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EPIPHYSODIAPHYSEAL GROWTH ZONES IN METAPODIUM AND ACROPODIUM OF CATTLE IN POSTNATAL ONTOGENESIS

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Abstract

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Anatomic and radiologic methods were used for the study and description of macroscopic changes in the epiphysodiaphyseal growth zones of the metapodium and acropodium of cattle in the postnatal developmental period. The results were obtained from 79 clinically healthy animals of the Czech Red-Spotted cattle aged from birth to 15 years. Localization of the epiphysodiaphyseal zone in the metapodium and acropodium of calves and juvenile cattle was determined by means of external orientation points on a live animal. We are suggesting their possible access during experimental and clinical interventions. By means of comparison of radiographs with osteologically treated preparations, a typical RTG-picture of different parts of the epiphysodiaphyseal growth zones in the metapodium and proximal and middle phalanges of the digits was described. The ontogenetic developmental series of the postnatal period was used to study changes in the RTG-picture and in the epiphysodiaphyseal growth cartilage and the diaphyseal and epiphyseal osseous plates in the macrostructure. By destruction of the epiphysodiaphyseal growth cartilage the epiphysodiaphyseal growth zone grows into the epiphysodiaphyseal scar which gradually disappears due to inner rebuilding of the bone.

Development, epiphysodiaphyseal growth zones, anatomy and rentgenology, cattle.

The epiphysodiaphyseal growth zones are differentiated in cartilaginous bone patterns with establishment of epiphyseal ossification centres. Formation of secondary ossification centres in different skeletal bones of cattle limbs was described by Küpfer and Schinz (1923), Vokken (1950), Fedrigo (1957) and Lindsay (1969). They suggest that in the course of the seventh month of the intrauterine life secondary ossification centres appear in the phalanx proximalis and phalanx media and subsequently distal epiphyseal centres appear in the metapodium. Development of skeletal bones and disappearance of epiphysodiaphyseal growth cartilages in skeletal bones of domestic mammals in the prenatal and postnatal periods were studied by Vokken and Tarasov (1968). According to these authors establishment of a secondary ossification centre in the proximal ulnar epiphysis can be taken as a sign of terminated intrauterine development. Kolda (1936) and Barone (1966) have given more precisely defined data on disappearance of growth cartilages from the skeletal bones of domestic mammals. They have suggested that the epiphysodiaphyseal cartilages in the phalanx media in cattle disappear between the 15th–18th months after birth, in the phalanx proximalis between the 20th–24th months and in the metapodia at the age of 2 years and a half. The microscopic structure of the epiphyseal growth cartilage of cattle metatarsus in ontogenesis was studied by Lassila (1928). The author described changes in thickness and shape of the cartilage as well as alterations in microstructure of the epiphysodiaphyseal cartilage associated with its destruction. The microstructure of the epiphysis-diaphysis union and removal of epiphysodiaphyseal growth zone in man and dog was described by Haines (1975). In the epiphysodiaphyseal growth zone he differentiated, in addition to the epiphysodiaphyseal growth cartilage,

epiphyseal and diaphyseal bony plates which had been suggested by Hasselwander (1910). In radiographs these osseous plates appear as darker surfaces and are called by radiologists as "epiphyseal and metaphyseal zone of temporary calcification" (Bláha 1963). Binev (1970) carried out radiologic studies of limb bones of newborn and one-month old calves. His findings show that sharp boundaries in radiographs separate epiphyses of different bones in both groups. Burt et al. (1968) only present a list of epiphysodiaphyseal cartilages on the limb bones which can be studied by radiologic methods. The RTG-picture of the cattle carpal joint was described by Funk (1966) on the basis of comparative osteological material, and, the growth changes on distal digit phalanges in cattle were described by Simon (1963). The epiphyses and apophyses of limb bones in a foal were radiologically studied by Schmidt (1960) and those in a pig by Szemes (1962). Besides listing epiphyses and apophyses of different limb bones and their morphological description the authors also mention in the passing the period of disappearance of epiphysodiaphyseal growth cartilages. It is this problem that was concerned with by Weiss (1972) in the pig and by Smith and Allock (1960) in the dog. Rajtová (1974) and Nowicki (1972, 1974) carried out radiologic studies of postnatal development of limbs bones in the sheep and goat Nowicki (1975) in the pig and Bressou et al. (1957, 1959) in the dog and cat.

The autopodium of thecattle is quite accessible for radiological and clinical examination. However, there is a lack of data on localization, morphology and RTG-picture of epiphysodiaphyseal growth zones in the autopodium in the developmental period. Considering the fact that various metabolic disorders in cattle are often accompanied by skeletal diseases (Seffner and Wujanz 1973) and that necessary literature data on macrostructure of the developing skeleton are not available (McCallum et al. 1970) we have focused our attention on these problems and described macroscopic structural changes in the epiphysodiaphyseal growth zones of metapodium and acropodium and their RTG-picture and topography on a live animal in the postnatal ontogenetic period.

Materials and Methods

We have studied metapodium and acropodium on the total of 79 clinically healthy animals of the Czech Red-Spotted cattle of both sexes, from birth to the age of 15 years. In the course of the experiment we made, at monthly intervals, radiographs of the metapodium and thoracic and pelvic-limb digits — radiographs of dead animals were made once and those of live animals repeteadly. For this we used a portable X-ray equipment MEGA-META 125 of the Radiologic Section of the Department of Surgery of the University of Veterinary Science in Brno. A part of the material studied was treated by using anatomic methods. We prepared mediolateral and dorsopalmar (dorsoplantar) sections, and, some of the sections were treated by the method of differential staining of the bone tissue with the use of alizarin-red (Červený 1972) and the others were treated by boiling maceration and bleaching in hydrogen peroxide. In the same way were osteologically treated some unsawn autopodia. More details are given in the following table:

Experimental material

Age of animals	Number of animals and their sex		Number of samples treated by different methods		
	♂	♀	RTG	Differential staining with alizarin	Osteologic methods
Newborn	12	6	18	8	—
2 weeks	9	5	14	3	—
1 month	7	5	12	2	1
2 months	3	3	6	—	—
3 months	3	3	6	—	—
4 months	1	1	2	—	—
6 months	2	2	4	1	1
8 months	2	1	3	1	2
12 months	2	—	2	—	1
20 months	2	1	3	1	2
2 years	1	—	1	—	—
2.5 years	2	1	3	—	2
5 years	—	2	2	—	2
6 years	—	1	1	—	1
15 years	—	2	2	—	2
Total	46	33	79	16	14

Results

When examining epiphysodiaphyseal growths zones of the metapodium and acropodium of cattle during postnatal development, an epiphysodiaphyseal growth cartilage, to which the epiphyseal and diaphyseal osseous plates are attached (Fig. 4, 5 and 19), can be macroscopically well distinguished on osteologically-treated and alizarin-red-stained preparations as well as in radiographs. On the metapodium, the epiphyseal growth zones are localized on the distal part of the phalanx proximalis and phalanx media while on the digits they can be seen in the proximal part. They lay on perpendicular plane to longitudinal axis of the mentioned bones and their course was sinuous. With increasing age, in the whole period of active

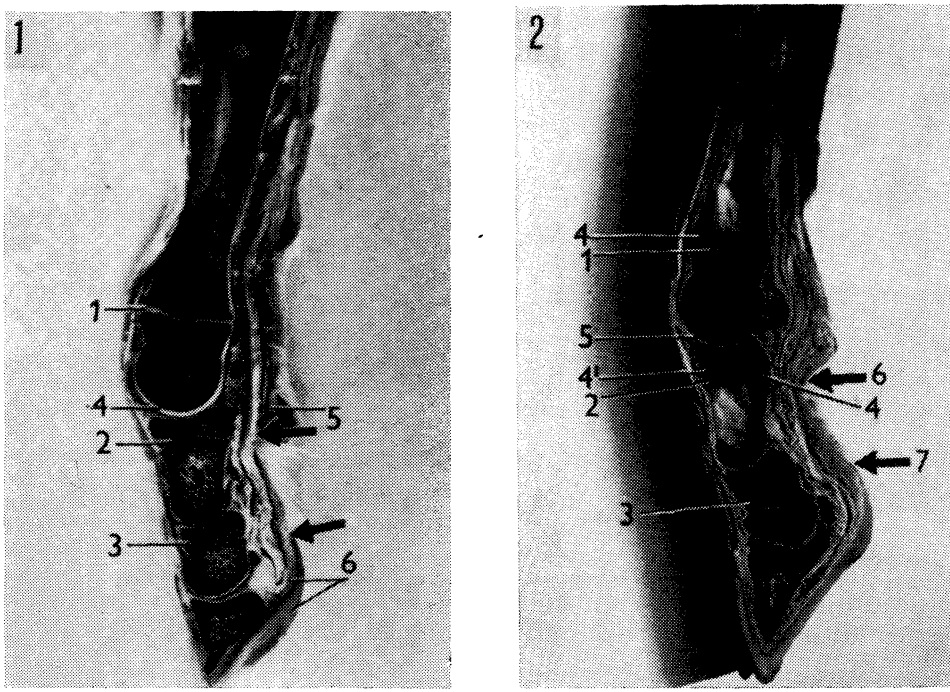
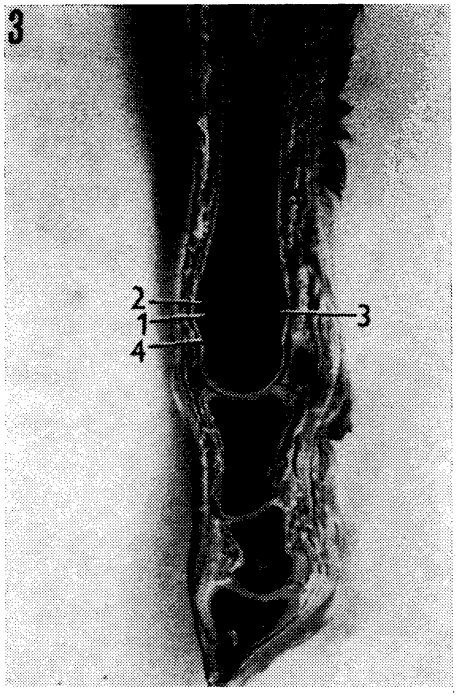


Fig. 1. Sagittal section through fourth digit and metatarsus of right pelvic limb of new-born calf (osseous tissue differentially stained with alizarin red).
1, 2, 3 — epiphysodiaphyseal growth zones of metapodium (1), of proximal (2) and middle phalanx of the digit (3), 4 — articulatio metatarsophalangea, 5 — rudiment of the fifth digit; arrow at level of lower edge of small claw basis to epiphysodiaphyseal growth zone in phalanx proximalis, 6 — torus ungulae; arrow at level of the proximal edge of torus ungulae to epiphysodiaphyseal growth zone in phalanx media.
Fig. 2. Sagittal section through the fourth digit and metacarpus of left pelvic limb of cattle aged 6 months. (Osseous tissue differentially stained with alizarin red.)
1, 2, 3 — Epiphysodiaphyseal growth zones, less conspicuous epiphysodiaphyseal cartilages, 4 — deep red colour represents diaphyseal and 4′ epiphyseal bony plates of epiphysodiaphyseal growth zones, 5— articulatio metacarpophalangea, 6 — rudiment of fifth digit, 7 — proximal edge of bulbs of hoof, arrows to changed topographical conditions in epiphysodiaphyseal growth zones of digit phalanges and external orientation points, proximal edge of bulbs of hoof and basis of small claws.



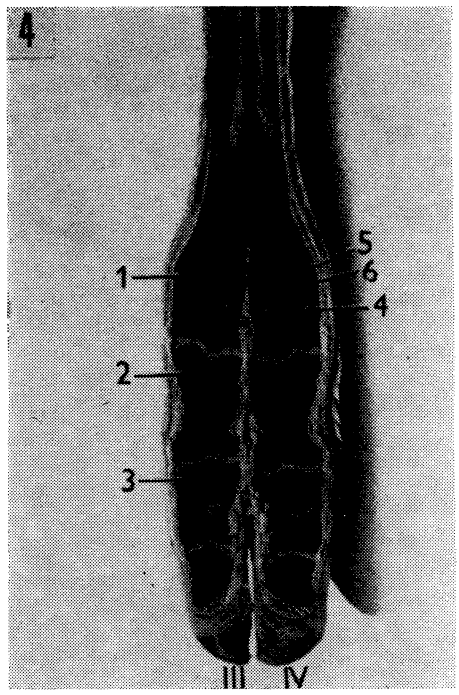


Fig. 3. Sagittal section through third digit and metatarsus of left pelvic limb of a 2-week old calf. (Osseous tissue differentially stained with alizarin red.)
1 — epiphysodiaphyseal growth zone of metatarsus with conspicuous growth cartilage and more deeply coloured (2) epiphyseal and (3) diaphyseal bony plates, 4 — epiphysodiaphyseal growth cartilage passing to cartilaginous coating of ossification centre of epiphyse.
Fig. 4. Mediolateral section through main digits and metatarsi of right pelvic limb of 2-week old calf. (Osseous tissue differentially stained with alizarin red.)
1, 2, 3 — Epiphysodiaphyseal growth cartilages of metatarsi (1), proximal phalanges of digits (2) and middle phalanges of digits (3), 4 — yet-separated epiphyses of main metatarsi, 5 — diaphyseal and 6 — epiphyseal bony plates.

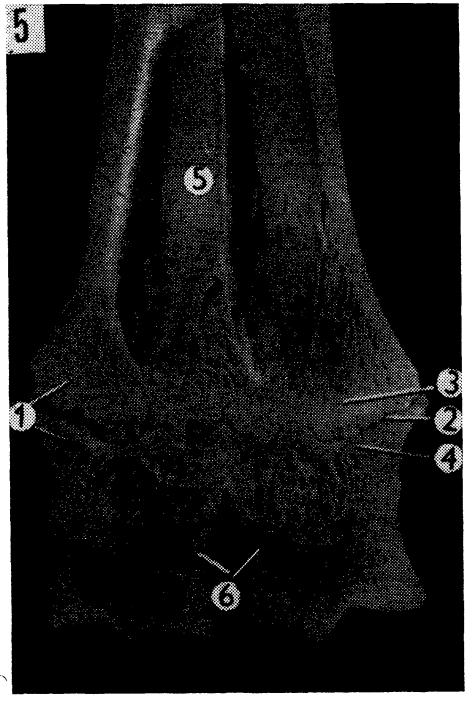
growth of the bone to the length, the sinuous course is more marked than in fetuses and new-born animals and the epiphysodiaphyseal growth cartilages get thinner. The margins of the ends of epiphyses and diaphyses adjacent to the epiphysodiaphyseal growth cartilage project over the smooth surface of the bones so that they are easily palpable through the skin.

The epiphysodiaphyseal growth zones of the two main metapodial bones, of the thoracic limbs are situated on the border of the distal quarters of the metacarpus, those of the pelvic limbs are situated on the border of the distal fifths of the metatarsus. Owing to the course of the muscle tendons, the epiphysodiaphyseal growth zone can be palpated on the limb with slight flexion of the digits in the articulatio metacarpophalangea and/or articulatio metatarsophalangea on the dorsomedial of dorsolateral side of the metapodium. A prominent transition of the epiphysis to the diaphysis on the dorsolateral of dorsomedial perimeter of the metapodium can be easily palpated 2.5—3 cm proximally to the distal end of the metapodial trochlea in newborn calves and 4—6 cm proximally to the distal end of

the metapodial trochlea in older animals. Thus it is possible, by means of palpation, to precisely establish localization of the epiphysodiaphyseal growth zone. In animals with terminated longitudinal growth of bones this prominence is unpalpable because of the skin thickness, although it can be seen on the surface of a bone after maceration.

The epiphysodiaphyseal growth zone of the proximal phalanx of the digit is situated on the border of the proximal quarters of the bone length. On a live animal, its localization is determined by projection of the perpendicular plane to the long axis of the proximal phalanx of the digit projected at the level of the distal margin of the small claw basis (Fig. 1). These growth zones can be palpated at the same site on the abaxial surfaces of the third and fourth digits. In older calves over six months of age a 1—2 cm shift of the epiphysodiaphyseal growth zone with respect to the basis of the small claws, due to morphological changes in the digits in the course of their growth, can be observed (Fig. 2).

The epiphysodiaphyseal growth zone of the middle phalanx is also situated on the border of the proximal quarters of the middle phalanx length. From the



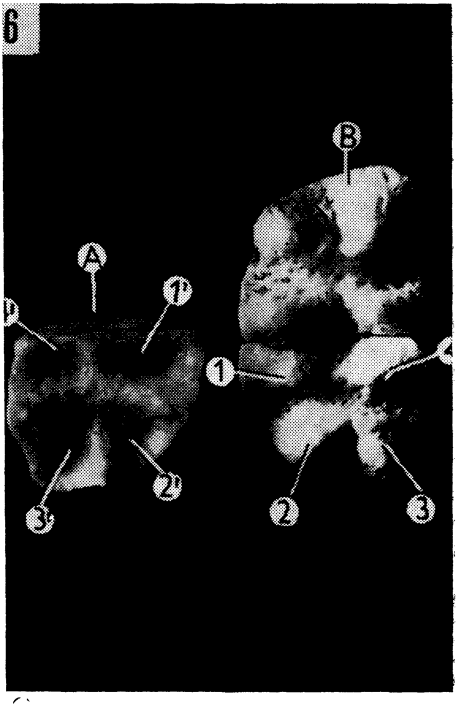
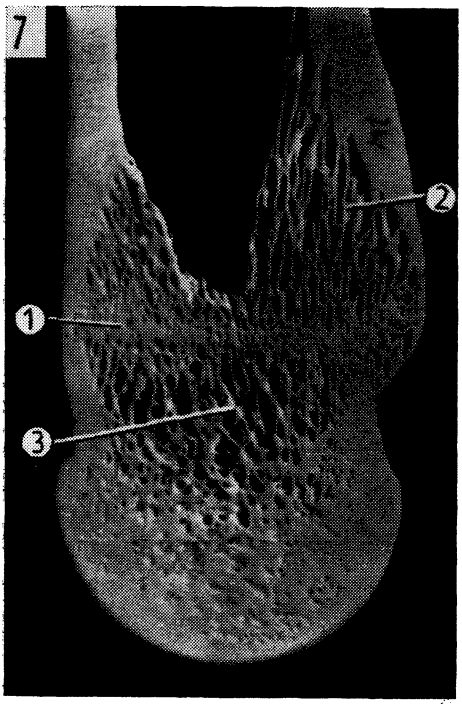


Fig. 5. Mediolateral section through distal end of left metatarsus of a 20-month old bull. 1 — epiphysodiaphyseal growth zone, 2 — gap indicating macerated epiphysodiaphyseal growth cartilage, 3 — diaphyseal and 4 — epiphyseal bony plate of growth zone, 5 — os metatarsale III et IV, 6 — joined epiphyses of both bones.

Fig. 6. View of contact surfaces of epiphyse (A) and diaphyse (B) of right os metacarpale III et IV of a 6-month old calf. Os metacarpale — III epiphyse inverted before dorsal surface of metacarpus. 1, 2, 3, 4 — tubercles in apexes of trapezoidal perimeter of diaphyseal contact surface, 1′, 2′, 3′, 4′ — corresponding grooves on contact surface of epiphyse.



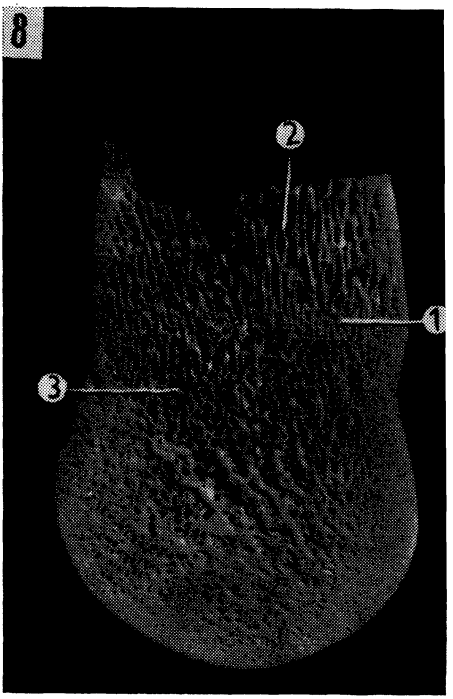


Fig. 7. Sagittal panel cut through distal end of metatarsus of a 5-year old cow.
1 — concentrated bony trabeculae of epiphysodiaphyseal scar, 2 — trabeculae of diaphyseal spongy substance, 3 — trabeculae of epiphyseal spongy substance.

Fig. 8. — Sagittal panel cut through distal end of metatarsus of a 15-year old cow.
1 — reduced bone trabeculae of epiphysodiaphyseal scar due to inner rebuilding of bones; 2 — trabeculae of diaphyseal spongy substance, 3 — trabeculae of epiphyseal spongy substance.

external view, this zone on the thoracic and pelvic limbs is situated on the transverse plane projected on the middle phalanx of the digit at the level of the highest point of the proximal margin of the horny bulbs (Fig. 1). In older animals, similarly as in the phalanx proximalis, a shift in the above-mentioned projections due to change in growth relations can be observed. The epiphysodiaphyseal zone, too, shows a 1—2 cm shift more proximally to this plane (Fig. 2).

On radiographs, the epiphysodiaphyseal cartilage of the epiphysodiaphyseal growth zone of the metapodium and acropodium is drawn as an undulated clear line. Along both sides of this clear line, parallel shadows of epiphyseal and diaphyseal bony plates are drawn (Figs 14 and 19). Parts of epiphysodiaphyseal growth zones where new cartilage calcifies and is destructed to arise new bony tissue can be observed in the radiographs. These are sites with higher mineral supplementation, and the mineral substances are responsible for deeper shadow in these areas of the growth zone. In this respect, higher activity can be recorded on the diaphyseal bony plate. The epiphyseal bony plate is represented by a contrasting narrow shadowy demarcation near the epiphyseal surface of the epiphysodiaphyseal growth cartilage and the diaphyseal bony plate is represented by a wider and diffuse shadow. Changes were found in this bony area in the post-

natal period, and above all changes associated with destruction of the epiphysodiaphyseal growth zones and rebuilding of bone structure in later age. Undulated lines of epiphysodiaphyseal growth zones of metapodia can be identified on the radiographs and derived according to osteologic preparations of the metapodia with separated epiphyses. A relief of the contrast surfaces of both diaphysis and epiphysis can be seen in these preparations (Fig. 6). Four tubercles with four grooves between them are always identified on the distal epiphyses of the metacarpus and metatarsus. The tubercles are situated approximately in the middle of the trapezoidal perimeter of the contact surfaces of the epiphyses and are cross--distributed. Corresponding grooves and tubercles are situated matrix like on the contact surfaces on the diaphyses of these bones which fit into one another, including epiphysodiaphyseal cartilage between. On the diaphyses these tubercles are situated in the corners of the trapezoidal perimeter of the contact surfaces. In radiographs the undulated epiphysodiaphyseal cartilage included between

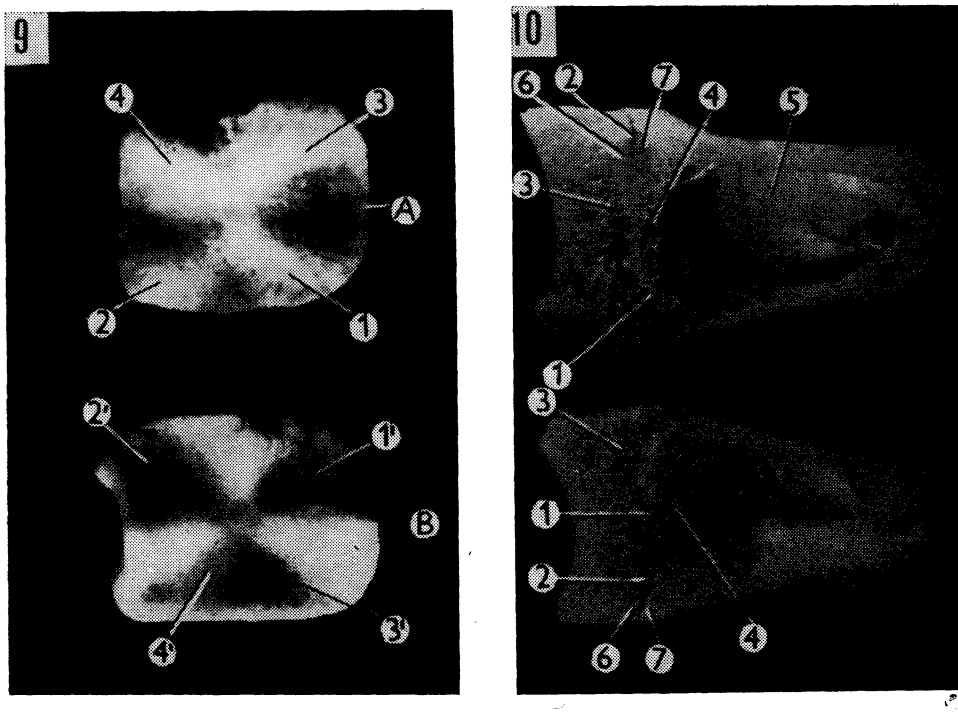
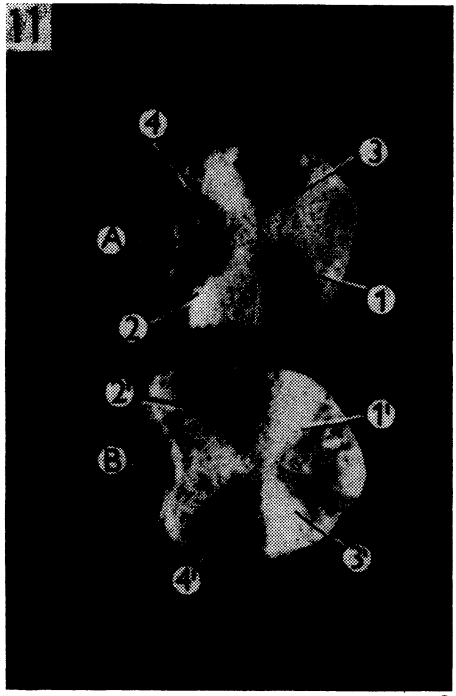


Fig. 9. View of contact surfaces of diaphyse (A) and epiphyse (B) of proximal phalanx of fourth digit of right thoracic limb of a6-month old calf. Proximal phalanx epiphyse is inverted abaxially to diaphyse.

1, 2, 3, 4 — tubercles in apexes of trapezoidal perimeter of diaphyseal contact surface, 1′, 2′, 3′, 4′ — corresponding grooves on contact surface of epiphyse.

Fig. 10. Cut surfaces of sagittally — cut proximal third phalans of digit in thoracic limb of a 20-month old bull.

1 — bony trabeculae of epiphysodiaphyseal scar, 2 — gap indicating hitherto remaining part of epiphysodiaphyseal growth cartilage after maceration, 3 — epiphyseal spongy substance, 4 — diaphyseal spongy substance, 5 — medullary cavity of diaphyse, 6 — epiphyseal and 7 — diaphyseal bony plates of epiphysodiaphyseal growth zone.



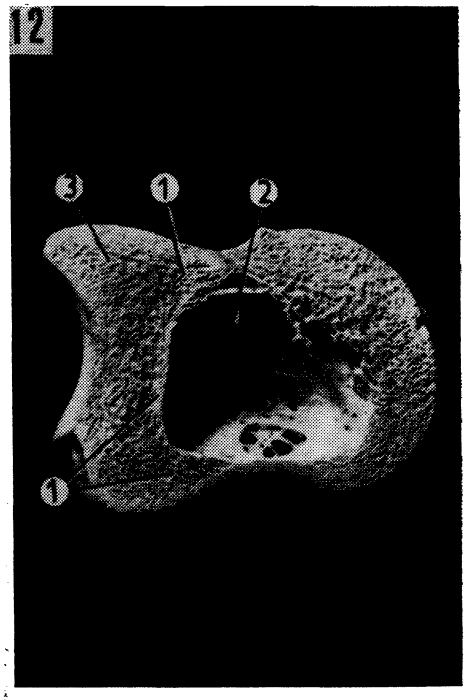
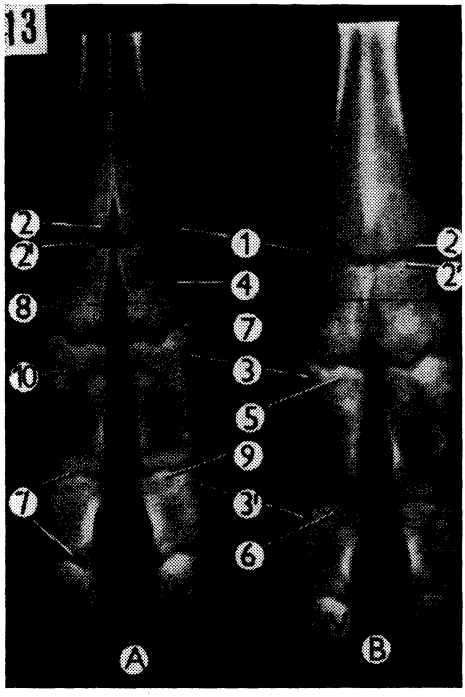


Fig. 11. — View of contact surfaces of diaphyse (A) and epiphyse (B) of middle phalanx of fourth digit in right thoracic limb of a 6-month calf. Epiphyse of middle phalanx of the digit is abaxially inverted. 1, 2, 3, 4 — tubercles in apexes of trapezoidal perimeter of diaphyseal contact surface, 1′, 2′, 3′, 4′ — corresponding grooves on epiphyseal contact surface.
Fig. 12. Sagittal cut through middle phalanx of fourth digit in right pelvic limb of 5-year old cow. 1 — unmarked epiphysodiaphyseal scar representing proximal wall of medullary cavity of bone, 2 — medullary cavity, 3 — epiphyseal spongy substance.

the above described tubercles and grooves is represented under dorsopalmar projection by two to three undulated or parallel or one-another-crossed clear lines with a marked proximally projected apex of the epiphyseal ossification centre in the middle long axis of both the third and the fourth metacarpus and/or metatarsus. The clear lines are accompanied by shadows of the epiphyseal and diaphyseal bony plates of the epiphysodiaphyseal growth zone (Fig. 17). Under mediolateral projection the RTG-picture is similar (Fig. 16).

In newborn animals the epiphysodiaphyseal growth cartilages on the metacarpus are approximately 1 cm thick, on metatarsus approximately 1.5 cm thick and in radiographs they can be seen both under dorsopalmar (dorsoplantar) and mediolateral projection. In this period of life the undulation of the growth zone is not conspicuous (Fig. 13) and dilatation of the peripheral perimeter of the epiphysodiaphyseal growth cartilage is evident. In 2-week-old calves the undulation is more marked and the clear line of the epiphysodiaphyseal growth cartilage is narrower. In older animals up to two years, too, the clear lines of the epiphysodiaphyseal growth cartilage can be well distinguished. In both positions of the epiphysodiaphyseal growth cartilage clear lines of shadows re-

presenting the diaphyseal bony plate can be seen especially on the diaphyseal side and those representing the epiphyseal bony plates on the epiphyseal side. These shadows correspond to areas with deeper discoloration on sagittal macrosections through the metapodium differently stained with alizarin red (Fig. 4). In radiographs from newborn calves the shades of the epiphyseal and diaphyseal bony plates in the epiphysodiaphyseal growth zone are not marked. They are more conspicuous in radiographs from 2-week-old calves (Fig. 14) and can be traced in radiographs till the period of epiphysis-diaphysis joining. In cattle of 2 years and a half we have radiographically recorded the initial stage of removal



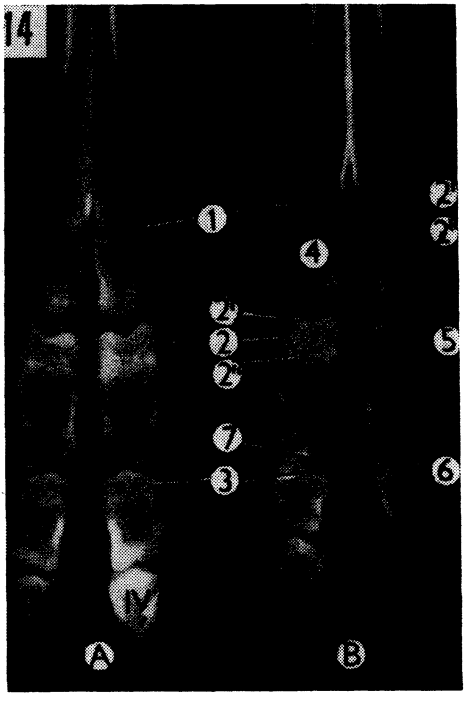
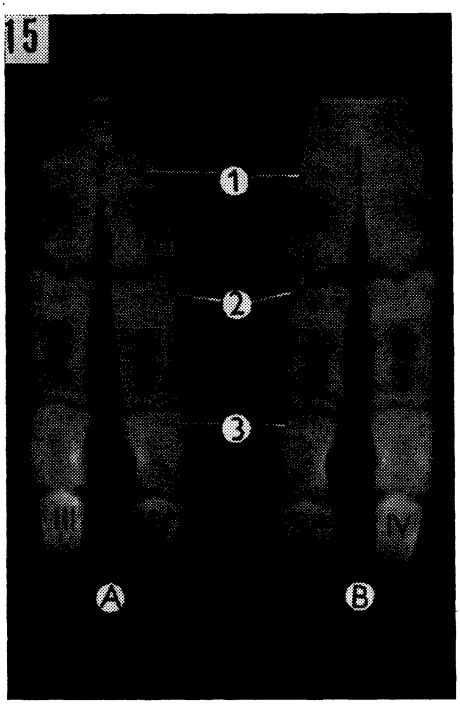


Fig. 13. Radiograph of epiphysodiaphyseal growth zones of metapodium and digit phalanges of left pelvic (A) and left thoracic (B) limbs of a new-born calf. (Plantodorsal and palmodorsal projection).

1 — cleared epiphysodiaphyseal growth cartilages of metapodia, 2 — 2′ — unmarked shadows of diaphyseal and epiphyseal bony plates of epiphysodiaphyseal growth zone of metapodium, 3 — epiphysodiaphyseal growth zone in phalanx proximalis and 3′ — phalanx media, 4, 5, 6 — epiphyses of metapodia (4), proximal (5) and middle (6) phalanges of digits, 7 — clear lines indicating joint cavities of metapodial joints and digit phalanges, 8 — ossification centres for ossa sesamoidea phalangis proximalis, 9 — processus extensorius phalangis mediae, 10 — distal prominence of epiphysodiaphyseal growth zone, III — third digit, IV — fourth digit.

Fig 14. Radiograph of epiphysodiaphyseal growth zones of metapodium and phalanges of digits in right pelvic (A) and right thoracic (B) limbs of a 2-week old calf. (Plantodorsal and palmodorsal projection.)

1, 2, 3 — clear epiphysodiaphyseal growth cartilages in growth zones, 2′ — shadow of diaphyseal and 2″ — epiphyseal bony plates of epiphysodiaphyseal growth zone, 4 — metapodial epiphyses, 5 — epiphyses of proximal and 6 — middle phalanges of digits, 7 — processus extensorius phalangis mediae.



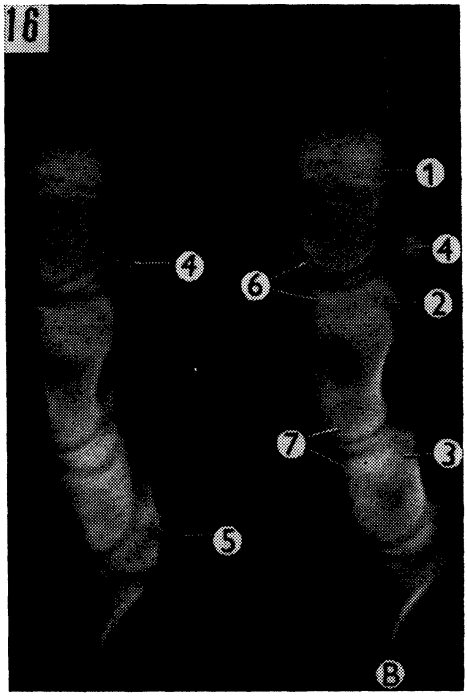


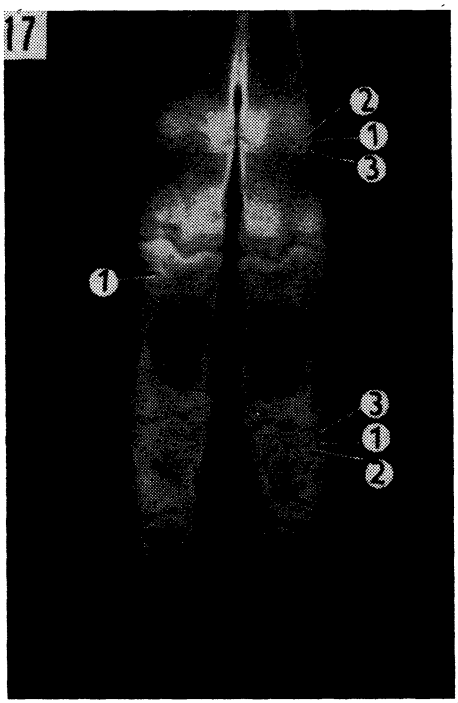
Fig. 15. Radiograph of epiphysodiaphyseal growth zones of metapodia and acropodia of right (A) and left (B) pelvic limb bones of a 1-month old calf (plantodorsal projection).
1, 2, 3 — undulated clear lines of epiphysodiaphyseal cartilage bordered with wider shadow of diaphyseal and narrower shadow of epiphyseal bony plates of metapodial (1), phalanx proximalis (2) and phalanx media (3) growth zones.
Fig. 16. Radiograph of epiphysodiaphyseal growth zones of metapodia and acropodia of right (A) and left (B) pelvic limbs of a 1-month calf under lateromedial oblique (A) and mediolateral (B) vertical projections. Clear lines of epiphysodiaphyseal cartilages are multipled and crossed one another due to oblique projection.
1, 2, 3 — epiphysodiaphyseal growth zones of metapodia (1), phalanx proximalis (2) and phalanx media (3), 4 — ossa sesamoidea phalangis proximalis, 5 — ossa sesamoidea phalangis distalis, 6 — articulatio metatarsophalangea, 7 — articulatio interphalangea proximalis.

of the epiphysodiaphyseal growth cartilage in the metacarpus. The cartilage is being gradually replaced by means of epiphyso-diaphyseal synostosis and clear lines representing cartilage can be seen in radiographs only in limited areas of the epiphysodiaphyseal growth zone (Fig. 22).

The radiographs from adult cattle aged 5, 6 and 15 years present, at the site of the epiphysodiaphyseal growth zones, shadows of concentrated osseous trabeculae deflected in accordance with the course of the previous epiphysodiaphyseal growth zones (Fig. 23). These remnants of the epiphysodiaphyseal growth zones, which are called epiphysodiaphyseal scars, are conspicouous on sagittal macrosections through the metapodia (Fig. 7). In older animals, as it can be seen on the material from a 15-year old cow, marrow cavities, owing to inner rebuilding of bones in the metapodia, develop even in the distal direction and the trabeculae of the spongy substance in this area are rebuilt to such an extent that remnants

of once active epiphysodiaphyseal growth zones — the osseous trabeculae of the epiphysodiaphyseal scar — here and there had been resorbed and in radiographs and sagittal sections of the bones they are drawn incomplete (Figs 8 and 24).

The epiphysodiaphyseal growth zones of the proximal phalanx, too, can be well traced by radiological methods. The typical undulation of the epiphysodiaphyseal growth cartilage and of the adjacent epiphyseal and diaphyseal bony plates of the growth zone is conditioned by the shape of the contact diaphyseal and epiphyseal surfaces. On the contact surfaces of these parts of the proximal phalanx, too, similarly as on the contact surface between the diaphysis and epiphysis and the epiphysodiaphyseal growth cartilage on the metapodium, four tubercles and four grooves can be seen (Fig. 9). On the distally situated diaphysis the tubercles are located, similarly as on the metapodial diaphysis, in the corners of the rectangle-shaped perimeter of the contact surface of the proximal phalanx diaphysis and epiphysis. To these tubercles correspond, matrix-like, grooves in the corners of the rectangle-shaped perimeter of the contact surface of the proximally-laying epiphysis. On the epiphyses, too, are four tubercles, but their peaks are situated approximately in the middle of the sides of the rectangle-shaped



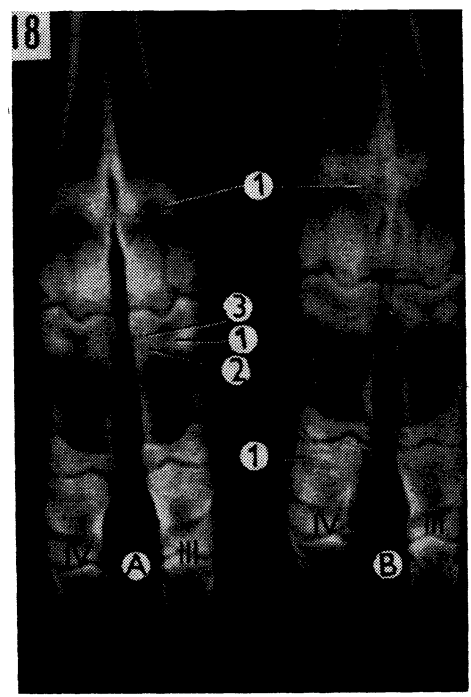
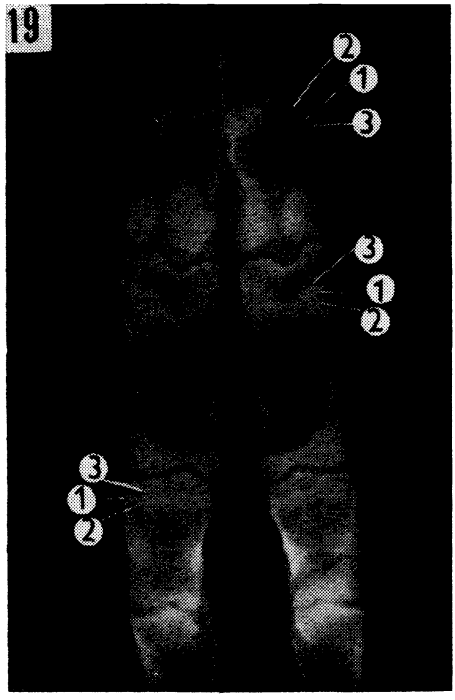


Fig. 17. Radiograph of epiphysodiaphyseal growth zones of metacarpus and digit phalanges of left thoracic limb of 3-month old calf (dorsopalmar projection).
1 — clear lines of epiphysodiaphyseal cartilages of growth zone, 2 — shadow of diaphyseal and 3 — epiphyseal bony plate of growth zone.
Fig. 18. Radiograph of epiphysodiaphyseal growth zones of metacarpal bones and digit phalanges of left (A) and right (B) thoracic limb of a 6-month calf. (Palmodorsal projection.)
For Legend see Fig. 17.



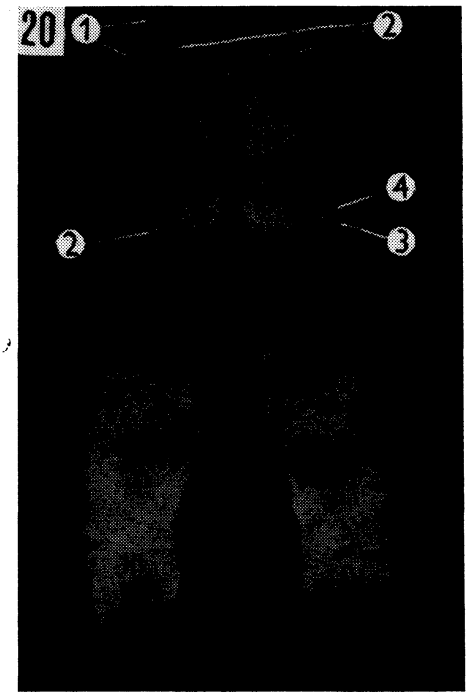


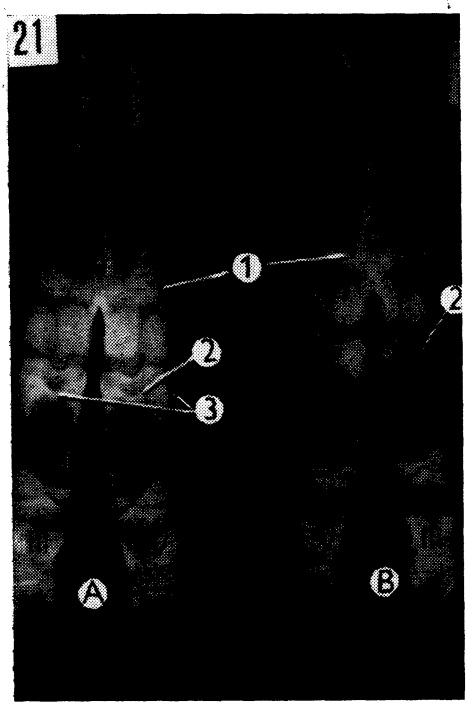
Fig. 19. Radiograph of epiphysodiaphyseal growth zones of metatarsal bones and digit phalanges of right pelvic limb of a 8-month calf. (Plantodorsal projection.)
For Legend see Fig. 17.

Fig. 20. Radiograph of epiphysodiaphyseal growth zones of metacarpal bones and digit phalanges of left thoracic limb of a 20-month cattle. (Dorsopalmar projection.)
1 — epiphysodiaphyseal growth zone of metapodium after union of epiphyses, 2 — clear lines of epiphysodiaphyseal growth cartilage, 3 — diaphyseal and 4 — epiphyseal bony plates of epiphysodiaphyseal growth zones.

perimeter of the contact surface. The dorsopalmar (dorsoplantar) as well as mediolateral projection presents the tubercles and grooves of the contact surfaces situated one behind the other, and consequently the epiphysodiaphyseal growth cartilage included between them and the parallel diaphyseal and epiphyseal bony plates are represented in the radiographs as an undulated clear line distally inclinating to the longitudinal axis of the digit phalanx and lined, along both sides, with the shadow of the epiphyseal and diaphyseal bony plates of the epiphysodiaphyseal growth zone. The line of the epiphysodiaphyseal growth zone of the proximal phalanx in the radiographs under dorsopalmar (dorsoplantar) projection appears parallel to the joint groove line of the phalanx basis. In newborn as well as in older animals the undulated line of the epiphysodiaphyseal phalanx of the digit can be well distinguished and the projection of the diaphyseal and epiphyseal bony plates is getting more contrast with increasing age. The epiphyseal bony plate produce a narrower and more marked shadowy line, while the diaphyseal bony plate is represented as wider diffuse shadow. At the age of 20 months, when partial removal of the epiphysodiaphyseal growth cartilage was recorded, these bony plates were here and there synostically joined in a higher

degree, or, after total destruction of the cartilage, their union was complete (Figs 10 and 21). In the radiographs, the epiphysodiaphyseal growth zone at this developmental stage is represented by a more conspicuous shadow of irregular width and sporadical clear slot-like points of residual cartilage (Fig. 21). In older animals, i. e. two or more years old, epiphysodiaphyseal scars (Fig. 22) can be seen in the area of the epiphysodiaphyseal zone in the radiographs. With increasing age, the demarcation line of the epiphysodiaphyseal scar is, similarly as in bones of the metapodium, obscure due to the rebuilding that had occurred in the bones (Figs 23 and 24).

The epiphysodiaphyseal growth zones of the middle phalanges of the digit show undulated course in the radiographs as do the epiphysodiaphyseal growth zones of the proximal phalanges of the digits. This similarity results from the



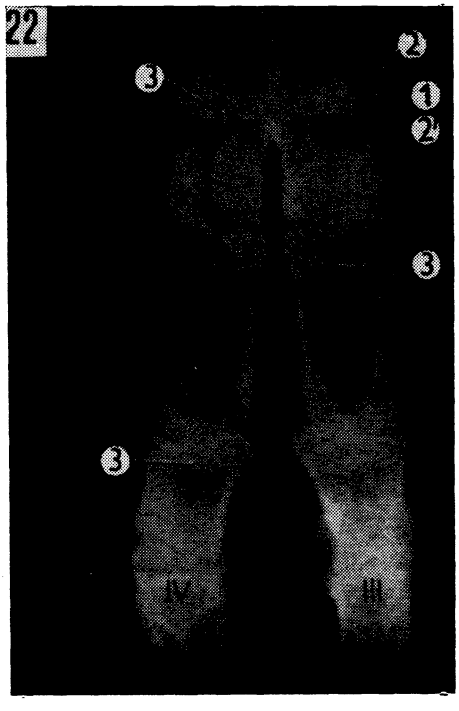
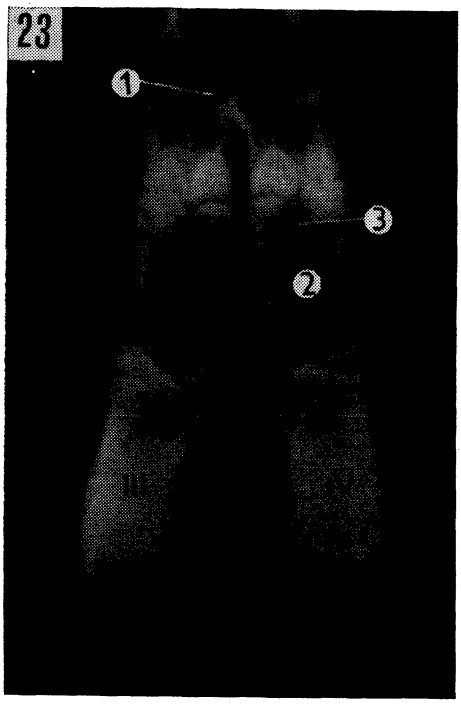


Fig. 21. Radiograph of epiphysodiaphyseal growth zones of metapodia and digits of left thoracic (A) and right pelvic (B) limb of a 20-month bull. (Dorsopalmar and dorsoplantar projection.) 1 — in epiphysodiaphyseal growth zones of metapodia growth cartilages are fully preserved, 2 — in epiphysodiaphyseal growth zones of digit phalanges in pelvic limb cartilage is removed and clear lines of cartilage is replaced by shadow of concentrated bony trabeculae of "epiphysodiaphyseal scar" where synostosis of epiphysis and diaphysis takes place, 3 — slot-like clearing in epiphysodiaphyseal growth zone of proximal phalanx of third and fourth digit in thoracic limb indicating remnants of epiphysodiaphyseal cartilage.

Fig. 22. Radiograph of epiphysodiaphyseal growth zones on metacarpus and phalanx of digits of left thoracic limb of a two-and-half years old cow. (Palmodorsal projection.) 1 — clear lines of remnants of epiphysodiaphyseal growth cartilage along perimeter of growth zone, 2 — diaphyseal and (2′ —) epiphyseal bony plates of growth zone fused after destruction of growth cartilage to form (3 —) concentration of osseous trabeculae of epiphysodiaphyseal scar.



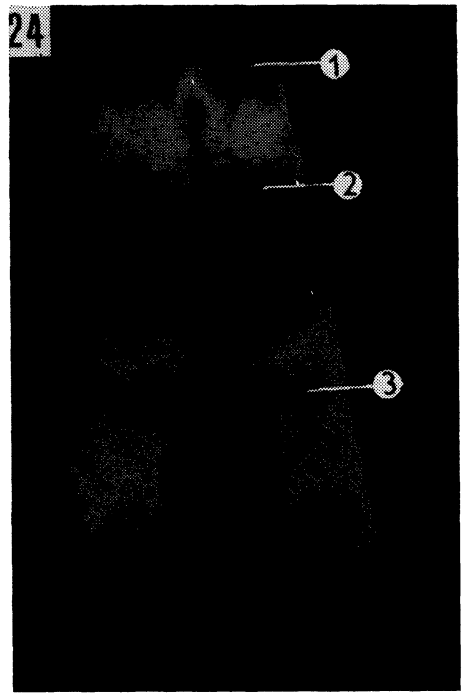


Fig. 23. Radiograph of distal end of left thoracic limb of a 6-year old cow. (Dorsopalmar projection.) 1 — osseous trabeculae of epiphysodiaphyseal scar of metacarpus to match line of epiphysodiaphyseal growth cartilage; 2 — rebuilding of inner structure in phalanx proximalis during postnatal development results in development of medullary cavities and 3 — partial resorption of osseous trabeculae of epiphysodiaphyseal scar.
Fig. 24. Radiograph of distal end of left pelvic limb of a 15-year old cow. (Dorsoplantar projection.) 1 — markedly resorbed osseous trabeculae of epiphysodiaphyseal scar of metatarsal bones and (2 —) proximal and (3 —) middle phalanges of digits due to inner rebuilding of bone.

similar shape of the contact surfaces of the diaphysis and epiphysis of the middle phalanx of the digit which include epiphysodiaphyseal growth cartilage as it is on the proximal phalanx of the digit (Fig. 11). The tubercles, however, are almost half lower and the grooves half shallower, their localization being correspondent. The dorsopalmar (dorsoplantar) projection of the epiphysodiaphyseal growth cartilages, too, is represented in radiographs as clear line slightly undulated along the phalanx perimeter and distally concave in the phalanx axis. The clear line of the epiphysodiaphyseal growth cartilage, too, is bordered by shadows of the epiphyseal and diaphyseal bony plates. The distal flection of the epiphysodiaphyseal growth zone line of the middle phalanx of the digit is, due to lower tubercles and shallower grooves, less conspicuous than on the proximal phalanx of the digit. The sagittal ridge of the joint groove of the middle phalanx basis is terminated by a proximally-projecting extensor process on the dorsal side. This joint groove ridge and the extensor process of the middle phalanx of the digit is represented in radiographs as a proximally-projecting antipole to the distal flection of this growth zone (Fig. 14). Under mediolateral projection, the RTG-picture of the epiphysodiaphyseal growth zone in the middle phalanx of the

digit conforms with that in the proximal phalanx, except the shallower distal flection. If X-rays pass at oblique angle to the epiphysodiaphyseal growth zone plane, all details on the uneven contact surface of the epiphysis and diaphysis are drawn separated and thus the undulated shape of the epiphysodiaphyseal growth zone is represented in the radiographs as two or more clear and shadowy lines deposited one above the other. A similar situation can be also found in the phalanx proximalis. The finding reported here was recorded in radiographs of animals aged from birth to the period when the epiphysodiaphyseal growth cartilage was disappearing. In the animals of 20 months or more, epiphysodiaphyseal scars were observed in the epiphysodiaphyseal growth zone; these scars, however, were not marked because no larger central marrow cavity is produced in the middle-phalanx epiphysis, as it is in the epiphysis of the proximal phalanx of the digit and the metapodia, which would contribute to better contrast of massed bony trabeculae of the epiphysodiaphyseal scar. In adult cattle, owing to rebuilding of bones during postnatal development, the bony trabeculae of the epiphysodiaphyseal scar get into direct contact with developed diaphyseal marrow cavity (Fig. 12) and during further bone rebuilding they gradually fuse with the spongious substance of the proximal end of the phalanx, so that they cannot be well distinguished in radiographs as well as sagittal macrosections through bones.

Discussion

The studies concerned with disorders in mineral metabolism of cattle have faced a number of unexplained problems associated with skeleton morphology. The problem of topographoanatomic and radiologic knowledge of growth zones in the skeleton in the postnatal developmental period represents one of these problems.

McCallum et al. (1970) have emphasized importance for clinical diagnosis of knowledge of ossification centres and growth sites on the skeleton. Of major importance in this respect is the knowledge that can be employed in clinical and laboratory examination of farm animals kept under large-scale farming conditions. Besides a number of biochemical and clinical laboratory methods radiologic examination of the skeleton must also be considered. Thus not only more complete view of skeleton health can be obtained, but also of the stage of its development and maturity. The epiphysodiaphyseal growth zones in the skeleton of domestic mammals have been neglected both in anatomic and radiologic studies, although marked morphologic changes occur in these areas during the development of an individual. We have succeeded in recording these changes even in radiographs. The literature dealing with origination of ossification centres in different bones of cattle (Küpfer and Schinz 1923; Vokken 1950; Fedrigo 1957; Vokken and Tarasov 1968 and Lindsay 1969) presents chronological survey of ossification onsets in bones and is of basic importance for determination of skeleton maturity of an individual both in fetal and postnatal developmental periods. Nevertheless it has not contributed to the knowledge of growth zones. Of more importance in this respect are literature data on dissappearance of growth epiphysodiaphyseal zones on the skeleton (Kolda 1936; Vokken and Tarasov 1968). However the authors have mostly stated chronological sequence of destruction of growth zones but they have not given more details of anatomic and radiologic conditions. Microscopically, these sites have been studied in greater details (Haines 1975). In one case we recorded the period of disappearance of

growth zones of the metapodium in an animal aged 2 years and a half and on proximal phalanges of the digits in three animals at the age of 20 months after birth. Chronologically, this time is in accordance with the data of Kolda (1936) and Barone (1966). The radiographic findings were also confirmed on osteologically treated osseous material from the same animals. Burt et al. (1968), it is true, carried out radiological studies of the growth zones on young cattle limbs, however they have solely listed ossification centres and growth cartilages that are radiologically detectable on the limbs. Although Binev et al. (1970) described normal RTG-picture of limb bones and joints in calves, they have not described the epiphysodiaphyseal growth zones of different bones in detail and they have only given a general description of the RTG-picture of limb bone epiphyses. We have tried to study the epiphysodiaphyseal growth zones in the postnatal ontogenetic period and on the basis of comparison of radiographs with the anatomic conditions on the processed topographic and osteologic preparations from the same animals, and, to detect macromorphologic alterations in the structure as well as in radiographs.

Localization of the epiphysodiaphyseal growth zones in the autopodium and proximal and middle phalanges of the digits in our investigations was determined with the aid of external orientation points on a live animal. The orientation points settled can be utilized for routine clinical examination of these parts of the skeleton as well as for eventual experimental interventions in the growth epiphysodiaphyseal zone and for taking bioptates from these parts of the skeleton.

Although a number of authors have studied the RTG-picture of limb skeleton development in different animal species both in prenatal and postnatal period (Bressou et al. 1957, 1959; Schmidt 1960; Szemes 1962; Nowicki 1972, 1975, etc.), they have not dealt in their studies with the epiphysodiaphyseal growth zone. Developmental knowledge in the literature of macrostructure and the RTG--picture of the cattle limb skeleton during postnatal development is only fragmentary and is limited to some parts of the limb skeleton (Funk 1966; Simon 1963) or to early postnatal periods (Burt et al. 1968; Binev 1970). In radiological studies the epiphysodiaphyseal growth zones radiographs mostly are merely stated (Carlson 1967; Morgan 1972) without presenting a detailed description of these important parts of bones. Nor data on developmental changes in the morphological structure and the RTG-picture of the epiphysodiaphyseal growth zones in cattle are available. In this respect we have tried to contribute to this knowledge of the period from birth to adult age.

There is no uniform nomenclature concerning the sites of longitudinal growth of long bones at the level of the epiphysodiaphyseal border. Such denomination, no doubt, must include the site from which an intensive cell proliferation arises, i. e. the epiphysodiaphyseal cartilage or the fibrous plate and also areas where young osseous tissue arises and is rebuilt. They are areas adjacent to the epiphysodiaphyseal growth cartilage and growth fibrous plate denominated as epiphyseal and diaphyseal osseous plates (Hasselwander 1910; Haines 1975) which can be microscopically differentiated as parts of calcified cartilage, erosion line, osteoid and ossiform parts of the adjacent secondarily-rebuilt bone trabeculae at the diaphyseal side, and, substantially the same parts, but considerably reduced except the massed bone trabeculae, at the epiphyseal side. For these differentiated areas ensuring longitudinal growth of long bones we have chosen a summary denomination „epiphysodiaphyseal growth zone". This denomination is substantiated both for the epiphysodiaphyseal growth zones where it is the cartilage that

represents the proliferating tissue and for the epiphysodiaphyseal growth zone described by Smith (1962) where it is the fibrous tissue that represents the proliferating element.

In this growth zone we could macroscopically and radiologically differentiate the epiphysodiaphyseal cartilage and the adjacent epiphyseal and diaphyseal bony plate, and, at the same time we could detect anatomic as well as radiologic changes in these of the epiphysodiaphyseal zone in the course of postnatal development. The shading size of the epiphysodiaphyseal growth cartilage and its contrast along both sides of the clear line depends on the content of radiologically-contrast mineral elements in these areas of the epiphysodiaphyseal growth zone. Oblique projection of X-ray produces that clear lines of the epiphysodiaphyseal cartilage appear multiple and laying one above the other or even crossed one another. It must be taken into account that under lateral projection the projection of the epiphysodiaphyseal zones of the two digits will overlap one another. Of interest is comparison of alizarin-red-stained macrosections through the metapodium and the digits with the radiographic findings. Darker and deeper discoloration of the bone trabeculae in the epiphyseal and especially diaphyseal bony plate areas corresponds to the shadows in the radiographs observed in the same areas of the epiphysodiaphyseal growth zone. This discoloration indicates a higher massing of the spongions substance trabeculae and a higher content of calcium salts to which alizarin red shows a specific affinity (Lillie 1965; Puchtler et al. 1969).

Conclusion

We have studied localization of the epiphysodiaphyseal growth zone on the skeleton of the metapodium and acropodium in cattle and possibility of their tracing during experimental and clinical interventions. By using anatomic and radiologic methods we have studied and described macroscopic changes in the area of growth zones in the metapodium and acropodium in the postnatal developmental period. The results were obtained from 79 clinically healthy animals of the Czech Red-Spotted cattle aged from birth till the age of 15 years.

We are proposing the denomination „epiphysodiaphyseal growth zone" for the longitudinal growth sites in long bones. The epiphysodiaphyseal growth zone includes the epiphysodiaphyseal growth cartilage and diaphyseal and epiphyseal bony plates. These are well distinguishable on anatomic macrosection through bones as well as in radiographs.

The epiphysodiaphyseal growth cartilage is represented in radiographs by an undulated clear line. Along this clear line, parallel shadows of the epiphyseal and diaphyseal bony plates can be seen. The epiphyseal bony plate is represented by a narrow contrast shadow with sharp boundaries and the diaphyseal bony plate is indicated by a wider difuse shadow.

Localization of the epiphysodiaphyseal zones in the metapodium and proximal and middle phalanges of the digits of calves and juvenile cattle was determined with the aid of external orientation points on a live animal. Access for eventual intervention in the epiphysodiaphyseal growth zone of the metapodium and acropodium in calves is proposed from the dorsoabaxial side at the levels of settled orientation points, with necessary correction in the juvenile cattle.

By means of comparison of radiographs and osteologically processed preparations of the cattle metapodium and acropodium skeleton we described a typical

RTG-picture of different parts of the epiphysodiaphyseal growth zones in the metapodium and proximal and middle phalanx of the digit.

During postnatal developmental period, with increasing age of the animal clear lines indicating the epiphysodiaphyseal growth cartilage in the radiographs get narrower and the shades of the epiphyseal and diaphyseal bony plate are more marked. The RTG-picture of the epiphysodiaphyseal growth zones does not change more subtantially until the period of partial destruction of the cartilages in the growth zone after complete union of the diaphysis and epiphysis.

In the period of partial destruction of the epiphysodiaphyseal growth cartilages the clear line indicating the epiphysodiaphyseal growth cartilages is here and there interrupted by shadows of the synostotic union of the epiphysis and diaphysis.

After total destruction of the epiphysodiaphyseal growth cartilage, shadows of bone trabeculae of the epiphysodiaphyseal scar were described in the radiographs. These scars gradually disappear in accordance with increasing age due to inner rebuilding of bones.

Epifýsodiafýsární růstové zóny metapodia a akropodia skotu v postnatální ontogeneze

Anatomickými metodami a rentgenologicky jsme prostudovali a popsali makroskopické změny v epifýsodiafýsárních růstových zónách metapodia a akropodia u skotu v postnatálním období vývoje. Výsledky jsme získali na 79 jedincích klinicky zdravého skotu červenostrakatého plemene ve věku od narození do 15. roku. Umístění epifýsodiafýsárních zón na metapodiu a akropodiu u telat a juvenilního skotu jsme vymezili pomocí zevních orientačních bodů na živém zvířeti. Navrhujeme možnosti jejich dosažení při experimentálních a klinických zákrocích. Na základě srovnání rentgenogramů a osteologicky zpracovaných preparátů jsme popsali typický rentgenový obraz jednotlivých částí epifýsodiafýsárních růstových zón metapodia a proximálních a středních článků prstů. Na ontogenetické vývojové řadě postnatálního období vývoje jsme sledovali změny na rentgenovém obraze a v makrostruktuře epifýsodiafýsární růstové chrupavky a diafýsární a epifýsární kostěné ploténky. Zánikem epifýsodiafýsární růstové chrupavky se epifýsodiafýsární růstová zóna mění v epifýsodiafýsární jizvu, která v důsledku vnitřní přestavby kosti postupně mizí.

Эпифизео-диафизарные зоны роста метаподия и акроподия крупного рогатого скота в период постнатального онтогенеза

Анатомическими методами и рентгенологически были нами исследованы и описаны макроскопические изменения в эпифизео-диафизарных зонах роста метаподия и акроподия рогатого скота в постнатальный период развития. Результаты были нами получены на 79 клинически здоровых коровах Красно-пестрого племени в возрасте со дня рождения до 15 лет. Расположение эпифизео-диафизарных зон на метаподии и акроподии телят и молодняка были нами определены с помощью наружных ориентировочных точек на живом животном. Предлагаются возможности их достижения в ходе экспериментальных и клинических вмешательства. На основе сравнения рентгенограми и остеологически обработанных препаратов нами было описано характерное рентгеновское изображение отдельных частей эпифизео-диафизарных зон роста метаподия и основных и средних фаланг пальцев. На онтогенети-

ческом ряде развития поснатального периода нами наблюдались изменения рентгеновского изображения и макроструктуры эпифизео-диафизарного хряща роста и эпифизарных и диафизарных костных пластинок. Исчезновением эпифизео-диафизарного хряща роста меняется эпифизео-диафизарная зона роста в эпифизео-диафизарный рубец, которы вследствие внутренней перестройки кости постепенно исчезает.

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