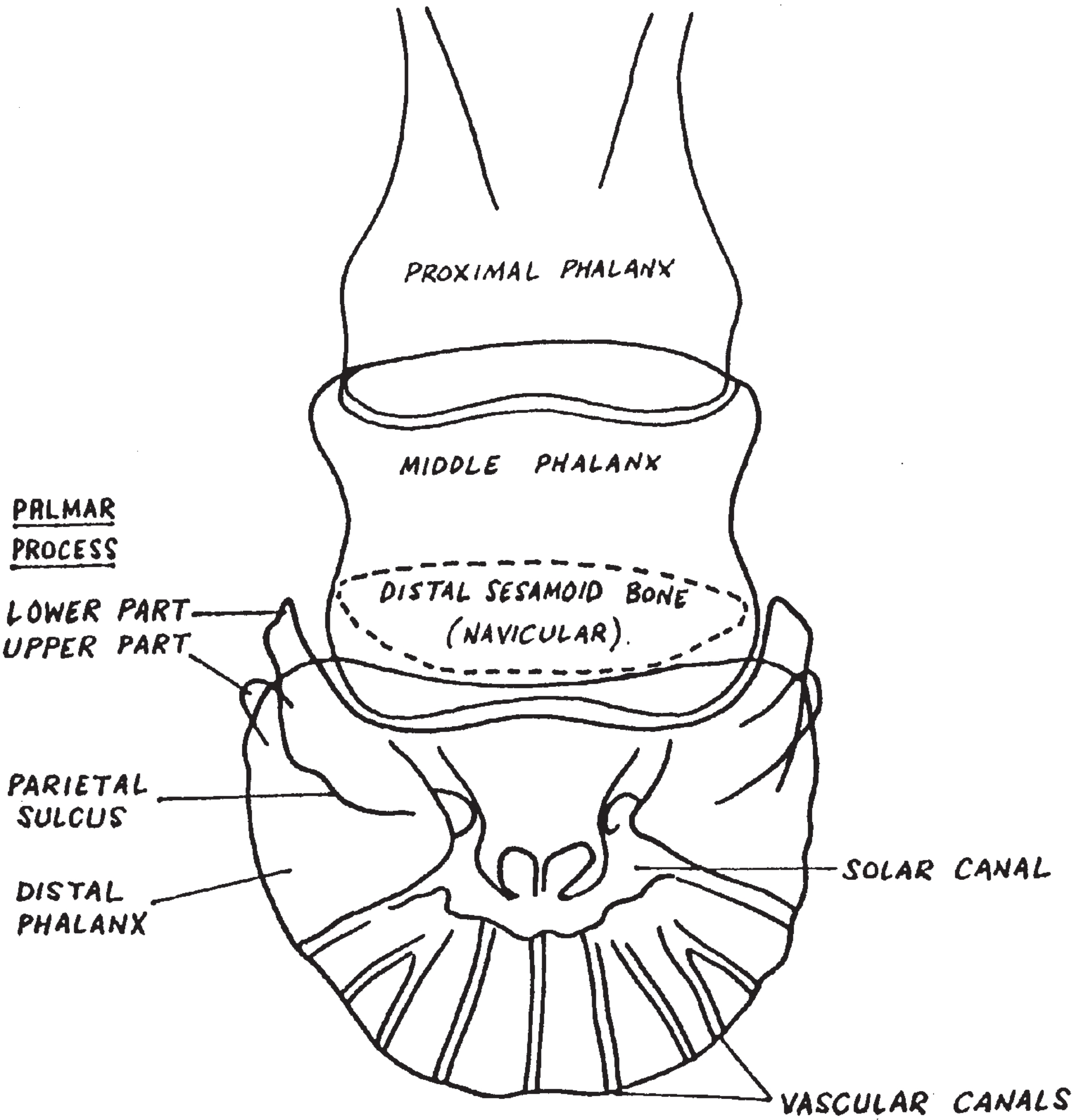


Figure A4–F: Radiographic dorsopalmar view of the distal phalanx

Appendix 5

Average Fusion Times of Some Important Ephiphyses

N.B. It is not necessary to memorise this table. These represent times of complete closure of the epiphysis. Early stages of closure in the central epiphysis may begin much earlier .

Prepared from Curgy , J.J. (1965) Apparition et soudure des Points D'Ossification des Membres chez les Mammiferes Mem. Mus. Nat. Hist. Nat. Ser . A, 32, 3.

	HORSE	DOG	CAT
FORE LIMB			
SCAPULA			
– Supraglenoid Tubercle	10-12m	6m	8m
HUMERUS			
– Proximal Epiphysis	around 3 $^{1}/_{2}$ yrs	13m	11m
– Distal Epiphysis	15-18m	6m	8m
RADIUS			
– Proximal Epiphysis	15-18m	11m	8m
– Distal Epiphysis	around 3 $^{1}/_{2}$ yrs	11m	11m
ULNA			
– Proximal Epiphysis	around 3 $^{1}/_{2}$ yrs	9m	10m
– Distal Epiphysis	birth	11m	11m
METACARPUS			
– Distal Epiphysis	15-16m	8m	8-11m
PHALANGES			
– Proximal Epiphysis	12-15m	7m	7-11m

	HORSE	DOG	CAT
HIND LIMB			
PELVIS:			
ILIUM-ISCHIUM-PUBIS	10-12m	21-24 wks	8m
– Iliac Crest	4 1/2 -5 yrs	18-24m	–
– Tuber Ischii	4 1/2 -5 yrs	18-24m	9 1/2 m
– Pubic Symphysis	–	6m	–
FEMUR			
– Head	3-3 1/2 yrs	11m	8m
– Lesser Trochanter	–	11 1/2 m	8m
– Greater Trochanter	–	11m	8m
– Distal Epiphysis	3 1/2 yrs	11 1/2 m	8m
TIBIA			
– Tibial Tuberosity	–	10m	8m
– Proximal Epiphysis	3 1/2 yrs	13m	11m
– Distal Epiphysis	2 yrs	11m	11m
FIBULA			
– Proximal epiphysis	–	12m	11m
– Distal Epiphysis	2 yrs	–	11m
METATARSUS			
– Distal Epiphysis	15-16m	8m	8-11m
PHALANGES			
– Proximal Epiphysis	12-15m	6m	7-8m