ANATOMICAL STUDIES ON BOVINE SYNDACTYLISM

by

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INTRODUCTION

Investigations and research undertaken at other institutions and also by the Department of Dairy Science at Kansas State University established bovine syndactylism as a hereditary abnormality. However, not all the genetical aspects had been clarified. Syndactylism in cattle was described as a partial or total fusion of the two functional digits, affecting one or more limbs of the same individual, and caused by a recessive gene with variable expressivity and possibly pleiotropic effects.

A brief survey over the anatomical work done in this field revealed that the previous investigations had been somewhat restricted. First, only those limbs which showed syndactylism externally, had undergone a closer anatomical examination and dissection, whereas the other, apparently normal limbs of the same individual had not been studied. Second, among the affected limbs, only the structures distal to the carpus or tarsus had been described and, as far as the pelvic limbs were concerned, only the osteology and external characteristics had been studied. Furthermore, with one exception, the pedigree of those syndactylous animals which had been described anatomically in some detail was either unknown or not recorded.

All these omitted or neglected details of the problem were deemed to deserve some closer attention and consideration in the present study.

MATERIALS AND METHODS

The specimens were of various ages, and all belonged to the Holstein breed of cattle. A total of sixty-four limbs (thirty-four thoracic and thirty pelvic) from seventeen individual animals was examined. Among the thoracic limbs ten were complete, twenty had been dismembered at the distal forearm or the radio-carpal joint, and four had been amputated below the carpus. Among the pelvic limbs ten were complete, sixteen had been amputated at the distal part of the leg or at the tibio-tarsal joint, and four below the tarsus (Table 1)*.

Twelve thoracic and twelve pelvic limbs were embalmed with a solution containing formalin (12%), glycerine (3.7%), acetic acid (0.5%), and water (83.8%). The arteries of these limbs were subsequently injected with concentrated or diluted red latex. Two thoracic limbs were preserved in a similar formalin solution, but the arteries were not injected. Sixteen thoracic and fourteen pelvic limbs were preserved by freezing. Four thoracic and four pelvic limbs were dissected in the fresh state.

About two-thirds of the embalmed limbs were stored for several days prior to the dissection in a one per cent phenol solution. Thus, the limbs were soaked and their dissection rendered better results as compared to the unsoaked limbs whose firmness made the dissection of delicate structures, especially nerves, very difficult.

Most limbs were first examined externally, and changes from the normal appearance were recorded. Measurements of the dewclaws and hooves of the syndactylous limbs were taken, and asymmetrical dewclaws of otherwise normal limbs were also measured. Later the numerical results of these proportions were

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* All tables in Appendix

judged not to be so expressive as brief comparative verbal statements. A few initial radiographs taken were likewise not more informative than an osteological study, and the former method was therefore abandoned.

A detailed dissection was performed which consisted of a thorough comparative examination of all soft structures such as muscles, tendons, ligaments, arteries, veins, and nerves. Any deviation from the normal pattern was recorded in writing or in diagramatic sketches. Photographs of the most conspicuous features were taken. An accurate dissection of the smaller nerves and blood vessels was often difficult, since the firmness, texture, and color of these structures frequently contrasted little from the surrounding connective and adipose tissue.

Following dissection the limbs were macerated. The soft structures of the frozen and fresh limbs were decomposed in water. The embalmed limbs had to be macerated by boiling, since their flesh would not decompose by water maceration. The isolated bones were simultaneously defatted with a commercial detergent and bleached with a commercial liquid bleach. The bones were then ready to be studied, described, and photographed.

The limbs of the animals number 051A, 72A, 38A, 63A, 39A, 6A, and 12B had been macerated by the Department of Dairy Science. Among them, only 12B and 051A had been dissected and partially described prior to the maceration. The normal limbs of 83B and of the unlabeled specimen were dissected by first year veterinary students.

The limbs of 29B and of the 202 day fetus, though all apparently normal externally, were studied since these animals had at least one syndactylous parent. It was therefore deemed necessary to check them for any hidden indication of syndactylism.

REVIEW OF LITERATURE

The literature reviewed covered mainly the anatomical aspects of bovine syndactylism. The genetics involved were noticed, but not covered extensively and emphatically. The anatomy review was directed at two fields; the normal anatomy of the bovine limbs, and the anatomy of syndactylous bovine limbs.

Chauveau (2), and Vaughan (25) presented a rather general description of the osteology, arthrology, and myology of the bovine limbs. The nerves and blood vessels were briefly compared to those of the horse without details.

Ellenberger (5) published several figures of the structures on the bovine limbs, clear details in the area of the digits were absent however.

Foust (7) presented two semischematic views of the distal part of the bovine forelimb, showing the arteries, nerves, tendons, and ligaments.

Getty (8) presented diagrams of the nerve supply to the digits.

Habel (9), McLeod (14), and Peterson (17) gave detailed descriptions and diagrams of the structures on the bovine limbs. The osteology was not included.

Way (26) presented a pictorial study of the anatomy of the bovine foot.

The modern standard textbooks which included Ellenberger and Baum (6), Sisson and Grossman (22), and Nickel, Schummer, and Seiferle (16) provided accurate information about the anatomy of the bovine limbs.

The most meticulous study of the anatomy of syndactylism in cattle was written by Steiner (23), whose work covered mainly the thoracic limb. Included in his work was an extensive review of literature, and an internal and external classification of the various degrees of fusion he found.

Eldridge, Smith, and McLeod (4) published an article on syndactylism in Holstein-Friesian cattle containing also anatomical observations on the thoracic limbs.

Eldridge (3) gave in his report a short description of syndactylous hooves. The rest of the publication treated the genetical aspects.

Kitt (12), and Joest (10) summarized the external and osteological appearance of syndactylism in cattle.

Further brief reports on syndactylism in various breeds of cattle were published. Shibata and Ishihara (18 and 19) described the genetics and, in a general manner, the external features of thirty-three syndactylous calves in Japan. They did not mention anatomically significant details. Two publications of Singh (20 and 21), and one of Kale (11) described cases of syndactylism in Indian cattle. The anatomical study covered only the hooves of the animals involved. Bonfanti's (1) description of one case in Italy and Sterba's (24) article about a case in Czechoslovakia included mainly external and osteological observations. Krölling (13) discussed two cases in Austria giving a short description of the exterior and the osteology with emphasis on the embryological aspects of the problem.

OBSERVATIONS

Each paragraph of the observations was divided into two parts. In the first part the normal anatomy of the structures considered was described in a condensed form. In the second part the same structures were described the way they were developed on syndactylous limbs and/or the slight deviations found on apparently normal limbs. In order to restrict the length of the description to a reasonable proportion, only the distal part of the limbs, where most of the structural deviations occurred, were described in detail.

External Appearance

Both the thoracic and pelvic normal limbs presented the typical artiodactylous picture with two unilaterally symmetrical functional digits, separated by an interdigital cleft, and two likewise symmetrical accessory digits, which were located at each side of the posterior aspect of the fetlock. The ends of the digits were covered by the hooves, their shape was recorded in the Plates I and II*.

A typical syndactylous limb (Plate I) showed the following deviations: There was only one weight bearing digit which was placed in the axis of the limb. This single digit appeared to be somewhat thicker than one digit of a normal limb, but not as wide as two combined normal functional digits. This fact often made the fetlock appear to be wider. The syndactylous hoof of young specimens had the shape of a bilaterally compressed truncated cone with the base located proximally. In older specimens the hoof was often curled and resembled a duck's bill, or the wall was bent either laterally or medially. Frequently there was a shallow sagittal groove on each side in the posterior part of the wall extending sometimes from the coronary border to the ground border. In other words, the posterior part of the hoof was constricted. The walls of older specimens were often marked by several ridges running parallel to the coronary border. The sole surface was more or less oval in outline, but otherwise similar to the normal, that is, slightly concave with no indication of supplementary structures such as a frog or a bar. On some hooves the excessively grown horn of the bulb covered the horn of the sole to a greater or lesser extent. In rarer cases the horn of the wall had overgrown the sole.

* All plates in Appendix

In a few cases the two original hooves were only partially fused and had a median cleft of various depth, location, and length.

The two dewclaws found on all syndactylous limbs were often unequal in size and sometimes not attached at the same level. The lateral was usually larger than the medial, in one specimen the medial was larger, and a few times both had the same size.

Otherwise normal cloven-hooved limbs of syndactylous animals sometimes showed a larger lateral dewclaw as one external sign of a deviation. The other sign was a pronounced median groove extending dorsally from the fetlock to the interdigital cleft.

Skin abrasions of various degrees were sometimes observed. They occurred both on syndactylous and normal limbs and were located on the dorsal surface, most frequently at the distal end of the carpus.

The fifteen mule-footed individuals showed total or partial syndactylism on twenty-nine thoracic and four pelvic limbs. Whenever a pelvic limb of an individual was affected, both thoracic limbs showed syndactylism too. When only one pelvic limb was affected, it was either the right or the left, and in the only case with one syndactylous thoracic limb, it was the right. The control limbs of the animal 29B and of the 202 day fetus showed no external signs of syndactylism (Table 2).

Osteology

The normal thoracic limb presented, in its distal part, the following osteological characteristics. There were six carpal bones. In the proximal row from medial to lateral were the radial carpal, intermediate carpal, ulnar carpal, and accessory carpal bones. In the distal row there was the fused second and third carpal bone medially and the fourth carpal bone laterally.

The functional or large metacarpal bone consisted of the fused third and fourth metacarpals. The early anlage of two separate bones was indicated by an incomplete sagittal bony partition of the medullary cavity, a shallow dorsal vascular groove, a perforating canal to the volar surface at each end of the groove, and by a deep sagittal notch which separated the two distal trochleae. Each trochlea was divided by a sagittal ridge into a smaller axial and a wider abaxial part. A rudimentary fifth metacarpal bone, 3-5 cm. long, articulated with the lateral proximal extremity of the large metacarpal bone. The functional third and fourth digits articulated with the corresponding metacarpal trochleae and each one presented a first, second, and third phalanx, which were unilaterally symmetrical. Four proximal sesamoid bones - two for each digit - were at the volar surface of the metacarpo-phalangeal joint. The two axial ones were slightly larger than the abaxial ones. Each digit had one distal sesamoid bone which articulated with the volar surface of the distal interphalangeal joint.

Various degrees of fusion were observed on the thoracic syndactylous limbs (Tables 3 and 4, Plates III, IV, and V). The most proximal deviations occurred at the carpus. In most cases the intermediate and ulnar carpal bones were fused to a greater or lesser extent. The fusion was complete on the volar side. In three cases the radial, intermediate, and ulnar carpal bones formed one single bone. In one case the radial and intermediate carpal bones were fused, and in one case all six carpal bones remained separate. The distal extremity of the large metacarpal bone indicated stages of the fusion-process. The slightest sign was a very narrow intertrochlear notch. In the next stage the notch was absent, but there were still two trochleae, separated by a shallow sagittal groove. A further advanced degree was expressed by one continuous trochlea with two sagittal ridges. The highest degree was one trochlea with one ridge. The distal perforating canal and the vascular groove were as a rule present in cases with two distinguishable trochleae and disappeared in stages of completer fusion. On highly fused metacarpal bones of older specimens a vascular groove was sometimes observed which crossed from the medial proximal volar side of the bone to about the dorsal midline descending distally for a shorter or longer distance. In most cases of bilateral syndactylism, the right metacarpal bones were slightly shorter than the left, a few had the same length, and in one the left was shorter.

The small metacarpal bones presented many variations with occasionally bizarre shapes. In cases of little general fusion only the fifth metacarpal was present. In more advanced stages a second metacarpal appeared on the medial proximal side of the large metacarpal bone and was often partially fused with the latter. The higher the degree of fusion the better developed were the small metacarpals. The same general rule applied also to the phalanges of the rudimentary digits number two and five. In a few cases true joints were observed between rudimentary phalanges, or small metacarpals and the corresponding first phalanges. Sometimes a small metacarpal bone consisted of a proximal and a distal part which were connected by dense fibrous connective tissue.

The number of proximal sesamoid bones was another indicator for the stage of fusion. In a slight fusion all four were present. Three indicated a medium degree of fusion, and two were found in the most advanced cases. In the stages with three the two original axial sesamoids showed various individual pictures of fusion.

On the phalanges the articular surfaces also presented various degrees of union. Two volar foramina for the terminal part of the volar digital vessels were regularly observed on fused third phalanges. Some other findings were recorded in Table 4.

The normal left thoracic limb of 83B, and the thoracic limbs of the control specimens showed no osteological abnormalities.

Proceeding from the hock joint distally, the normal pelvic limb showed the following osteological characteristics. There were five tarsal bones; the tibial tarsal, the fibular tarsal, the first tarsal, the fused second and third tarsal, and the fused central and fourth tarsal bone. The large metatarsal bone was similar to the large metacarpal bone, but relatively longer and almost square in cross section. The dorsal vascular groove was deeper and the proximal perforating canal was narrow or absent. A small, inconstant, metatarsal bone number two was on the medial side of the proximal extremity of the large metatarsal. The first and second phalanges were slightly shorter than on the thoracic limb, otherwise the digits were similar to the thoracic limb.

Syndactylous pelvic limbs generally showed a lesser degree of fusion than the syndactylous thoracic limbs of the same individual. The most proximal osteological deviations occurred at the tarsal bones, where various fusions were observed. All large metatarsals still presented two distal trochleae and the distal perforating canal was always present. Differences in length between the right and left metatarsal of the same individual were noticed. The small metatarsal bones and their phalanges showed no increase in size as compared to the normal. The number of proximal sesamoids was never less than three. The phalanges showed correspondingly less advanced degrees of fusion.

Externally normal pelvic limbs of syndactylous animals showed little or no osteological abnormalities. Deviations observed were fusion of the first tarsal bone to the large metatarsal bone and partial fusion of the lateral or medial or both pairs of the proximal sesamoid bones. The pelvic limbs of the control specimens were osteologically normal.

Tendons and Ligaments

The normal thoracic limb had three digital extensor muscles. The tendons of the common digital extensor muscle and the medial digital extensor muscle passed dorsolaterally over the carpus. The common digital extensor tendon divided at the distal end of the metacarpus into one branch for each of the two functional digits. Each branch, surrounded by a dorsal digital synovial sheath, was inserted on the extensor process of the corresponding third phalanx. The medial digital extensor tendon ran medial and close to the common digital extensor tendon to insert mainly on the dorsomedial surface of the second phalanx of the medial digit. The lateral digital extensor tendon passed laterally over the carpus and inserted on the dorsolateral surface of the second phalanx of the lateral digit.

The two digital flexor muscles occupied the volar aspect of the limb. The superficial digital flexor muscle continued as a superficial tendon which passed over the volar carpal annular ligament, and as a deep tendon which passed under the same ligament. The deep tendon received some muscular bands from the deep digital flexor tendon and united with the superficial tendon in the middle of the metacarpus. The united superficial digital flexor tendon soon divided into a tendon for each functional digit. Each tendon, together with a band from the superficial part of the suspensory ligament, formed a tube in the fetlock region through which passed the corresponding tendon of the deep digital flexor muscle. The insertion of the superficial digital flexor tendons was on the volar surface of the corresponding second phalanx.

The common tendon of the deep digital flexor muscle passed through the carpal canal and descended on the metacarpus, where it was located deep to the superficial digital flexor tendon and superficial to the suspensory ligament. At the distal end of the metacarpus it divided into one tendon for each of the two functional digits which passed through the above mentioned tube and over the distal sesamoid bone to insert on the volar border of the third phalanx. The deep volar digital fascia formed on each digit three annular ligaments which kept the flexor tendons in their position.

The suspensory ligament was fibro-muscular in structure and originated as a flat band from the deep volar carpal ligament. At the middle of the metacarpus it detached the above mentioned fibrous superficial part. The more muscular remainder of the suspensory ligament divided at the distal third of the metacarpus into three parts: a medial abaxial band, a lateral abaxial band, and a strong central part. The latter part subsequently divided into a medial axial band, a lateral axial band, and a middle branch. The final result of the divisions was five branches. About one-half of each abaxial band attached to the abaxial proximal sesamoid bones, the remainder continued dorsad to connect to the corresponding proper digital extensor tendons. The middle branch passed through the intertrochlear notch of the metacarpal bone, proceeded dorsad and bifurcated to attach to each proper digital extensor tendon.

The intersesamoidean ligament tied the four proximal sesamoids into a unit. The lateral and medial sesamoidean ligaments connected the abaxial surface of the abaxial sesamoids to the metacarpal bone and the first phalanges. The distal sesamoidean ligaments which attached the sesamoids to the first phalanges included the cruciate ligaments, the middle, and the deep ligaments.

Several ligaments attached the distal sesamoid bones firmly to the second and third phalanges.

The reinforced metacarpal and digital fascia fastened the dewclaws in their position by a dewclaw plate, which connected the two dewclaws, and by a proximal and a distal ligament for each dewclaw.

The interphalangeal and metacarpo-phalangeal joints had the usual collateral ligaments.

A proximal and a distal interdigital ligament limited the spreading of the two functional digits.

The tendons and ligaments of syndactylous thoracic limbs were arranged as follows. The three definitely separated digital extensor tendons passed normally over the carpus and descended on the metacarpus. At the level of the fetlock the tendons became flatter and wider and fused to form a broad common aponeurotic plate which inserted mainly on the extensor surface of the second and of the third phalanx. A dorsal digital synovial sheath was absent. On both thoracic limbs of specimen 12B the lateral digital extensor tendon detached a small branch to the lateral dewclaw. On the right thoracic limb of specimen 078A this branch was paired.

The superficial digital flexor tendon was normal to about the middle of the metacarpus. Here it gave off, in many cases, one (seldom two) thin, 3-10 cm. long tendon which inserted on the base of the lateral dewclaw (Table 5). In one case the small thin tendon was reconnected to the chief tendon by two 1 cm. wide flat muscular bands. The chief tendon of the superficial digital flexor muscle remained undivided, received the superficial digital flexor muscle to form a tube around the single deep digital flexor tendon, and inserted on the volar surface of the second phalanx. Sometimes one or two fibrous bands attached the tubular part of the superficial digital flexor tendon to the intersesamoidean or distal sesamoidean ligaments.

The deep digital flexor tendon remained undivided, but had an otherwise normal course. In two cases (specimens 078A IF and 12B IF) a thin branch to the base of the lateral dewclaw was detached. The deep digital fascia formed three single annular ligaments for the digital flexor tendons.

The suspensory ligament consisted of a superficial fibrous part and a deep part which was muscular in young specimens. The superficial part was sometimes a flat wide band. In other cases there were two bands, or only one band on either the lateral or medial side. In many cases the superficial part of the suspensory ligament not only aided in the formation of a tube for the deep digital flexor tendon, but also detached a considerable portion to the superficial proximal border of the proximal sesamoid bones. The deep part of the suspensory ligament did not always show a clear division into branches. As a general rule, however, the number of branches corresponded to the number of proximal sesamoid bones. There was on each side a rather thin and wide connection to the aponeurotic terminal part of the digital extensor tendons. In three cases the lateral branch of the deep suspensory ligament detached a band to one of the rudimentary bones of the lateral dewclaw. The intersesamoidean and the medial and lateral sesamoidean ligaments were normal. The middle distal sesamoidean ligaments were well developed and converged slightly distally. Between them there were sparse fibers of indistinct direction which represented the deep distal sesamoidean ligaments. The collateral ligaments of the metacarpo-phalangeal and the phalangeal joints, and the ligaments of the distal sesamoid bone were normally developed for the single functional digit. The ligaments of the two dewclaws showed no deviation from the normal pattern. There was no place for interdigital ligaments on a single toe.

Specimen 83B LF was the only apparently normal limb of a syndactylous animal. On this limb the superficial digital flexor tendon detached a branch to the base of the lateral dewclaw, and the lateral abaxial branch of the suspensory ligament was connected by a small tendon to the first phalanx of the rudimentary fifth digit.

Distal to the tarsus the arrangement of the tendons and ligaments of the normal pelvic limb was very similar to that of the thoracic limb. The deep digital flexor muscle had three heads. The tendons of the large flexor hallucis longus muscle and of the small tibialis posterior muscle were joined below the tarsus by the tendon of the third head of the muscle.

On syndactylous pelvic limbs the arrangement of the extensor tendons corresponded to the description given for thoracic syndactylous limbs. Since the degree of fusion was less advanced on pelvic limbs the structure of the flexor tendons and suspensory ligaments was closer to normal (Table 5). The deep digital flexor tendon of the unlabeled right pelvic limb bifurcated above the fetlock. Eight centimeters further distally the two branches fused again into one (Plate VIII). The rest of the ligaments corresponded to those of thoracic syndactylous limbs. Examination of the tibialis posterior muscle was possible only on the unlabeled right pelvic limb, where it was present.

Apparently normal pelvic limbs of syndactylous animals showed some slight abnormalities. The tibialis posterior muscle and its tendon were absent on both limbs of the specimens 1, 3, 19B, and 83B, and on the right side of number 2. Not all limbs permitted study in this regard, since some had been dismembered too far distally. The deep digital flexor tendon of specimen 078A RR detached on the medial side a branch to the dewclaw plate. Both pelvic limbs of specimen 83B showed the pectineus muscle extending further distally than normal. The medial digital extensor tendon of specimen number 2 LR consisted of initially two parts which fused below the tarsus.

The Blood Supply

The arteries which supplied the distal part of the normal thoracic limb were arranged in a dorsal and a volar group (Plates IX and X). On the dorsal side the small dorsal metacarpal artery arose from the rete carpi dorsale and descended in the vascular groove of the metacarpal bone. Two anastomoses connected the dorsal metacarpal artery with the volar side. The proximal perforating metacarpal artery and the distal perforating metacarpal artery passed through the corresponding canals of the metacarpal bone and joined the subcarpal and distal volar arch respectively. At the fetlock the dorsal metacarpal artery continued as the dorsal common digital artery which divided into the two proper dorsal digital arteries and anastomosed as the perforating interdigital artery through the interdigital space with the volar common digital artery.

On the volar side of the forearm the median artery terminated by dividing into the larger ulnar artery and the radial artery. The ulnar artery passed through the carpal canal on the medial side of the digital flexor tendons and descended as the volar common digital artery in the same relation to the tendons to about the middle of the metacarpus, where it inclined backward to the superficial surface of the tendons. At the distal third of the metacarpus the volar common digital artery was connected to the medial deep volar metacarpal artery and formed thus part of the distal volar arch. The volar common digital artery detached the two axial arteries of the dewclaws, subsequently divided in the interdigital space into the two axial volar digital arteries, and anastomosed with the dorsal common digital artery as mentioned. The radial artery descended subcutaneously over the mediovolar surface of the carpus and continued on the medial side of the digital flexor tendons as the medial deep volar metacarpal artery. It had connections with the rete carpi volare, the subcarpal arch, and the deep part of the distal volar arch and continued as the medial volar proper digital artery which supplied an abaxial branch to the medial dewclaw. An inconstant middle and a lateral deep volar metacarpal artery connected the proximal with the distal volar arch, and from the latter arch arose the lateral volar proper digital artery.

The veins were as a rule satellites of the arteries. The dorsal metacarpal vein was, however, subcutaneous and the medial volar metacarpal vein, a satellite of the radial artery, was the largest vein in the metacarpal area.

On the syndactylous thoracic limbs the same parent arteries participated in the supply of the distal part of the limb (Plate IX and X). Dorsally there was a tiny dorsal metacarpal artery which ended at the end of the metacarpus in all specimens studied. A distal perforating metacarpal artery was observed only in those limbs showing little digital fusion. In many cases where the distal perforating metacarpal artery was absent the dorsal metacarpal artery arose from the medial deep volar metacarpal artery at the proximal extremity of the metacarpus. A vascular groove on the metacarpal bone indicated in older specimens the course of this vessel. The distal perforating metacarpal artery was sometimes replaced by an anastomosis which turned around the lateral or medial distal border of the metacarpal bone to reach the distal volar arch.

The median artery terminated normally by dividing into the ulnar and the radial artery. In about half of the cases these two vessels fused again at the distal third of the metacarpus, shortly before entering into the formation of the distal volar arch. This common trunk divided after a short course into the medial volar digital artery and the lateral volar digital artery, and a third branch which turned deep under the suspensory ligament to form part of the distal volar arch. The lateral volar digital artery crossed over the superficial surface of the superficial digital flexor tendon to reach the laterovolar surface of the digit. The medial volar digital artery descended on the mediovolar side of the digit. Arising either from the medial or lateral volar digital artery, or from both was a small superficial axial vessel which ran downward between the dewclaws. The always present superficial lateral volar metacarpal artery joined the lateral volar digital artery at the level of the upper border of the lateral dewclaw. The two volar digital arteries descended on each side of the flexor tendons. As they passed under the base of the dewclaws each supplied the corresponding dewclaw with usually two branches. Slightly above the pastern joint there was a volar anastomosis between the two digital arteries. A second volar anastomosis occurred at the distal extremity of the second phalanx. Both connections were deep to the flexor tendons. Other branches of the two volar digital arteries were one artery to the bulb of the hoof and one proximal and one distal dorsal branch which took over the supply of the dorsal area of the digit, since the dorsal metacarpal artery ended at the fetlock. The two volar digital arteries terminated by entering the lateral and medial volar foramen of the third phalanx where they formed an anastomosing arch.

In those cases where the radial and ulnar artery remained separate, the ulnar artery divided into the two volar digital arteries, and the radial artery joined the medial volar digital artery a short distance below that bifurcation.

In one case the radial artery alone formed the medial volar digital artery, and the ulnar artery continued only as the lateral volar digital artery. Both parent arteries were, however, connected deeply to the distal volar arch.

Shortly before terminating, the radial artery was connected to the distal volar arch. The latter showed many individual variations which also occur on normal limbs. Arising from its deep part, which was located between the volar surface of the metacarpal bone and the suspensory ligament, there was an irregular middle deep volar metacarpal artery, and in some instances a distal perforating metacarpal branch.

The veins showed, as expected, even more variations in their smaller branches. The subcutaneous dorsal metacarpal vein originated from two to three radicles on the dorsal surface of the digit. The largest radicle was lateral and regularly had a branch which passed under the dorsal ligament of the dewclaw to anastomose with the distal volar venous arch. The lateral volar digital vein ran, in its proximal part, parallel but at a considerable distance dorsal to the lateral volar digital artery. The vein passed lateral to the base of the lateral dewclaw to reach the distal volar venous arch. The medial volar digital vein followed the course of the corresponding artery. Both digital veins had the same dorsal branches and volar anastomoses as the digital arteries. The medial volar metacarpal vein was the largest vein in the metacarpal area. In the distal two-thirds of the metacarpus the vein was located at some distance from the corresponding radial artery between the postero-lateral border of the metacarpal bone and the suspensory ligament. Further proximal the vein was closely associated with the radial artery. The lateral volar metacarpal vein was located under the suspensory ligament. The great metacarpal vein, the satellite of the ulnar artery, was rather small.

The left thoracic limb of specimen 83B showed no deviations in the vascular pattern.

The vascularisation of the distal part of the normal pelvic limb was as follows. Dorsally the anterior tibial artery continued as the well developed dorsal metatarsal artery. The latter descended in the deep vascular groove of the metatarsal bone and anastomosed by the perforating tarsal artery with the proximal plantar arch, and by the perforating metatarsal artery with the distal plantar arch. The dorsal metatarsal artery continued at the fetlock as the dorsal common digital artery which corresponded to the same vessel on the thoracic limb.

On the plantar side the medial tarsal artery divided above the tarsus into the larger medial plantar artery which continued as the superficial medial plantar metatarsal artery, and into the lateral plantar artery which continued as the superficial lateral plantar metatarsal artery. Both of these arteries communicated with the proximal and distal plantar arch and had the same relation to the fascia and flexor tendons as the corresponding metacarpal arteries. The deep plantar metatarsal artery was located on the plantar surface of the metatarsal bone, and connected the proximal with the distal plantar arch. Arising from the distal plantar arch were the lateral abaxial digital artery, the medial abaxial digital artery, and the plantar common digital artery all of which showed a similar arrangement as described for the thoracic limb.

The course of the veins below the tarsus was similar to that of the arteries. The dorsal metatarsal vein and the lateral tarsal vein united above the tarsus to form the recurrent tarsal vein, and the medial plantar vein continued above the tarsus as the saphenous vein.

On the syndactylous pelvic limb the dorsal metatarsal artery was well developed. The large perforating metatarsal artery was connected to the distal plantar arch. A single tiny branch, which corresponded to the dorsal common digital artery, continued the dorsal metatarsal artery to the level of the fetlock. The rest of the dorsal surface of the digit was supplied by branches of the plantar digital arteries. The arteries on the plantar surface of the metatarsus followed the normal pattern. A lateral plantar digital artery, a medial plantar digital artery, and a small axial artery arose from the distal plantar arch. In the proximal half of the first phalanx the two plantar digital arteries had a plantar anastomosis on which the above mentioned axial artery ended. At the same level each digital artery gave off a dorsal branch. Each dewclaw was supplied by a branch off the corresponding digital artery. Another anastomosis between the digital arteries occurred at the distal half of the second phalanx. At the same level another pair of dorsal branches anastomosed dorsally. As on the thoracic syndactylous limb, the two digital arteries terminated by entering the plantar foramina of the third phalanx.

The dorsal metatarsal vein ran in its initial part parallel and close to the lateral plantar digital vein. The former vein anastomosed laterally with the distal plantar venous arch and joined the saphenous vein instead of the recurrent tarsal vein. The rest of the veins followed the syndactylous arterial pattern.

The vascular system of apparently normal pelvic limbs of syndactylous animals showed a few deviations. In three cases (specimens 83B LR and RR, and 1 RR) the dorsal metatarsal vein joined the saphenous vein instead of the recurrent tarsal vein. On both pelvic limbs of specimen 078A the superficial medial plantar metatarsal artery divided into two branches which united again at the distal end of the metatarsus.

The Nerve Supply

Three nerves of the brachial plexus supplied branches to the distal part of the normal thoracic limb (Plates XIII and XIV). The cutaneous branch of the radial nerve descended on the dorsal aspect of the metacarpus as the dorsal metacarpal nerve which divided into the medial dorsal abaxial, and the medial and lateral dorsal axial digital nerves. The ulnar nerve divided in the volar area of the forearm into a superficial branch (superficial lateral volar metacarpal nerve) which became the lateral abaxial dorsal digital nerve, and into a deep branch (deep lateral volar metacarpal nerve) which formed the lateral abaxial volar digital nerve, together with a branch of the median nerve. The median nerve descended on the mediovolar side of the metacarpus as the medial volar metacarpal nerve which divided into the three remaining volar digital nerves. The axial volar digital nerves and the branch to the lateral abaxial volar digital nerve crossed over the superficial digital flexor tendon. The volar axial digital nerves sent a reinforcing branch to the dorsal axial digital nerves through the interdigital cleft.

The innervation of the syndactylous thoracic limbs was as follows (Plates XIII and XIV). The cutaneous branch of the radial nerve descended as the dorsal metacarpal nerve to the distal part of the metacarpus and was located medial to the digital extensor tendons. In the distal third of the metacarpus the nerve divided into three to four branches which did not reach the distal end of the digit. The major of these branches turned medially and ended on the abaxial side of the medial dewclaw. There the branch lay close to the medial volar abaxial digital nerve to which it possibly supplied a few fibers. An axial branch ramified over the extensor tendons in the fetlock, and a smaller lateral branch was traced to the abaxial aspect of the lateral dewclaw.

The ulnar nerve divided in the distal volar part of the forearm as usual into a superficial and a deep branch. The delicate superficial branch emerged above the accessory carpal bone between the insertions of the flexor carpi ulnaris muscle and ulnaris lateralis muscle, descended subcutaneously on the laterovolar side of the metacarpus, and could be traced to the lateral border of the lateral dewclaw. It was located lateral to the rudimentary phalanges of the fifth digit. The deep branch descended as the deep lateral volar metacarpal nerve on the metacarpus. It was covered by the metacarpal fascia and ran medial to, when present, phalanges of the fifth digit. The deep branch ended at the base of the lateral dewclaw, where a few of its fibers seemed to join the lateral volar digital nerve.

The median nerve was the main supply to the digit. It descended as the large medial volar metacarpal nerve to about the middle of the metacarpus. It was covered by the metacarpal fascia. The nerve then divided into two equal branches. The medial branch continued to run distad along the abaxial border of the medial dewclaw as the medial volar digital nerve to innervate the medio-volar side of the digit. Just above the coronary border of the hoof one branch was given off at right angles which proceeded dorsad, and another branch was found to supply the digital cushion. The lateral branch of the medial volar metacarpal nerve crossed over the superficial digital flexor tendon to become the lateral volar digital nerve. It proceeded distad under the base of the lateral dewclaw, covered here by the, when present, small tendon from the superficial digital flexor to the base of the lateral dewclaw, and running under the phalanges of the rudimentary fifth digit. Its further course and branches corresponded to that of the medial volar digital nerve. As the lateral volar digital nerve crossed over the flexor tendons it detached a tiny branch which descended in the midline between the dewclaws to terminate at the level of their distal border.

The peroneal nerve furnished the four dorsal digital nerves of the normal pelvic limb, and the tibial nerve supplied the four plantar digital nerves (Plates XV and XVI). Descending on the dorsal surface of the leg were the superficial and the deep peroneal nerves. The former continued on the metatarsus as the superficial dorsal metatarsal nerve, and the latter continued as the deep dorsal metatarsal nerve and was located in the vascular groove of the metatarsal bone. In about the middle of the metatarsus the superficial dorsal metatarsal nerve gave off the lateral and the medial dorsal abaxial digital nerves and continued as the parent trunk to the distal end of the metatarsus, where it divided into the two dorsal axial digital nerves and communicated with the deep dorsal metatarsal nerve. The latter anastomosed through the interdigital space with the plantar axial digital nerves.

The tibial nerve divided above the tarsus into the larger medial plantar nerve and the lateral plantar nerve. The latter nerve descended on the lateral side of the deep digital flexor tendon, was covered by the metatarsal fascia, and continued as the lateral plantar abaxial digital nerve. The medial plantar nerve ran distad on the medial side of the deep digital flexor tendon and gave off above the fetlock a medial branch which crossed over the superficial digital flexor tendon to reach the interdigital space where it divided into the two plantar axial digital nerves. The continuation of the medial plantar nerve became the medial plantar abaxial digital nerve.

Unlabeled specimen RR was the only syndactylous pelvic limb available for a detailed dissection and showed the following innervation (Plates XV and XVI). Dorsally a superficial and two deep dorsal metatarsal nerves descended normally. The superficial dorsal metatarsal nerve divided at the middle of the metatarsus into a medial and a lateral branch. Both branches could be traced to the level of the fetlock. The lateral branch detached a middle branch which anastomosed at the level of the fetlock joint with the medial deep dorsal metatarsal nerve. The medial and the lateral deep dorsal metatarsal nerves ran parallel and close to each other in the vascular groove of the large metatarsal bone. The medial branch emerged through a split in the tendon of the long digital extensor muscle to reinforce the middle branch of the superficial dorsal metatarsal nerve which was traced a little further distally. The lateral deep dorsal metatarsal nerve descended close to the midline of the digit and was traced to the proximal part of the third phalanx. The lateral and the medial plantar nerve continued as the corresponding plantar digital nerves. In the distal third of the metatarsus the medial plantar nerve detached a branch which crossed over the superficial digital flexor tendon to the midline of the limb, where it divided into a deep branch which was lost between the sesamoids, and into a superficial branch which was traced descending in the axis of the digit to the middle of the second phalanx.

DISCUSSION

The findings concerning the normal anatomy of the bovine limbs agreed with the descriptions of other authors. A lack of a world or even nation-wide uniform nomenclature was noticed in the pertinent literature.

Detailed anatomical reports covering other than the osteology of bovine syndactylism were scarce. Only Steiner (23) and Eldridge, Smith and McLeod (4) mentioned different external stages of fusion. According to the external classification of Steiner (23) a first group showed an axial dorsal cleft in the hoof and two dewclaws of equal size. The next degree was characterized by a completely fused hoof and an enlarged lateral dewclaw. In the highest degree the hoof was completely fused and the two dewclaws were of equal size. In the only dissected case of Eldridge, Smith and McLeod (4) the lateral dewclaw was larger. Shibata and Ishihara (18), Bonfanti (1), and Krölling (13) reported the presence of two dewclaws which were presumably normal and of equal size. The cases observed in this study did not allow a classification as suggested by Steiner (23), since a case with a split hoof also showed a larger lateral dewclaw. The development of the lateral dewclaw appeared to be independent of the degree of fusion on the hoof. Only the shape of the hoof allowed an external classification into partial or total syndactylism. No case in this study showed a divided dewclaw as Steiner (23) reported in two of his specimens.

The phenomenon of a larger lateral dewclaw was found in this study not to be limited to syndactylous limbs only, but was observed also on many normal pelvic limbs of syndactylous individuals. Eldridge, Smith, and McLeod (4) observed, like this author, a pronounced dorsal axial groove from the fetlock to the interdigital cleft occurring on many normal pelvic limbs of syndactylous animals.

The shape of the syndactylous hooves used in this study corresponded to the descriptions of Steiner (23) and Eldridge, Smith and McLeod (4). The small ground surface of syndactylous hooves appeared to be inadequate for weight support. In fact, all authors emphasized the weakness and poor ability to walk of the affected animals. The skin abrasions at the carpus and fetlock confirmed this fact. Their presence indicated that the animals must have been lying on the ground for long periods of time and that they possibly walked on the carpus before standing up completely. Such decubiti were also described by Steiner (23) and Krölling (13).

The fifteen syndactylous individuals examined in this study showed fifteen right thoracic, fourteen left thoracic, and four pelvic limbs affected. These findings confirmed the observations of Steiner (23) who found eleven right thoracic, eight left thoracic, and three pelvic limbs affected, and of Singh and Bhattacharya (21) whose eleven individuals had eleven right thoracic, ten left thoracic, and no pelvic limbs malformed. This preference of the thoracic limbs to be affected with syndactylism was found to continue through the reports of single cases. Bonfanti (1) and Kale (11) each described one case of bilateral thoracic syndactylism. Sterba (24) had one case of a right thoracic syndactylous limb. Krölling (13) reported two cases with both thoracic and the right pelvic limbs affected, and Eldridge, Smith, and McLeod (4) had two cases of bilateral thoracic syndactylism. Motohashi's (15) twenty-six cases had fourteen specimens with both thoracic and six specimens with all four limbs affected. The present study confirmed furthermore, that pelvic limbs alone never showed syndactylism unless both thoracic limbs of the individual concerned were single-toed.

Steiner (23) found that in cases of bilateral thoracic syndactylism the right often showed a higher degree of fusion than the left. An osteological check in this regard confirmed Steiner's (23) observation. Eleven out of fourteen individuals with bilateral thoracic syndactylism showed a higher degree of fusion on the right side. The other three animals had the same degree of fusion on both thoracic limbs. The higher stage of union was expressed by a shorter metacarpus, by the absence of the distal perforating metacarpal canal, by the structure of the distal metacarpal trochlea, by a lesser number of proximal sesamoid bones, and by the structure of the phalanges. The small number of pelvic syndactylous limbs did not reveal a preference for a more advanced fusion of one side. The pelvic syndactylous limbs had only slight to medium stages of fusion. All thoracic limbs of the three individuals with pelvic syndactylism showed higher stages of fusion than the pelvic, which was in agreement with the findings of Steiner (23). As in Steiner's (23) study, it was observed in this study that the fusion of the hoof often was more advanced than that of the underlying structures. Steiner's (23) remark that the second phalanges fused first, and were followed by the third and first, was confirmed in this study. In the thirty-three syndactylous digits the second phalanges were fused completely in thirty cases, two had two separate proximal and distal articular surfaces, and in one case the second phalanges remained separate. The third phalanges were completely fused in twenty-seven cases, partially fused in four cases, and separate in two cases. The first phalanges were completely fused in sixteen, partially fused in fourteen, and separate in three cases. The shape of the metacarpal bones and phalanges of syndactylous animals corresponded to the descriptions in the literature.

The fusion of the intermediate and ulnar carpal bones, as reported in the single dissected case of Eldridge, Smith, and McLeod (4), proved to be not accidental. Almost all cases of thoracic syndactylism in this study showed fusion of two or more carpal bones. Explaining this fact as a response to the unnatural stress exerted on the syndactylous limbs in standing and walking, that is a postnatally developed synostosis, was unsatisfactory. Fusion of carpal bones was also observed in very young individuals and was therefore considered to be the most proximal osteological deviation encountered in syndactylism of thoracic limbs. The small number of pelvic syndactylous limbs were not informative enough to explain the observed fusions of tarsal bones in a similar manner. Hints in this regard were absent in the literature.

The fusion of lateral or medial pairs of sesamoid bones on normal pelvic limbs of syndactylous animals was observed only in the specimens over twenty-four months of age. In the young specimens the proximal sesamoids were usually represented by about pea-sized ossification centers surrounded by a large amount of cartilage. It was, therefore, impossible to tell at an early age whether these sesamoids would really remain separate or not, and to classify these fusions as either hereditary or acquired postnatally. Fusion of the first tarsal to the large metatarsal bone was observed in one young and one old specimen which were a very small percentage of the total cases. No reports in these two regards were found in the literature.

The observations on the tendons and ligaments made in this study were generally in agreement with Steiner's (23) report. Eldridge, Smith and McLeod (4) differentiated the insertions of the tendons of the three digital extensor muscles, and described the reinforcing slips from the suspensory ligament as not joining the extensor tendons but ending blindly in the fascia. In this study the thin aponeurotic plate formed by all three digital extensor tendons and the reinforcement by a lateral and a medial wide slip from the suspensory ligament was observed clearly in each case. Sterba (24) showed in a diagrammatic illustration, a division of the common digital extensor tendon which inserted on the two extensor processes of the partially fused third phalanx. No other author mentioned the small branch from the lateral digital extensor tendon to the lateral dewclaw which was observed in this study in three cases.

Eldridge, Smith, and McLeod (4) reported that the superficial digital flexor tendon inserted on the first phalanx instead of, as normally, on the second phalanx. The present study confirmed Steniner's (23) findings of an insertion on the second phalanx. An additional feature, which no other author reported, was the often present branch from the superficial digital flexor tendon to the lateral dewclaw. This branch underlined, so to speak, the better development of the fifth digit.

Both Steiner (23) and Eldridge, Smith, and McLeod (4) found an undivided tendon of the deep digital flexor muscle. None of their cases showed the peculiar bifurcation and reunion observed in this study on the unlabeled right pelvic limb. Branches from the deep digital flexor tendon to the lateral dewclaw were not reported by other investigators. The attachment of the superficial part of the suspensory ligament to the proximal sesamoid bones was also noted by Steiner (23), not however, by Eldridge, Smith, and McLeod (4). Deviations in the tendons of apparently normal limbs of syndactylous specimens were not reported in the literature.

The basic vascular pattern of syndactylous thoracic limbs found in this study was in agreement with Steiner (23). Eldridge, Smith, and McLeod (4) stated that the medial and lateral deep volar metacarpal arteries ended blindly in the distal metacarpal fascia. It could be assumed that the latter authors did not inject the arteries with latex and were, therefore, unable to trace these tiny branches to the distal volar arch. The vascular injection method used in this study allowed the examination of the arterial supply in more detail, as illustrated on the Plates IX and X. The nerve supply of thoracic syndactylous limbs was found to be similar to the description by Steiner (23), and Eldridge, Smith, and McLeod (4).

Only the external and osteological appearance of syndactylous pelvic limbs was described in the pertinent literature. In this study only one syndactylous pelvic limb was available for a detailed study of the soft structures. This was considered to furnish sufficient information to establish the basic pattern. Concluding from the observations on the thoracic syndactylous limbs it was assumed, however, that pelvic syndactylous limbs also would present some individual variations in the arrangement of the soft structures.

The detailed study of apparently unaffected limbs of syndactylous animals was unfortunately not possible in all cases. The deviations observed in almost all cases examined were interpreted not to be merely accidental, but rather the result of the same hereditary principle acting, however, in a very weakened and unconspicuous manner.

SUMMARY

The gross anatomical structures of sixty-four bovine limbs procured from fifteen syndactylous individuals and two individuals with syndactylous parentage were studied and compared to the normal anatomy. Of the fifteen individuals with total or partial syndactylism, one case had only the right thoracic limb affected, eleven cases had both thoracic limbs affected, and one case of each showing syndactylism on both thoracic and the left pelvic limb, both thoracic

and the right pelvic limb, and on all four limbs.

The external signs of syndactylism were one single functional digit with a single hoof. An enlarged lateral dewclaw was observed in many cases. Incomplete degrees of fusion were characterized by a dorsal median cleft of various depth and length in the hoof. Skin abrasions dorsally at the carpus and fetlock indicated the poor walking ability of the animals. Deformities of the syndactylous hooves, often present in older specimens, underlined this impairment.

The most proximal deviation in the osteology of syndactylous limbs was found at the carpus where the intermediate and ulnar carpal bones were fused in the majority of the cases. The distal extremities of the metacarpal bones presented a distinct series of degrees of fusion. First, the intertrochlear notch became narrow, next the intertrochlear notch disappeared and one trochlea with two sagittal ridges was observed, then the two sagittal ridges were placed closely, and finally, in the highest degree of fusion, there was only one sagittal ridge on the metacarpal trochlea. The distal perforating metacarpal canal disappeared in higher stages of union. Most of the right metacarpal bones were shorter than the corresponding left. The number of proximal sesamoid bones varied from four to two. On the phalanges various degrees of fusion were best seen on the structure of their articular surfaces. The fusion of the two functional digits was accompanied by a better development of the normally rudimentary fifth and second metacarpal bones and the corresponding phalanges. In a survey over the phalanges of the functional syndactylous digit, the second phalanges were found to present the most advanced fusions, followed consecutively by the third and first phalanges. On eleven individuals with bilateral thoracic syndactylism, the degree of fusion was higher on the right limb than on the corresponding left. The pelvic syndactylous limbs showed less advanced stages of fusion as compared to the thoracic limbs. The most proximal fusions on pelvic limbs occurred between individual tarsal bones. Further distally, the pattern of osteological union was similar to the thoracic syndactylous limb. The distal perforating metatarsal canal was always present, and the number of proximal sesamoid bones was never less than three.

The tendons and ligaments of syndactylous limbs were adapted to the single digit. The tendons of the three ditial extensor muscles fused at the fetlock into a wide aponeurotic plate which received on each side a reinforcing branch from the deep suspensory ligament and inserted on the second and third phalanx. The tendons of the superficial and deep digital flexor muscles remained, as a rule, undivided and showed a normal insertion on the one functional digit. A small branch from the tendon of the superficial digital flexor muscle to the lateral dewclaw was often observed. In rarer cases, a branch from the tendon of the lateral digital extensor muscle or of the deep digital flexor muscle was detached to the lateral dewclaw. The superficial part of the suspensory ligament, besides joining the tubular portion of the tendon of the superficial digital flexor muscle, attached by a wide band to the proximal sesamoid bones. The number of branches of the deep suspensory ligament was reduced. In a few cases fibrous bands attached the tubular portion of the tendon of the superficial digital flexor muscle to the intersesamoidean ligament. Corresponding adaptations were observed on the tendons and ligaments of pelvic syndactylous limbs.

The parent arteries in the metacarpal area of thoracic syndactylous limbs corresponded to the normal. The dorsal metacarpal artery ended at the fetlock, and the distal perforating metacarpal artery was absent in advanced degrees of syndactylism. A lateral and a medial volar digital artery supplied the single digit. These two digital arteries originated either from the reunited trunk of the ulnar and radial artery, or from the ulnar artery. The common volar digital artery was rudimentary and arose from either the medial or the lateral or both volar digital arteries. The volar digital arteries supplied the dewclaws and the dorsal area of the digit with smaller branches. They had two volar anastomoses and terminated in the third phalanx where they formed an anastomosing arch. The veins of thoracic syndactylous limbs generally followed the arterial pattern. The lateral radicle of the dorsal metacarpal vein anastomosed with the distal volar venous arch. The proximal part of the lateral volar digital vein was at considerable distance dorsal to the lateral volar digital artery. The arteries of the pelvic syndactylous limb above the distal plantar arch were normal. Arising from the distal plantar arch were a lateral and a medial plantar digital artery, and a small axial artery. The two plantar digital arteries had the same branches and termination as the corresponding arteries of thoracic syndactylous limbs. The well developed dorsal metatarsal artery continued as a small axial branch to the fetlock. A well developed distal perforating metatarsal artery was present. The veins of pelvic syndactylous limbs followed generally the arterial pattern. The dorsal metatarsal vein joined the saphenous vein instead of the recurrent tarsal vein.

The continuation of the median nerve formed the lateral and the medial volar digital nerve which were the two main digital nerves observed on thoracic syndactylous limbs. The dorsal metacarpal nerve divided into branches which were traced to the abaxial aspects of the two dewclaws. The superficial and the deep branch of the ulnar nerve ended in the area of the lateral dewclaw. The medial volar digital nerve received possibly some fibers from the dorsal metacarpal nerve, and likewise, the lateral volar digital nerve from the deep branch of the ulnar nerve. On the pelvic syndactylous limb the lateral and the medial plantar nerve continued as the corresponding digital nerves which were the main supply of the single digit. The medial plantar nerve detached a small plantar axial digital branch. One superficial and two deep dorsal metatarsal nerves were observed. The lateral and the medial branch of the superficial dorsal metatarsal nerve ended at the level of the fetlock. The medial deep dorsal metatarsal nerve reinforced the middle branch of the superficial dorsal metatarsal nerve. The lateral deep dorsal metatarsal nerve descended in the axis of the digit to the proximal end of the third phalanx.

Grossly normal pelvic limbs of syndactylous animals showed minor deviations of internal anatomical structures. Most frequently observed was fusion of the first tarsal bone to the large metatarsal bone and union of the lateral or medial pair of the proximal sesamoid bones, absence of the tibialis posterior muscle, and the dorsal metatarsal vein joining the saphenous vein. The only normal thoracic limb found among syndactylous individuals had a branch from the deep suspensory ligament to the lateral dewclaw. No deviations were noted on the limbs of the two normal individuals with syndactylous parentage.

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LITERATURE CITED

(1) Bonfanti, C.
Su di un raro ed interessante caso di sindattilia nel vitello. Ateneo Parmense. 14:469-479. 1942.

(2) Chauveau, A.
The comparative anatomy of the domesticated animals. New York: Appleton, 1901.

(3) Eldridge, F. E.
A report on single-toed cattle. Reprint from Holstein-Friesian World, February 19, 1955.

(4) Eldridge, F. E., W. H. Smith, and W. M. McLeod.
Syndactylism in Holstein-Friesian cattle. Jour. Hered. 42(5): 241-250. 1951.

(5) Ellenberger, W.
Leisering's atlas of the anatomy of the horse. Second edition. Chicago: Eger. 1909.

(6) Ellenberger, W., and H. Baum.
Handbuch der vergleichenden Anatomie der Haustiere. Berlin: Springer-Verlag, 1943.

(7) Foust, H. L., and R. Getty.
Atlas and dissection guide for the study of the anatomy of domestic animals. Third edition. Ames: Iowa State College Press, 1954.

(8) Getty, R.
Atlas for applied veterinary anatomy. Minneapolis: Burgess, 1955.

(9) Habel, R. E.
Guide to the dissection of the cow. Ann Arbor: Edwards, 1955.

(10) Joest, E.
Handbuch der speziellen pathologischen Anatomie der Haustiere. Band 5, Berlin: Richard Schoetz, 1929.

(11) Kale, G. C.
Freak of nature. A case of soliped bull. Indian Vet. Jour. 24(5): 350. 1948.

(12) Kitt, Th.
Lehrbuch der pathologischen Anatomie der Haustiere. Stuttgart: Ferdinand Enke, 1921.

(13) Krölling, O.
Beitrag zur morphogenetischen und erbbiologischen Beurteilung der Syndaktylie beim Rind, Wien, Tierärztl, Monatsschr. 3:129-139. 1956.

(14) McLeod, W. M.
Bovine anatomy. Minneapolis: Burgess, 1958.

(15) Motohashi, H.
On twenty-six cases of syndactylous anomaly in the Nipponese improved cattle. Tottori Soc. Agric. Sci. 10:212-236. 1954.

(16) Nickel, R., A. Schummer, and E. Seiferle.
Lehrbuch der Anatomie der Haustiere. Band 1, Berlin: Paul Parey, 1954.

(17) Peterson, D. R.
Laboratory guide to the dissection and study of the anatomy of the domestic ruminants. Stillwater: Oklahoma State University, 1958.

(18) Shibata, S., and M. Ishihara.
Studies on hereditary defects in Japanese native cattle. Zootechn. Exp. Station, Chiba City, Research Bul. 54. 1948.

(19) Shibata, S., and M. Ishihara.
Studies on hereditary defects in Japanese native cattle. Japan. Jour. Zootech. Sci. 19:63-66. 1949.

(20) Singh, S., and R. K. Tandon.
A short note on calves with unbifurcated hooves. Indian Jour. Vet. Sci. and Anim. Husb. 12(1):61. 1942.

(21) Singh, S., and P. Bhattacharya.
Inheritance of syndactylism in Hariana breed of cattle. Indian Jour. Vet. Sci. and Anim. Husb. 19(2):153-159. 1949.

(22) Sisson, S., and J. D. Grossman.
The anatomy of the domestic animals. Philadelphia: Saunders, 1953.

(23) Steiner, A.
Über Syndaktylie beim Rind. Dissertation, Zürich, 1945.

(24) Sterbo, O.
Syndactylism in a pig and a cow. Sbornik Vys. Sk. Zemedelsk. Les. Fak. Brno, Ser. B. 4(25):147-150. 1956.

(25) Vaughan, I.
Strangeways' veterinary anatomy. Chicago: Keener, 1907.

(26) Way, R.
The anatomy of the bovine foot. Philadelphia: University of Pennsylvania Press, 1954.

APPENDIX

Table 1. Description of the specimens and preservation technique used in this study.

Animal Number	Age	Sex	Limbs available No.	Limbs available dismembered at	Preservation
078A	25 mos.	male	4	distal forearm & distal leg	Formalin, Latex
83B	1 mo.	fem.	4	shoulder girdle & pelvic girdle	Formalin, Latex
29B	53 mos.	fem.	4	distal forearm & distal leg	Fresh
19B	37 mos.	fem.	4	distal forearm & distal leg	Refrigeration
1	3 wks.	male	4	shoulder girdle & pelvic girdle	Formalin, Latex
2	2½ wks.	male	4	shoulder girdle & pelvic girdle	Formalin, Latex
3	2 wks.	male	4	shoulder girdle & pelvic girdle	Formalin, Latex
unlabeled	2 mos.	male	4	shoulder girdle & pelvic girdle	Formalin, Latex
202 day fetus		male	4	proximal carpal & tarsal joint	Refrigeration
213 day fetus		fem.	2	metacarpus	Formalin
051A	35 mos.	male	2	forearm	Refrigeration
72A	6 mos.	fem.	4	distal forearm & distal leg	Refrigeration
38A	51 mos.	fem.	4	forearm & metatarsus	Refrigeration
63A	24 mos.	fem.	4	forearm & leg	Refrigeration
39A	44 mos.	fem.	4	metacarpus & metatarsus	Refrigeration
6A	70 mos.	fem.	4	forearm & leg	Refrigeration
12B	28 mos.	fem.	4	carpus & tarsus	Refrigeration

Table 2. External observations.

No.	Limb	Functional digits	Dewclaws	Hooves	Skin abrasions at
078A	LF [1]	total syndact.	lat. larger	curled, ridges, bent medially	carpus, coronary border
078A	RF [2]	total syndact.	lat. larger	ridges, constricted, bent medially	carpus, fetlock
078A	LR [3]	normal, median groove	lat. larger	normal	proximal metatarsus plantar
078A	RR [4]	normal, median groove	differ in shape	normal	distension of bursa calcan. subtend.
83B	LF	normal, median groove	lat. larger	normal	none
83B	RF	total syndact.	lat. larger	no other defects	carpus
83B	LR	normal	no report	normal	no report
83B	RR	normal	no report	normal	no report
29B	all four	normal	normal	normal	normal
19B	LF	total syndact.	lat. lower	no other defects	none
19B	RF	total syndact.	lat. lower	bent laterally	none
19B	LR	normal	med. larger	normal	none
19B	RR	normal	same size	normal	none
1	LF	total syndact.	lat. larger	constricted, bent medially	carpus
1	RF	total syndact.	lat. larger	constricted, bent laterally	carpus
1	LR	normal, median groove	lat. larger	normal	none
1	RR	normal, median groove	same size	normal	none
2	LF	total syndact.	lat. larger	constricted	none
2	RF	total syndact.	lat. larger	constricted	none
2	LR	normal, median groove	lat. larger	normal	none
2	RR	normal, median groove	lat. larger	normal	none

Table 2 (cont.)

No.	Limb	Functional digits	Dewclaws	Hooves	Skin abrasions at
3	LF	total syndact.	lat. larger	constricted	carpus, coronary border
3	RF	total syndact.	lat. larger	constricted	carpus, coronary border
3	LR	normal	lat. larger	normal	none
3	RR	normal, median groove	lat. larger	normal	none
unlabeled	LF	total syndact.	lat. larger	ridges	none
unlabeled	RF	total syndact.	lat. larger	ridges, constricted	none
unlabeled	LR	normal	normal	normal	none
unlabeled	RR	total syndact.	same size	ridges, constricted	none
202 day fetus	all four	normal	normal	normal	-
213 day fetus	LF	syndact.	no report	shallow median cleft in dorsal wall	-
213 day fetus	RF	total syndact.	no report	constricted	-
051A	LF	total syndact.	no report	curled, bent med.	no report
051A	RF	total syndact.	no report	curled, bent lat.	no report
72A	LF	syndact.	same size	sole fused, deep median cleft in dorsal wall	no report
72A	RF	total syndact.	lat. larger	slightly curled	no report
72A	both R	normal	no report	normal	no report
38A	LF	syndact.	no report	split toe, median ridge on inner surface of dorsal wall	no report
38A	RF	total syndact.	no report	curled, ridges	no report
38A	both R	normal	no report	normal	no report
63A	LF	total syndact.	no report	bent medially	no report
63A	RF	total syndact.	no report	bent laterally	no report
63A	both R	normal	no report	normal	no report

Table 2 (concl.)

No.	Limb	Functional digits	Dewclaws	Hooves	Skin abrasions at
39A	LF	total syndact.	no report	curled, bent medially, ridges	no report
39A	RF	total syndact.	no report	curled, bent medially, ridges	no report
39A	LR	total syndact.	no report	curled, bent medially, ridges	no report
39A	RR	normal	no report	normal	no report
6A	LF	total syndact.	lat. larger	curled, bent medially	no report
6A	RF	total syndact.	no report	slightly curled, bent medially	no report
6A	LR	normal	lat. larger	slight fusion on axial coronary border	no report
6A	RR	normal	no report	slight fusion on axial coronary border	no report
12B	LF	total syndact.	lat. larger	no other defects	no report
12B	RF	total syndact.	same size	bent laterally	no report
12B	LR	total syndact.	same size	bent laterally	no report
12B	RR	syndact.	lat. larger	curled, deep median groove in dorsal wall	no report

[1]LF designates left thoracic.
[2]RF designates right thoracic.
[3]LR designates left pelvic.
[4]RR designates right pelvic.
med. designates medial.
lat. designates lateral.

Table 3. Osteological characteristics of the carpal, tarsal, metacarpal, and metatarsal bones.

Specimen	carpals tarsals	Large metacarpus and metatarsus perforating canals	distal trochlea	Remarks
078A LF	(cr+ci+cu)*	normal	two, notch narrow	
078A RF	(cr+ci+cu)	distal absent	two, small groove betw.	15 mm shorter1
078A LR	normal	normal	normal	
078A RR	normal	normal	normal	
83B LF	normal	normal	normal	
83B RF	(ci+cu)	distal absent	one, two sagitt. ridges	10 mm shorter
83B LR	normal	normal	normal	
83B RR	normal	normal	normal	
29B LF	normal	normal	normal	
29B RF	normal	normal	normal	
29B LR	normal	normal	normal	
29B RR	normal	normal	normal	
19B LF	(ci+cu)	both absent	one, one sagitt, ridge	
19B RF	(cr+ci+cu)	both absent	one, one sagitt. ridge	10 mm shorter
19B LR	normal	normal	normal	
19B RR	normal	normal	normal	
1 LF	(ci+cu)	both absent	one, one sagitt. ridge	
1 RF	(ci+cu)	both absent	one, one sagitt. ridge	4 mm shorter
1 LR	normal	normal	normal	
1 RR	normal	normal	normal	
2 LF	(ci+cu)	normal	two, notch narrow	
2 RF	normal	normal	two, notch narrow	same length
2 LR	normal	normal	normal	
2 RR	normal	normal	normal	
3 LF	(ci+cu)	both absent	one, one sagitt. ridge	
3 RF	(ci+cu)	both absent	one, one sagitt. ridge	2 mm shorter
3 LR	normal	normal	normal	
3 RR	normal	normal	normal	
unl. LF	(ci+cu)	normal	two, notch narrow	
unl. RF	(ci+cu)	distal absent	one, one sagitt. ridge	5 mm shorter
unl. LR	normal	normal	normal	
unl. RR	(tl+large mt)	normal	two, notch narrow	
202 fet. all four	normal	normal	normal	
213 fet. LF	unavailable	normal	two, notch narrow	
213 fet. RF	unavailable	distal absent	one, two sagitt. ridges	

Table 3 (concl.)

Specimen	carpals / tarsals	Large metacarpus and metatarsus: perforating canals	Large metacarpus and metatarsus: distal trochlea	Remarks
051A LF	(ci+cu)	distal absent	one, one sagitt. ridge	
051A RF	(ci+cu)	distal absent	one, one sagitt. ridge	3 mm shorter
72A LF	(ci+cu)	normal	normal	
72A RF	(ci+cu)	normal	one, two sagitt. ridges	5 mm shorter
72A LR	normal	normal	normal	
72A RR	normal	normal	normal	
38A LF	(ci+cu)	normal	normal	
38A RF	(ci+cu)	normal	one, two sagitt. ridges	8 mm shorter
38A LR	normal	normal	normal	
38A RR	normal	normal	normal	
63A LF	(ci+cu)	normal	one, two sagitt. ridges	
63A RF	(ci+cu)	distal absent	one, two sagitt. ridges	5 mm shorter
63A LR	normal	normal	normal	
63A RR	normal	normal	normal	
39A LF	unavailable	distal absent	one, one sagitt. ridge	
39A RF	unavailable	distal absent	one, one sagitt. ridge	same length
39A LR	unavailable	normal	two, small groove betw.	
39A RR	unavailable	normal	normal	10 mm longer
6A LF	(ci+cu)	distal absent	one, one sagitt. ridge	
6A RF	(ci+cu)	distal absent	one, one sagitt. ridge	same length
6A LR	(t1+large mt)	normal	normal	
6A RR	(t1+large mt)	normal	normal	
12B LF	normal	distal absent	one, one sagitt. ridge	
12B RF	(cr+ci)	distal absent	one, one sagitt. ridge	5 mm longer
12B LR	normal	normal	two, notch narrow	
12B RR	(t1+t2+3)	normal	normal	2 mm shorter

**The brackets designate a fusion of normally separate bones.
cr designates the radial carpal bone.
ci designates the intermediate carpal bone.
cu designates the ulnar carpal bone.
t1 designates the first tarsal bone.
t2+3 designates the normally fused second and third tarsal bone.
large mt designates the large metatarsal bone.
1 length compared to corresponding left bone of the same individual.

Table 4. Osteological characteristics of the phalanges and sesamoid bones.

Specimen	Proximal sesamoids No.	Proximal sesamoids characteristics	Phalanx I	Phalanx II	Phalanx III	Dist. sesam.
078A LF	3	axial larger	fus.[1],2 prox.[2] art.[3]	compl.[4] fus.	fus., 2 art., dors.[5] median groove	2
078A RF	3	all partially fus.	fus.,2 prox. art.	compl. fus.	compl. fus.	1
078A LR	4	medial pair fus.	two normal	two normal	two normal	2
078A RR	4	lat.& med. pr. fus.	two normal	two normal	two normal	2
83B LF	4	normal	two normal	two normal	two normal	2
83B RF	3	axial smaller	compl. fus.	compl. fus.	compl. fus.	1
83B LR	4	normal	two normal	two normal	two normal	2
83B RR	4	normal	two normal	two normal	two normal	2
29B all four		normal	normal	normal	normal	
19B LF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
19B RF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
19B LR	4	lat. or med.pr.fus.	two normal	two normal	two normal	2
19B RR	4	normal	two normal	two normal	two normal	2
1 LF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
1 RF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
1 both R		normal	normal	normal	normal	
2 LF	3	axial larger	fus.,2 prox. art.	compl. fus.	fus., dors. median groove	1
2 RF	3	axial larger	fus.,2 prox. art.	compl. fus.	compl. fus.	1
2 both R		normal	normal	normal	normal	
3 LF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
3 RF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
3 both R		normal	normal	normal	normal	
unl. LF	3	axial larger	fus.,2 prox. art.	compl. fus.	compl. fus.	1
unl. RF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
unl. LR	4	normal	normal	normal	normal	2
unl. RR	4	axials larger	fus.,2 prox. art.	compl. fus.	compl. fus.	1
202 fet. all four		normal	normal	normal	normal	
213 fet.LF	3	axial larger	fus.,2 prox. art.	fused	fus., 2 art., cleft	1
213 fet.RF	2	same size	fus.,2 prox. art.	compl. fus.	compl. fus.	1
051A LF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
051A RF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
72A LF	4	normal	two normal	two normal	two normal	2
72A RF	2	same size	fus.,2 prox. art.	compl. fus.	compl. fus.	1

Table 4 (concl.)

Specimen	Proximal sesamoids No.	Proximal sesamoids characteristics	Phalanx I	Phalanx II	Phalanx III	Dist. Sesam.
72A LR	4	normal	two normal	two normal	two normal	2
72A RR	4	normal	two normal	two normal	two normal	2
38A LF	4	axial two fus.	two, vol.[6] tub.[7]	fus., 2 prox. and 2 dist. art.	two, close contact	2
38A RF	3	same size	fus., 2 prox. art.	compl. fus.	compl. fus.	1
38A LR	4	lat.& med. pr. fus.	two normal	two normal	two normal	2
38A RR	4	lat.& med. pr. fus.	two normal	two normal	two normal	2
63A LF	3	same size	fus., 2 prox. art.	compl. fus.	compl. fus.	1
63A RF	3	same size	fus., 2 prox. art.	compl. fus.	compl. fus.	1
63A LR	4	lat. pair fus.	two normal	two normal	two normal	2
63A RR	4	lat.& med. pr. fus.	two normal	two normal	two normal	2
39A LF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
39A RF	2	same size	compl. fused	compl. fus.	compl. fus.	1
39A LR	3	axial large	fus.,2 prox. art.	compl. fus.	compl. fus.	1
39A RR	4	normal	normal,med. larger	normal	normal, med. wider	2
6A LF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
6A RF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
6A LR	4	normal	two normal	two normal	two, med. smaller	2
6A RR	4	med. pr. fus.	two normal	two normal	two, med. larger	2
12B LF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
12B RF	2	same size	compl. fus.	compl. fus.	compl. fus.	1
12B LR	4	lat.& med. pr. fus.	fus.,2 prox. art.	compl. fus.	compl. fus.	1
12B RR	4	lat.& med. pr. fus.	two, close togeth.	fus.,2 prox. & two dist. art.	very little axial fusion	1

1 designates a fusion of two normally separate bones.
2 designates proximal.
3 designates articular surface.
4 designates complete, completely.
5 designates dorsal.
6 designates volar.
7 designates tubercle.

Table 5. Characteristics of tendons and ligaments of syndactylous limbs.

Specimen	Superficial digital flexor tendon: Branch to lateral dewclaw	Superficial digital flexor tendon: Tubular part attached to intersesam. ligament	Superficial part of suspensory ligament: Structure of part to tube	Superficial part of suspensory ligament: Attachm. to prox. sesamoids	Deep suspensory ligament: No. of main branches	Deep suspensory ligament: Accessory branches
078A LF	5cm long	no record	no record	no record	one wide	none
078A RF	4cm long	no record	no record	no record	one wide	none
83B RF	5cm long	no record	two bands	no record	two	to lat. dewclaw
1 LF	4 cm long	yes	two bands	yes	one wide	none
1 RF	4cm long	yes	one band	yes	two	none
2 LF	no	no	one band	yes	two	to lat. dewclaw
2 RF	no	no	one band	yes	two	none
3 LF	no	no	one band	yes	two	none
3 RF	two, 3 cm	no	one band	yes	two	none
unl. LF	10cm long	yes	one lat. bd.	yes	two	to lat. dewclaw
unl. RF	4cm long	no	one med. bd.	yes	two	to lat. dewclaw
unl. RR	no	no	one band	yes	three	none
213 fet.LF	no	no	one band	yes	one wide	none
213 fet.RF	no	no	one band	no	two	none
12B LF*	yes	no report	one band	no report	two	to lat. dewclaw
12B RF*	no report	no report	no report	no report	two	to lat. 3rd phal.
12B LR*	no report	no report	one band	no report	five	no report
12B RR*	no report	no report	two bands	no report	five	no report

* Reported by Dairy Department.

EXPLANATION OF PLATE I

Fig. 1. Volar view of a normal right thoracic bovine limb.

Fig. 2. Volar view of a syndactylous limb with a larger lateral dewclaw (specimen 2 RF).

PLATE I

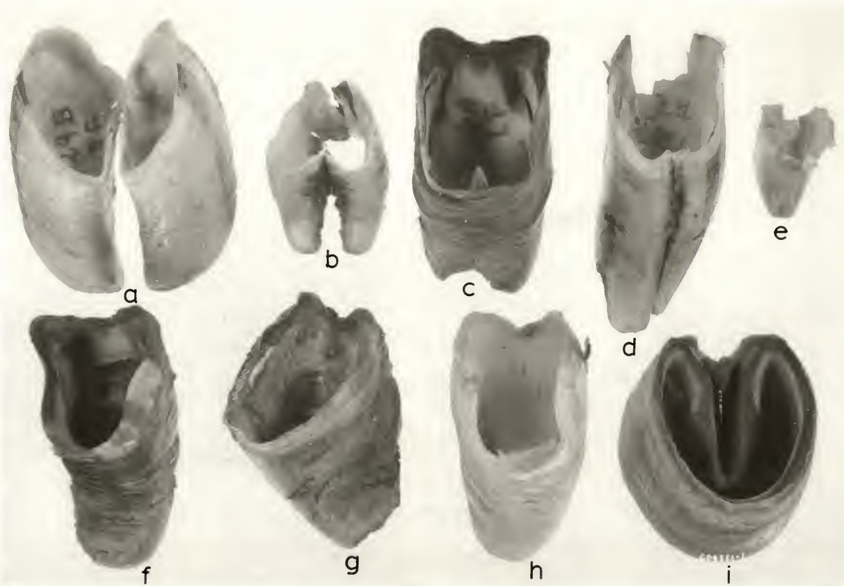
Fig. 1 Fig. 2

EXPLANATION OF PLATE II

Dorsal view of isolated hooves.

a. Normal bovine hooves (specimen 29B RF).
b. Syndactylous bovine hoof with deep axial cleft in dorsal wall and split toe. The axial wall and the posterior part of the sole are fused (specimen 72A LF).
c. Syndactylous bovine hoof with split toe and axial ridge on inner dorsal wall (specimen 38A LF).
d. Syndactylous bovine hoof with axial cleft in dorsal wall (specimen 12B RR).
e. Syndactylous bovine hoof with slight axial cleft in dorsal wall (213 day fetus LF).
f. Curled syndactylous bovine hoof with pronounced ridges (specimen 38A RF).
g. Curled and medially bent syndactylous bovine hoof (specimen 39A RF).
h. Symmetrical syndactylous hoof with no other defects (specimen 19B LF).
i. Normal equine hoof for comparison.

PLATE II



EXPLANATION OF PLATE III

Dorsal view of metacarpal bones, showing various degrees of fusion.

a. Normal large metacarpal and fifth metacarpal bone of bovine animal, showing the vascular groove, the proximal and distal perforating canals, the two distal trochleae, and the intertrochlear notch, (specimen 29B LF).
b. Narrow intertrochlear notch (specimen 078A LF).
c. One trochlea with two far apart sagittal ridges (specimen 63A LF).
d. One trochlea with two closely located sagittal ridges. Distal perforating canal absent (specimen 63A RF, 5 mm shorter than 63A LF).
e. One trochlea with one wide and flat sagittal ridge. A vascular groove crosses over the medial half of the bone, indicating origin of dorsal metacarpal artery from medial volar deep metacarpal artery (specimen 6A RF).
f. Higher and narrower sagittal ridge, vascular groove from medial border to midline, large fifth metacarpal bone, fused in middle to the large metacarpal bone (specimen 6A LF, same length like 6A RF).
g. Pronounced sagittal ridge on trochlea, well developed fifth and second metacarpal bone (specimen 12B LF).
h. Equine metacarpal bone for comparison.

PLATE III

EXPLANATION OF PLATE IV

Fig. 1. Various degrees of fusion on the proximal sesamoid bones.

a. Normal specimen 29B LF.
b. Specimen 38A LF.
c. Specimen 39A LR.
d. Specimen 078A LF.
e. Specimen 38A RF.
f. Specimen 078A RF.
g. Specimen 12B RF.

Fig. 2. A series of fifth metacarpal bones. The left in the top row is from a normal specimen, all others are from syndactylous specimens.

PLATE IV

Fig. 1 Fig. 2

EXPLANATION OF PLATE V

Dorsal view of a series of digits showing progressive degrees of fusion.

a. All three pairs of phalanges are separate (normal specimen 29B LF).
b. The two second phalanges are fused, their proximal and distal articular surfaces are separate. The third phalanges are closely located (specimen 38A LF).
c. The second and third pair of phalanges are fused, their articular surfaces are separate (specimen 12B RR).
d. All three pairs of phalanges are fused. The proximal articular surface of the first phalanx is double. The third phalanx shows an axial dorsal cleft and two articular surfaces (213 day fetus LF).
e. The stage of fusion is similar to the preceding (specimen 078A LF).
f. All three pairs of phalanges are fused. The first phalanx shows two separate proximal articular surfaces (unlabeled specimen RR).
g. The stage of fusion is similar to the preceding. The two proximal articular surfaces are closer located (specimen 38A RF).
h. All three pairs of phalanges are fused and their articular surfaces are single (specimen 12B LF).
i. An equine digit for comparison.

PLATE V

EXPLANATION OF PLATE VI

Dorsal view of a syndactylous limb after removal of the skin, fascia, nerves, and veins. The tendons of the three digital extensor muscles form a thin aponeurotic plate in the fetlock area (specimen 2 LF).

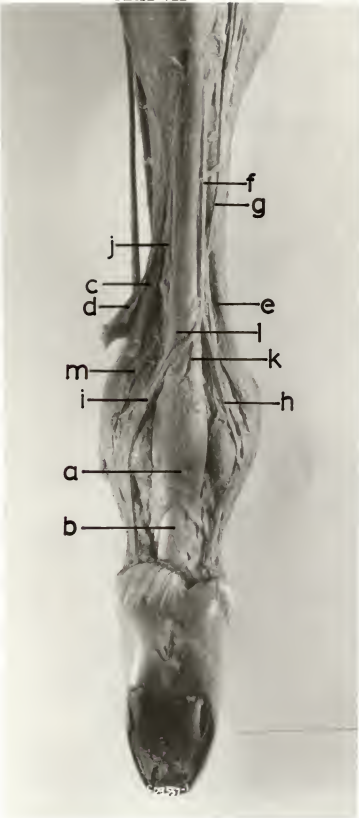
PLATE VI

EXPLANATION OF PLATE VII

Volar view of a syndactylous limb after removal of the skin and fascia (specimen 2 LF).

a. Superficial digital flexor tendon.
b. Deep digital flexor tendon.
c. Lateral branch of deep suspensory ligament with
d. Branch to lateral dewclaw.
e. Medial branch of deep suspensory ligament.
f. Volar common digital (ulnar) artery.
g. Medial deep volar metacarpal (radial) artery.
h. Medial volar digital artery.
i. Lateral volar digital artery.
j. Lateral deep volar metacarpal artery.
k. Axial arterial branch.
l. Lateral volar digital nerve.
m. Lateral volar digital vein.

PLATE VII



EXPLANATION OF PLATE VIII

Fig. 1. Volar view of metacarpo-phalangeal joint. The suspensory ligament and the proximal sesamoid bones are reflected distad. Two branches of the deep suspensory ligament, three proximal sesamoids, and the distal metacarpal trochlea with two closely located sagittal ridges are shown (specimen 83B RF).

Fig. 2. The deep digital flexor tendon is bifurcated for a distance of about 8 cm (unlabeled specimen RR).

PLATE VIII

Fig. 1 Fig. 2

EXPLANATION OF PLATE IX

Diagram of dorsal arteries in distal part of left thoracic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

a. Rete carpi dorsale.
b. Proximal perforating metacarpal.
c. Dorsal metacarpal.
d. Distal perforating metacarpal.
e. Dorsal common digital.
f. Perforating interdigital.
g. Proper dorsal digitals.
h. Branches from volar digitals.

PLATE IX

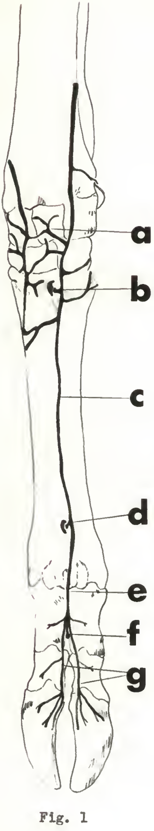


Fig. 1

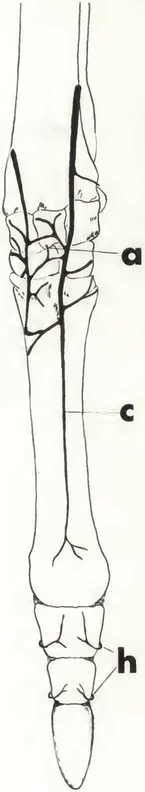


Fig. 2

EXPLANATION OF PLATE X

Diagram of volar arteries in distal part of left thoracic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

a. Median.
b. Ulnar.
c. Radial.
d. Rete carpi volare.
e. Proximal perforating metacarpal.
f. Lateral deep volar metacarpal.
g. Middle deep volar metacarpal.
h. Medial deep volar metacarpal.
i. Distal perforating metacarpal.
j. Distal volar arch.
k. Volar common digital.
l. Lateral volar proper digital.
m. Medial volar proper digital.
n. Anastomosis to dorsal common digital.

PLATE X

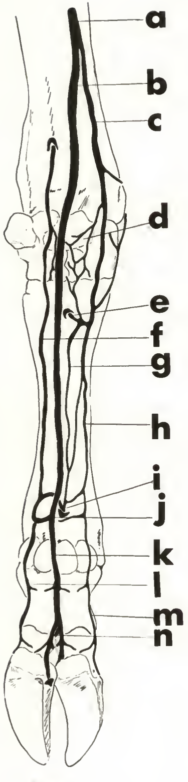


Fig. 1

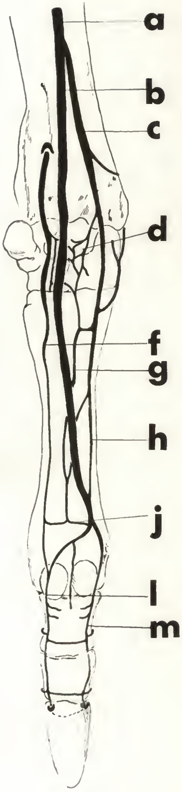


Fig. 2

EXPLANATION OF PLATE XI

Diagram of dorsal arteries in distal part of left pelvic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

a. Anterior tibial.
b. Perforating tarsal.
c. Dorsal metatarsal.
d. Perforating metatarsal.
e. Dorsal common digital.
f. Perforating interdigital.
g. Dorsal proper digitals.
h. Branches from plantar digitals.

PLATE XI

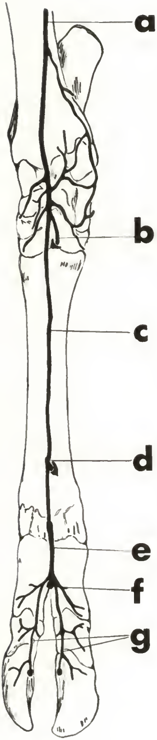


Fig. 1

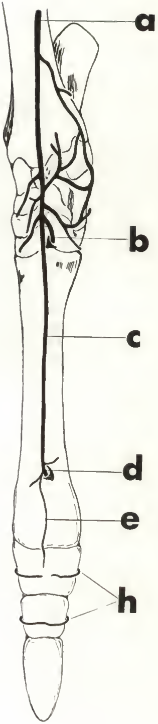


Fig. 2

EXPLANATION OF PLATE XII

Diagram of plantar arteries in distal part of left pelvic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

- a. Medial tarsal.
- b. Perforating tarsal.
- c. Proximal plantar arch.
- d. Medial superficial plantar metatarsal.
- e. Lateral superficial plantar metatarsal.
- f. Deep plantar metatarsal.
- g. Distal plantar arch.
- h. Perforating metatarsal.
- i. Plantar common digital.
- j. Plantar digitals.
- k. Dorsal branches.

PLATE XII

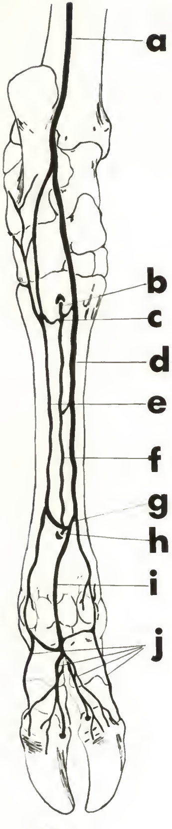


Fig. 1

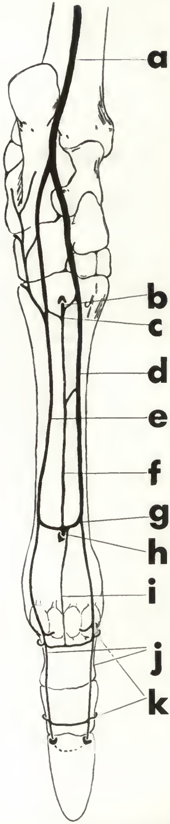


Fig. 2

EXPLANATION OF PLATE XIII

Diagram of dorsal nerves in distal part of left thoracic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

a. Dorsal metacarpal.
b. Superficial branch of ulnar.
c. Lateral dorsal abaxial digital.
d. Lateral dorsal axial digital.
e. Medial dorsal axial digital.
f. Medial dorsal abaxial digital.

PLATE XIII

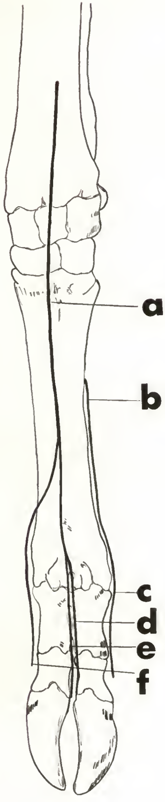


Fig. 1

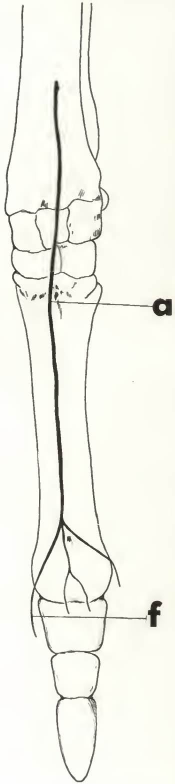


Fig. 2

EXPLANATION OF PLATE XIV

Diagram of volar nerves in distal part of left thoracic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

a. Median.
b. Ulnar.
c. Superficial branch of ulnar.
d. Deep branch of ulnar.
e. Medial volar metacarpal.
f. Deep lateral volar metacarpal.
g. Volar digitals.
h. Branch to dorsal axial digitals.

PLATE XIV

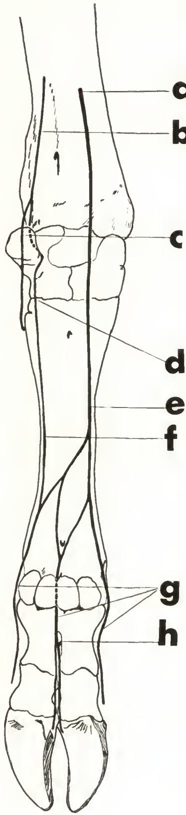


Fig. 1

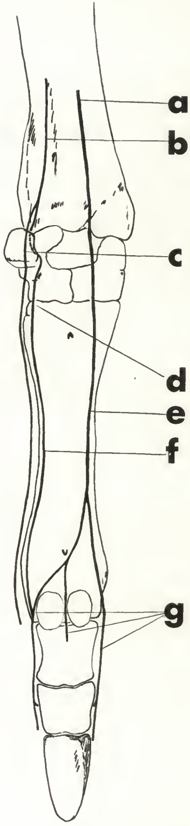


Fig. 2

EXPLANATION OF PLATE XV

Diagram of dorsal nerves in distal part of left pelvic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

a. Superficial peroneal.
b. Deep peroneal.
c. Superficial dorsal metatarsal.
d. Deep dorsal metatarsal.
e. Communication with axial plantar digitals.
f. Dorsal digitals.

PLATE XV

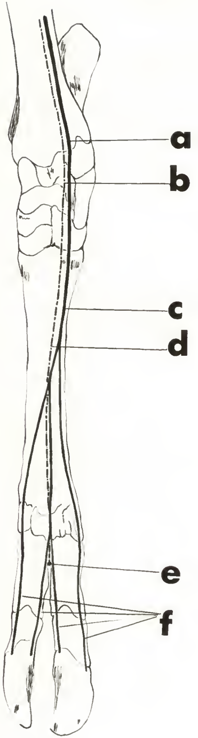


Fig. 1

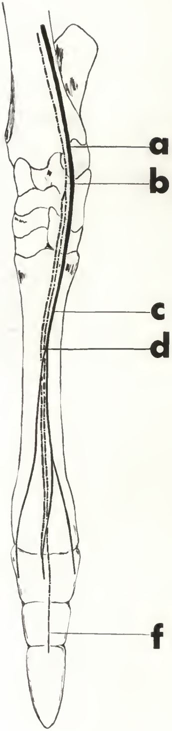


Fig. 2

EXPLANATION OF PLATE XVI

Diagram of plantar nerves in distal part of left pelvic limb.

Fig. 1. Normal specimen.

Fig. 2. Syndactylous specimen.

a. Tibial.
b. Medial plantar.
c. Lateral plantar.
d. Lateral branch of medial plantar.
e. Medial branch of medial plantar.

PLATE XVI

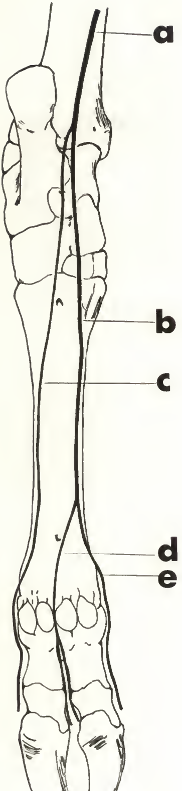


Fig. 1

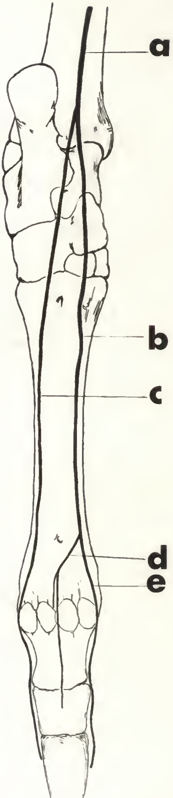


Fig. 2

ANATOMICAL STUDIES ON BOVINE SYNDACTYLISM

by

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AN ABSTRACT OF A MASTER'S THESIS

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Sixty-four bovine limbs, procured from fifteen syndactylous and two individuals with syndactylous parentage, were studied in order to obtain more anatomical information about bovine syndactylism. The normal anatomy of the bovine limbs was reviewed and compared with the findings on the syndactylous limbs.

Prior to the dissection, many limbs were embalmed in a formalin solution and their arteries were injected with red latex, and a few were preserved by refrigeration. The external characteristics were recorded and the soft structures were carefully dissected and studied. The remaining specimens were macerated. Photographs and diagrams of some conspicuous findings were prepared, and the significant results of each individual limb were summarized in tables.

The limbs of the two individuals with syndactylous parentage were normal in all respects. The fifteen syndactylous individuals showed in one case the right thoracic limb affected with syndactylism, in eleven cases both thoracic limbs were affected, and in one case, single-toes were present on both thoracic and the left pelvic limb, in one case on both thoracic and the right pelvic limb, and in one case on all four limbs.

External signs of syndactylism were a single functional digit with a completely or partially fused hoof, and the lateral dewclaw was often enlarged. On the bones of syndactylous individuals various stages of fusion were noted which involved the areas distal to the forearm or leg respectively. In the same individual the degree of fusion was higher on the right than on the left thoracic limb. The pelvic limbs showed less advanced fusion as compared to the thoracic limbs. The union of the functional digits was accompanied by a better development of the fifth and second metacarpal bones and the corresponding phalanges.

The tendons of the three digital extensor muscles formed on syndactylous limbs a common aponeurotic plate which inserted on the second and third phalanx. The tendons of the superficial and deep digital flexor muscles as a rule remained undivided. A small tendinous branch from mostly the superficial digital flexor tendon was detached to the lateral dewclaw. The superficial suspensory ligament not only aided in forming a tube around the deep digital flexor tendon but also attached, usually by a wide band, to the proximal sesamoid bones. The number of branches of the deep suspensory ligament was reduced, thin slips of it joined the plate of the digital extensor tendons.

The main blood supply to the syndactylous digits was by a lateral and a medial volar or plantar digital artery. The axial digital branches were rudimentary or absent, and the dorsal metapodial arteries ended at the fetlock. The venous pattern corresponded in general to the arterial.

On thoracic syndactylous limbs the continuation of the median nerve formed a lateral and a medial volar digital nerve, which were the main nerve supply of the single digit. A lateral and a medial plantar digital nerve, each the continuation of the corresponding plantar nerve, were the main nerve supply of the single digit on the pelvic limb.

Almost all apperently normal limbs of syndactylous individuals showed minor anatomical deviations. Most frequently observed examples were an enlarged lateral dewclaw, fusions of pairs of proximal sesamoid bones, and absence of the tibialis posterior muscle.