PATTERNS OF OSSIFICATION IN THE FELINE FOETUS

A study of the foetal development of the skeleton
of the feline using comparative methods

Two volumes

VOLUME I

by

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INTRODUCTION.

The development of the bones of the foetus has been recorded in the literature since before the sixteenth century, when Coiter's "Anatomical Treatise on the Bones of an Aborted Foetus of a Six-month-old Infant", (Herrlinger '51) stimulated interest in this work on human material. In the succeeding centuries the amount of interest in human foetal skeletal development increased and the methods of investigation developed along three main streams, (a) histological examination of serial sections both with and without histo-chemical processing (b) clearing of the specimen, both with and without subsequent staining *e.g.*, alizarin red S (c) radiography, both with and without metallic impregnation to increase radiopacity.

The use of alizarin red stain (sodium alizarin sulphonate) to colour bone was originally devised from experiments using madder fed to animals to stain bone red. Such uses are recorded as early as the sixteenth century by Lemnius (1581) and after by Belchier (1736). In the earlier experiments the madder was fed as the vegetable root (*rubia tinctorum*) but from this root there was later extracted the dye alizarin (Cameron, 1932) which had been combined in glucose combination as ruberythric acid. Later procedures involved the clearing of embryos with caustic and glycerin, being cited by Beale (1858) using NaOH and glycerin, and by Schultze (1897) who used KOH for clearing. Later workers such as Lundvall (1905), Dawson (1926) and Hollister (1934) evolved techniques for both staining the bones with alizarin red S and clearing the soft tissues using KOH. The technique of Hood and Neil (1948) will be described later in the text.

Radiographic studies of foetal skeletal development can be traced back to the work of Bade (1900) which is remarkable in that it appeared only five years after the discovery of X-rays. The use of X-rays for the detection of the foetal skeleton has been faulted (O'Rahilly and Meyer, 1956) for the lack of contrast found on the radiographs between the foetal skeletal elements and surrounding soft tissues, particularly in early foetuses. However, impregnation with heavy metal salts as described by Hodges (1953) has improved upon the deficiency in contrast by enhancing the radiopacity of the foetal skeleton. This is produced by a partial replacement of calcium by silver. It is known and reported that silver nitrate is not strictly specific for calcium but is only a means of demonstration of a deposit of inorganic material which is in fact in most instances composed of calcium phosphate or carbonate. This is stated by Cameron (1930) who further comments that, as it happens that insoluble phosphates or carbonates are nearly always those of calcium, the test is usually regarded as sufficiently specific for this element. It is also true that alizarin is also not specific for calcium, (Pearse, 1953), in that the surrounding soft tissues may be involved.

However, O'Rahilly and Meyer (1956) show in their work on human foetuses that soft tissue impregnation did not interfere with the detection of the skeleton. They further found that, in foetal material, the most critical method of detecting osseous tissue was histological but that the difference in time of detection using alizarin staining and silver impregnation with radiography was not great. In a later report Meyer and O'Rahilly (1958) observed that when an initial positive response was obtained with alizarin red S or silver nitrate this coincided fairly closely with the formation of the periosteal collar. They observed that silver nitrate was deposited not only in the circumferential osseous areas but also in the calcified cartilage in the centre of the shaft. The deposition of alizarin red S appears to be similar in nature, according to the description of Zawisch (1956).

It is the intention of this thesis to produce a study of the bony development in the feline foetus throughout its entire foetal life to parturition, based on the use of these three main methods of examination. The findings obtained by the various methods are correlated and an attempt made to assess their suitability and accuracy for detecting and measuring subsequent bone growth.

In the literature of the study of osteogenesis of the cat there is comparatively little to be found concerning the foetal stage of development. In 1845, Strauss-Durckheim described in his "Anatomy of the Cat", the centres of ossification for the skeleton but gave no particular attention to foetal development. In 1881, Mivart St. George, in his treatise on the development of the cat, described the emergence of the skeleton from embryonic stage through foetal growth. In this work, a sequence of growth is revealed as well as the derivation of the primary structures. Also a list of centres of ossification is compiled but no precise dates of appearance are given.

Lesbre, in his notable communication on the anatomy of mammals presented at Lyons in 1897, described the general conceptions of the time regarding the order and mode of appearance of the centres of ossification in the domestic animals. Some reference is made to the cat but most of the information is related to the dog. Again the description is more of the pattern of ossification and little detail is given on particular times of appearance. Jayne's "Mammalian Anatomy" 1898 gives a comprehensive description of the centres of ossification of the complete skeleton. Jayne comments on centres present at birth and gives line drawings of some bones as they are at birth.

In all the preceding works the findings were from observations made on gross dissection material and light microscopy. With the use of alizarin red staining Schaeffer in 1932 ascribed dates for times of appearance of the centres of ossification in the appendicular skeleton of the feline foetus. This study was also carried out on other species. Schaeffer was able to relate crown-rump measurements to post-coital dates thus giving a fairly accurate assessment of the times of appearance. This was followed in 1933 by the work of Drews in which the foetal development of the skull was studied. Again, this last work was based on results of alizarin red staining. Bourdelle and Bressou 1952, in their text book of the anatomy of the dog and cat, describe the numbers of centres of ossification for some bones of the skeleton but only give times for post-natal development. Bressou et al., produced two articles in 1959 in which radiographic studies were applied to the development of the manus and pes of the cat. Here these two regions are described as they appear on radiographs of kittens, taken at birth. Hare (1959) gives an illustrated description of the radiographic appearance of the adult skull. The most recent radiographic work is that carried out by Smith and published in 1968 and 1969, when the development of the appendicular skeleton of the kitten is progressively described from birth, both as individual bones and as part of the skeleton as a whole. Those centres present at birth are described and illustrated by tracings of radiographs.

This thesis is the first time that a description has been given of the radiographic appearance of the development of the feline foetal skeleton either in the foetus in its natural state or impregnated with silver nitrate. The development of the appendicular skeleton and skull has been described using alizarin red staining but the number of litters used was limited i.e., 28 litters by Schaeffer (1932) and 25 litters by Drews (1933). The number of litters studied in this work is 90 of which 60 were stained with alizarin red. Also a description is given here of the development of the vertebral column, ribs and sternum, which is the first time that this region has been reported on in detail.

MATERIALS AND METHODS

For this study two groups of foetuses were used. The majority of the foetuses were obtained without known conception dates and thus their foetal age in days of gestation had to be calculated. This collection will be referred to as Group A.

A further collection of foetuses with known conception dates was made, and thus the age of gestation of each foetus was accurately known. This collection will be referred to as Group B.

GROUP A.

The foetuses of Group A were from 90 litters and the total number of individuals was 288. The foetuses were mainly obtained from the uteri of recently killed cadavers while others arrived at the department in either 10% formalin or 75% alcohol. Others, yet again, were obtained by caesarian section from pregnant female cats which had unknown mating dates. Those foetuses which were viable were overdosed with sodium pentobarbitone given intraperitoneally. The foetuses were measured for crown-rump length and were also weighed. As the preserving media varied in individuals, whilst some were fresh, the weights were not used in the assessment of the ages of the foetuses. Crown-rump measurements, and the assessed ages (i.e., time since mating) are shown in Table I. Any individual which was obviously malformed or grossly smaller than its litter mates was discarded.

Windle and Griffen (1931), Windle and Fish (1932) and Windle, O'Donnel and Glasshagle (1933), give, in their articles, tables of c.r. measurements of feline foetuses and where known, times since mating of the mothers of those foetuses. Farris (1950) has assimilated these figures and, by contributing a number of his own findings, has compiled a list of c.r. measurements and corresponding times since mating. These measurements are used in this study to give an approximate age to the foetuses under investigation. A further list of c.r. measurements of foetuses of known conception dates was made to determine the accuracy of the previous system of ageing.

The foetuses of each litter were radiographed in both lateral and dorso-ventral positions, using fast non-screen film. The Ma.s. ranged from 15-28 with a variation in K.v. of 38-48. The variation depended on the density of the foetus. The film-focal distance was 39 ins. In order to increase the radiopacity of the developing centres, 51 foetuses from 42 litters were impregnated with an aqueous solution of silver nitrate as described by Hodges (1953). The technique commences with fixation of the foetus for approximately 48 hours in 95% alcohol. It is then transferred to an aqueous solution of silver nitrate, 0.5% (volumetric). After two or three days of immersion in silver nitrate, there is partial replacement of calcium by silver in the extremities of the primary ossification centres, and eventually throughout all the calcified parts of the skeleton. Little silver is deposited in the soft tissues unless the immersion is continued for a prolonged period. The specimens were radiographed after impregnation using similar readings to those already described. After radiographing the entire foetus, the heads were removed and radiographed separately in lateral and dorso-ventral positions. The heads were then either sectioned in the median plane and the two halves radiographed or had the mandible and dome of the cranium removed to allow clearer dorso-ventral images to be obtained. If the number of foetuses in a litter allowed, both these sections were carried out in representatives from each litter.

Where numbers permitted, a foetus from each litter which was received in the fresh state was stained by the alizarin red S technique (Hood and Neil, 1948) and examined under a dissection microscope. The specimens were photographed either directly or through the microscope depending on the size of the structure examined. The staining technique is as follows, being that described by Hood and Neill (1948), except for a degree of variation in times in stain, and in solutions. The foetus is first eviscerated and, in the case of a larger specimen, skinned entirely. The specimen is then kept in 95% alcohol for 24 hours before being transferred to 2% KOH. The period for immersion in this solution varies from 1 - 3 days depending on the size of the foetus. It is then transferred to a container of 1 - 10,000 Alizarin Red S in 2% KOH for 6 - 8 hours before returning to 2%KOH for 24 hours. Two solutions are prepared as follows:

Solution I	2% KOH	150 cc.
	0.2% Formalin	50 cc.
	Glycerin	300 cc.
Solution II	2% KOH	100 cc.
	Glycerin	400 cc.

The specimen is first placed in solution 1 for 2 to 5 days at room temperature, the solution being replenished once during this interval, and then in solution II for the same period of time and at the same temperature with a similar replenishment of the solution. After this the specimen is left in glycerin until fully cleared, replacing the glycerin if necessary. The specimens are finally stored in fresh glycerin.

Meyer and O'Rahilly (1958) state that the first positive reaction with the alizarin method and the first signs of appearance of increased opacity on radiographs coincide fairly closely with the laying down of the periosteal collar which is detected histologically. Therefore these methods do not demonstrate the onset of true endochondral ossification, i.e., the appearance of a centre of ossification which is said to be constituted only when the osteogenic cells, osteoblasts and capillaries invading from the periosteal collar reach the interior of the mid-section of the cartilage model (Ham, 1965).

To clarify this point and to enable establishment of the time difference between the first positive reaction with the alizarin red method, the silver nitrate impregnation method and the true onset of a centre of ossification, foetuses from 35 litters were examined histologically. The specimens were fixed in 10% formalin and then, after washing, placed in a solution of 35 parts 90% formic acid and 65 parts 20% sodium citrate. This brought about decalcification of the specimen, the time of immersion varying with the foetal age of the specimen. The average time was 14 days. The specimens were then processed and embedded in paraffin wax before sectioning at 7μ thickness. Every 25th. section was mounted and stained with H. and E. Where the number of foetuses per litter allowed, the sections were made in three planes, i.e., transverse, frontal and parasaggital. Histological examination helped to determine the type of ossification and the time of onset of that process, except in the skull where only the type of ossification was observed due to insufficient suitable specimens being available for judging the time of onset by histological methods. See Appendix II

Thus, in this study a positive reaction with either the alizarin red technique or first sign of opacity on a radiograph, either with or without silver impregnation, is taken to represent the onset of ossification, the nature of the type of ossification, where possible, having been observed on histological section. Using these methods of examination the development of the bony structures of the foetuses is described and illustrated in detail and recorded in tabulated form. The skeletal system, for purposes of description is divided into three sections, the appendicular skeleton, the axial skeleton without skull, and the skull, including the mandible.

In cases where the litter was to be removed from an intact pregnant cat, the mother was radiographed in order to obtain exposures of the foetuses <u>in utero</u>. The number of female cats thus examined was 47, of which the majority were freshly killed cadavers, the remainder being still alive. Both lateral and ventro-dorsal exposures were taken of the abdominal region, using fast non-screen film with a K.v. of 65 and Ma.s. 30. Film-focal distance was 39 ins. The ages of the foetuses removed from the uteri were subsequently calculated as previously described and thus a date of gestation could be given to correspond to the radiographs of the pregnant females. The radiographs of the adult female cats were examined for the appearance, size and position of the uterus and for the presence of foetal skeletal elements. The chronological order of the appearance of the skeletal elements was recorded and tabulated. When a bony element of a foetus was recorded as visible on the radiograph of the pregnant mother, the radiograph of the individual foetuses taken from the uterus of that mother was consulted to confirm that the bony element was actually visible in the foetuses. Once a skeletal segment was noted within the pregnant cat, its repeated presence was checked in subsequent radiographs of later pregnancies.

GROUP B.

The foetuses of Group B were of known conception date. A group of adult female domestic cats were kept in an enclosed cat house, being a room 10ft x 14ft. with a large area of window space. The females were allowed free range within the room and were fed a diet of fresh uncooked meat when this was available, supplemented by tinned meat. They were provided with full cream evaporated milk which was diluted by 50% water. The milk contained 33 i.u.'s of Vitamin D per fluid ounce. The room was ventilated by open roof grills and by an extractor fan, while artificial heat was provided on a thermostatic control to maintain a constant ambient temperature of $60^{\circ}C$. The lighting was controlled by a time switch to supplement normal daylight variation so as to provide a constant 16 hours of illumination in every 24 hours. The females were observed daily for signs of oestrus e.g., rolling and adopting a praying position with "padding" of the fore-paws. Such a female was removed from the house and liberated in a smaller cage which was divided by a median partition. A mature entire male domestic cat was placed in the other section of the cage and after about one hour the partition was withdrawn so that coitus could take place. The female was left with the male for 48 hours before returning to the larger cat house.

The pregnant females were selected at specific days of gestation and radiographed on that day. Both dorso-ventral and lateral projections were taken using fast non screen film with K.v. 65 and Ma.s 30. Film focal distance was 39 ins. The females were then anaesthetised by intravenous thiopentone and maintained on halothane using a Boyle's closed circuit anaesthetic apparatus. The foetuses were removed from the uterus using either a ventral mid-line or lateral flank incision. The foetal membranes were removed if they detached easily but were allowed to remain if there was risk of undue haemorrhage. The operational sites were sutured using chromic cat-gut in the uterine wall and monofilament nylon in the abdominal wall and skin. Procaine penicillin 150,000 i.u. was given intramuscularly on each of the first three days post-operatively. The same females were used for such purposes on up to four occasions, the site for the operation being varied in each case. It was common to find omental adhesions at the site of previous uterine incisions, but these were slight and easily broken down. On each successive operation the cat-gut was found to have been reabsorbed from the uterine wall.

The foetuses obtained in this manner were measured for C.R. length as given in table 2. The foetuses in each litter were all radiographed and then, where numbers per litter allowed, subjected to the same processes for examination as the foetuses of Group A, using the same techniques. A list of the number of litters and their foetal ages is given in table 2. The purpose of obtaining foetuses thus is to allow assessment to be made on the osteogenesis of the foetuses in Group A by comparing the results of Group A with those of foetuses of known foetal age from group B.

RESULTS

The observations made on the foetuses of Group A after processing with the described methods are given in the following section.

The estimated day of gestation is given along with the C.R. length by which the estimation was made. However, when a structure makes its initial appearance in a foetus, the estimated day of gestation and the mean C.R. length of the litter are recorded as well as the method of preparations of the specimen. Although each different method may reveal this development on the same estimated day of gestation; the C.R. length is not necessarily the same due to the variation of sizes noted above. This arises since not every litter had enough foetuses to be examined by all four methods.

The illustrations were selected to demonstrate several points and therefore were not necessarily that of the specific litter mentioned in the text at that point.

Each bone is described separately along with the relevant historical findings and conclusions.

OSSA MEMBRI THORACICI

Clavicula.

Jayne (1898) notes that the clavicle is developed in membrane from a single centre of ossification. Schaeffer (1932) verifies its presence in a foetus of 4.6 cm. C.R. (28 days P.C.) while Smith (1968) describes it as a small sliver of bone seen on a radiograph at birth.

Period of gestation 21-30 days.

Histology. The presence of calcified tissue in the mesenchymal condensations forming the membranous origins of the calvicle was evident at 24 days (C.R. 17 mm.) but the degree of calcification was slight. By 27 days (C.R. 23 mm.) there was further evidence of the process of calcification of this centre, with the deposition of calcified matrix and appearance of osteoblasts.

Radiography of the foetus.

In foetuses within this range there was no indication on radiographs of the presence of calcification of the clavicle.

Radiography of the foetus impregnated with Silver Nitrate.

The youngest foetus examined in this section was estimated at before 24 days (C.R. under 17 mm.) of gestation but there was no evidence of the clavicle on radiography. In three litters of age 30 days (C.R. 29 mm.), silver nitrate staining revealed the presence of the clavicle. This image was quite distinct and had a curved medial (cranial) extremity (Fig. Sn3).

Alizarin red staining of the foetus.

The earliest foetus examined in this series was aged at less than 24 days (C.R. under 17 mm.) and this was negative for evidence of the clavicle. Alizarin staining, of foetuses aged 28 days (C.R. 25 mm.) indicated the presence of calcification of the clavicle, apparent as a red stained rod in all specimens. In three of the foetuses of 30 days (C.R. 29 mm.), the clavicle was also present as a red stained rod (Figs. AZ3 and AZ4) but, in one other of 30 days the clavicular precursor was devoid of stain.

Period of gestation 31-40 days.

Radiography of foetus.

The faint image of the clavicle could be seen in 2 out of 3 foetuses of age 31 days (C.R. 35 mm.). In the 33 day foetus (C.R. 38 mm.) the clavicle was seen as a distinct spot with little longitudinal dimension (Figs. X1 and X2). Again, at 34 days (C.R. 43 mm.) this spot was obvious but it was not until 38 days (C.R. 58 mm.) that definite contours could be established. Then the hook-like appearance of its medial (proximal) extremity was apparent and the thin body could be discerned and by the 40th. day (66 mm.) its curved appearance was quite distinct (Fig. X5).

Radiography of foetus impregnated with silver nitrate.

In the foetus of 31 days (C.R. 35 mm.) prepared with silver nitrate the clavicle was easily recognisable by its thin body and curved appearance (Fig. Sn5). Its increase in length was continued throughout this period but its diameter remained fairly constant (Fig. Sn18).

Alizarin red staining of foetus.

The clavicle was recognisable in the 31 day (C.R. 35mm.) foetus as a fine body with an enlarged curved medial (proximal) extemity. It was well stained by the alizarin (Figs. AZ6 and AZ9).

Period of gestation 41-50 days.

Radiography of the foetus.

Throughout this period the clavicle appeared to maintain its relative overall growth and retained its curved appearance (Figs. X5 and X6).

Radiography of foetus impregnated with silver nitrate.

The impregnation with silver helped to demonstrate more clearly the characteristic curved appearance of the clavicle (Fig. Sn20).

Alizarin red staining of foetus.

The clavicle tookup stain throughout this period (Fig. AZ49).

Period of gestation 51-60 days.

Radiography of foetus.

During this period there was some growth relative to the increase in size of the foetus but little change in the shape of the clavicle (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

There was no significant alteration in the clavicular outline during this period (Figs. Sn48, Sn49 and Sn51).

Alizarin red staining of the foetus.

The clavicle was stained to show its curved shaft and its somewhat flattened and enlarged lateral (distal) extremity. It maintained slight growth in size over this period (Fig. AZ109).

Period of gestation 61 days onward.

Radiography of foetus.

There was no change noticeable in the clavicle (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The slender curved outline of the shaft was easily apparent at birth (Fig. Sn56).

Alizarin red staining of foetus.

The curved shaft could be seen in its position cranial to the proximal epiphysis of the humerus (Fig. AZ116).

CONCLUSIONS.

Histologically the calcification of the clavicle was seen at 24 days (C.R. 16mm.) when there was confirmation of the work of Jayne (1898) that the development was in membrane. There did not appear to be any secondary cartilaginous development during the prenatal stage. Alizarin red staining detected the clavicle by 28 days (C.R. 25 mm.) which correlated with Schaeffer's (1932) findings, but radiographically the clavicle did not make its appearance until after 30 days. Impregnation with silver nitrate however allowed the clavicle to become apparent on radiographs of foetuses of 30 days (C.R. 29 mm.).

Scapula

The scapula in the foetus is described in the literature as developing from one primary centre which is apparent at birth. This is stated by Strauss-Durckheim (1845), Lesbre (1897) and Bourdelle *et al.*, (1953). None of these authors gives further details of time of appearance of centres. Mivart (1881) makes an unusual statement, that the supraspinous part of the scapula ossifies as a separate plate of bone which is quite distinct from the rest at birth. The supraspinous part is difficult to define. If, by the supraspinous part, it is meant the supraspinous fossa then this is not substantiated by the other authors. Jayne (1898) illustrates the scapula at birth and shows it to have developed from one centre forming both body and spine. Smith (1968) describes it at birth as a slightly distorted D with a definite spine resembling the adult form. Schaeffer (1932) gives the time of appearance of this centre of the body including spine as 4.6 cm C.R. which he ages as 28 days post coitus.

Period of gestation 21-30 days.

Histology.

The cells at the centre of the cartilaginous model were seen to be swollen in the foetuses of 24 days (C.R. 17 mm) and by 27 days (C.R. 23 mm.) these cells were swollen with intracellular vacuoles. This picture was again seen in the foetuses of 30 days (C.R. 32 mm.).

Radiography of foetus

There was no evidence of bony changes occurring in the scapula using this method.

Radiography of foetus impregnated with silver nitrate.

In foetuses earlier than 30 days prepared by this method there was no evidence of the presence of the bony scapula on the radiograph. Three litters were aged at the 30th day of gestation but their C. R. length ranged as follows, 29.1 mm., 31 mm. and 31.2 mm. Of those, only the foetus of C. R. 31 mm. evinced the presence of a scapular body and this was shown as a faint band with a distinct mid-line of greater density representing a spine. The other two foetuses, although demonstrating a humeral shaft, did not display a scapular body.

Alizarin red staining of foetus.

In none of the series was a scapula observed to have taken up the stain.

Period of gestation 31-40 days.

Histology

In the foetus of 31 days (C. R. 35 mm.) there was calcification of the outer collar of the scapular model and invasion into the central portion of the model where the cartilage cells were collapsing. By 33 days (C. R. 38 mm.) there was a centre of ossification present in the centre of the scapular body.

Radiography of foetus

There was no trace of a bony scapula on the foetal radiographs until the 33rd day (C. R. 38 mm.) (Figs. X1 and X2). In these foetuses there was a faint band which represented the scapular body and this rather indefinite shape was there at 34 days (C. R. 43 mm.). At 35 days (C. R. 44.2 mm.) this band was assuming a triangular appearance and a denser line was showing, bisecting the triangle. This form was more distinct at 36 days (C. R. 49 mm.) when on a lateral plate the scapular spine was revealed and on a dorso-ventral exposure could be seen projecting from the body of the scapula. On a lateral plate the total dorso/ventral length was approximately 4 mm. and the region of greatest breadth (cranio/caudal) was 2.5 mm. At 38 days (C. R. 58 mm.) the cranial and caudal borders of the scapula were most distinct but dorsally the border was difficult to define. The overall dimensions were similar but by 40 days (C. R. 66 mm.) had increased to 6 mm. in length and 4 mm. in breadth (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

In the foetus of 31 days (C. R. 35 mm.) the scapula was apparent as a triangular band with a distinct median line representing the spine. The spine was indistinct but the other outlines were clear. The dimensions were approximately 1.5 mm. in length by 1 mm. in breadth (Fig. Sn4). By 34 days (C. R. 43 mm.) the scapular body had increased in size (2.5 mm. by 2.25 mm.) and the infra and supraspinous fossae were denser than previously (Fig. Sn8).

At 37 days (C.R. 56.5 mm.) the borders of the scapula were most distinct (Fig. Sn12) and the overall size was 4 mm. by 3.5 mm. This had increased to 6 mm. by 5.5 mm. at 40 days (C.R. 67 mm.). At 40 days (C.R. 67 mm.) the spine had lost its straight line appearance and now curved slightly in a caudal direction (Fig. Sn17). On the dorso/ventral exposure it could be seen projecting from the scapular body at almost a right angle (Fig. Sn18).

Alizarin red staining of foetus.

In the foetus of 31 days (C.R. 35 mm.) the scapula was stained to reveal a transverse band with a distinct spine rising from it (Figs. AZ8, AZ10) and by 33 days (C.R. 39 mm.) the length of the body was increased to give a more rhomboidal shape to the structure (Fig. AZ15). The spine was then seen projecting beyond the dorsal border. This change in shape was repeated at 34 days (C.R. 43 mm.) and by 35 days (C.R. 44.2 mm.) there was beginning to appear a definite neck, with narrowing of the cranial and caudal borders to meet distally (Fig. AZ18). By 38 days (C.R. 58 mm.) the contour of the scapula bore a greater resemblance to the adult form with a spine, neck, cranial and caudal borders denser in bone and a thinning of the body in the infra- and supraspinous fossae (Fig. AZ25). There was a gradual increase in overall size up to the 40th day (C.R. 66 mm.).

Period of gestation 41-50 days

Radiography of the foetus

The scapular outline was triangular with a distinct line running dorso-ventrally towards the scapular neck. The line was somewhat curved in a caudal direction and represented the spine. This was thicker at its distal end due to the curve of the spine. The scapular body continued to enlarge throughout this period and its dimensions were recorded thus :-

41 days (C.R. 73 mm.) 4 mm. in breadth 6.5 mm. in length (Figs. X3, X4 and X5)

45 days (C.R. 86 mm.) 6.5 mm. in breadth 9 mm. in length.

By this stage the outline of the cranial and caudal borders was difficult to delineate due to the increase in soft tissue in the area. The spine was still distinct and allowed a longitudinal measurement to be taken.

50 days (C.R. 102 mm.) 8 mm. in breadth 10 mm. in length.

By now the caudal angle of the scapula was acute whereas the cranial angle was distinctly rounded in appearance. This change in outline was becoming evident at 44 days (C.R. 84 mm.) and gradually altered to give this appearance at 50 days (C.R. 102 mm.) (Figs. X6 and X7).

Radiography of the foetus impregnated with silver nitrate.

The scapular outline was still triangular at 41 days (C.R. 73 mm.) but by 43 days (C.R. 82.5 mm.) the rounding of the cranial angle was in evidence (Fig. Sn20). The spine appeared to project dorsally over the dorsal border. At 45 days (C.R. 86 mm.) this rounding of the cranial angle was a distinct feature. The gradual increase in size was noted throughout this period (Fig. Sn25).

Alizarin red staining of foetus

The scapular outline was more apparent using this method. Whereas the cranial angle of the scapula was rounded on the radiograph, it had in fact a small pointed prolongation (Fig. AZ50).

Period of gestation 51 - 60 days

Radiography of foetus

During this period the scapula increased in size and bone density but its shape altered little. The cranial angle of the dorsal border became more rounded in appearance. The increase in dimensions was recorded thus :-

51 days (C. R. 105 mm.) 8 mm. in breadth 10.5 mm. in length.

56 days (C. R. 120 mm.) 10 mm. in breadth 12.5 mm. in length.

60 days (C. R. 136 mm.) 13 mm. in breadth 14.0 mm. in length.

In the 60 day (C. R. 136 mm.) foetus, the distal end of the spine was thicker (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The distal extremity of the spine was becoming wider in appearance (Fig. Sn33). By 56 days (C. R. 120 mm.) it had a rounded flattened appearance at its distal end with the increased diameter directed caudally (Fig. Sn44). At 60 days, this rounded extension could be seen projecting out from the caudal edge of the distal part of the spine. This represented the area of the paracromion process (Processus suprahamatus) (Fig. Sn51) which therefore appeared to be an extension of the spine and not a separate centre of ossification.

Alizarin red staining of foetus.

The cranial border of the scapula bore a sharp angulation at the region of confluence of the cranial and dorsal edges. The proximal extension of the spine beyond the dorsal border was still apparent at 51 days (C. R. 105 mm.) but its degree of projection became reduced during this period and at 58 days (C. R. 130 mm.) was only slightly projecting beyond the dorsal border. At the distal end of the spine there was apparent at 51 days (C. R. 105 mm.) a rounded and flattened caudal projection. This continued to increase in circumference (Fig. AZ73) and by 54 days (C. R. 112 mm.) was a distinct structure (Fig. AZ89). Its presence and increase in size continued and at 59 days (C. R. 133 mm.) it was a blunt caudal projection abutting from just short of the distal extremity of the spine.

Period of gestation 61 days onward

Radiography of foetus.

There were no significant alterations in the scapular outline (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The caudal projection close to the distal end of the spine was well illustrated at birth by the technique (Fig. Sn51).

Alizarin red staining of foetus.

The paracromion process (Processus Suprahamatus) was obvious as a blunt projection from the caudal aspect of the distal end of the spine (Figs. AZ116, AZ114).

Conclusions.

Histologically there was evidence of the onset of ossification before 30 days (C.R. 29 mm.) but it was 33 days (C.R. 38 mm.) before a periosteal bud was established in the scapular body with the deposition of calcified tissue. On radiography of the silver nitrate impregnated specimens, a 30 day foetus (C.R. 29.1 mm.) demonstrated a scapula but it was not until 31 days (C.R. 35 mm.) that this appearance became a constant feature. The untreated foetuses did not show scapular bodies until 33 days (C.R. 39.8 mm.). In the fresh and silver preparations of these ages the scapula possessed a visible spine. Alizarin red staining failed to detect bony scapular development until the foetus of 31 days (C.R. 35 mm.) which, compared to the findings of Schaeffer (1932) was earlier than his foetal measurement figure (35 mm. compared to 46 mm. C.R.) but later if one takes his time post-coitus i.e., 28 days. The neck of the scapula was more clearly defined in the second half of the 31 - 40 day period but the paracromion process was not in evidence until the middle of the 51 - 60 day period.

Humerus.

In previous literature there is agreement that the centre for the diaphysis of the humerus is present at birth. This is reported by Strauss-Durckheim (1845) and Mivart (1881) but no specific time of appearance is given. Lesbre (1897) states that the centre for the diaphysis appears in the course of the 4th. week of gestation and that two other centres appear after birth. Jayne (1898) concurs with the diaphyseal centre being present at birth but further states that a small centre is visible in the upper extremity. This finding is further supported by the work of Schaeffer (1932) who found a diaphyseal centre appearing at 4.6 cm. C.R. (28 days P.C.) and also a centre for the proximal epiphysis appearing at 14.5 cm. C.R. (55 days P.C.). However, Smith (1968) in his radiographic survey states only that the diaphysis was present at birth and that the proximal end was slightly convex. The centre for the prox. epiphysis may be present by the 1st. week: it was present in all the animals of 2 weeks or over.

Period of gestation 21-30 days.

Histology.

In the 24 day foetus (C.R. 17 mm.) there were degenerating cartilage cells present at the middle of the model shaft of the humerus. Collapse of these cells was evident in the foetuses of 27 days (C.R. 23 mm.) and by 30 days (C.R. 29 mm.) the periosteal collar contained calcified tissue and a periosteal bud was penetrating the collapsed centre of the cartilaginous shaft.

Radiography of foetus.

There was no evidence of the presence of a calcified humeral shaft in the foetuses examined.

Radiography of the foetus impregnated with silver nitrate.

The earliest foetus to indicate the presence of a humeral shaft was aged at 30 days, (C.R. 29.1mm.). In another two foetuses of similar age the humeral shaft was a constant feature. It appeared as a rod of total length 1mm. (Fig. Sn3).

Alizarin red staining of foetus.

In foetuses of age 28 days (C.R. 25 and 26mm.) the humerus was seen to have taken up the stain revealing the rod-like shaft (Fig. AZ1). However, in another foetus of C.R. 26mm., the humeral precursor remained devoid of colour. In the foetuses of C.R. 29 and 29.1mm. and age 30 days, the humeral shaft was staining red, (Fig. AZ4), but this result was not found in a similarly aged foetus C.R. 32mm.

Period of gestation 31-40 days.

Histology.

The 31 day foetus (C.R. 35mm.) demonstrated a centre of ossification present at the middle of the shaft with replacement of the cartilage with calcified tissue already commencing.

Radiography of foetus.

The humerus was just visible as a minute rod in two foetuses of age 31 days (C.R. 35mm) but was indistinct in another of the same age. By the 33rd. day (C.R. (38 mm.) the rod-shaped shaft was a distinct entity in foetuses from 3 litters (Figs. X2). This presence was confirmed in both litters of 34 days (C.R. 43 mm.) where the shape was greater in its longitudinal direction. At 35 days (C.R. 44.2 mm.) the humeral shaft was approximately 1.25 mm. in its total length and was slightly narrowed at its central portion. By the estimated age of 36 days (C.R. 49 mm.) the shaft was of distinct form with a diaphyseal waist and widening of the extremities. Its total length was now 4.25 mm. On the plate of foetus 37 days (C.R. 56.5 mm.) the humeral shaft was seen to be forming a slightly S-shaped contour, characteristic of the adult form. This was best seen on a lateral exposure. The total humeral length was similar to that of the previous foetus. At age 38 days (C.R. 58 mm.) the familiar S contour of the humeral shaft was distinct and the proximal extremity was already beginning to be of greater diameter than the distal. Total length on a lateral plate was 5.25 mm. At 40 days (C.R. 66 mm.) the total length had increased to 6.25 mm. (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The humeral shaft was quite apparent on the radiography of foetus 31 days (C.R. 35 mm.) and was almost 2 mm. in length (Fig. Sn4). There was a narrowing of the shaft at its central region with the extremities flaring slightly and at 34 days (C.R. 43 mm.) the S curve of the longitudinal direction of the shaft was becoming apparent. The total length was now approximately 3 mm. (Fig. Sn8). By 37 days (C.R. 56.5 mm.) the S-shape was obvious and the proximal extremity appeared greater in diameter than the distal. Total length had again increased, to 5 mm. At the extremity there were pale areas of decreased density and this area was wider at the proximal extremity (Fig. Sn12). However, at 39 days although the total length had remained virtually the same, this pale area was now as dense as the rest of shaft. Length at 40 days (C.R. 67 mm.) was 6 mm. (Fig. Sn14). The silver impregnation enhanced the radiopacity of the developing shaft so that measurements of the shaft were in advance of those taken from fresh specimens.

Alizarin red staining of foetus.

In the foetus of 31 days (C.R. 35 mm.) the humeral shaft was an obvious feature having taken up stain (Fig. AZ10). It was a cylindrical structure and already the middle portion was narrowing compared to the extremities as well as staining more strongly. At 33 days (C.R. 39 mm.) the proximal extremity could be seen to be of greater diameter than the distal (Fig. AZ15). This trend was continued through to 34 and 35 days (C.R. 43 and 44.2 mm.). In the 35th. day foetus (C.R. 44.2 mm.) a cranio-lateral ridge could be seen to be developing, suggesting the beginnings of the deltoid crest and in the 36th. day foetus (C.R. 49 mm.) the S-shape of the shaft was becoming obvious (Fig. AZ21). Also the distal extremity was progressively more flattened in a cranio-caudal dimension giving a broadening effect to the extreme distal end of the shaft (Fig. AZ32). This remodelling was seen in the 39th. day (C.R. 63 mm.) foetus and by 40 days (C.R. 66 mm.) the humeral shaft had increased in total length, retaining its S-shape (Fig. AZ33). The proximal end was more massive with a broadening of the extreme distal end.

Period of gestation 41-50 days.

Radiography of foetus.

The humerus was showing an S contour on lateral exposure and had a narrowing of the diaphysis with widening at the extremities (Figs. X3, X4 and X5). Its total length increased throughout this period and was recorded thus:

41 days (C.R. 73mm) 7.5mm.

45 days (C.R. 86mm) 11 mm.

50 days (C.R. 102mm) 12 mm.

At 46 days (C.R. 88mm.) there was seen an apparent bifid appearance of the distal extremity and this divided appearance, although indistinct continued to be evident during the remaining period (Fig. X6).

Radiography of foetus impregnated with silver nitrate.

The silver impregnation helped to demonstrate the outlines of the shaft and the rate of growth. At the distal end, the incomplete division of the extremity could be seen from 44 days onwards.

Alizarin red staining of foetus.

The alizarin stain was able to reveal the development at the distal extremity which was not obvious on the radiographs. At 43 days (C.R. 82.5mm.) a slight projection from the medial aspect of the distal extremity could be observed. Concurrently the caudal aspect of the distal portion was becoming concave in form. By 44 days (C.R. 84mm.) this projection was more obvious. At 46 days (C.R. 88mm.) a fine spicule, staining red could be seen projecting distally from the medial aspect of the distal extremity and forming a gap between it and the humeral shaft (Figs. AZ43, AZ49 and AZ51). This was the initiation of the development of the supracondylar foramen. This projection continued to grow increasing in length with the humeral shaft but maintaining the gap between them (Fig. AZ61).

Period of gestation 51-60 days.

Radiography of foetus.

Areas of reduced bone density were evident, extending along the interior of the shaft. There were little islands of bone apparent in them. This change would seem to indicate the development of a medullary cavity recognisable on radiography. These areas coalesced gradually to form a medullary area extending from just within each extremity. At 54 days (C.R. 112 mm.) the appearance was still somewhat patchy, but the radiolucent area extended to the distal extremity. The proximal extremity still retained a greater degree of density. The radiolucent area increased proximally with age and at 60 days (C.R. 136 mm.), the cavity was extensive throughout the shaft. The external outline of the bone did not alter greatly and the increases in length were recorded thus:

51 days (C.R. 105 mm.) 14 mm.

56 days (C.R. 120 mm.) 18 mm.

60 days (C.R. 136 mm.) 19 mm.

In the foetus of 59 days (C.R. 133 mm.) there was an indistinct projection pointing distally from the medial aspect of the distal extremity

(Figs. X8 and X9). This was seen on a dorso/ventral plate but this was not repeated in the foetuses of 60 days (C.R. 136 mm.).

Radiography of foetus impregnated with silver nitrate.

In the foetus of 51 days (C.R. 105 mm.) the outline of the distal extremity indicated the formation of a divided shaft. However, in this same region, another structure on the medial aspect of the bone could be seen developing. This was a blunt projection pointing distally from the medial aspect just above the extreme distal edge (Fig. Sn33). This was evident again in the 52nd. day foetus (C.R. 108 mm.) and on the dorso-ventral plate of the 53rd. day foetus (C.R. length 109 mm.), the flat-ended projection could be seen pointing distally with a gap between it and the main shaft (Fig. Sn39). This projection continued to increase in thickness and length to correspond with similar changes in the dimensions of the shaft. At 60 days (C.R. 136 mm.) the projection was a strong prolongation lying medially but not projecting beyond the distal extremity of the shaft proper (Figs. Sn51 and Sn52).

Alizarin red staining of foetus.

The distal extremity of the humerus was differentiating from a single shaft into two component columns. This division was evident as a depression, situated caudally, which partially divided the shaft. A similar depression appeared cranially very shortly after but was not of such a great depth. These depressions deepened, the caudal remaining greater in its concavity, so that at 54 days (C.R. 112 mm.) the distal shaft had the appearance of two columns separated by the depressions

(Fig. AZ82). The depressions were never completely penetrating so that the two columns were at all times joined by continuous calcified tissue. At the medial aspect of the extremity, the distally projecting bone offshoot continued to increase in size in proportion to the shaft but remained separate from it at the distal end. At the proximal end of the shaft, a pointed peak appeared at the most cranial rim of the proximal edge. This was extremely slight at 51 days (C.R. 105 mm.) but by 54 days (C.R. 112 mm.) was clearly observed and continued to be present throughout the rest of the period (Fig. AZ99).

<u>Period of gestation 61 days onward.</u>

<u>Radiography of foetus.</u>

The doubled appearance of the distal end of the shaft was apparent as was the medial projection already desribed (Figs. X10 and X11). In a litter which was one day post-partum, a small speck was seen lying proximal to the proximal end of the humeral shaft. It was just visible and was taken to represent the commencement of calcification of the proximal epiphysis of the humerus. This finding was repeated in two out of the three litters examined at two days post-partum. The speck was seen to be placed slightly caudal to the centre of the proximal end. This was on a lateral plate. In four litters of three days post-partum only two showed evidence of a proximal epiphysis.

Length at 61 days (C.R. 140 mm.)	18.5 mm.
At birth	19.0 mm.

Radiography of foetus impregnated with silver nitrate.

Silver impregnation failed to demonstrate the presence of a proximal epiphysis of the humerus in a foetus at birth (Fig. Sn56).

Alizarin red staining of foetus.

This technique demonstrated a small cap staining red situated over and above the proximal extremity of the humerus (Fig. AZ116). On the lateral face of the proximal shaft a fine ridge was evident running down from the proximal perimeter for approximately 3 mm.

Conclusions.

The earliest signs of bony enlargement in the humerus was seen histologically in the foetus of 30 days (C.R. 29 mm.) but not radiographically until 30 days (C.R. 29.1mm.) in the silver nitrate preparations and 31 days (C.R. 35 mm.) in untreated specimens. Lesbre's (1897) observation of the appearance of the humeral shaft in the fourth week of gestation is remarkably accurate as is Schaeffer's (1932) date post-coitus i.e., 28 days. However, his figure for C.R. length of the foetus with the first humeral shafts is 46 mm. as compared to these findings in alizarin specimens of C.R. 25 and 26 mm. The alizarin stained specimens demonstrated the beginnings of the deltoid crest being seen from 35 days (C.R. 44.2 mm.) onward. The initiation of the development of the supracondylar foramen was best demonstrated and earliest seen in the alizarin red specimens of 43 days (C.R. 82.5 mm.) onward. Radiographically this was not observed fully until the commencement of the 51 day (C.R. 105 mm.) period. The centre for the proximal epiphysis of the humerus was observed radiographically post-partum and in later foetuses. The observations of Smith (1968) were similar to this. Alizarin red staining at this period indicated the presence of the epiphyseal cap shortly before birth, i.e., at C.R. 146 mm. Schaeffer's (1932) figure for C.R. length at which this centre is seen correlates with this i.e., 145 mm. but he gives this C.R. length an age of 55 days post-coitus.

Radius

The radius is said to develop from 3 centres, one for the diaphysis and one for each extremity. This is agreed on by Strauss-Durckheim (1845), Mivart (1881) and Bourdelle (1953). Jayne (1898) gives an additional centre for the tuberosity which he says appears after birth. Lesbre (1897) further states that the primary centre appears in the course of the 4th week of gestation in the dog and cat while Schaeffer (1931) observed the diaphysis in a foetus of C. R. 4. 6 cm. (28 p. c.). Bressou et al., (1959) saw the diaphysis of the radius as entirely or almost entirely ossified at birth. Smith (1968) describes the shaft of the radius as being radiographically present at birth.

Period of gestation 21 - 30 days

Histology

The 24 and 27 day foetuses (C. R. 17 mm. and 23 mm.) demonstrated degeneration of the cartilage cells so that by 30 days (C. R. 29 mm.) calcification of the central collar was evident with collapse of the cartilaginous centre of the shaft.

Period of gestation 21 - 30 days

Radiography of foetus

There was no indication of a bony element of the radius during this period on radiography of the foetus.

Radiography of foetus impregnated with silver nitrate.

In the three foetuses of 30 days (C.R. 29.1 mm., 31 mm., and 31.2 mm.) the radius was present as a small rod of approximately two thirds the length of the humeral shaft and narrower in diameter (Fig. Sn3).

Alizarin red staining of foetus.

In foetuses of age 28 days (C.R. 25 mm. and 26 mm.), the shaft of the radius had taken up stain and appeared as a short rod of uniform diameter (Fig. AZ1). In the other foetus of C.R. 26 mm. there was no uptake of stain. In the foetus of 30days (C.R. 29.1 mm.) the radius again showed as a stained rod but in the other foetus of similar age it was unaffected by the stain.

Period of gestation 31 - 40 days

Histology

The 31 day foetus (C.R. 35 mm.) had a calcified periosteal collar at the middle of the cartilaginous model of the shaft. The replacement of this tissue with calcified material was continuing in the 33 day foetus (C.R. 38 mm.).

Radiography of foetus

The shaft of the radius was not apparent in any of the foetuses of 31 days (C.R. 35 mm.) but made its first appearance in a foetus of 33 days (C.R. 38 mm.). Here it was a very short rod lying alongside the ulna (Fig. X2).

By 34 days (C.R. 43 mm.) the outline was more distinct and the image was seen to possess a greater length, almost 1 mm. At 36 days (C.R. 49 mm.) the outline was distinct and the ulna could be observed lying caudal to the radius with its proximal extremity lying more proximally in the limb with a similar discrepancy at the distal end when viewed laterally. However their total length was equal i.e., 4 mm., taken from a dorso/ventral exposure. The foetus of 38 days (C.R. 58 mm.) illustrated the proximal superimposition of the radius on the ulna, on a dorso/ventral exposure.

This was observed at 35 days (C.R. 44.2 mm.) but was by now more marked. The ulnar shaft appeared to be of greater mass than that of the radius but their total length remained equal. At 40 days (C.R. 66 mm.) the length of the shaft of the radius had increased to 7 mm. on a dorso/ventral exposure (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate

The radial shaft was quite distinct in the foetus of 31 days (C.R. 35 mm.) and its position relative to the ulnar shaft was such as to be placed more distally in the limb. Its total length was approximately 1.25 mm. (Fig. Sn4). At 34 days (C.R. 43 mm.) on a dorso/ventral exposure, the radius could be seen to overlie the ulna proximally and the length had increased to 2 mm. (Fig. Sn9). By 37 days (C.R. 56.5 mm.), this had increased to 4.5 mm. (Fig. Sn12).

Alizarin red staining of foetus.

The foetuses of 31 days (C.R. 35 mm.) all demonstrated stained radial shafts which were placed more distally in the limb than the ulnar shafts (Fig. AZ10). The cylindrical shaft was fairly uniform and there was a steady increase in length throughout this period. At 36 days (C.R. 49 mm.) the slight dorsal curvature of the shaft was becoming noticeable (Fig. AZ21), and by 40 days (C.R. 66 mm.) was distinct (Fig. AZ33).

Period of gestation 41 - 50 days

Radiography of foetus

The radius appeared as a dorsal curving shaft closely related to the ulnar shaft (Figs. X6 and X7). The growth of the radius was recorded thus :-

41 days (C.R. 73 mm.) - 8 mm.

45 days (C.R. 86 mm.) - 11 mm.

50 days (C.R. 102 mm.) - 12 mm.

Radiography of foetus impregnated with silver nitrate

The silver impregnation helped to demonstrate the outlines of the shaft and the rate of growth (Figs. Sn27 and Sn31).

Alizarin red staining of foetus.

The radial shaft stained throughout this period. The cranio/caudal flattening of the shaft was more evident by this method and the proximal and distal extremities could be seen in close apposition to the ulna with a greater space between them centrally (Figs. AZ43 and AZ47). At 47 days (C.R. 92 mm) a flattened ridge was becoming apparent on the caudal proximal end of the radial shaft opposite the corresponding cranial border of the ulna. This ridge was more clearly defined at 50 days (C.R. 102 mm.) (Figs. AZ56 and AZ63).

Radiography of foetus

At 51 days (C.R. 105 mm.) the interior of the radial shaft revealed patches of radiolucency which were present throughout its length. The patches coalesced to extend throughout the length of the shaft to just short of the extremities. The change was virtually over by 56 days (C.R. 120 mm.) (C.R. 120 mm.) and completed by 60 days (C.R. 136 mm.) (Figs. X8 and X9). The diameter of the shaft increased in this period, being greater towards the distal extremity.

The increase in length was recorded thus :-

51 days (C.R. 105 mm.) 12.5 mm.

56 days (C.R. 120 mm.) 16 mm.

60 days (C.R. 136 mm.) 17 mm.

Radiography of foetus impregnated with silver nitrate

The radial shaft continued to increase in length and diameter throughout this period (Figs. Sn33, Sn51 and Sn52).

Alizarin red staining of foetus.

On the caudal surface of the proximal end of the radial shaft, just distal to the extreme edge, the surface was flattening. This area was fairly discrete and was the region which lay closest to the ulnar shaft. By 54 days (C.R. 112 mm.) the periphery of the area was slightly raised laterally, aiding in demarcating the region (Figs. AZ80 and AZ85). The rather transversely flattened appearance of the entire shaft was apparent throughout this period (Figs. AZ89 and AZ110).

Period of gestation 61 days onward

Radiography of foetus.

The proximal end of the radius on its caudal face was flattened, even slightly concave, giving the impression of a slight ridge at the rim of the area. This was seen at 61 days onward (C.R. 140 mm.) (Figs. X10 and X11).

61 days (C.R. 140 mm.) 18 mm. in length.

At birth 18 mm. in length.

Radiography of foetus impregnated with silver nitrate.

The flattening of the caudal face of the proximal shaft was demonstrated by this technique (Fig. Sn56).

Alizarin red staining of foetus

The caudal face of the proximal shaft could be observed in close approximation to the ulnar shaft with a flattening of the former (Figs. AZ114, AZ116).

Conclusions.

The early observation of the shaft by Lesbre in the course of the fourth week of gestation concurs with the findings here, in that the histological picture was of calcified tissue at thirty days (C.R. 29 mm.) while the alizarin stain was seen at 28 days (C.R. 25 mm.). Radiographically, 30 days (C.R. 29.1 mm.) was the time of appearance of the shaft when impregnated with silver nitrate and 33 days (C.R. 38 mm.) the time for the fresh specimens. Schaeffer (1932) gives a date of 28 days post-coitus which would fit with the time of appearance but his C. R. measurement of 46 mm. would appear too large compared with the findings of 29-30 mm. There was evidence of the beginnings of the radial tuberosity at the proximal end, caudal face, at the end of the 51-60 day period. The shaft was well ossified at birth, agreeing with the radiographic evidence of Bressou et al., (1959) and Smith (1968).

Ulna.

Strauss-Durckheim (1845) and Mivart (1881) describe 3 centres of ossification for the ulna, one being for the shaft. Lesbre (1897) notes the diaphyseal centre as appearing in the course of the 4th. week but that the extremities are entirely cartilaginous at birth. Jayne (1898) illustrates an ulna at birth showing the diaphysis as ossified and the proximal end of the olecranon and the distal extremity as cartilage. Schaeffer (1932) observed in a foetus of 4.6 cm. (C.R. (28 p.c.) the shaft of the ulna. Bressou et al. (1959) state that, at birth, the diaphysis of the ulna is entirely or almost entirely ossified and this is similar to Smith's (1968) finding that the shaft of the ulna appeared on radiographs of new born kittens. He further states that it was slightly club-shaped with the proximal end being the larger.

Period of gestation 21-30 days.

Histology.

The 24 and 27 day foetuses (C.R. 17 mm. and 23 mm.) demonstrated degeneration of the cartilage cells so that by 30 days (C.R. 29mm.) calcification of the central collar was evident with collapse of the cartilaginous centre of the shaft.

Radiography of foetus.

There was no evidence of bony change in the ulna during this period.

Radiography of foetus impregnated with silver nitrate.

In the three foetuses of 30 days C.R. 29.31 and 31.2 mm. the ulna was present as a small rod of identical dimensions to the radius but placed caudally on a lateral radiograph (Fig. Sn3).

Alizarin red staining of foetus.

The ulnar precursor of one of the foetuses of 28 days (C.R. 25 mm.) was stained (Fig. AZ1), while that of the other was unaffected. Similarly with the foetuses of 30 days only one, C.R. 29.1 mm. had a stained ulna present.

Period of gestation 31-40 days.

Histology.

The 31 day foetus (C.R. 35 mm.) had a calcified periosteal collar at the middle of the cartilaginous model of the shaft. The replacement of this tissue with calcified material was continuing in the 33 day foetus (C.R. 38 mm.).

Radiography of foetus.

The shaft of the ulna was indiscernable at 31 (C.R. 35 mm.) days, appearing at 33 days (C.R. 39 mm.) (Figs. X1 and X2). In the foetus of 34 days (C.R. 43 mm.) the faint outline of the ulnar shaft could also be detected lying alongside that of the radius. It was marginally shorter than the latter. The foetus of 35 days (C.R. 44.2 mm.) illustrated a more definite outline and the radial and ulnar shafts were of approximately equal length.

At 36 days (C.R. 49 mm.)..... (as radius, page 45)..... remained equal. The ulnar shaft was now widening at its proximal extremity and by the 40th. day (C.R. 66 mm.) the entire shaft had reached 7 mm. in length (Figs. X3, X4 and X5).

Radiography of the foetus impregnated with silver nitrate.

The ulnar shaft was quite distinct in the foetus of 31 days (C.R. 35 mm.) and its position relative to the radial shaft was such as to be placed more proximally in the limb. At this stage the proximal end of the shaft had increased in diameter compared to the opposite end with quite distinct flaring of the outline. This appearance was again seen in the later foetuses. At 40 days (C.R. 66 mm.) the length had reached 8 mm.

Alizarin red staining of foetus.

The ulnar shaft was stained in the foetuses of 31 days (C.R. 35 mm.) and the more proximal position of this shaft to that of the radius was already evident (Fig. AZ10). The two shafts were however of similar dimensions with only their position distinguishing them. By 33 days (C.R. 38 mm.) the ulnar shaft was of greater length but the contours of the two bones were still similar (Fig. AZ15). In the foetus of 35 days (C.R. 44.2 mm.) the proximal extremity of the ulnar shaft was commencing to broaden and by 36 days (C.R. 49 mm.) was more massive than the distal extremity (Fig. AZ21). By the 40th. day (C.R. 66 mm.) the proximal end was seen to be showing lateral flattening of the shaft (Figs. AZ30 and AZ33).

Period of gestation 41-50 days.

Radiography of foetus.

The ulna was apparent alongside the radius, its proximal extremity being proximal to that of the radius (Figs. X3, X4 and X5). The length of the shaft increased over this period and was recorded thus:

41 days (C.R. 73 mm.) 9 mm.

45 days (C.R. 86 mm.) 11 mm.

By now the proximal end of the ulna was club-shaped and more massive than the distal end. On a lateral plate there was a slight concavity of the cortex of the ulnar shaft opposite the proximal end of the radius (Figs. X6 and X7).

50 days (C.R. 102 mm.) 12 mm. There was still a distinct gap between the radius and ulna throughout their entire length.

Radiography of foetus impregnated with silver nitrate.

The increase in mass and rounding of outline of the proximal end of the ulna was demonstrated by this technique in the foetus of 43 days (C.R. 82.5 mm.) as was the progression in size (Fig. Sn20).

Alizarin red staining of foetus.

The ulnar shaft stained throughout this period. This technique helped to demonstrate the actual formation taking place at the proximal end. Although this extremity was enlarging and rounding off to appear club-shaped on the radiographs, the true proximal surface of this extremity was in fact flattened and sloping from a lower cranial edge to a higher caudal rim (Fig. AZ61). The shaft of the ulna remained thick compared to the form seen in the adult (Fig. AZ47).

Period of gestation 51-60 days.

Radiography.

In the 51 day foetus (C.R. 105 mm.) the medullary cavity was represented by a radiolucent area which occupied the interior of the shaft but did not extend into the proximal extremity. This extremity was rounded and club-shaped. By 56 days (C.R. 120 mm.) the radiolucent areas had coalesced and this darkened area now extended into the proximal extremity which was altering in shape. In the foetus of 53 days (C.R. 108.3 mm.) the cranial face of the proximal extremity was flattening and by 56 days (C.R. 120 mm.) it was concave. This alteration was continued throughout the period and by 60 days (C.R. 136 mm.) there was a distinct proximal promontory, distal and cranial to which, the concave border led into a raised ridge opposite to the proximal extremity of the radius (Figs. X10 and X11). The increases in total length were recorded thus:

51 days (C.R. 105 mm.) 14 mm.

56 days (C.R. 120 mm.) 18 mm.

60 days (C.R. 136 mm.) 19 mm.

Radiography of foetus impregnated with silver nitrate.

The apparent remodelling of the proximal extremity previously described, was demonstrated by this method and at 51 days (C.R. 105 mm.) the flattening of the extremity was already visible (Figs. Sn33, Sn51 and Sn52).

Alizarin red staining of foetus.

The proximal extremity was still rather club-like at 51 days (C.R. 105 mm.) but by 53 days (C.R. 108.3 mm.) a depression was developing on the proximal summit giving the appearance of two rather pointed lateral projections (Figs. AZ82 and AZ109). The depression on the proximal summit remained a feature during the period. The cranial surface of the proximal end was distinctly flattened and from the most proximal point sloped downward and cranially to a transverse ridge. The sloping surface was concave when viewed laterally. This ridge was immediately opposite to the most proximal extremity of the radial shaft. This slope was present throughout this period (Figs. AZ84 and AZ100).

Period of gestation 61 days onward.

Radiography of foetus.

The outline of the shaft did not alter. The length was measured thus:

61 days (C.R. 140 mm.)	19 mm.
At birth	19 mm.

(Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

No further developments in the outline of the shaft were demonstrated (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The outline of the shaft and proximal end did not alter from that previously described (Fig. AZ114).

Conclusions.

The appearance of the shaft in the fourth week of gestation described by Lesbre (1897) would appear to correspond fairly well to the finding, where the histological picture was of calcified tissue at 30 days (C.R. 29 mm.) and alizarin staining at 28 days (C.R. 25 mm.). Radiographically the centres were apparent in untreated specimens at 33 days (C.R. 39 mm.) and in silver nitrate impregnated foetuses at 30 days (C.R. 29.1 mm.). Schaeffer's (1932) date of 28 days post-coitus would appear to be within the range of these findings but his C.R. assessment of 46 mm. is large compared to 29-31 mm. C.R. measurement of this series. The descriptions of the radiographic appearance given by both Bressou et al. (1959) and Smith (1968) are similar to present findings. The start of development of the coronoid process was demonstrated by alizarin red staining toward the end of the 51-60 day period.

Carpus.

In the literature there is no reference to any ossification of the carpus taking place before birth.

Using the described techniques, no evidence of ossification of the elements of the carpus was detected during foetal life.

Metacarpus.

Ossa metacarpalia II - V.

The diaphyses of the 2nd to 5th. metacarpal bones are evident at birth. This is reported by both Smith (1968) and Bressou et al. (1959) using radiographic methods. Lesbre (1897) states that the bony parts of the diaphyses of the metacarpals appear at the same time as the primary points of other long bones of the limbs or very little after. Schaeffer (1932) notes that the diaphyses of these metacarpals are seen at 6.3 cm. C.R. (31 days p.c.).

Period of gestation 21-30 days.

Radiography of foetus.

There was no evidence of calcification during this period.

Radiography of foetus impregnated with silver nitrate.

There was no evidence of impregnation of the shafts.

Alizarin red staining of foetus.

None of these elements was staining.

Period of gestation 31-40 days.

Histology.

The foetus of 31 days (C.R. 35 mm.) evidenced swelling of the cells in the central sector of the cartilaginous models. There was present calcified material in the peripheral collar of tissue at the central region of the shaft of the models by 34 days (C.R. 44 mm.) and this was followed by degeneration and collapse of these cells and invasion of blood vessels and cells from the overlying calcifying layer. This was the state of development seen in the foetus of 38 days (C.R. 58 mm.).

Radiography of foetus.

Until the foetus of 36 days (C.R. 49 mm.) the metacarpal bones were not visible on radiographs. In the foetus of 36 days (C.R. 49 mm.) the shafts of the second to the fifth metacarpal bones were seen as short rods. They were of unequal length, the axial two being larger than the abaxial with the fifth being the smallest. The 37 day foetus (C.R. 56.5 mm.) gave a similar picture but by the 38th. day (C.R. 58 mm.) the third and fourth metacarpals were more distal in position and still of greater total length than the second and fifth. The former were approximately 1 mm. in length with the latter about two thirds that length. By the 40th. day (C.R. 66 mm.) the fifth shaft was markedly shorter being almost 1 mm. compared to the third and fourth which were almost 2 mm. (Figs. X3, X4 and X5). These measurements were taken on a dorso/ventral exposure.

Radiography of the foetus impregnated with silver nitrate.

The first indications of the presence of calcified shafts on the metacarpals were seen in the foetus of 34 days (C.R. 43 mm.). Here all four metacarpals were seen as short rods but that of the fifth was much smaller and indistinct (Fig. Sn8). By 37 days (C.R. 56.5 mm.) the shafts had all increased in length but the fifth was still shorter than the others. The shafts of metacarpals three and four were approaching 1 mm. (Fig. Sn12). The fifth remained shorter during this period compared to the third and fourth (Fig. Sn18).

Alizarin red staining of foetus.

The metacarpals remained unstained in the foetuses of 31 days (C.R. 35 mm.) whilst at 33 days (C.R. 39 mm.) the short cylinders of the stained tissue could be seen immediately proximal to the digits II, III and IV, the fifth metacarpal remaining unstained (Figs. AZ11 and AZ16). The 34 and 35 day foetuses (C.R. 44 and 44.2 mm.) demonstrated all four metacarpals, the fifth being shorter and less densely stained. At 36 days (C.R. 55 mm.) the shafts of all four were clearly marked with the relative lengths as before. The shafts increased in length up to 40 days (C.R. 66 mm.) and their extremities had become slightly flared by this time (Fig. AZ32).

Period of gestation 41-50 days.

Radiography of foetus.

The shafts of metacarpals five were still the shortest with the third and fourth the longest and the second intermediate (Figs. X3, X4 and X5). The measurements throughout this period were:

41 days (C.R. 73 mm.)	metacarpal 3 and 4	-	2 mm. approx.
	" 5	-	1 mm. " .
45 days (C.R. 86 mm.)	metacarpal 3 and 4	-	3 mm. " .
	" 5	-	2 mm. " .
50 days (C.R. 102 mm.)		-	little change if any

(Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

Growth of all shafts was evident during the period. (Figs. Sn19 and Sn31).

Alizarin red staining of foetus.

The shaft of the metacarpal bones took up stain throughout this period (Fig. AZ62).

Period of gestation 51-60 days.

Radiography of foetus.

In the 51 day foetus (C.R. 105 mm.) the interior of the shafts exhibited patchy radiolucent areas and these reorganised to form darkened areas extending to both extremities. This was evident by 56 days (C.R. 120 mm.) and confirmed in the later foetuses. Length of shaft was recorded with the shafts of the third and fourth remaining longer than the second and fifth.:

51 days (C.R. 105 mm.) 2.5 mm. II and V : 3 mm. III and IV

56 days (C.R. 120 mm.) 4.0 mm. II and V : 5 mm. III and IV

60 days (C.R. 136 mm.) 4.0 mm. II and V : 5 mm. III and IV

(Figs. X8 amd X9).

Increase in length took place predominantly in the first half of this period.

Radiography of foetus impregnated with silver nitrate.

Progress in length was observed during this period (Figs. Sn33, Sn51 and Sn52).

Alizarin red staining of foetus.

The shafts of the metacarpals continued to increase in size (Fig. AZ110).

Period of gestation 61 days onward.

Radiography of foetus.

The lengths of the shafts were recorded thus:

61 days (C.R. 140 mm.) 4 mm. II and V : 5 mm. III and IV (Figs. X10 and X11)

At birth 4.5 mm. II and V : 5 mm. III and IV

Radiography of foetus impregnated with silver nitrate.

The proximal ends of the shafts were more rounded in outline compared to the flattened distal edges (Fig. Sn56).

Alizarin red staining of foetus.

The proximal ends of the shafts were more flattened from side to side and more rounded on the proximal surface. The distal ends remained more flattened from before backward and had an even distal edge (Fig. AZ110).

Conclusions.

The range of time of detection of development of the centres for the metacarpals was from 33 to 36 days (C.R. 38 to 49 mm.) varying with the technique used. The alizarin stain was positive at 33 days i.e., C.R. 39 mm. compared to Schaeffer's (1932) figure of 31 days post-coitus which he assesses as C.R. 63 mm. but histologically there was only present at this stage a calcified periosteal collar and so it would appear that it was this that was staining and not the true centre of ossification. Histologically this true centre was not fully confirmed until 36 to 38 days (C.R. 49 to 58 mm.). Radiographically the silver nitrate impregnated specimens revealed the image of the developing metacarpals at 34 days (C.R. 43 mm.) while the fresh specimens were not positive for these centres till 36 days (C.R. 49 mm.). Lesbre's (1897) statement that the metacarpal centres appear a little after those of the other long bones holds true when compared with these findings.

Ossa metacarpale I.

The diaphysis of this metacarpal bone is evident at birth according to the work of Bressou et al. (1959) and Smith (1968). Schaeffer (1932) describes the diaphysis being apparent at 8.4 cm. C.R. (38 days p.c.). Smith (1968) raises the question as to whether this diaphysis is a metacarpal bone proper or a phalangeal shaft as it has a secondary centre appearing at its proximal extremity. The metcarpals II-V have a distal epiphysis. Conversely, the phalanges I and II have a proximal epiphysis. These findings are supported by the previous authors except Jayne (1898) who gives the metacarpal I a distal epiphysis and the metacarpals II - V a proximal centre.

Manus.

Digit I.

The three long elements of this digit will be called the proximal, middle and the distal. Lesbre (1897) states that the middle and distal develop at the same time as the 2nd. and 3rd. phalanges of the other digits. Schaeffer (1932) describes 2 phalangeal elements, the first being present at 8.6 cm. C.R. (41 days p.c.) and the second at 6.3 C.R. (31 days p.c.). Smith (1968) on his radiographs of new born kittens reports the presence of the two phalangeal elements.

Period of gestation 21-30 days.

Radiography of foetus.

There was no evidence of calcification during this period.

Radiography of foetus impregnated with silver nitrate.

There was no evidence of the presence of the elements of the first digit on the radiographs.

Alizarin red staining of foetus.

None of the elements of digit I was staining.

Period of gestation 31-40 days.

Histology.

The histological picture was similar in both time sequence and appearance to that seen in the developing phalanges I, II and III of the other digits of the manus in that there was primary calcification of the distal element by 34 days (C.R. 44 mm.) and the proximal and middle elements by 39 days (C.R. 63 mm.). True centres of ossification were not observed until 39 days (C.R. 63 mm.) and 44 days (C.R. 85 mm.) respectively.

Period of gestation 31-40 days.

Radiography of foetus.

The distal element was first detected in the foetus of 36 days (C.R. 49 mm.) when it was seen as a small spot at the distal extremity of digit I. This picture was constant until the foetus of day 40 (C.R. 66 mm.) when the proximal bony element became apparent in a position parallel with and medial to the second metacarpal. That was in foetuses of 66 and 67 mm. In a foetus of 68.9 mm. the middle bony element could also be seen.

Radiography of foetus impregnated with silver nitrate.

The distal element was not seen in the foetus of 31 days (C.R. 35 mm.) but was represented by a small dot in a foetus of 34 days (C.R. 43 mm.) and its appearance was verified in the foetus of 37 days (C.R. 56.5 mm.) where the dot was now well defined and triangular in contour (Fig. Sn12). However, the foetuses of 39 and 40 days (C.R. 65 and 67mm.) failed to reveal the presence of the other elements of digit I.

Alizarin red staining of foetus.

The distal element was first apparent as a stained speck in the foetuses of 33 days (C.R. 38 mm.) (Fig. AZ15), but it was 36 days

(C.R. 49 mm.) before there was any great substance to the body of this structure. From this on, the size of the body increased and at 40 days (C.R. 66 mm.) it had a cone-shaped appearance (Fig. AZ26). The other two elements did not pick up stain until in the foetus of 39 days (C.R. 63 mm.) there was a slight trace of stain in the most proximal element and this again was the case in one of the foetuses of 40 days (C.R. 66 mm.). In another foetus of 40 days the proximal, middle and distal elements were all present.

Period of gestation 41-50 days.

Radiography of foetus.

At 41 days (C.R. 73 mm.) the proximal and distal elements were present but the middle element was not apparent. However in the foetus of 42 days (C.R. 78 mm.) they were all present. The proximal element was rod-like but the middle element was just a transverse band and this latter shape was converted to a more rod-like one by the 44th. day (C.R. 84mm.). The increase in length of the proximal and middle elements was progressive and at 50 days (C.R. 102 mm.) they were rod-shaped being of approximately equal size. The distal element was cone shaped (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

In the foetus of 41 days (C.R. 73 mm.) the distal element was present but it was not until the 43rd. day (C.R. 82.5 mm.) that the proximal and middle elements made an appearance. The middle element was still only slight in size (Sn19). By 44 days (C.R. 84 mm.) all the elements were distinct and by 45 days (C.R. 86 mm.) the proximal element was rod shaped, the middle was squarer and small while the third was cone shaped with a flattened base (Fig. Sn27). By 50 days (C.R. 102 mm.) the proximal and middle elements were approximately equal in size and both rather square in shape (Fig. Sn31).

Alizarin red staining of foetus.

In the foetus of 41 days (C.R. 75 mm.) only the proximal and distal elements were seen to have taken up stain but in the 42 day foetus (C.R. 80 mm.) all three elements were stained (Fig. AZ36). The proximal element gradually attained a cylindrical shape with a narrowing of the diaphysis but the middle element tended to remain much shorter with less diaphyseal definition. The distal element at 42 days (C.R. 80 mm.) was rather cone shaped. This change was noticeable at 46 days (C.R. 90 mm.) and was increasingly developed throughout this period (Figs. AZ49, AZ50, AZ61 and AZ62).

Period of gestation 51-60 days.

Radiography of foetus.

The increase in size of the three elements was continued throughout this period. The appearance of the proximal and middle elements remained more cuboidal than elongated (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The first element developed a more rod like appearance while the second element remained cuboidal (Fig. Sn52).

Alizarin red staining of foetus.

The three elements progressed in size during this period (Figs. AZ63, AZ100 and AZ110).

Period of gestation 61 days onward.

Radiography of foetus.

The three bony elements remained constant in form during this period (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The second bony element was still more cuboidal in shape whilst the third element appeared more pointed (Fig. Sn55).

Alizarin red staining of foetus.

The bony elements were stained showing the outline of the bodies.

Conclusions.

The distal element was the first to appear using all the techniques, being first detected by alizarin red staining at 33 days, C.R. length 39 mm., to be followed by the appearance on a radiograph of a silver nitrate impregnated foetus at 34 days (C.R. 43 mm.) and a fresh specimen at 36 days (C.R. 49 mm.). The histological features at 34 days (C.R. 44 mm.) were of a degenerating cartilage model with primary calcification but a true centre of ossification was not seen until 39 days (C.R. 63 mm.). This compared less favourably with the time and C.R. length given by Schaeffer (1932) of

31 days post coitus and 63 mm. C.R. length. The other two elements appeared within the range of 39 to 42 days (C.R. 63 mm. to 80 mm.) the proximal element being observed earliest in alizarin stained specimens. Silver nitrate impregnation failed to reveal the structures till 43 days (C.R. 82.5 mm.) although they were already apparent on radiographs of fresh specimens at 40 days (C.R. 66 mm.). Histologically the appearance of the changes of calcification and ossification were similar in time to that of the distal element. In comparing these results with alizarin staining to those given by Schaeffer (1932) several discrepancies occur e.g.,

proximal element	38 days post coitus,			84 mm. C.R.-Schaeffer	
	39 days	"	"	, 63 mm. Present results	
middle element	41 days	"	"	, 86 mm. C.R.-Schaeffer	
	43 days	"	"	, 82 mm. C.R.-Present results.	

In comparing the times of ossification of the proximal element with the time for the metacarpal centres for the remaining digits of the manus and with the time for the proximal phalanges of digits II to V, there would appear to be a closer comparison with the latter. This would seem to indicate that the three elements of digit I represent the phalanges proper with an absence of a metacarpal element. This would agree with the findings of Smith (1968).

Ossa Digitorum Manus

Phalanx Proximalis (Digits II - V)

The centres of ossification for the diaphyses of these bones are apparent at birth as are shown in the work of Bressou et al., (1959) and Smith (1968). The former authors further remark that in the phalanges the medullary canal is not clearly distinguished. Strauss-Durckheim (1845), Mivart (1881) and Jayne (1898) state that the epiphysis is at the base of the bone and Lesbre (1897), Schaeffer (1932), Bourdelle and Bressou (1953), Bressou et al., (1959) and Smith (1968) indicate the epiphysis to be at the proximal end. It is to be presumed that the base referred to is in fact the proximal extremity.

Phalanx Media (Digits II - V)

The diaphyseal centre was seen at birth by Bressou et al., (1959) and Smith (1968). Lesbre (1897) places its appearance as during the second half of gestation and after the appearance of the 1st phalanx. Schaeffer (1932) reports the presence of the shafts of phalanx 2 of III and IV digits in a foetus of 8.4 cm. (38 days p.c.) and the shafts of phalanx 2 of II and V in a foetus of 8.6 cm. (41 days p.c.).

Phalanx Distalis (Digits II - V)

There is agreement by the previous authors that the third phalanx develops from one single centre. Schaeffer (1932) identifies it in a foetus of 6.3 cm. (31 days p.c.) whilst Smith (1968) found it evident in radiographs of litters at birth.

Ossa Digitorum Manus (II - V).

Period of gestation 20-30 days

Radiography of the foetus.

There was no evidence of calcification.

Radiography of foetus impregnated with silver nitrate.

There was no evidence of their presence on the radiographs.

Alizarin red staining of foetus.

None of these elements was staining.

Period of gestation 31-40 days

Histology

The third phalanx was apparent as a cartilaginous model at the onset of this period but by 34 days (C. R. 44 mm.) primary calcification of the matrix and peripheral tissue at the base of the model was evident. There was accompanying degeneration of the cartilage cells of this region to make way for invading osteoblastic elements. By 39 days (C. R. 63 mm.) there was considerable calcification of this phalanx with formation of bony tissue, spreading throughout the centre.

The first and second phalanges exhibited calcified ground substance around the cartilage cells at the middle of the model shaft with concurrent degeneration of these cells at 39 days (C. R. 63 mm.). The process appeared to be more advanced in the first phalanx.

Radiography of foetus

There was no indication of the presence of these elements until the radiograph of the foetus of 36 days (C. R. 49 mm.). Here the third phalanges of digits two to four were obvious as small triangular dots but the third phalanx of digit five was less obvious. This latter phalanx only became really distinct at 38 days (C. R. 58 mm.). It was not until the 40th day (C. R. 66 mm.) foetus that phalanx I appeared. Its image was almost rectangular being broader than long and it was only apparent in digits two to four. The second phalanx was not present in the foetuses C. R. 66 mm. and 67 mm. but was present in the foetus C. R. 68.9 mm. Its shaft could be seen in digits two to four and also the first phalanx was now present in digit five (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The third phalanx was not seen in the 31 day foetus (C. R. 35 mm.) but on examining the 34 day (C. R. 43 mm.) specimen there was a small dot at the extremity of the second and third digits. In the 37 day foetuses (C. R. 56.5 mm.) these dots had enlarged and were triangular in shape being present in digits two to four (Fig. Sn12). By day 39 (C. R. 63 mm.) there was a centre for the shaft of phalanx I of digit three (Fig. Sn.13), and by day 40 (C. R. 67 mm.) a similar centre was present in digits two to five but it was still very small in digit five (Fig. Sn18). In the other digits this centre was a narrow band placed transversely. There was still no evidence of phalanx II.

Alizarin red staining of foetus

The 31 day foetus (C. R. 35 mm.) lacked the staining of any phalanges. At 33 days (C. R. 39 mm.) the third phalanges of digits two, three and four were apparent as small pointed specks at the distal extremity of each digit (Fig. AZ15). At 34 days (C. R. 43 mm.) the fifth digit demonstrated its third phalanx and from this stage the size of the phalangeal body increased becoming cone shaped, the apex of the cone pointing distally. The first uptake of stain by phalanx I occurred at 38 days (C. R. 58 mm.) and in this case there was a faint colouration of the first phalanx of digit three. In the foetus of 39 days (C. R. 63 mm.) the first phalanx of digits two to four was apparent (Fig. AZ32) and by 40 days (C. R. 66 mm.) the first phalanx of digits two to five was seen. Phalanx II did not appear until this last stage, i.e., 40 days (C. R. 66 mm.) when it was seen in digits two, three and four.

Period of gestation 41-50 days

Histology

By 44 days (C. R. 85 mm.) the collapse of the cartilage cells at the centre of the shaft was advanced and there had been invasion of the area with blood vessels and osteoblasts. The area was surrounded by a calcified collar of tissue. These findings were seen in both the first and second phalanges.

Radiography of foetus

The first and third phalanges of digits 2 and 5 were to be seen in the foetus of 41 days (C. R. 73 mm.) but the second phalanges were only present in digits 2 - 4 and then only as faint outlines (Figs. X3, X4 and X5 show the difficulty in demonstrating them). On the foetuses of 42 days (C. R. 78 mm.) the second phalanx of digit 5 was just visible whilst the other second phalanges were becoming clearer, being rectangular in shape. At 44 days (C. R. 84 mm.) the outlines of all the phalanges were becoming more clearly defined and by 45 days (C. R. 86 mm.) they were obvious in digits 2 - 5. At 50 days (C. R. 102 mm.) the first phalanges had achieved a greater length than the second phalanges whilst the third phalanges were now quite pointed at their distal extremities (Fig. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The first and third phalanges of digits II - IV were present in the foetus of 41 days (C. R. 73 mm.) and there was a small spot present to indicate the appearance of the shaft of the second phalanx of digit III. The centres of the first phalanges were small bands while the third phalanges were a larger more triangular shape. In the foetus of 43 days (C. R. 82.5 mm.) the shafts of phalanges I, II and III of digits II - V were all present although the centre for the second phalanx of digit V was still very slight (Fig. Sn19). At 44 days (C. R. 84 mm.) the shaft of the first phalanx was well formed and demonstrating narrowing of the diaphyseal waist. The third phalanges were cone shaped with apices directly distally. The second phalanx remained short and did not exhibit such a marked narrowing of its central portion (Fig. Sn21). This appearance still held at 50 days (C. R. 102 mm.) although there had been a general increase in size of all phalanges (Fig. Sn31). It was difficult to view the second phalanx in a true dorso-ventral plane as the X-ray beam tended to pass through the longitudinal axis of the developing shaft. This was due to the second phalanx being in its normal position of flexion in relation to the first phalanx.

Alizarin red staining of foetus.

By the 43rd day (C.R. 82.5 mm.) all the bony elements of the digits II - V were distinct in their form. The diaphyseal narrowing of the first phalanx was demonstrated as the shaft matured but the second phalanx did not achieve the equivalent stage in degree of remodelling. The angulation between the first and second phalanges was shown throughout the age range. The third phalanges, already cone shaped, could be seen to flatten on their lateral aspects producing a narrower body. The pointed apex became more hook-like in a distal direction. These changes began to manifest themselves at 45 days (C.R. 86 mm.) (Figs. AZ49 and AZ50), and were easily recognised at 50 days (C.R. 102 mm.) (Fig. AZ62).

Period of gestation 51-60 days

Radiography of foetus.

The first and second phalanges increased predominantly in length whilst the third phalanx retained its pointed appearance. The density of the bone appeared uniform until the 54th day (C.R. 112 mm.) when radiolucent areas were apparent in the central shafts and by 56 days (C.R. 120 mm.)

these were coalescing to form a fairly uniform dark area in the shaft. This change was continued throughout the remainder of the period (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

This technique helped to reveal the pointed nature of the distal extremities of the third phalanges (Fig. Sn52).

Alizarin red staining of foetus

The phalanges increased in size during this period. The proximal extremities of the first phalanges became more transversely flattened during this period (Figs. AZ63, AZ100 and AZ110).

Period of gestation 61 days onward

Radiography of foetus.

The phalanges made a slight increase in size during this period (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The third phalanges appeared more pointed in shape (Fig. Sn55).

Alizarin red staining of foetus.

The three phalanges did not appear significantly altered in shape.

Conclusions

The third phalanx (distalis) was the first to make its appearance known, by staining with alizarin in a 33 day (C.R. 38 mm.) foetus in digits II, III and IV and in digit V in a 34 day foetus (C.R. 44 mm.). The histological picture at this stage was of primary calcification at the base of the cartilage model with some calcified material present at the periphery. By the 39th day (C.R. 63 mm.) there was a centre of ossification present in the centre of the third phalanx with deposition of bone spicules. Alizarin staining revealed the first phalanx (proximalis) at 38 days (C.R. 58 mm.) and the second phalanx (media) at 40 days (C.R. 69 mm.). However histologically there was only to be seen a degree of primary calcification at the centre of the shaft with an accompanying degeneration of the cartilage cells. The process was more advanced in the first phalanx than in the second. The first and second phalanges did not display centres of ossification until the beginning of the period 41 - 50 days and by 44 days (C.R. 84 mm.) there was present bony tissue within the centre of the shaft.

Radiographically the centres began appearing at 34 days (C.R. 43 mm.) in the silver impregnated specimens, with the third phalanx appearing earliest followed by the first at 39 days (C.R. 63 mm.) and the second at 41 days (C.R. 73 mm.). Radiography of the fresh specimens produced an image for the third phalanx at 36 days (C.R. 49 mm.), one for the first at 40 days (C.R. 66 mm.) and the second at 41 days (C.R. 73 mm.).

APPENDICULAR SKELETON

OSSA MEMBRI PELVINI

Ossa Coxae

Lesbre (1897) describes the development of the os coxae as coming from 3 main centres. Those are one each for the ilium, ischium and pubis. These ossify away from the region of the cotyloid cavity; the ilium at the same time as the scapula; the ischium a little later and pubis last. Jayne (1898) illustrates the innominate bone of a kitten shortly before birth and at birth. Both illustrations show a diaphysis for the ilium, ischium and pubis, with cartilaginous extremities and cotyloid cavity. Schaeffer (1932) indicates the presence of the shafts of the ilium, ischium and pubis as follows:

ilium	-	6.3 cm. C.R. (31 days p.c.)
ischium	-	8.4 cm. C.R. (38 days p.c.)
pubis	-	13 cm. C.R. (53 days p.c.)

Smith (1968) in his radiographic work does not describe the pelvic region.

Ilium

Period of gestation 31 -40 days.

Histology.

The foetuses at the commencement of this period still possessed cartilaginous precursors for the ilial centres but the cells were swollen and beginning to disintegrate. At 33 days (C.R. 38 mm.) a collar of calcified tissue was formed around the middle of the model and there was invasion of blood vessels into the collapsing interior. By 35 days (C.R. 44.2 mm.) the centre was established with calcified tissue now evident within the ilial shaft.

Radiography of foetus.

This made its first appearance in the foetuses of 36 days (C.R. 49 mm.). A short band was seen running in a parasagittal position medial to the proximal extremity of the femoral shaft. This was on a dorso/ventral exposure, the lateral exposure still showing the presence of the ilium but with a reduction in the definition of its outline. By 38 days (C.R. 58 mm.) the band had narrowed so that its greatest length ran craniocaudally. Its outline was clearer on lateral examination and by 40 days (C.R. 66 mm.) this outline was approximately rectangular (Fig. X3). At this age, on dorso-ventral exposure, the narrowed shafts were slightly divergent at their cranial extremities (Figs. X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The foetus of 34 days (C.R. 43 mm.) had present a shaft of the ilium, seen on both a lateral and dorso/ventral exposure. This was not observed in the earlier foetuses. The outline was of a rectangular band on a lateral view with a concave dorsal border (Figs. Sn8 and Sn9). This shape of the dorsal border was still evident at 37 days (C.R. 56.5 mm.) when the body had increased in size. On a dorso/ventral view at this stage there was a slight medial projection from the body. At 39 days (C.R. 63 mm.) the concavity was not so distinct and by 40 days (C.R. 67 mm.) the body was narrowed centrally on lateral view, with a medial prominence on dorso/ventral exposure. The overall size had increased (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

Foetuses of three litters of 31 days (C.R. 35 mm.) were processed but the ilium was stained in only one of them (Fig. AZ10). It appeared as a small plaque with a greater width caudally. The appearance was similar in the foetuses of 33 days (C.R. 39 mm.) but by 34 days (C.R. 43 mm.) the cranial end was expanding so that by 35 days (C.R. 44.2 mm.) the ilium appeared as a flattened plate with a narrowed central portion and expanded cranial and caudal extremities, the former being of greatest diameter (Fig. AZ18). The ilium continued to increase in size but retained this shape throughout the period (Fig. AZ33). At 40 days (C.R. 66 mm.) the medial aspect of the body bore a slight projection, pointing towards midline.

Period of gestation 41-50 days.

Radiography of foetus.

The shaft of the ilium at 41 days (C.R. 73 mm.) was rectangular in outline on a lateral projection with a degree of narrowing dorso-ventrally at its central portion (Fig. X3). On dorso-ventral exposure there was a slight medial eminence projecting from the shaft towards mid-line (Figs. X4 and X5). At 42 days (C.R. 78 mm.) the narrowing of the central portion of the shaft was more obvious. By 44 days (C.R. 84mm.) the shaft was divided into a cranial and caudal portion by a distinctly narrowed waist, the cranial portion being of greater size than the caudal. The overall size of the shaft, continued to increase in this period and the cranial and caudal extremities became rounded and better defined (Fig. X7). On a dorso-ventral exposure, the cranial ends of the ilial shafts could be seen to be becoming divergent (Fig. X6).

Radiography of foetus impregnated with silver nitrate.

The silver impregnation helped to illustrate the development of the rounded contour of the cranial border and the narrowing of the central portion of the shaft (Fig. Sn19). The medial eminence of the facies auricularis became more evident from 45 days (C.R. 86 mm.) onward (Fig. Sn27), and by the 50th. day (C.R. 102 mm.) a roughened auricular surface could be observed (Fig. Sn31).

Alizarin red staining of foetus.

The alteration of outline and reshaping of the ilial shaft was illustrated by the staining technique. The divergence of the ilial wings was becoming obvious at 46 days (C.R. 88 mm.) and the hollowing of the depression of the facies glutea was showing (Fig. AZ52). Also medially the development of the raised facies auricularis was progressing.

Period of gestation 51-60 days.

Radiography of foetus.

The size of the ilium increased without noticeably altering the outline of the radiographic image (Figs. X8 and X9). The bone density remained fairly uniform until the end of this period when a darker area, longitudinally running, could be seen in the interior of the ilial shaft as viewed on a dorso-ventral projection. These areas were again visible on later radiographs and were taken to represent reabsorption of bone within the shaft of the ilium.

Radiography of foetus impregnated with silver nitrate.

The increase in dimension was observed (Figs. Sn33 and Sn51) and the technique illustrated the irregular surfaces on the medial aspect of the ilial shaft in the region of the facies auricularis. This was seen on a dorso-ventral projection (Fig. Sn47).

Alizarin red staining of foetus.

In the foetus of 51 days (C.R. 105 mm.) the two ilial shafts were beginning to alter in position, and by 53 days (C.R. 108.3 mm.) the two shafts had rotated so that their dorsal borders were closer to midline (Fig. AZ89). There was also an outgrowth from the medial aspect of the ilial shaft which was pointing towards midline. This was at the level of one third of the way from the proximal end. This angulation and the presence of the projection continued throughout the period. The cranial and caudal border which at the beginning of this period was slightly thickened, became increasingly so, giving a flattened cranial and caudal edge as opposed to the finer narrower edge found dorsally and ventrally (Fig. AZ104 and AZ107).

Period of gestation 61 days onward.

Radiography of foetus.

The inward development of the auricular face of the ilial shaft was well defined in the 61 day (C.R. 140 mm.) foetus and at birth onward the close approximation of the ilium to the sacral vertebrae was obvious. These observations were on dorso-ventral plates (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

The facies auricularis was well defined by this technique (Fig. Sn55).

Alizarin red staining of foetus.

The thickness of the body was increased and the cranial and caudal borders were wider. The outline remained constant and the close approximation of the ilium to the sacral vertebrae could be seen.

Ischium

Period of gestation 31-40 days.

Histology.

The precursor of the ischial shaft remained cartilaginous till the end of this period but the cells at the middle were swelling and showing evidence of disintegration by 39 days (C.R. 63 mm.). In the foetus of 40 days (C.R. 66 mm.) the shaft was surrounded by a calcifying layer and invasion of the centre was seen with blood vessels and osteoblastic cells. Succeeding foetuses evidenced the progressive calcification and ossification of the shaft.

Radiography of foetus.

The first indication of the presence of the shaft of the ischium was seen in the foetuses of litters of 38 days (C.R. 58 mm.). In them could be seen a small spot placed caudal to, but in the same parasagittal plane as the shaft of the ilium. This was on a dorso/ventral plate, but the shaft could also be observed on lateral exposure. In the foetuses of 40 days (C.R. 66 mm.) the shaft of the ischium had assumed a more rod-like appearance on dorso/ventral exposure but was more rectangular when observed laterally (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The foetus of 37 days was the first foetus found to have evidence of the presence of the ischium using this technique. Here it was but a small speck placed caudal to the ilium (Fig. Sn12). Little increase in size was seen at 39 days (Fig. Sn14), but in the 40 day foetus (C.R. 67 mm.) the ischium was distinct, being irregularly oval in shape (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

Of the two litters of 36 days, only the foetus of litter C.R. 49mm. displayed a stained ischium (Fig. AZ21). This was seen as a small speck placed caudal to the ilium. The foetus of 37 days (C.R. 56.5 mm.) did not have this present but, at 38 days (C.R. 58 mm.) the ischium was seen as an irregular plate somewhat triangular in shape. This increased in size during the remainder of the period (Fig. AZ33).

Period of gestation 41-50 days.

Radiography of foetus.

The shaft of the ischium at 41 days (C.R. 73 mm.) was still small and about half the size of that of the ilium, being almost square in shape on a lateral view (Fig. X3). On a dorso-ventral exposure, the outline was more oblong (Figs, X4 and X5). The shape on lateral view gradually altered so that at 44 days (C.R. 84 mm.), the cranial portion was larger than the caudal and the shaft on dorso-ventral exposure was compressed laterally. The overall size continued to increase throughout this period and the cranial border became more irregular in outline (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The silver technique helped to demonstrate the change in outline occurring in the ischium at this period. These changes corresponded with those described under radiography (Figs. Sn19, Sn20, Sn31 and Sn33).

Alizarin red staining of foetus.

The ischial shaft was stained throughout this period and its alteration in shape illustrated (Figs. AZ50 and AZ61). During this period there appeared to be a rotation of the shaft around its longitudinal axis so that the ventral boundaries were in closer proximity (Fig. AZ52).

Period of gestation 51-60 days.

Radiography of foetus.

The size of the ischium increased without noticeably altering the outline of the radiographic image. The bone density remained fairly uniform until the foetus of 58 days (C.R. 130 mm.) when darker areas, longitudinally running, could be seen in the interior of the ischium shaft as viewed on a dorso-ventral projection. These areas were again visible on later radiographs and were taken to represent reabsorption of bone within the shaft of the ischium (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The outline of the ischium remained constant during this period, the shaft increasing in overall size (Figs. Sn31, Sn33, Sn51 and Sn52). Towards the end of the period, there was occurring flattening of the surface of the cranial end of the lateral border when viewed dorso-ventrally.

Alizarin red staining of foetus.

At 51 days (C.R. 105 mm.) the shafts of the two ischii were rotated so that their ventral borders were closer to midline. The most caudal border was now thickened with a flattened edge producing the rim of the ischial arch (Fig. AZ86). Laterally at the junction of the cranial and ventral border there was differentiating a depression. By 53 days (C.R. 108.3 mm.) the depression had a raised lip caudally and in the 54 day (C.R. 112 mm.) foetus, the depression was of greater depth (Fig. AZ87). The area approximated closely to the cartilaginous femoral head (Fig. AZ107). At this stage, also, a medial projection could be seen ventrally and this continued in size with increasing age, and at 59 days (C.R. 133 mm.) was seen as a pointed prolongation directed towards mid-line (Fig. AZ106).

Period of gestation 61 days onward.

Radiography of foetus.

At the region of the lateral and cranial border on a dorso-ventral plate at 61 days (C.R. 140 mm.) there was appearing a slight depression, giving a flattened, evenly concave outline to this angle. At birth this flattened area was more distinct (Fig. X11) and by three days post-partum it was obvious.

Radiography of foetus impregnated with silver nitrate.

The flattening at the cranial part of the lateral border was demonstrated by this method (Fig. Sn55).

Alizarin red staining of foetus.

The depression in the future acetabular region was distinct. The ischial body was now extending considerably in a medial direction by means of the cranially projecting process.

Pubis.

Period of gestation 51-60 days.

Histology.

It was not until the foetus of 54 days (C.R. 112 mm.) that invasion of the now degenerating interior of the cartilaginous pubis occurred. From the enveloping calcifying layer penetration of blood vessels and cells to the interior was seen.

Radiography of foetus.

The pubis was not evident on the foetal radiographs until 54 days (C.R. 112 mm.) when it could be seen as a small rod lying opposite and medial to the gap between the ilium and ischium. The presence of this rod was not as evident on a lateral view. Traces of the pubic shaft could be seen in foetuses from all 5 litters of 54 days, but the size of the rod differed in the various litters. The presence of the pubic bones was confirmed in the litters of 56 days (C.R. 120 mm.) and continued to be evident throughout this period but even by 60 days (C.R. 136 mm.) it was still only a very slight rod seen on dorso-ventral view (Fig. X8).

Radiography of foetus impregnated with silver nitrate.

The first evidence of the presence of the pubic bone was in the dorso-ventral radiograph of foetus of 54 days.(C.R. 112 mm.). Three litters of 54 days were impregnated with silver and in all these, the pubic shafts were revealed as small specks lying medial to the gap between the ilial and ischial shafts (Fig. Sn41). The pubic image was closer to the cranial end of the ischium. The pubis was again obvious in the litter of 56 days (C.R. 121 mm.) where it was assuming a more rod-like appearance. It could now be observed on a lateral plate (Figs. Sn44 and Sn45). The shape of the pubic shaft in the foetuses of 57 and 58 days (C.R. 125 and 130 mm.) was not as distinct but its presence was confirmed in all the succeeding litters in this group.

Alizarin red staining of foetus.

The pubis was first stained in a foetus of 53 days (C.R. 108.3mm.) and its presence was a constant feature after that. At the 53 days stage, it was somewhat irregularly oval in outline but in the 54 day (C.R. 112 mm.) foetus (Fig. AZ79) it had assumed a rod-like appearance which was maintained during the period (Figs. AZ106 and AZ104).

Period of gestation 61 days onward.

Radiography of foetus.

The pubic bones were bar like, directed in a V formation, one to either side of mid-line (Fig. X11). They increased in length and by three days post-partum had come considerably closer to mid-line.

Radiography of foetus impregnated with silver nitrate.

The pubic bones were placed in a V position with the point of the V close to mid-line and the outer limbs originating level with the distal end of the ilial shaft (Fig. Sn55).

Alizarin red staining of foetus.

The pubic bones in the foetus at birth made up the limbs of a V. In the foetus of one day post-partum the pubis stained only as two small oval shapes (Fig. AZ119). In the foetus of two days post-partum the pubic bones were larger and more rectangular.

Ossa Coxae

Conclusions.

Alizarin red staining and histological examination gave the first evidence of the onset of the development of the bony shafts of the three principal components of the pelvic bones. The ilium was the first to appear at 31 to 33 days (C.R. 35-39 mm.) but was not seen on radiographs till 34 days (C.R. 43 mm.) for silver nitrate impregnated specimens and 36 days (C.R. 49 mm.) for fresh specimens. The alizarin result is close to the 31 days post coitus given by Schaeffer (1932) but the C.R. measurement of 35 mm. does not concur with Schaeffer's figure of 63 mm. C.R.

The ischium was first seen as a stained rod in an alizarin preparation at 36 days (C.R. 49 mm.) but no changes were observed histologically until three days after this. Radiographically the first appearance was at 37 days (C.R. 56.5 mm.) in silver nitrate and 38 days (C.R. 58 mm.) fresh specimens. Schaeffer (1932) described his alizarin specimens as having a stained ischial shaft at 38 days post coitus but he gave them a C.R. length of 34 mm. which does not compare with the present results of C.R. 55-60 mm.

The appearance of the pubis is fairly constant in its date, using all the techniques, being 54 days (C.R. 110 mm.) except for the alizarin specimens at 53 days (C.R. 108 mm.). This latter figure compares exactly with Schaeffer's post coital date of 53 days but is at odds with his figure of 130 mm. C.R. length.

The acetabular area remained cartilaginous during gestation which correlates with the findings of Lesbre (1897) and Jayne (1898). The moulding of the acetabular depression was becoming apparent at the commencement of the period 51-60 days and was best demonstrated by the alizarin red technique.

Femur.

Lesbre (1897) states that the diaphyseal centre for this bone appears in the course of the fourth week but the epiphyses only appear after birth. Schaeffer (1932) notes the appearance of the diaphysis in a foetus of 4.6 cm. (28 days p.c.) whilst Smith (1968) remarks that the shaft is represented on radiographs of newborn kittens.

Period of gestation 21-30 days.

Histology.

The 24 and 27 day foetuses (C.R. 17 and 23 mm.) revealed degeneration of the cartilage model at its middle portion and by 30 days (C.R. 29 mm.) there was some calcification of the surrounding collar. However, there was no collapse as yet of the central portion.

Radiography of the foetus.

In the foetuses within this range there was no evidence of calcified tissue in the femoral shaft.

Radiography of foetuses impregnated with silver nitrate.

The earlier foetuses revealed no significant findings until 30 days (C.R. 29.1, 31, and 31.2 mm.). In these three foetuses the femur was represented by a shaft of length 0.5 mm. and of similar breadth, giving it an almost square appearance (Fig. Sn3).

Alizarin red staining of foetus.

Three foetuses each from a different litter of 28 days were examined by this method. In one foetus, from the litter of C.R. 25 mm., the femur was represented by a red stained shaft of rod-like appearance (Fig. A21). In the remaining two foetuses from litters both of C.R. 26 mm., the femur was represented in one by a red speck whilst in the other there was no staining. Four foetuses each from a litter of 30 days were also examined, of which three were positive for staining of the femoral shaft with only the foetus from the litter C.R. 32 mm. remaining negative.

Period of gestation 31-40 days.

Histology.

The 31 day (C.R. 35 mm.) foetus showed the beginnings of collapse of the cartilage model but it was not until 33 days (C.R. 38 mm.) that invasion of the centre from the periphery could be seen.

Radiography of foetus.

Foetuses from three litter of 31 days (C.R. 35 mm.) were examined and from two of these evidence of the presence of the femoral shaft was detected. It appeared as an indistinct speck, and was seen on both dorso/ventral and lateral plates. The foetus of the third litter revealed no such structure. In the foetus of 33 days (C.R. 38 mm.) the speck had become more regular in form but was still extremely small (Fig. X1 and X2). The image at 34 days (C.R. 43 mm.) was almost square and by 36 days (C.R. 49 mm.) there was a rod-like shaft clearly visible of length 1.5 mm. By 38 days (C.R. 58 mm.) the length was 2.5 mm. and at 40 days (C.R. 66 mm.) the shaft was a narrow rod of 6 mm. slightly wider at its extremities.

Radiography of foetus impregnated with silver nitrate.

The femoral shaft was seen on both a dorso/ventral and lateral exposure at 31 days (C.R. 35 mm.) as a short rod which was denser at its centre (Figs. Sn4 and Sn5). By 34 days (C.R. 43 mm.) it had increased in total length and was narrowing in its central position (Fig. Sn8). The shaft continued to lengthen throughout the period, retaining its narrowed waist (Sn17).

Alizarin red staining of foetus.

The shaft, in the foetus of 31 days (C.R. 35 mm.) was a short cylinder, but by 33 days (C.R. 39 mm.) there was a narrowing of the central portion (Fig. AZ11). The shaft increased in length and diameter throughout the remainder of the period.

Period of gestation 41-50 days.

Radiography of foetus.

The femur of the 41 day foetus (C.R. 73 mm.) was 7 mm. in length on a lateral exposure and could be seen to have a narrowed diaphysis (Figs. X3, X4 and X5). The shaft continued to increase in dimensions over the period and its change was recorded thus.

45 days (C.R. 86 mm.) - 10 mm. in length.

The girth of the bone had increased overall but it still retained the narrowed diaphysis.

50 days (C.R. 102 mm.) - 11 mm. in length (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The femoral shaft continued to increase in its dimensions throughout this period (Figs. Sn20 and Sn33).

Alizarin red staining of foetus.

The shaft was stained throughout this period and the increase in size was illustrated (Fig. AZ61).

Period of gestation 51-60 days.

Radiography of foetus.

At 51 days (C.R. 105 mm.) the femur showed a narrow radiolucent area which was situated in the distal two thirds of the shaft. At the proximal end on the caudal border, just distal to the true proximal edge, there was a projection developing. This was observed on a dorso-ventral plate. By 56 days (C.R. 120 mm.) the radiolucent area was extending from just within the proximal and distal extremities, presumably representing a medullary space (Fig. X9). On the dorso-ventral plate, the projection described previously was more protuberant but still rounded (Fig. X8). By 60 days (C.R. 138 mm.) the summit of this protuberance was more pointed. The measurements of lengths were recorded thus:

51 days (C.R. 105 mm.) - 12 mm.

56 days (C.R. 120 mm.) - 17 mm.

60 days (C.R. 136 mm.) - 18 mm.

Radiography of foetus impregnated with silver nitrate.

The development of the proximal protuberance described under radiography was well demonstrated by this method (Figs. Sn39 and Sn47).

Alizarin red staining of foetus.

In the 52 day foetus (C. R. 108 mm.) the proximal extremity had a flattened surface whose caudal rim dipped down toward the middle of the shaft for a short space (Fig. AZ79). This produced the appearance of an elevation of the rim lateral and medial to this lip. This latter elevation rose in succeeding foetuses but not greatly above the level of the rim. At 59 days (C.R. 133 mm.) a medial swelling of the cortex was observed just below the level of the proximal adge (Figs. AZ104 and AZ105). This was also seen on the 60 day foetus (C.R. 136 mm.).

Period of gestation 61 days onward.

Radiography of foetus.

The projection situated at the proximal end and directed caudally on a dorso-ventral plate was a distinct entity. The shaft proximal to this projection narrowed to give a more conical appearance of the proximal end (Fig. X11). The shaft length was:

at 61 days (C.R. 140 mm.) - 18 mm.

at birth - 18 mm.

Radiography of foetus impregnated with silver nitrate.

The proximal projection was an obvious feature using this technique and the narrowing of the most proximal region was noticeable (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The medial projection was present but remained fairly constant in size. The flat surface of the distal extremity was now rounded cranially with a more flattened caudal border (Fig. AZ108).

Conclusions.

The alizarin staining technique allowed detection of calcified tissue at 28 days (C.R. 25 mm.) but radiographically the silver nitrate preparation did not show till 30 days (C.R. 29 mm.) There was evidence histologically of calcified tissue at this date. Radiography of the untreated foetus was negative for the femoral shaft until 31 days (C.R. 35 mm.). The date of Schaeffer's (1932) alizarin specimen, being 28 days, was in line with these findings but the C.R. length of 46mm. does not agree with the findings of 26 to 32 mm.

The longitudinal growth of the shaft in the latter part of the 31-40 day period was most marked, enlarging from 2.5 mm. at 38 days to 6 mm. by 40 days. The differentiation of the proximal end of the femoral shaft with separation of the collum femoris from the base of the trochanter major by the fossa trochanterica was demonstrated in the later part of the 51 to 60 day period as was the formation of the trochanter minor.

Tibia.

Lesbre (1897) states that the appearance of the tibial diaphysis is at about the same time as that of the radius. Schaeffer (1932) has the shaft present in a foetus of 4.6 cm. C.R. (28 days p.c.). Smith (1968) notes its presence in radiographs of newborn kittens, and similarly Bressou et al. (1959) describe the diaphysis as almost entirely ossified at birth.

Period of gestation 21-30 days.

Histology.

The 24 and 27 day foetuses (C.R. 17 mm. and 23 mm.) revealed degeneration of the cartilage model at its middle portion and by 30 (C.R. 29 mm.) days there was some calcification of the surrounding collar. However, there was no collapse as yet of the central portion.

Radiography of foetus.

No evidence of a calcified tibia was detected within this age range.

Radiography of foetus impregnated with silver nitrate.

The first sign of a tibial shaft was seen in three foetuses of 30 day (C.R. 29.1, 31 and 31.2 mm.). This was seen as a small rod lying in the image of the hind limb being narrower than the image of the femoral shaft (Fig. Sn3).

Alizarin red staining of foetus.

The tibial shaft was first seen to take up stain in the foetus of 28 days (C.R. 25 mm.) where it was seen as a short rod (Fig. AZ1). However, in the two foetuses of 28 days there was no staining of the tibial shaft. At 30 days (C.R. 29.1 mm.) the shaft was stained but this was not the case in the other foetuses of 30 days.

Period of gestation 31-40 days.

Histology.

The 31 day foetus (C.R. 35 mm.) showed the beginnings of collapse of the cartilage model but it was not until 33 days (C.R. 38 mm.) that invasion of the centre from the periphery could be seen.

Radiography of foetus.

Foetuses from 3 litters of 31 days (C.R. 35 mm.) were examined and only in one litter was there evidence of the appearance of the shaft of the tibial.

This was an elongated spot in the tibial region and was seen on a dorso/ventral exposure. In the three litters of 33 days, the foetuses of litters C.R. 39 mm. and 39.8 mm. displayed the presence of the tibia (Fig. X2). At 34 days, the litter C.R. 43 mm. lacked an obvious presence, but the foetus of litter 44 mm. had a distinct rod present in the hind limb. By 36 days (C.R. 49 mm.) the tibial shaft was clear in form with a length of 3 mm. It was seen on both a lateral and dorso/ventral exposure and alongside was the fibular shaft. The tibial shaft continued to increase in form and length, measuring 6 mm. at 40 days (C.R. 66 mm.) and appearing wider in its proximal half.

Radiography of foetus impregnated with silver nitrate.

At 31 days (C.R. 35 mm.) the tibial shaft was evident as a short rod with a denser central portion (Sn4) - this increased in length, and at 34 days (C.R. 43 mm.) there was a visible narrowing of the central region of the shaft compared to the extremities (Fig. Sn8). By 37 days the proximal extemity was slightly wider than its opposite and there was a cup-like effect seen in the structure of the proximal end (Fig. Sn12). This gave the impression that the outer layer was ossifying, but the central portion of the extremity was still cartilaginous. By 39 days (C.R. 63 mm.) this apparent depression was filling in (Fig. Sn14) and by 40 days (C.R. 66 mm.) was no longer apparent. In the 40 days foetus (C.R. 66 mm.) on a lateral exposure a slight irregularity of the cranial border, approximately one third of the way from the proximal end, could be seen (Fig. Sn17).

Alizarin red staining of foetus.

The foetus of 31 days (C.R. 35 mm.) had a stained tibial shaft which was cylindrical but short. The shaft increased in length and by 33 days (C.R. 38 mm.) there was a narrowing of the central portion (Fig. AZ11). At 36 days (C.R. 55 mm.) it was observed that the cranial border of the proximal extremity was staining in advance of the remaining rim (Figs. AZ21, 22 and 23) and this cranial prolongation of the cranial lip was seen throughout the rest of the period. In the foetuses of 40 days (C.R. 66 mm.) a step-like irregularity of the cranial surface of the shaft at approximately one third from the proximal end was observed (Fig. AZ34).

Period of gestation 41-50 days.

The tibial shaft in the foetus of 41 days (C.R. 73 mm.) was 6.5 mm. in length on the dorso/ventral exposure (Fig. X4). On a lateral exposure the proximal end could be seen to be more massive than the distal end but there was still a narrowing at the diaphysis (Figs. X3 and X5). The fibular shaft could be seen lying alongside the shaft and was more slender. The tibial shaft continued to enlarge throughout the period (Fig. X6) and its growth was recorded as:

45 days (C.R. 86 mm.) - 10 mm. in length.

50 days (C.R. 102 mm.) - 11 mm. in length.

The cranial border of the proximal third of the shaft became rounded, curving in a cranial direction, as seen on a lateral plate (Fig. X7). This appearance was becoming apparent throughout the preceding 5 days.

Radiography of foetus impregnated with silver nitrate.

The rounded appearance of the proximal cranial border was evident earlier in this period using the silver technique. It was obvious at 43 days (C.R. 82.5 mm.) (Fig. Sn20), and by the 50th. day (C.R. 102 mm.) was easily seen on a lateral plate. The stepped feature on the cranial border remained during the period.

Alizarin red staining of foetus.

At 43 days (C.R. 82.5 mm.) the flattened surface of the proximal extremity displayed a proximal projection at its cranial rim, this projection continuing to increase in size and become more cranio-lateral. The prominence of the proximal third of the shaft on its cranial surface continued to increase throughout the period, in pace with the overall increase in tibial size (Fig. AZ44).

Period of gestation 51-60 days.

Radiography of foetus.

The tibial shaft exhibited in its interior a radiolucent area which was in the form of an irregular streak running longitudinally. The area increased in width with the increase in diameter of the shaft and by the end of the period extended the entire length of the bone to just within the extremities (Figs. X8 and X9). Measurements of length were recorded thus:

51 days (C.R. 105 mm.)	-	12.5 mm. in length
56 days (C.R. 120 mm.)	-	16.5 mm. "
60 days (C.R. 136 mm.)	-	16.5 mm. "

Radiography of foetus impregnated with silver nitrate.

The cranial border of the tibial shaft continued to demonstrate a slightly stepped feature on the cranial border at about one quarter of the way down the shaft (Fig. Sn38). This step-like cleft was apparent as a distinct irregularity on the cranial contour of the shaft. It remained a feature throughout the remainder of the period (Fig. Sn51).

Alizarin red staining of foetus.

There was an irregularity on the cranio-lateral surface of the shaft in the foetus of 51 days (C.R. 105 mm.) and this step-like gap was evident from then on. At 54 days (C.R. 112 mm.) there was seen a darker staining spot on the edge of this step and this remained a constant feature (Fig. AZ92). The proximal tibial extremity was flat and irregularly rounded at 51 days (C.R. 105 mm.) but became increasingly triangular in shape (Figs. AZ76 and AZ77), and the most cranially placed angle of the triangle dipped down as a shallow groove in foetuses of 56 days and older. (Fig. AZ104).

Period of gestation 61 days onward.

Radiography of foetus.

The tibial shaft measurements were as follows:

61 days (C.R. 140 mm.)	- 16.5 mm. in length		
At birth	- 16.5 mm.	"	(Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The step-like image seen on the cranial border of the shaft in the previous period was not so distinct at birth. The edge was more rounded with a denser area of tissue marking the area. There was apparent at the distal end just above the margin an area of reduced radiolucency in a crescent shape. This was evident on both lateral and dorso/ventral exposure (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The step-like process was replaced by a slightly raised " scar " of darker staining tissue. At the distal extremity, to either side of the shaft just above the distal end there were small darker staining patches on the surface of the shaft (Fig. AZ118).

Conclusions.

There was evidence histologically of calcified ground substance and periosteal collar in the latter half of the 21-30 day period but the arrival of a periosteal bud did not occur until 31 days (C.R. 35 mm.) onward. The alizarin red stained specimens were positive at 28 days (C.R. 25 mm.) followed by the radiographic appearance of the silver nitrate impregnated tibial shafts in foetuses of 30 days (C.R. 29 mm.). Radiography of fresh foetuses did not reveal the tibia till 31 days (C.R. 35 mm.) and even this was not consistent till 33 days (C.R. 38 mm.). The observations of Schaeffer (1932) therefore tally as far as days post-coitus are concerned (being 28 days), but the C.R. length that he attributes to this age of 46 mm. is far in excess of the findings of 23 to 26 mm. The tibia does appear at approximately the same time as the radius as stated by Lesbre (1897).

The position at which there appeared a step-like ridge on the cranial aspect of the proximal half of the shaft at the 40 day stage would approximate to the position of attachment of the ligamentum patellae. At the termination of the period of gestation there was alteration in the bone density at the positions where ligaments of the tibiotarsal joint would make their proximal attachments.

Fibula.

Lesbre (1897) places the appearance of the primary centre as at the same time as the tibia or shortly after. Schaeffer (1932) names its appearance at 4.6 cm. (28 days p.c.). Smith (1968) reports its presence at birth as an ossified diaphysis and this is further verified by Bressou *et al.* (1959).

Period of gestation 21-30 days.

Histology.

The 24 and 27 day (C.R. 17 mm. and 23 mm.) foetuses revealed degeneration of the cartilage model at its middle portion and by 30 days (C.R. 29 mm.) there was some calcification of the surrounding collar. However, there was no collapse as yet of the central portion.

Radiography of foetus.

No evidence of a calcified fibula was detected within this age range.

Radiography of foetus impregnated with silver nitrate.

The first sign of a fibular shaft was seen in two foetuses of 30 days (C.R. 29.1 mm. and 31 mm.). This was seen on a lateral radiograph as a small rod lying caudal to the tibial shaft and almost half its size. In the foetus (C.R. 31.2 mm.) there was no evidence of the presence of the fibula.

Alizarin red staining of foetus.

The fibular shaft was first seen to take up stain in the foetus of 28 days (C.R. 25 mm.) where it was seen as a short rod lying parallel with the tibia and of very similar size (Fig. AZ1). However, in the two other foetuses of 28 days there was an absence of staining of the tibial and fibular shafts. At 30 days (C.R. 29.1 mm.) the fibular shaft was stained but this was not the case in the other foetus of 30 days.

Period of gestation 31-40 days.

Histology.

The 31 day (C.R. 35 mm.) foetus showed the beginnings of collapse of the cartilage model but it was not until 33 days (C.R. 38 mm.) that invasion of the centre from the periphery could be seen.

Radiography of foetus.

A fibular shaft could not be identified until the 36th. day (C.R. 49 mm.) but it was possible that the fibular shaft was overlaid by the tibial shaft on the dorso/ventral exposure. At 36 days (C.R. 49 mm.) the fibular shaft was seen as a narrow line running alongside and lateral to the tibia on the dorso/ventral plate. It was still not clearly defined on a lateral plate. Its length was 2.5 mm. approximately.

In the foetuses of 38 days (C.R. 58 mm.) the outline both on dorso/ventral and lateral exposure was indistinct in one, but of more regular outline in the other. By 40 days (C.R. 66 mm.) the shaft was constantly apparent as a narrow line lying alongside and lateral to the tibia as seen on a dorso/ventral exposure (Fig. X4). The length of the shaft was 6 mm. It was also distinct on a lateral plate (Fig. X3).

Radiography of the foetus impregnated with silver nitrate.

On the lateral radiograph of the foetus of 31 days (C.R. 35 mm.) the shaft of the fibula could be seen as an elongated spot lying caudal to the tibia (Fig. Sn4) and by 34 days (C.R. 43 mm.) this had lengthened to virtually the equivalent of the tibia (Fig. Sn9). It was now observed on both lateral and dorso/ventral projections. It continued to lenghen throughout the period remaining slender in form compared with the tibial shaft (Fig. Sn18).

Alizarin red staining of foetus.

The shaft was seen at 31 days (C.R. 35 mm.) as a short rod lying alongside the tibia but finer and shorter (Fig. AZ10). The length of the shaft continued to increase and by 36 days (C.R. 49 mm.) it could be seen that the distal portion was of greater diameter than the proximal (Fig. AZ22). This situation was continued and in the last half of the period the shaft was distorting slightly to give a more curved appearance.

Period of gestation 41-50 days.

Radiography of foetus.

The fibular shaft of the 41 day (C.R. 73 mm.) foetus was slender and of almost equal length to that of the tibia. The extremities were slightly expanded (Figs. X3 and X4). Total length was approximately 6.0 mm. The proximal extremity was slightly more distal in the limb than the corresponding extremity of the tibia. On the dorso/ventral view the two shafts on some projections crossed over at the distal third but appeared separate on lateral viewing (Figs. X6 and X7). Growth continued throughout this period and was recorded thus:

45 days (C.R. 86 mm.) - 9 mm.

50 days (C.R. 102 mm.) - 10 mm.

Radiography of foetus impregnated with silver nitrate.

The progressive growth of the slender fibular shaft was noted throughout this period (Figs. Sn21 and Sn31).

Alizarin red staining of foetus.

The shaft was stained throughout this period and there was a somewhat spiralling effect produced throughout its length (Fig. AZ78).

Period of gestation 51-60 days.

Radiography of foetus.

The ulnar outline changed little in shape, only increasing in overall length and thickening somewhat. (Figs. X8 and X9).

51 days (C.R. 105 mm.) - 12 mm.

56 days (C.R. 120 mm.) - 15.5 mm.

60 days (C.R. 136 mm.) - 15.5 mm.

Radiography of foetus impregnated with silver nitrate.

The increase in size of the fibular shaft was noted. The distal portion remained greater in mass throughout this period (Sn33 and Sn51).

Alizarin red staining of foetus.

The distal end of the shaft of the fibula, on the aspect most approximate to the tibia, was producing a more flattened outline as it became apparently more closely applied to the tibial shaft in this region. This became noticeable at 54 days (C.R. 112 mm.) and the appearance continued for the rest of the period (Fig. AZ85).

Period of gestation 61 days onward.

Radiography of foetus.

The measurements of the shaft were:

61 days (C.R. 140 mm.) - 16 mm.

at birth - 16 mm. (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

There were no significant alterations evident in the ulnar shaft (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

There was no further indication of change in the shaft.

Conclusions.

The fibular shaft was apparent in the alizarin stained specimens of 28 days (C.R. 25 mm.) and consistent in its presence by 30 days (C.R. 29 mm.). Radiographically this latter time was also the day of appearance of the fibular shaft when impregnated with silver nitrate, but the shaft in fresh specimens did not appear till the 36th. day (C.R. 49 mm.). Histologically there was evidence of primary calcification from 27 days (C.R. 23 mm.)

onward but the foetuses of 33 days (C.R. 38 mm.) were the first to exhibit a true centre of ossification. These times of appearance approximated closely with the date post-coitus given by Schaeffer (1932) but again his stated C.R. length of 46 mm. was well in excess of the range of 25-32 mm. which represented the C.R. lengths in these findings.

Tarsus.

Schaeffer (1932) describes the presence of centres for the body of the calcaneus in a foetus of 11.5 cm. C.R. (49 days p.c.). The centre for the talus appears only at 13 cm. C.R. (53 days p.c.). Bressou et al. (1959) note the appearance of the calcanean centre in a radiograph of a kitten at birth as being fairly well developed, with a club shaped form, rounded and larger at the bottom. They continue that the talus has a centre of ossification of very recent appearance and is only a large spot placed below the medial to the lower extremity of the calcaneus and in front of metatarsal III. In the radiographs of Smith (1968) a centre was present at birth for the calcaneus and talus.

Period of gestation 41-50 days.

Histology.

The mode of development was by endochondral ossification when examined histologically. In a foetus of 44 days (C.R. 85 mm.) there was evidence of degeneration of the cartilage cells at the plantar aspect of the cartilaginous model with accompanying calcification of the ground substance. By 46 days (C.R. 90 mm.)there were the first signs of invasion of the interior of the body by oesteogenic cells.

Radiography of foetus.

The earliest sign of any of the elements of the tarsus was seen at 47 days. In the foetus of a litter of C.R. 91 mm., there was a very faint spot caudally in the tarsal region, but the outline was indefinite. In the foetus of litter C.R. 92 mm. the outline was more precise giving the appearance of a rounded spot placed dorso-caudally in the tarsal region (Fig. X7). This was on a lateral exposure but it could also be viewed on a dorso-ventral plate there being placed almost centrally in the tarsal region (Fig. X6). This spot improved in definition and by 50 days (C.R. 102 mm.) was somewhat rectangular in appearance, being greater in its longitudinal axis on a lateral exposure. This spot was the centre of ossification for the body of the calcaneus.

Radiography of foetus impregnated with silver nitrate.

Using this method the earliest sign of the presence of the calcaneus was seen at 44 days (C.R. 84 mm.) as a small dot in the dorso-caudal area of the tarsal region i.e., on a lateral exposure (Fig. Sn22). The dorso-ventral view was central in position (Fig. Sn21).

Alizarin red staining of foetus.

There was no uptake of stain by any of the tarsal elements until the 44th. day (C.R. 84 mm.) (Figs. AZ43, 45 and 46). In that foetus an area, the shape of a roundly folded leaf lying on its side with its concave surface directed cranially, was stained red. This increased in size with the dorsal border enlarging more than the ventral border. The thickness of this leaf-shape was also increasing (Fig. AZ61). This stained element was the body of the calcaneus.

Period of gestation 51-60 days.

Radiography of foetus.

In the radiograph of the foetus of 51 days (C.R. 105 mm.) the calcaneus could be seen placed caudally in the tarsal region. It was small and oval in shape with its longitudinal axis running along the similar axis of the limb i.e., on a lateral plate. On dorso-ventral the shape was squarer. These forms increased in size in foetuses of 53 and 54 days (C.R. 109 and 112 mm.) when the shape became more uniformly rectangular on both positions of exposure. By 56 days (C.R. 120 mm.) the proximal segment of the bone was narrower than the distal and this was most particularly noticeable on the dorso-ventral exposure. This appearance was accentuated in the later foetuses (Figs. X8 and X9) and at 60 days (C.R. 136 mm.), calcaneus was irregularly rectangular with a larger more rounded distal segment and a narrow flattened proximal border.

Radiography of foetus impregnated with silver nitrate.

The calcaneus at 51 days (C.R. 105 mm.) and on a lateral plate, was wider distally (Fig. Sn33). On a dorso-ventral view, it had a concave cranial border giving the impression of a curved leaf of calcified tissue (Fig. Sn35). At 54 days (C.R. 112 mm.) the concave cranial border, on a dorso-ventral exposure, was lost as the surface filled in (Fig. Sn45). The body continued to increase in size and by 56 days (C.R. 121 mm.) it was an irregular rectangle with a wider base (Fig. Sn44). The increase in size between 56 (C.R. 121 mm.) and 60 days (C.R. 136 mm.) was extremely small (Figs. Sn51 and Sn52).

Alizarin red staining of foetus.

The calcaneus continued to demonstrate a concave cranial face giving it a folded leaf-like appearance. The depth of the body from the cranial to plantar face was increasing by the 54th. day (C.R. 112 mm.) (Fig. AZ78), and by the 56th. day (C.R. 120 mm.) the body had a more cuboidal shape but retained its cranial concavity throughout the period. The distal half of the body was longer and more bulbous than the proximal half (Fig. AZ92).

Period of gestation 61 days onward.

Radiography of foetus.

The outline of the calcaneus was narrow in its proximal half, on the cranial face of which a concavity was becoming evident and at birth was quite distinct (Fig. X10). On a dorso-ventral exposure during this period the talus could be readily seen through the image of the calcaneus (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

The calcanean outline revealed the proximal cranial concavity with a more bulbous distal portion (Fig. Sn56).

Alizarin red staining of foetus.

The calcaneus remained concave on its cranial face but was of greater mass (Fig. AZ118).

Talus.

Period of gestation 51-60 days.

Histology.

Ossification was from a cartilaginous precursor which had already undergone degeneration of its cells and calcification of the ground substance by 54 days (C.R. 112 mm.). There was evidence of the commencement of invasion of the centre by osteogenic tissue from the periphery.

Radiography of foetus.

In the radiographs of foetuses 51 to 53 days (C.R. 105-109 mm.) the only element visible in the tarsal region was the body of the calcaneus. In the foetus of 54 days (C.R. 112 mm.) the talus first appeared. This was evident on a lateral plate as a small oval structure placed cranial to the distal cranial angle of the cancaneus. On a dorso-ventral view, this was masked by the body of the calcaneus. Of the five litters of 54 days (C.R. 112-115 mm.) the presence of the body of the talus was obvious in three but just evident in the other two being only an indistinct speck. In the foetuses of 3 litters of 56 days (C.R. 120-122 mm.) two had obvious centres for the talus whilst the remaining one was indistinct. In the first litter of 57 days (C.R. 125 mm.) the talus was evident in both hind limbs of 4 of the six individuals examined. In another, only the talus of one hind limb was evident whilst the remaining foetus lacked any evidence of the development of a body for the talus. In the three litters of 58 days (C.R. 130 mm.) the foetuses of two had an element present representing the talus but the foetuses of the remaining litter had none. However, the foetuses of 59 (C.R. 133 mm.) and 60 days (C.R. 136 mm.) demonstrated a talus on a lateral plate (Fig. X9). On a true dorso-ventral exposure, this was still masked by the calcaneus but its outline could be seen indistinctly through the calcanean image. It lay in the distal segment of the calcanean image.(Fig. X8).

Radiography of foetus impregnated with silver nitrate.

In the three litters of 54 days (C.R. 112-114 mm.) the foetuses examined demonstrated the presence of a talus lying, as a spot, cranial to the distal end of the calcaneus. These litters were the first of this series to show such a structure (Figs. Sn40 and Sn41), except for one litter of 51 days (C.R. 105 mm.) where it was seen on lateral plates. Its presence was not repeated in subsequent litters until 54 days (C.R. 112 mm.).

Alizarin red staining of foetus.

The body of the talus was not seen staining until the foetus of 54 days (C.R. 112 mm.) and even then it was missing in one foetus out of the five examined. The talus appeared as a small oval structure with rather an irregular outline (Fig. AZ79). It increased in size during this period but remained irregularly oval in shape (Fig. AZ104). There was no staining of the talus in one of the foetuses of 58 days (C.R. 130 mm.), whereas, in the other two 58 day foetuses examined, the stained body of the talus was evident.

Period of gestation 61 days onward.

Radiography of foetus.

This structure increased in size during the period but remained oval in shape (Fig. X10). The density of the structure was such as to allow it to be discerned through the image of the calcaneus on a dorso-ventral plate (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

The outline at birth was still oval with a slightly flatter cranial face. (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The talus remained oval in shape and was stained in all the foetuses examined (Fig. AZ118).

Conclusions.

The bony development of the tarsus in foetal life is limited to two centres - one each for the calcanean body and talus. The development is by endochrondral ossification and the bony changes are seen histologically to occur between 44 and 54 days (C.R. 85 mm. and 112 mm.) with the calcaneous appearing first. Alizarin red staining of the calcaneous exhibited its presence at 44 days, 84 mm. C.R. length, as did impregnation with silver nitrate when radiographed but radiography of the fresh foetuses did not prove positive until 47 days (C.R. 91 mm.). This compares with Schaeffer's (1932) figures of 49 days post coitus and 115 mm. C.R. length. The centre for the talus was first revealed by all the methods at 54 days, C.R. length 112 mm. compared to Schaeffer's results of 53 days, 130 mm.

C.R. length. The radiographic appearance of the tarsus at birth would appear to be as described by Bressou et al. (1959). and Smith (1968).

Metatarsus.

Ossa Metatarsalia (Digits II - V).

Lesbre (1897) states that the primary centres appear at the same times as the diaphyses of the other long bones of the limbs or a little after. In Schaeffer's (1932) series the shafts are present in foetuses of C.R. length 6.5 cm. (32 days p.c.). In the radiographic reports Bressou et al. (1959) relate that the diaphyses are almost entirely ossified at birth and this concurs with the findings of Smith (1968).

Period of gestation 31-40 days.

Histology.

The foetus of 31 days (C.R. 35 mm.) evidenced swelling of the cells in the central sector of the cartilaginous models. There was present calcified material in the peripheral collar of tissue at the central region of the shaft of the models by 34 days (C.R. 44 mm.) this was followed by degeneration and collapse of these cells with invasion of blood vessels and cells from the overlying calcifying layer. This was the state of development seen in the foetus of 38 days (C.R. 58 mm.).

Radiography of foetus.

At 36 days (C.R. 49 mm.) the faint outlines of the metatarsal shafts could be discerned. The presence of the fifth was indefinite. Their presence became more apparent at 38 days (C.R. 58 mm.) giving a rod-like appearance, and by 40 days (C.R. 66 mm.) the shafts were distinct in form with the third and fourth marginally larger than the other two. The length of the shafts of III and IV was approximately 1.5 mm.

Radiography of foetus impregnated with silver nitrate.

The four shafts were prominent in the foetus of 37 days (Fig. Sn12) although the fifth was shortest and the second and fifth remained shorter at 40 days (C.R. 66 mm.) by which time all the shafts had increased in size. The proximal ends formed an arc with the ends of the III and IV most distal (Fig. Sn18).

Alizarin red staining of foetus.

The first sign of staining of the metatarsal was seen in a foetus of 34 days (C.R. 43 mm.) but such staining was absent in the following foetus of 35 days (C.R. 44.2 mm.) However, in the 36 day foetuses (C.R. 49 mm.) the shafts were seen as short cylinders of stained tissue with the fifth being slightly shorter than the others (Fig. AZ21). The length of the stained shaft continued to increase over the remainder of the period (Fig. AZ33).

Period of gestation 41-50 days.

Radiography of foetus.

The metatarsals were all present in the 41 day foetus (C.R. 73 mm.) with the third and fourth greatest in length and the fifth shortest:

41 days (C.R. 73 mm.) 1.5 mm., III and IV : 0.75 mm. II and V in length.

Figs. X3, X4 and X5).

45 days (C.R. 86 mm.) 2.5 mm. III and IV ; 2 mm. II and V in length. (Figs. X6 and X7).

50 days (C.R. 102 mm.) 3.5 mm. III and IV : 3 mm. in length.

Radiography of foetus impregnated with silver nitrate.

The shafts of the metatarsals increased in dimensions over this period (Figs. Sn21 and Sn31).

Alizarin red staining of foetus.

The shafts were stained throughout this period, illustrating the increase in size of these elements (Fig. AZ62). The arc formed by the proximal end of the shafts are seen in this figure.

Period of gestation 51-60 days.

Radiography of foetus.

In the 51 day foetus (C.R. 105 mm.) the interior of the shafts exhibited patchy radiolucent areas and these reorganised to form darkened areas extending to both extremities. This was evident by 56 days (C.R. 120 mm.) and confirmed in the later foetuses. Lengths of shaft were recorded with the shafts of the third and fourth remaining longer than the second and fifth (Figs. X8 and X9).

51 days (C.R. 105 mm.)	4.0 mm.	in length	digits	III and IV
	3.0 mm.	"	"	II and V
56 days (C.R. 120 mm.)	5.5 mm.	"	"	III and IV
	5.0 mm.	"	"	II and V
60 days (C.R. 136 mm.)	7.0 mm.	"	"	III and IV
	6.0 mm.	"	"	II and V

Radiography of foetus impregnated with silver nitrate.

The shafts of the metatarsals increased slowly in size during this period (Figs. Sn33 and Sn55).

Alizarin red staining of foetus.

The stained shafts demonstrated an increase in length with widening of the extremities particularly at the proximal end (Figs. AZ78 and AZ104).

Period of gestation 61 days onward.

Radiography of foetus.

The measurements of the lengths of the shafts of these bones were:

at 61 days (C.R. 140 mm.)	II and V - 6.0 mm.	III and IV - 7.0 mm.
at birth	II and V - 6.0 mm.	III and IV - 7.0 mm.

(Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

Both ends of the shafts were flattened in appearance (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

Both extremities were flattened transversely with an even edge (Fig. AZ114).

Conclusions.

The first staining of the shafts of these bones was seen in foetuses of 34 days (C.R. 43 mm.) to be followed by the radiographic appearance of the silver impregnated shafts of 37 days (C.R. 56.5 mm.). By this time the shafts were also apparent on radiographs of fresh specimens and histologically, there was seen a centre of ossification present in the centre of the shaft. Calcification of the ground substance at this site had been evident histologically since 34 days (C.R. 43 mm.).

Schaeffer's (1932) record of stained shafts at 32 days post coitus is perhaps slightly early compared to these findings but the C.R. length of 65 mm. which he attributes to these foetuses is large compared to the detected C.R. length of 43 mm. The appearance of the diaphysis at birth is similar to the description of Bressou et al. (1959) and that of Smith (1968).

Pes.

Digit I.

The literature gives no relevant information on the development of this digit in the cat save the report of Smith (1968) who relates that a centre was seen in the region of the developing tarsal bones at about 9 weeks post partum for the rudiment of the most medial metapodium of the hind limb.

There was no evidence of development of any centres of ossification for this digit during foetal life and histologically no cartilaginous precursor was observed in the foetuses examined.

Ossa Digitorum Pedis.

Phalanx Proximalis (Digits II - V).

This diaphyseal centre appears in the second half of gestation according to Lesbre (1897) and Schaeffer (1932) dates it as 11.5 cm. C.R. (49 days p.c.). On radiographs of new born kittens, Bressou et al. (1959) describe the diaphyses as scarcely beginning to have an elongated form and Smith (1968) shows the centres to be present.

Phalanx Media (Digits II - V).

Lesbre (1897) states that the primary centres appear in the second half of gestation and after the appearance of the first phalanx. Schaeffer (1932) fixes the time of appearance at 11.5 cm. (49 days p.c.). Bressou et al. (1959) remark that the points of ossification of the second phalanges of digits IV and V are of more recent appearance than the others, especially those of digit V whilst Smith (1968) finds the centres to be present at birth.

Phalanx Distalis (Digits II - V).

Schaeffer's (1932) figures for the appearance of phalanx III differ for each digit and are as follows:

Phalanx III (D. III and IV)   7.1 cm. C.R. (35 days p.c.)

Phalanx III (D. II and V)   8.4 cm. C.R. (47 days p.c.)

Smith (1968) and Bressou *et al.* (1959) note the presence of this single centre in new born kittens.

Period of gestation 31-40 days.

Ossa Digitorum Pedis (II - V).

Histology.

The third phalanx was apparent as a cartilaginous model at the onset of this period but by 34 days (C.R. 43 mm.) primary calcification of the matrix and peripheral tissue at the proximal end of the model was evident. These was accompanying degeneration of the cartilage cells of this region to make way for invading osteoblastic elements. By 39 days (C.R. 63 mm.) there was considerable calcification of this phalanx with formation of bony tissue, spreading throughout the centre.

The first and second phalanges exhibited calcified ground substance around the cartilage cells at the middle of the model shaft with concurrent degeneration of these cells. The process appeared to be more advanced in the first phalanx.

Radiography of foetus.

In the three litters of 40 days (C.R. 66 mm.) there was evidence of the presence of the third phalanges of digits II - IV. These appeared as faint spots on the extreme end of the digits. Also in the foetuses from litter C.R. 68.9 mm. there were seen faint transverse bands indicating the initiation of the appearance of the first phalanges of digit II - IV. All these findings were seen on dorso/ventral exposures.

Radiography of foetus impregnated with silver nitrate.

The third phalanges could be seen in all four digits in the foetuses of 37 days (Fig. Sn12), but it was not until 40 days that the first phalanges of digits III and IV were seen as narrow transverse bands (Fig. Sn18).

Alizarin red staining of foetus.

The third phalanges appeared as small specks of stained tissue in one of the foetuses of 36 days (C.R. 49 mm.) (Fig. AZ21) and again in the foetus of 37 days (C.R. 56.5 mm.). The specks became larger and their triangular shape became better defined during the remainder of the period. In the foetuses of 40 days (C.R. 66 mm.) the first phalanges of digits II - IV were apparent as short stained cylinders lying distal to the metatarsals (Fig. AZ33).

Period of gestation 41-50 days.

Histology.

By 44 days (C.R. 85 mm.) the collapse of the cartilage cells at the centre of the shaft was advanced and there had been invasion of the area with blood vessels and osteoblasts. The area was surrounded by a calcified collar of tissue. These findings were seen in both the first and second phalanges. The process of ossification was now more advanced in the third phalanx.

Radiography of foetus.

The first and third phalanges of digits II - V were to be seen on the foetus of 41 days (C.R. 73 mm.) but the second phalanges were only present in digits II - IV and then only as faint outlines. On the foetuses of 42 days (C.R. 78 mm.) the second phalanx of digit V was just visible whilst the other second phalanges were becoming clearer, being rectangular in shape. At 44 days (C.R. 84 mm.) the outlines of all the phalanges were becoming more clearly defined and by 45 days (C.R. 86 mm.) they were obvious in digits II - V although they did not all show well on the prints (Figs. X6 and X7). At 50 days (C.R. 102 mm.) the first phalanges had achieved a greater length than the second phalanges whilst the third phalanges were now quite pointed at their distal extemities.

Radiography of foetus impregnated with silver nitrate.

The first and third phalanges of digits II - IV were present in the foetus of 41 days (C.R. 73 mm.) and there was a small spot present to indicate the appearance of the shaft of the second phalanx of digit III. The centres of the first phalanges were small bands while the third phalanges were a larger more triangular shape. In the foetus of 43 days, (C, R. 82.5 mm.) the shafts of phalanges I, II and III of digits II - V were all present, although the centre for the second phalanx of digit V was still very slight. At 44 days (C.R. 84 mm.) the shafts of the phalanges were well formed and demonstrated narrowing of the diaphyseal waist. The third phalanges were cone shaped with apices directed distally. However, the second phalanx remained shorter in length and did not exhibit such a marked narrowing of the central portion (Fig. Sn21). This appearance still held at 50 days (C.R. 102 mm.) although there had been a general increase in size of all the phalanges (Fig. Sn31). It was difficult to view the second phalanx on a true dorso/ventral plane as the X-ray beam tended to pass along the longitudinal axis of the shaft. This was due to the first and second phalanges now being set at an angle to each other. This angle was one of plantar flexion.

Alizarin red staining of foetus.

By the 43rd. day (C.R. 82.5 mm.) all the bony elements of digits II - V were distinct in their form (Fig. AZ38). The diaphyseal narrowing of the first phalanges was demonstrated as the shaft matured but the second phalanges did not achieve the equivalent length or degree of reshaping. The angulation between phalanges I and II was shown throughout the age range. The third phalanges, already cone shaped, could be seen to be showing later compression producing a narrower body. The pointed apex became more hook-like in a plantar direction. These changes began to manifest themselves at 46 days (C.R. 88 mm.) (Fig. AZ50), and were easily recognised at 50 days (C.R. 102 mm.) (Fig. AZ61).

Period of gestation 51-60 days.

Radiography of foetus.

The shafts of the phalanges of the pes increased in size in this period. The shafts of phalanx II elongated to a greater extent giving a more rod-like appearance. The density of bone appeared uniform until the 54th. day (C.R. 112 mm.) when radiolucent areas were apparent in the central shafts and by 56 days (C.R. 120 mm.) were coalescing to form a fairly uniform dark area in the shaft. This change was continued throughout the remainder of this period (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The bodies of these elements made a steady progress in dimension (Figs. Sn40 and Sn51).

Alizarin red staining of the foetus.

The staining elements of the phalanges increased in dimensions during this period (Figs. AZ77, AZ78 and AZ104).

Period of gestation 61 days onward.

Radiography of foetus.

The bony elements of the digits increased only slightly in size in this period (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The elements showed only slight increase in size by the day of birth (Fig. Sn56).

Alizarin red staining of foetus.

There were no significant changes in these structures.

Conclusions.

The third phalanx (distalis) was the first to make its appearance known, by staining with alizarin in a 36 day (C.R. 49 mm.) foetus in all four digits. The histological picture at this stage was of primary calcification at the base of the cartilage model with some calcified material present at the periphery. By the 39th. day (C.R. 63 mm.) there was a centre of ossification present in the centre of the third phalanx with deposition of bone spicules. Alizarin staining revealed the first phalanx (proximalis) at 40 days (C.R. 82 mm.). However, histologically there was only to be seen a degree of primary calcification at the centre of the shaft with accompanying degeneration of the cartilage cells. The process was more advanced in the first phalanx than in the second. The first and second phalanges did not display centres of ossification until the beginning of the period 41-50 days and by 44 days (C.R. 84 mm.) there was present bony tissue within the centre of the shaft.

Radiographically the centres began appearing at 37 days (C.R. 56 mm.) in the silver impregnated specimens, with the third phalanx appearing earliest followed by the first at 40 days (C.R. 69 mm.) and the second at 41 days (C.R. 73 mm.). Radiography of the fresh specimens produced an image for the first and third phalanx at 40 days (C.R. 66 mm.), second at 41 days (C.R. 73 mm.).

AXIAL SKELETON

COLUMNA VERTEBRALIS

Columna vertebralis.

Mivart (1881) describes the development of a vertebrae as from quadrate masses of tissue. These early masses of tissue do not correspond to the ultimate segmentation of the vertebral column. Each quadrate mass divides into a cranial and a caudal portion. Thus each definitive vertebra originates from the caudal and cranial section of two quadrate masses. The newly formed segments are then transformed into cartilage and thus a cartilaginous model of the vertebral column is formed.

Three centres of ossification are described for the primitive vertebra, two for the laminae and one for the centrum. Of each segment the original caudal part gives rise to the neural arch, transverse processes, proximal part of the rib and cephalic portion of the centrum, while the rest of the centrum is formed from the cranial end of the next quadrate mass of tissue. This method of development has its exceptions which will be discussed under each region. Mivart also states that the axial skeleton makes its appearance much earlier than the appendicular skeleton.

Of the early dorsal segments mentioned, the first of these corresponds in position with the atlas. However, the division of the first dorsal segment differs from those which succeed it in that, when it becomes segmented, its anterior half had nothing in front wherewith to coalesce and thus the atlas must be formed from half a primordial vertebra i.e., it is from the anterior half of the primordial segment instead of being formed like the other vertebrae from the hinder half of one primordial vertebra and the cranial half of the primordial vertebra next behind. This is the description of Strauss-Durckheim (1845), Mivart (1881) and Lesbre (1897) who all list three centres for the development of the atlas. These are one for the body and two for the lateral masses. Lesbre (1897) states that the centres are all present before birth.

The axis develops from the primary centres of a typical vertebra but has a number of additional centres. Strauss-Durckheim (1845) describes these as two for the odontoid process, whilst Mivart's (1881) explanation is that the odontoid process ossifies from two centres, placed side by side, which soon unite and that there is also an epiphysis at the apex of the odontoid process and one between it and the centrum of the axis as well as on the hinder surface of the latter. Thus it is said, the odontoid process ossifies as if it were, as in fact it is, the true centrum of the atlas vertbra. Lesbre (1897) merely indicates the presence of four primary centres and several epiphyses, giving only one centre for the odontoid process. He generalises by saying that the centres of the cervical vertebra appear in the first half of gestation. Jayne's (1898) facts are similar to those of Mivart (1881) in that he describes four additional centres, representing those of the body of the atlas which coalesces with it. These additional centres are one at the tip and one on each side of the odontoid process and one on the causal epiphyseal plate, usually coalesced with the cephalic epiphyseal plate of the true body of the axis. Smaller ossifications are said to appear later, on the edge of the spinous process and on the tip of the transverse process.

Strauss-Durckheim (1845) agrees with the concept of a centre for the centrum and two for the lateral masses. He differentiates the atlas and axis but also indicates that he found the first sacral vertebra to be original in that it has an additional centre on each transverse mass.

According to Lesbre (1897) vertebral ossification is slower in the dog, cat and rabbit than it is in the larger species; he notes that the last two or three coccygeal vertebrae are still cartilaginous at birth and that the three primitive bony points of each vertebra are still separated or even enveloped by cartilage i.e., no epiphyseal points have appeared. All the apophyses are cartilaginous and even the spines are scarcely present in the lumbo-sacral region. The fusion of the right and left vertebral lamina to each other occurs last at the lumbo-sacral region, this occurs before birth or rapidly after. Fusion of lamina and body occurs post-natally.

Jayne's (1898) observation of the development of the vertebral column includes little detail on foetal development. The vertebra has three primary centres i.e., one each for the lateral mass of the neural arch and one for the body.

In the structure of the coccygeal vertebra there are ascribed to a limited number of those vertebrae a pair of minute bones per vertebra which may or may not join with the ventrally directed processes of the centrum. These bones are called chevron bones by Crouch and ossa arcus haemalis by Frewein. The latter author describes their presence at the fourth to sixth or eight, or third to the seventh caudal vertebrae. Crouch narrates that the caudal vertebrae number from four to twenty six, the first six or seven being typical, the others being gradually reduced to little more than centra. He continues that the typical parts of a vertebra, such as a neural canal, transverse and articular processes occur only to the eighth or ninth caudal vertebra, the spinous process disappearing at the fourth.

Vertebrae cervicales.

Period of gestation 31-40 days.

Histology.

At the commencement of this period there was evidence of degenerating cartilage cells in the primordia of the vertebrae, becoming more extensive by the 35th. day (C.R. 44.2 mm.). In the 39 day (C.R. 63 mm.) foetus the already degenerating cores of the bodies and laminae of the cervical vertebrae were invaded by vascular components with accompanying calcified material and osteoblasts, this being more pronounced in the first two cervical vertebrae.

Radiography of foetus.

The cervical vertebrae were first observed in a foetus of 36 days (C.R. 49 mm.) when six centra could be seen lying along mid-line on a dorso/ventral exposure. Adjacent to each centrum there was a pair of laminae. These appeared as small spots of rounded appearance. Cranial to the first centrum visible, were placed a larger pair of laminae which were wing shaped and directed craniolateral. On a lateral exposure the two wing-like structures could be seen as well as the succeeding centra with their laminae lying dorsal to them. By 38 days (C.R. 58 mm.) the laminae had increased in size and were now larger than their corresponding centra when viewed on a dorso/ventral exposure. These comparative sizes were still evident at 40 days (C.R. 66 mm.).

Radiography of foetus impregnated with silver nitrate.

In the foetus of 34 days (C.R. 43 mm.) the laminae of the first three cervical vertebrae were first observed as small specks in the cranial neck region. They were observed on both lateral and dorso/ventral exposures (Figs. Sn8 and Sn9). On the latter exposure, at 37 days (C.R. 56.5 mm.) there were six centra lying in the cervical region with a pair of laminae lying opposite each of them. Cranial to these were two larger laminae which were flatter in shape and directed cranio-laterally (Fig. Sn12). By 39 days (C.R. 63 mm.) the laminae had increased in size and were now longer in comparison to the centra (Fig. Sn14). At 40 days (C.R. 66 mm.) the laminae were rectangular in shape on a lateral exposure with their greatest length extending dorsally. The pairs of laminae decreased in size from the cranial to caudal end of the series. The pair of laminae were more triangular in shape on dorso/ventral exposure (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

Foetuses of three litters of 31 days (C.R. 35 mm.) were examined using this method. In two of these litters there was present a pair of flattened laminae in the most cranial part of the cervical region. These were taken to be the alae of the atlas. In one of the foetuses of 33 days (C.R. 39 mm.) this pair of laminae was present and was followed caudally by a further pair of laminae smaller in size whilst in the other foetus only the anterior pair existed (Figs. AZ12 and AZ13). There were three centra present in each foetus, the most cranial of which lay beneath the second pair of laminae. At 34 days (C.R. 43 mm.) the picture was one of two pairs of laminae and three centra as described. In the foetus of litter of 35 days (C.R. 44.2 mm.) all the cervical laminae i.e. seven pairs, and six centra were present (Figs. AZ17 and AZ18). The centra were smooth and cylindrical whilst the laminae decreased markedly in size from first to seventh, the general shape being rectangular. By 37 days (C.R. 56.5 mm.) the first pair of laminae was larger than the second which in turn was considerably larger than the succeeding pairs. The first laminae were more elongated dorsally with a markedly pointed dorsal extremity. These structures retained a similar appearance at 38 days (C.R. 58 mm.) and by 40 days (C.R. 66 mm.) the first pair of laminae were converging dorsally whilst the more dorsal edges of the rectangular second laminae were being directed somewhat caudally (Figs. AZ30 and AZ31).

Period of gestation 41-50 days.

Radiography of foetus.

There were 6 centra present in the cervical series of vertebrae. The first pair of laminae were largest and on dorso/ventral viewing were divergent in position with the cranial extremities farthest removed from mid-line. There was no centrum corresponding to these laminae. The second pair of laminae were smaller and parasagittal in direction on dorso/ventral viewing (Figs. X4 and X5). On a lateral exposure these laminae were directed dorso/caudally. These laminae were dorsal to the centrum, a narrow gap existing, whilst the outline of the subsequent laminae serially diminished in size and appeared confluent with the outline of the centra (Figs. X3 and X5). All the elements increased in size over this period, and at 44 days (C.R. 84 mm.) a new centre appeared lying ventral to the first pair of laminae. This was a small speck and was seen only on the lateral plates of the foetuses of two litters (C.R. 84 mm. and 85 mm.), out of the three litters of this age. This centre was a constant feature in the older subsequent litters (Fig. X6) but was not observed on the lateral plates until after 47 days (C.R. 91 mm.) when it was seen on both projections. The last six pairs of laminae were becoming expanded at the dorsal border when viewed laterally and the laminae of the second cervical vertebra were distinctly angled in position, the apparent separation from the centrum having disappeared at 43 days (C.R. 82.5 mm.). The cranial border of the distal half of the laminae of the second cervical vertebra appeared to project forward on the plate of the 48 and 50 day foetuses (C.R. 94 mm. and 102 mm.).

Radiography of foetus impregnated with silver nitrate.

The centra of the cervical vertebrae 2-7 were present throughout this period. They were regularly irregular in shape, being almost oval on dorso/ventral viewing whilst on lateral exposure they were flattened dorsally but pointed ventrally. This gave an almost conical appearance. They increased in size during the period. The first pair of laminae were, on lateral viewing, almost rectangular but at their cranio/dorsal angle had a peaked projection (Fig. Sn22). During this period, the dorsal border became rounded and whilst the peak persisted, this cranial angle was more dorsal than the corresponding caudal angle (Fig. Sn32). On dorso/ventral viewing, the laminae appeared as divergent wings, and the peaked projection could be seen on the now lateral border of the image.

The laminae were now in close approximation to the exoccipital bones (Fig. Sn21). The laminae of the second vertebra were directed dorso/caudally and were generally rectangular in shape with expanded dorsal and caudal borders. The remaining laminae on lateral exposure had a more vertical position but whilst their caudal borders were straight, the cranial border was convex. The laminae of the last five cervical vertebrae also developed at 44 days (C.R. 84 mm.) a dense white area at the lower edge of the laminar plate, on lateral viewing (Fig. Sn25). On a dorso/ventral plate, these areas could be seen projecting slightly laterally (Fig. Sn21) and were repeated on a later dorso/ventral plate of 45 days (C.R. 86 mm.) (Fig. Sn27). A centre lying ventral to the first pair of laminae appeared first of all at 44 days (C.R. 84 mm.). It was apparent as a small spot in one of the litters (C.R. 85 mm.) but was more obvious as an oval body in the other two (Fig. Sn22). It could also be seen on dorso/ventral exposure lying slightly caudal to the first pair of laminae (Fig. Sn21). This centre increased in size during the remainder of the period.

Alizarin red staining of foetus.

At 41 days (C.R. 75 mm.) there were six short cylindrical centra present and lying relative to the second to seventh pair of laminae. The laminae of vertebrae 3-7 had truncated dorsal extremities and the third pair were round at this edge, whilst the six and seventh were more pointed. The ventral ends of the laminae 3-7 had small lateral projections. The first pairof laminae were wing like and their dorsal edges were directed toward mid-line. The second pair of laminae were directed caudally and were larger than succeeding pairs. They bore lateral projections at their ventral ends. By 43 days (C.R. 82.5 mm.) the first pair of laminae had developed a notch at the cranial border and were producing a lateral enlargement. There was also now present, lying ventral to and between the first pair of laminae a small rounded stained centre. This was extremely small but in the 44 day (C.R. 84 mm.) foetus could be seen to have increased in size. At this latter age, the laminae of vertebrae 3-7 could be seen to be developing a cranial projecting ridge which bore a flattened area upon its upper surface. The 45 day (C.R. 86 mm.) foetus had a larger pair of first laminae with expanded ventral borders and also the recently developed centre was of greater size. In the foetus of 47 days (C.R. 92 mm.) the previous features could be seen and the new centre bore a pointed ventral ridge. Here also a further centre had appeared, even more cranial to the previous one and more ventral in position. It was a transverse, plate-like structure. The remaining foetuses of the series had these two centres present and also the first pair of laminae had developed lateral projections from their lateral surfaces. This projection gave a distinctly wing-like appearance.

Period of gestation 51-60 days.

Radiography of foetus.

On a lateral exposure the laminae of the first vertebra could be seen lying dorsal to two centra, of which one was placed cranial and ventral to the laminae while the other smaller centra was still placed ventrally but closer in position to the laminae and also to the second vertebra. On dorso/ventral viewing the laminae could be seen to bear notches at their cranio/lateral angle and the two centra could be seen in midline, one lying transversely just cranial to the laminae and barlike in shape while the caudal centre appeared circular. The centra increased in size but maintained their relative positions and outlines. By 58 days (C.R. 130 mm.) the image of the bar-shaped cranial centrum was merging at each extremity with the image of the laminae. The laminae of the second vertebra showed a cranial projection on lateral viewing and this increased in size becoming more rounded at its tip by 54 days (C.R. 112 mm.). The dorsal edge of the lamina was initially slightly concave with a sharp cranial and caudal angle but gradually the length of the dorsal edge increased and the contour became convex with round cranial and caudal angles leading into concave cranial and caudal borders. The succeeding cervical vertebrae increased in size during the remainder of this period. The outline of the lamina had a cranial projection which gradually increased in size and thus came into closer proximity with the caudal edge of the preceding lamina. This approximation was noticeable at 54 days (C.R. 112 mm.) and the relationship of the adjacent laminae continued throughout the period. This was seen on a lateral projection (Fig. X9). On dorso-ventral viewing the laminae still were distinctly separated at 54 days (C.R. 112 mm.) but by 56 days (C.R. 120 mm.) there was fairly close approximation of adjacent laminae due to the presence of the cranial and caudal projections. Also, on dorso-ventral viewing, if the vertebrae were not radiographed in a true vertical plane, a narrow projection could be seen abutting from the laminae running in a caudal and lateral direction. This was hidden by the laminar image on true dorso-ventral viewing. This latter development was first seen at 54 days.

Radiography of foetus impregnated with silver nitrate.

The foetus of 51 days (C.R. 105 mm.) had a pair of laminae present for the first vertebra and, related to them, two centres one cranial to the other (Fig. Sn32). The more rostral was more ventral in position and bar-shaped on dorsal/ventral viewing. The second centre was larger on lateral viewing and more cube shaped (Fig. Sn39). It was in the same longitudinal plane as the other centra of the cervical region The laminae of the first vertebra bore notches at their cranio/lateral angle. The second vertebra had laminae with expanded dorsal borders, convex in outline, and with narrowing of the ventral half of the laminar plate. The laminae of the remaining cervical vertebrae had caudal prolongations of the dorsal border. The images of the centra of these vertebrae became masked by the laminar images which grew downward. This was becoming evident at 54 days (C.R. 112 mm.) (Fig. Sn40). The outlines of the last two cervical vertebrae were partially obscured by the forelimb and so detail was difficult to detect.

Alizarin red staining of foetus.

There were seven pairs of laminae present on the 51 day (C.R. 105 mm.) foetus and the first pair had two ventral bodies related to them whilst succeeding pairs had only two. The first pair of laminae had a notch on their cranial border and a laterally projecting wing. The most cranial ventral centre was shaped as a transverse bar (Figs. AZ93, AZ102 and AZ103). The second centre was slightly more dorsal in position and rounded (Fig. AZ103). The first pair of laminae and related ventral elements increased in size during the period and the cranial edge began to flatten becoming more closely approximated to the exoccipital bones. This was recognisable in a foetus of 54 days (C.R. 112 mm.) and remained thus for the latter part of the period (Fig. AZ92). The second laminae bore a dorsal process and a cranially projecting eminence developing from it. There was also a caudal eminence. The lateral projection from the laminar surface was truncated and directed caudally. The remaining cervical laminae had dorsal eminences which were inclined toward mid-line with a rounded dorsal border caudally (Fig. AZ75). The cranial border was extended as a process while lateral projections occurred from the laminar surface projecting caudally with truncated ends (Fig.AZ100). The dorsal eminences were closing toward midline by 54 days (C.R. 112 mm.) (Fig. AZ95 and AZ96) and the rounded caudal borders were approximating closer to the cranial processes of the succeeding vertebrae. Both these had flattened surfaces. By 56 days (C.R. 121 mm.) it could be appreciated that the before mentioned surfaces were closing and relating to each other on a horizontal plane (Fig. AZ97). The foetus of 58 days (C.R. 130 mm.) demonstrated the closing of the laminae to the centra when viewed ventrally (Figs. AZ102 and AZ103). A space still separated them but this space was decreasing.

Period of gestation 61 days onward.

Radiography of foetus.

The third to the seventh cervical vertebra had laminae which on lateral viewing had a dorsal process inclined slightly caudally and a cranial process. The latter was related in contour to the caudal border of the dorsal process of the preceding vertebra (Fig. X10). On dorso/ventral view transversely projecting processes were obvious, proceeding caudally. The second vertebra had a longer dorsal edge on the dorsal process of the lamina and lacked a cranial projection. Its centrum was in close proximity to the second centre of the first vertebra. The first vertebra had two laminae with a bar-like centre cranially and a round centre more caudally (Fig. XII). On a dorso/ventral projection the first centre could be seen to be still separated from the laminae but in a foetus of 3 days post-partum there appeared to be confluence of the images.

Radiography of foetus impregnated with silver nitrate.

The lateral plate showed the cervical vertebrae two to five to be closely related to each other at the region of their cranial/caudal projections of the laminae. The gaps between five, six and seven were greater (Fig. Sn56). The first and second ventral centres could be seen, the latter lying apparently within the first pair of laminae and closely related to the centrum of the second vertebra. On dorso/ventral plates the close relationship of cervical vertebrae two to five was evident as their laminar images appeared to overlap (Fig. Sn55).

Alizarin red staining of foetus.

The foetuses at birth had cervical vertebrae which had laminae closely approximated at their cranial and caudal projections. The plane of these articulations were more horizontal in direction. This did not apply to the first intervertebral joint where the laminae were still widely separated. The third to seventh pairs of laminae had blunt ended lateral projections which were directed somewhat caudally (Fig. AZ102). The second vertebrae also bore a pair of such projections but they were smaller (Fig. AZ112) and became confluent at their roots with the raised lateral wall of the laminae (Fig. AZ114).

Conclusions.

The cervical vertebrae in general were seen to develop from three principal centres, with the atlas and axis presenting extraordinary features.

The cervical vertebrae produced evidence of calcification of the laminae by staining with alizarin red as early as 31 days (C.R. 35 mm.) when the first pair were just evident. However, the remaining pairs of laminae were later to appear, not being constant until 35 days (C.R. 44.2 mm.) when seven pairs were seen. The centra appeared first at 33 days (C.R. 39 mm.) and by 35 days (C.R. 44.2 mm.) six centra were evident. Histologically, there was evidence of degeneration of cartilage cells in a 30 day (C.R. 29 mm.) foetus with some calcification of the ground substance. This was not extensive but was to be seen in both the centra and the laminae. By 35 days (C.R. 44.2 mm.) there were considerable areas of degenerating and dead cartilage cells within the developing laminae and centra but it was not until 39 days (C.R. 63 mm.) that invasion by vascular components was seen to occur giving rise to true centres of ossification. This was more pronounced in the first two cervical vertebrae. Radiographically, the appearance was earlier in the silver nitrate preparations with the first arrivals at 34 days (C.R. 43 mm.) whilst the unprepared specimens did not demonstrate these structures till 36 days (C.R. 49 mm.).

The cervical vertebrae 3-7 developed transverse processes, seen first in the alizarin red specimens at 41 days (C.R. 75 mm.) and then radiographically from 44 days (C.R. 84 mm.) onward. The development of articular processes in these vertebrae became apparent initially in the alizarin specimens at 44 days (C.R. 84 mm.) and radiographically their formation was noticed in the silver nitrate preparations at the end of the 41-50 day period and again at the commencement of the 51-60 day period in fresh specimens. It was noted that the plane of this articulation was by then more horizontal.

The axis was formed from three principal centres i.e., two for the laminae and one for the centrum, those appearing first at 33 days (C.R. 39 mm.) with alizarin staining and at 34 and 36 days (C.R. 43 and 49 mm.) radiographically, the earlier being in the silver nitrate specimens. There appeared by 44 days (C.R. 84 mm.) immediately cranial to this centrum, a further rounded centre which became more relative to the centrum of the second vertebra as gestation progressed. The appearance of this centre was observed at the same age using the various methods. This centre would appear to be that for the odontoid process but remained separate from the centrum of the second vertebra at birth.

The atlas appeared to develop from two centres for the laminae which appeared first of all the laminae of the cervical vertebra, at the 31st. day (C.R. 35 mm.) with alizarin red staining and at 34 and 36 days (C.R. 43 and 49 mm.) radiographically, the earlier being with silver nitrate impregnation. These centres were complemented by a third, more ventrally placed, transverse bar of calcified tissue arriving in the alizarin stained foetus of 47 days (C.R. 92 mm.) and on radiography of the foetus at 51 days (C.R. 105 mm.)

The view that the basic vertebra is formed from three principal centres (Mivart (1881; Strauss-Durckheim (1845); Lesbre (1897) and Jayne (1898) would appear to be in agreement with these findings but in foetal development only four centres were detected for the axis and three for the atlas. The odontoid process would seem to derive from one main centre which is in line with Lesbre's (1897) description. There was no evidence of the two centres described by Strauss-Durckheim (1845) and Mivart's (1881) and Jayne's (1898) description of two principal centres placed side by side, was not substantiated by these findings. There is, however, agreement with the listed authors as to the development of the atlas from three centres.

Mivart's (1881) statement that the axial skeleton makes its appearance before the appendicular would appear to be questionable as the results indicate that ossification of the first centres of the long bones was concurrent with that of the earliest centres of the axial skeleton.

Vertebrae thoracicae

Period of gestation 31-40 days.

Histology.

Throughout this period the cartilaginous precursors of the centra and laminae of the thoracic vertebrae were exhibiting swelling of the cells within them and progressive degeneration. In the foetus of 39 days (C.R. 63 mm.) invasion of the precursors by blood vessels and cellular tissue was evident. There were signs of deposits of calcified material at the periphery of the centra.

Radiography of foetus.

At 36 days (C.R. 49 mm.) the centra and laminae of the thoracic vertebrae were visible as small rounded spots with the laminae lying opposite and to either side of the thirteen centra. This was on a dorso/ventral view. On a lateral approach, the centra tended to be overshadowed by the proximal ends of the ribs. By 40 days (C.R. 66 mm.) the outlines of these centra and laminae had increased in size, particularly, the last three pairs of laminae which had increased in a longitudinal direction when viewed on a dorso/ventral projection, i.e. they were adopting an appearance more like that of the lumbar vertebrae (Fig. X5).

Radiography of foetus impregnated with silver nitrate.

The centra of the last four thoracic vertebrae were first seen at 34 days (C.R. 43 mm.) as small dots lying between the corresponding pairs of ribs (Fig. Sn9). By 37 days (C.R. 56.5 mm.) all the thirteen centra were present with their related pairs of laminae (Fig. Sn12). There was little change at 39 days (C.R. 63 mm.) but by 40 days (C.R. 67 mm.) the laminae were of greater height dorsally than cranio/caudally on a lateral exposure and larger than the centra on a dorso/ventral exposure (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

Foetuses of three litters of 31 days (C.R. 35 mm.) were examined using this method. The foetus of one of the litters had present the stained centra of the last three thoracic vertebrae, whilst the other two foetuses revealed nothing in this region. The centre of all thirteen vertebrae could be seen as stained rounded elements in the foetus of 33 days (C.R. 39 mm.) (Figs, AZ11 and AZ12) but in a following foetus of the same age (C.R. 39.8 mm.) only the centra of the last four thoracic vertebrae could be seen. In the former foetuses, the centra of the last three thoracic vertebrae were largest. In the foetus of 34 days (C.R. 43 mm.) all the thirteen centra were present and now the pairs of corresponding laminae were stained. The more cranial ones were extremely small increasing to the tenth pair which were the largest of the series (Fig. AZ18). These structures increased in size during the remaining period. The centra were short and cylindrical and the laminae at first were rectangular with their greatest length directed dorsally. However, by 37 days (C.R. 56.5 mm.) the last three pairs of laminae were becoming obviously greater in size and more triangular in shape, resembling the lumbar vertebrae (Fig. AZ26).

Period of gestation 41-50 days.

Radiography of foetus.

The laminae were rectangular in shape with the long axis directed dorsally except for the last three pairs which increased in breadth as well as height and were directed slightly forward. The direction of the first ten pairs gradually altered in the latter part of the period and at 50 days (C.R. 102 mm.) were directed somewhat dorso/caudally. Most centra remained short compared to those of the lumbar vertebrae but by 47 days (C.R. 91 mm.) the centra of the eleventh to thirteenth thoracic vertebrae had increased in length and resembled the centra of the lumbar region (Figs. X6 and X7).

Radiography of the foetus impregnated with silver nitrate.

The centra appeared as small oval structures on dorso/ventral projection and they were fairly constant in dimensions from the first to the eighth or ninth whereafter they increased in size to the thirteenth. The size of each increased during this period with the last three always longest. The centra of the 50 day (C.R. 102 mm.) foetus had scattered dark spaces within the substance giving a vacuolated appearance (Fig. Sn31). On lateral plates the laminae were at first rectangular in appearance with the longitudinal axis dorso/ventral except for the last three which were larger and had a convex cranial border, giving an angled appearance on lateral viewing. At 43 days (C.R. 82.5 mm.) there was a slight caudal inclination of the longitudinal axis of the laminae up to the level of thoracic vertebra nine, the tenth being almost vertical(Fig. Sn20). This angulation became increasingly manifest from 44 days (C.R. 84 mm.) with the tenth remaining almost vertical (Figs. Sn24 and Sn25). On dorso/ventral plates the laminae were somewhat irregular in form with a convex lateral border projecting cranio/laterally at 43 days (C.R. 82.5 mm.) and by 44 days (C.R. 84 mm.) the laminae appeared to have the cranial end diverging from midline. The ribs appeared to be in close proximity to the laminae on this projection (Fig. Sn21). These changes of appearance did not apply to the last three pairs of laminae which remained in parasaggital plane with expansion of the caudal end i.e., when seen on a dorso/ventral plate (Fig. Sn21).

Alizarin red staining of foetus.

At 41 days (C.R. 75 mm.) the centra were short cylinders except for the ultimate three which increased in length. The centra increased in size over the period but remained short in comparison to the centra of the other regions. The laminae of the first to the tenth vertebrae were vertical plates inclined toward mid-line dorsally and with the longitudinal axis directed caudally, the tenth pair however, being nearer the vertical plate (Fig. AZ50). They bore, about one third up the lateral face, a ridge directed laterally (Fig. AZ43). This ridge was more prominent cranially on the lateral surface. By 44 days (C.R. 84 mm.) this ridge had increased and was prominent laterally and cranially. It continued to increase in size in proportion to the increase in the laminae. The laminae of the eleventh to thirteenth vertebrae were more typical of the lumbar vertebrae, being more expanded caudally with a more vertical longitudinal axis (Fig. AZ47). They also bore posteriorly situated ridges which increased in size during the period.

Period of gestation 51-60 days.

Radiography of foetus.

The dorsal prolongation of the laminae enlarged over this period, the direction of the spine being caudal in the first nine, more vertical in the tenth and the shape altered in the caudal three. The ribs became more closely related to the thoracic vertebrae and by 54 days (C.R. 112 mm.) the images of the first ten ribs appeared to be in contact with the images of the corresponding thoracic vertebrae on a dorso/ventral plate. They lay to the cranial aspect of each pair of laminae. The remaining ribs still appeared to be separated from the vertebral bodies and lay directly opposite the corresponding laminae. The centra remained oval in shape on dorso/ventral viewing but on lateral viewing they were short rods (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The dorsal extensions of the laminae which were caudally directed in the first ten thoracic vertebrae increased in length (Fig. Sn34) and on dorso/ventral projection could be seen at the caudal aspect of the laminar shadow in the foetus of 52 days (C.R. 108 mm.) (Fig. Sn36). The transverse development of the laminae was also visible in these vertebrae whilst the laminae of the caudal three vertebrae developed a spur-like projection of the caudo/lateral angle on dorso/ventral projection (Fig. Sn35). This again was seen at 52 days (C.R. 108 mm.) and by 54 days (C.R. 112 mm.) was prominent (Fig. Sn41). The centra of this region were oval in shape. The first to the tenth pairs of ribs although in close proximity to the laminae of the corresponding vertebrae were not in contact with them. They lay cranial to the lateral tip of each lamina. The last three pairs of ribs were further removed from the corresponding laminae and were opposite the lateral tips of those structures. The observations were from dorso/ventral plates. Also on this projection the laminar images which had been lying alongside the image of the centra came to superimpose themselves on the periphery of the image of the centra. This was observed at 56 days (C.R. 121 mm.) (Fig. Sn45).

Alizarin red staining of foetus.

The laminae of the first ten vertebrae had dorsal eminences projecting caudally (Fig. AZ73). These had a thickened dorsal perimeter with a flattened edge. The laminae also bore transverse projections situated more ventrally on the lateral surface. These structures increased in size during this period and also grew closer to mid-line dorsally. The last three thoracic vertebrae were wider and their dorsal eminences were not so pointed nor were they directed caudally (Figs. AZ74 and AZ75). The laminae bore cranial and caudal projections, joined by a concave ridge but not at the same level, as the caudal was lower than the cranial. The ribs did not touch the thoracic vertebrae but were closer in proximity (Fig. AZ67).

Period of gestation 61 days onward.

Radiography of foetus.

The dorsal spines of the first ten thoracic vertebrae were pointed in appearance and directed caudally. At the cranial surface of the base of the laminae there appeared a round area of increased density, on lateral plates (Fig. X10). The image of the ribs appeared confluent with the vertebral image on a true dorso/ventral plate except for the last three ribs which were still separate from their vertebrae but the dividing space had narrowed. The last three vertebrae had wider laminae with square dorsal spines and cranial and caudal projections (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

On the dorso/ventral projection of the foetus at birth the last three thoracic vertebrae demonstrated caudo/lateral projections from the laminae and cranial to this the ribs could be seen in close proximity to the lateral laminae. The more cranial thoracic vertebrae had lateral projections from the laminae with the proximal rib apparently lying beneath the cranial angle of the image of this projection. The tenth thoracic vertebrae appeared as a transition between the two types of lateral processes possessing both to a small degree (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The first nine vertebrae had laterally expanding processes of the laminae lying above the head of the rib but not in contact with it. The last three thoracic vertebrae had processes also laterally placed but emanating from a more caudally placed root and directed in a distinctly caudal direction (Fig. AZ114). The tenth thoracic vertebrae was an intermediate form having a laterally directed process with a caudal eminence upon it (Fig. AZ117).

Conclusions.

The thoracic vertebrae appeared to develop prenatally from three centres i.e., two for the laminae and one for the centrum. These centres appeared at 33 days (C.R. 39 mm.) using alizarin red staining; followed by their radiographic appearance at 34 and 36 days (C.R. 43 and 49 mm.) the earlier being with silver nitrate impregnation. Histologically there was evidence of primary calcification during the period but a true centre of ossification was not verified until 39 days (C.R. 63 mm.). By the middle of the period 41-50 days the development of features distinguishing the last three thoracic vertebrae was becoming obvious. The transverse processes were seen developing in the alizarin specimens and later in the radiographs of foetuses of 52 days (C.R. 108 mm.) onward. The enlargement of the transverse processes of the terminal three thoracic vertebrae to produce mammillary and accessory processes was demonstrated in the specimens during the 51-60 day period by both alizarin staining and radiographic means. At birth the laminae were not united in dorsal midline.

Vertebrae lumbales

Period of gestation 31-40 days.

Histology.

Throughout this period the cartilaginous precursors of the centra and laminae of the lumbar vertebra were exhibiting swelling of the cells within them and progressive degeneration. In the foetus of 39 days (C.R. 63 mm.) invasion of the precursors by blood vessels and cellular tissue was evident. There were signs of deposits of calcified material at the periphery of the centra.

Radiography of foetus.

Seven centra with pairs of laminae, were seen for the first time in the foetus of 36 days (C.R. 49 mm.) where the structures were seen as small rounded spots. At 38 days (C.R. 58 mm.) the laminae were increased in their longitudinal dimension when seen on a dorso/ventral projection and the centra were now larger than the centra of vertebrae of other regions. This appearance was similar at 40 days (C.R. 66 mm.) (Fig. X5).

Radiography of foetus impregnated with silver nitrate.

The centra of the first three lumbar vertebrae were seen in the foetuses of 34 days (C.R. 43 mm.) (Fig. Sn9). They were small dots lying in midline. By 37 days (C.R. 56.5 mm.) all seven centra were present and opposite each was a pair of laminae. These were more irregular in shape than the laminae of proceding vertebrae and were also larger. Of the lumbar vertebrae themselves, the middle three of the group were larger and more advanced in development than the other members of the row (Fig. Sn12). By 40 days (C.R. 67 mm.) the laminae were more diamond shaped but with a slightly flattened dorsal tip. The centra increased in size and were narrower at the middle portion, but the central 3 vertebrae were still larger than their fellows (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

The foetuses of 33 days (C.R. 39 mm.) had stained centra for the first three or four of the series (Fig. AZ11). These were small rounded centres with the ultimate one just a speck. By 34 days (C.R. 43 mm.) seven centra and seven pairs of laminae were just staining representing all the lumbar vertebrae. This however was not the case in a foetus of 35 days (C.R. 44.2 mm.) where only the first three lumbar vertebrae were evident. In all the foetuses from 37 days (C.R. 56.5 mm.) onward seven centra and pairs of laminae were stained (Fig. AZ26). The centra were at first rounded in shape but became more cylindrical during the period. The laminae at 37 days (C.R. 56.5 mm.) were approximately triangular and by 38 days (C.R. 58 mm.) there were appearing at the upper ends of the cranial and caudal borders small pointed projections, the dorsal border meanwhile becoming more rounded. By the end of the period the laminae were seen to be curved with the convexity facing laterally so that the dorsal borders were now closer to midline.

Period of gestation 41-50 days.

Radiography of foetus.

The lamina appeared on lateral exposure as an almost quadralateral plate lying above a centrum of equal longitudinal length but short dorso-ventrally. There was a gap between the lamina and centrum, appearing as a black line. This gap appeared to close at the age of 45 days (C.R. 86 mm.) onward when a laminar outline appeared confluent with the centrum on a true lateral projection. The centra were now developing a narrow central waist and the laminae were increasing in size so that by 46 days (C.R. 88 mm.) the caudal border was projecting somewhat beyond the line of the vertical plane of the caudal end of the centrum. The enlargement of the proximal caudal border continued through the rest of the period (Fig. X7).

Radiography of foetus impregnated with silver nitrate.

The laminae of the lumbar vertebra appeared as narrow parasaggital strips on dorso/ventral viewing (Fig. Sn19) and on a lateral plate they had rounded cranial and caudal borders each with a projecting angle, leading up to a flat dorsal border. From the caudal angle of this latter border a projection extended caudally (Fig. Sn20). The laminae of the seventh lumbar vertebra were smaller than the rest and more oval in shape. All the laminae increased in size and by the 45th. day (C.R. 86 mm.) the dorsal border had lengthened, with the caudal projection prominent when seen on a lateral plate. The dorso/ventral view showed at 50 days (C.R. 102 mm.) a division of the caudal border of the laminae into two small projections

Fig. Sn31). The centra were rod-like on the lateral plates with a distinct narrowing of the central portion. The dorso/ventral view was almost circular and as the size of the body increased, the centre demonstrated small spaces of reduced radio-opacity. This commenced at 44 days (C.R. 84 mm.) and by 47 days (C.R. 92 mm.) there were two distinct black spots placed near the centre of the body. These were present during the remainder of this period (Fig. Sn31). Throughout the period a narrow space was maintained between the laminae and centrum on a lateral exposure.

Alizarin red staining of foetus.

The centra retained their cylindrical shape throughout this period, the last one being shorter than the rest but still having a narrowed central portion. The laminae were curved plates with the convexity lateral, and angled cranial and caudal borders. At these angles projected pointed protuberances, the caudal one of which was marginally more ventral in level. These features were present at 41 days (C.R. 75 mm.) and by 44 days (C.R. 84 mm.) the caudal projection was enlarging and bore a raised lateral ridge running to the lamina proper (Fig. AZ43). This increased in definition and by 50 days (C.R. 102 mm.) was an obvious feature on the lateral aspect of the laminae.

Period of gestation 51-60 days.

Radiography of foetus.

The lateral outline of the lumbar vertebrae demonstrated slight cranial and caudal projections from the corresponding borders of the laminae. Those projections increased in prominence and by 54 days (C.R. 112 mm.)

were obvious features. The outline of the laminae and centra increased steadily in size during the period (Fig. X9). On dorso/ventral viewing the centra at first appeared oval but by 54 days (C.R. 112 mm.) the lateral borders were flattening, giving a more cube-like appearance although the cranial and caudal edges were still rounded (Fig. X8).

Radiography of foetus impregnated with silver nitrate.

The laminae of the 51 day (C.R. 105 mm.) foetus had small protuberances from the cranial and caudal borders on lateral viewing (Fig. Sn32), and by 52 days (C.R. 108 mm.) these were more clearly defined. On dorso/ventral viewing the caudal projection was from the lateral angle of the lamina. On the same projection the image of the lamina was seen lying alongside the image of the centrum (Fig. Sn35) and by 54 days (C.R. 112 mm.) these two images were overlaid on a true dorso/ventral projection (Fig. Sn41). The vertebral elements continued to increase in size during this period.

Alizarin red staining of foetus.

The laminae of the lumbar vertebra were of greater cranio/caudal length and also bore cranial and caudal projections from the corresponding borders. The caudal projection was greater than the cranial (Fig. AZ67). The ventral end of the lamina was thickened when viewed on transverse section (Fig. AZ65) and this gave a curved appearance to the laminar plate with the concavity medially (Fig. AZ90). The centrum was flattened dorso/ventrally with a slight median ridge ventrally. Two small orifices could be seen, one on either side of this ridge (Fig. AZ66). This was the appearance of the 51 and 52 day (C.R. 105 and 108 mm.) foetuses. By 54 days (C.R. 112 mm.) the ventral edges of the laminae and centra were closely approximated although a narrow gap still existed. The two laminae of each vertebra were closer to each other dorsally but the gap was greater than that seen in the thoracic region (Fig. AZ90). The laminae were curved toward midline and when viewed dorsally there was a triangular appearance of the dorsal plate of the laminae (Fig. AZ91). The ventral end of the lamina was thickened and the cranial angle of this border was bulbous in appearance (Fig. AZ88). In the 56 day (C.R. 120 mm.) foetus the caudal prominence on the lateral aspect of the laminae was enlarging giving a pointed outline and the ridge connecting it with the cranial prominence was of clearer definition (Fig. AZ100). The dorsal edges of the laminae were gradually encroaching on midline and this growth continued throughout the remainder of the period (Fig. AZ106).

Period of gestation 61 days onward.

Radiography of foetus.

At 61 days (C.R. 140 mm.) the lamina had a long dorsal edge and a cranial and caudal projection, the caudal being the lower (Fig. X10). The caudal three lumbar vertebrae were seen to have small protuberances from their lateral borders when viewed on a dorso/ventral plane (Fig. X11). These protuberances enlarged and assumed a cranio/lateral direction so that in the foetus at birth they were seen as projections facing cranio/laterally. In a foetus of 2 days post-partum, they were also evident on lumbar vertebrae three and four but this was not seen in the three day post-partum foetuses.

Radiography of foetus impregnated with silver nitrate.

On the foetus at birth the lateral processes of the terminal three lumbar vertebrae were evident, directed cranio-laterally. The lumbar vertebrae three and four also had primordia of lateral processes but of greatly reduced size. These structures were seen on a dorso/ventral plate. The dorsal convergence of the laminae was also demonstrated on this plate but a narrow gap still persisted between the dorsal edges. (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The caudal three vertebrae of the lumbar group had small lateral projections protruding cranially while the third and fourth had at the same position small eminences. The cranial processes were closely related to the adjacent laminae so that the caudal processes of each proximal vertebra ran above the cranial process of the distal vertebra (Figs. AZ114 and AZ115). The centra were now distinctly flattened ventrally with a median raised ridge whilst the dorsal border was still convex in profile (Fig. AZ120).

Conclusions.

The development of the three principal centres for the lumbar vertebrae was seen during foetal life. The single centres for the centra and the paired centres for the laminae were first seen to be present at 33 days (C.R. 39 mm.) using alizarin red staining but in this case only the more cranial vertebrae of the group were seen. By 34 days (C.R. 43 mm.) all seven lumbar vertebrae were evident and by now they were also visible on radiography of the silver nitrate impregnated foetuses. Radiography of fresh specimens was not positive for these centres till 36 days (C.R. 49 mm.). Histologically, primary calcification was occurring throughout the period 31-40 days but a true centre of ossification was not seen in the centre until 39 days (C.R. 63 mm.). The development of processes representing the roots of the accessory and mammillary processes was becoming apparent in the alizarin red stained specimens as early as 37 days (C.R. 56.5 mm.) but was not shown on radiographs till the middle of the period 41-50 days. The roots of the transverse processes of the lumbar vertebrae did not appear till after 60 days (C.R. 136 mm.) and then only in the caudal three lumbar vertebrae.

The comment by Lesbre (1897) that the fusion of the vertebral laminae to each other occurs last in the lumbar region could not be proven as no fusion of laminae of any vertebrae was seen to occur during foetal life. Lesbre (1897) described it as happening before birth or rapidly after.

Vertebrae sacrales.

Period of gestation 31-40 days.

Radiography of foetus.

At 36 days (C.R. 49 mm.) the centrum of the first sacral vertebra was just visible but indistinct. It lay midline between the cranial portion of the shafts of the ilia on a dorso/ventral plate but was not visible on a lateral exposure. At 40 days (C.R. 66 mm.) three centra could be seen on a dorso/ventral exposure although they were small compared to centra of the previous regions.

Radiography of foetus impregnated with silver nitrate.

The centra of the first two sacral vertebrae were evident at 37 days (C.R. 56.5 mm.) at which stage also the first centrum was accompanied by a pair of laminae. However it was 40 days (C.R. 67 mm.) before all three centra were evident (Fig. Sn18). At this stage the first was much larger than the other two and had a pair of laminae apparent as small dots within the cranial limits of the ilia. The preceding findings were seen on dorso/ventral exposure but it was not until 40 days (C.R. 67 mm.) that the centra could be seen on a lateral exposure (Fig. Sn17).

Alizarin red staining of foetus.

The centrum of the first sacral vertebra was seen at 36 days (C.R. 49 mm.) as a rounded structure lying between the ilial shafts. In the foetus of 37 days (C.R. 56.5 mm.) the centra of the first sacral vertebra was obvious and the smaller second centrum was seen staining faintly. However, in subsequent foetuses of 38 and 39 days (C.R. 58 and 63 mm.) only the first body was seen (Fig. AZ26). By 40 days (C.R. 66 mm.) all three centra were present in both foetuses examined but in one of them, the lamina of the first and third sacral elements only were seen, whilst the other foetus had present a pair of laminae for all three sacral bodies (Fig. AZ34). These laminae were small flattened structures with the cranial pair the largest.

Period of gestation 41-50 days.

Radiography of foetus.

The foetuses of 41 and 42 days (C.R. 73 and 78 mm.) had all three sacral centra present but the first and second pair of laminae were the only ones constantly present (Figs. X3, X4 and X5). The third pair were only constant after 43 days (C.R. 82.5 mm.). The centra decreased in size from the first to the third and on dorso/ventral plates the transverse distance from the lateral tip of one lamina to the other decreased also, giving the triangular shape of the sacral region. The centra increased in size over the remaining period (Figs. X7 and X8).

Radiography of foetus impregnated with silver nitrate.

The foetus of 41 days (C.R. 73 mm.) had 3 centra present but the laminae of one and three only could be seen. At 43 days (C.R. 82.5mm) the laminae for the second and third sacral vertebra were just evident as small specks on dorso/ventral exposures. The laminae at 44 days (C.R. 84 mm.) were seen on a lateral plate as vertical bands lying above the sacral bodies (Fig. Sn22). They continued to increase in size as did the centra (Fig. Sn31).

Alizarin red staining of foetus.

The centra of the three sacral vertebrae diminished in size from one to three but they were all short compared to the preceding lumbar vertebrae. The pairs of laminae also diminished in size. They were curved plates with the long axis running dorso/ventrally and the convex surface placed laterally. The increase in size was gradual throughout the period (Figs. AZ52 and AZ43).

Period of gestation 51-60 days.

Radiography of foetus.

The laminae of the first sacral vertebra was much larger than the next with the third smallest. The first was rounded in shape with the remainder flattened laterally. The centra were rounded in form. They increased in size and by day 56 (C.R. 120 mm.) the centrum of the first was flattening laterally giving it a more cube-like appearance. By 58 days (C.R. 130 mm.) the laminae of the first sacral vertebrae were flattened on the lateral border giving by 60 days (C.R. 136 mm.) an almost triangular shape to the structures (Fig. X8). The flattened edge was approximated more closely with the ilium. Also at 58 days (C.R. 130 mm.) a pair of centres appeared ventral and lateral the first sacral centra, but their definition was poor.

Radiography of foetus impregnated with silver nitrate.

At 51 days (C.R. 105 mm.) the three centra and pairs of laminae were all present the components of the first being largest. The laminae of the first were divergent on a dorso/ventral exposure (Fig. Sn36) whilst their image was masked by the form of the ilium on a lateral plate. The laminae of the second and third on a lateral plate could be seen as rectangular plates with their smallest length dorso/ventral and angled slightly caudally (Fig. Sn37). The sacral elements increased in size and the first pair of laminae appeared to approach more closely the ilial shafts. This approximation was obvious by 54 days (C.R. 112 mm.) on a dorso/ventral plate (Fig. Sn41). The laminae of the second and third vertebrae developed a rounding of the dorsal border with a caudal prolongation of the caudal angle. (Fig. Sn40). In the foetus of 56 days (C.R. 120 mm.) there were present 2 centres immediately caudal to the laminae of the first sacral vertebra. They appeared rounded on dorso/ventral picture (Fig. Sn45) (Note 14 ribs with last on first lumbar vertebra) but could be seen on a lateral view through the image of the ilial shaft (Fig. Sn44). This pair of centres was seen in subsequent litters during this period.

Alizarin red staining of foetus.

The lamina were flattened and curved dorsally in towards midline (Figs. AZ63, AZ69 and AZ73). The centrum of the first sacral vertebra was flattened ventrally and appeared to have a small opening on this aspect. This was the appearance at 51 days (C.R. 105 mm.). At 52 days (C.R. 100 mm.) a small centre appeared ventro-lateral to the centrum of the first sacral vertebra and placed on a vertical line with the cranial edge of that lamina (Fig. AZ68 and AZ69). It was bilaterally present. Succeeding foetuses possessed this centre which continued to increase in size, at first oval and then becoming triangular in shape by 57 days (C.R. 125 mm.) (Fig. AZ103). The presence of this centre was constant in all the foetuses.

In one foetus of 54 days (C.R. 113 mm.) an extremely small speck was visible ventro/lateral to the centrum of the second sacral vertebra whilst a foetus of 56 days (C.R. 121 mm.) had similar small specks also related to the second and third sacral vertebrae. The later foetuses of the series all had a centre opposite the first centrum but nothing related to centra two and three.

Period of gestation 61 days onward.

Radiography of foetus.

The centres which had appeared caudal and ventral to the laminae of the first sacral vertebra were present in the remaining foetuses but their definition was variable in individuals as was their size (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

The first pair of sacral laminae had related caudo/lateral to them two small rounded centres. Also in this foetus a pair of distinct centres were apparent lateral to the laminae of the third sacral vertebra. These observations were on a dorso/ventral plate but the centres could also be observed on a lateral exposure when they were seen to be ventral to the centra (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The first sacral vertebra had related to its centrum a pair of centres which were roughly triangular in shape and by now of a size approximately half that of the centrum (Fig. AZ119). The laminae inclined to midline and were rectangular in shape with their longitudinal axis directed somewhat caudally.

Conclusions.

The sacral vertebrae appeared to develop in general from three principal centres as described by all the quoted authors, but in addition there appeared to be other additional paired centres developing in the transverse masses of the sacral elements. This would agree with the findings of Strauss-Durckheim (1845).

The centres for the centrum and laminae of the first sacral vertebra were the first to become apparent, the time being 36 days (C.R. 49 mm.) for the centra and 40 days (C.R. 66 mm.) for the laminae. The histological development was similar to that of the previous regions of the vertebral column. In alizarin specimens, the centra and laminae of all three sacral elements were present at 40 days (C.R. 66 mm.) and radiographically a day later. The centres in the lateral masses were a constant feature of only the first sacral vertebra but other individuals did have them at the second and even the third sacral vertebra. Those of the first sacral vertebra appeared in alizarin specimens at 52 days (C.R. 108 mm.) and again radiographically at 56 and 58 days (C.R. 121 and 130 mm.) the earlier being in the silver nitrate impregnated specimens.

Vertebrae caudales (coccygeae)

Period of gestation 31-40 days.

Radiography of foetus.

The centra of the coccygeal vertebrae did not make an appearance until 38 days (C.R. 58 mm.) when the bodies of approximately the first five could be seen on a lateral plate. They appeared as small indistinct specks but by 40 days (C.R. 66 mm.) the bodies had distinct rounded outlines and numbered eleven. They were visible on both a lateral and dorso/lateral projection.

Radiography of foetus impregnated with silver nitrate.

Six centra were seen in the cranial coccygeal region in the foetus of 34 days (C.R. 43 mm.) but by 40 days (C.R. 67 mm.) fifteen bodies could be seen. The first four were smaller than the succeeding six or seven, after which the size descreased yet again. The fifth and sixth appeared to have small laminae lying dorsal to them at 40 days (C.R. 67 mm.) (Fig. Sn17).

Alizarin red staining of foetus.

In the foetus from one of the litters of 36 days (C.R. 55 mm.) there were 2 centra of the coccygeal vertebrae faintly staining pink. These appeared to be the second and third coccygeal vertebrae. In the foetus of 37 days (C.R. 56.5 mm.) four bodies were present being numbers two to five. They were seen as small oval structures. The number had increased to seven by 38 days (C.R. 58 mm.) and by now the first coccygeal body had arrived (Fig. AZ26). The 39 day (C.R. 63 mm.) foetus however had only vertebral bodies two to six showing. The foetuses of 40 days (C.R. 66 mm.) had 16 bodies showing from number one onward and there were present small laminae over the bodies of the first seven in one foetus and five in the other (Fig. AZ34). The succeeding three vertebrae had a distinctly concave dorsal surface on their centra.

Period of gestation 41-50 days.

Radiography of foetus.

At 41 days (C.R. 73 mm.) the centra of twelve to fourteen coccygeal vertebrae were visible and in the case of one litter faint outlines of laminae were seen above the first four centra (Figs. X3 and X4). By 43 days (C.R. 82.5 mm.) seventeen to nineteen centra were visible but still only four had laminae present dorsally. At this stage, there could be seen a differential in size and shape of the centra. The first four were short whilst the succeeding centra increased in length giving a rod-like appearance. The total length of the centra began to decrease after the 8th. - 9th. vertebrae but the succeeding centra were still rod-like in outline. By 44 days (C.R. 84 mm.) the laminae visible were 5 pairs, they were larger and a space was present between them and the centra when viewed on a lateral projection. By 46 days (C.R. 88 mm.) there were two more pairs of laminae visible but the number varied between 5 and 7 in succeeding litters (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

In the 43 day (C.R. 82.5 mm.) foetus nineteen centra were seen with five pairs of laminae present dorsal to the first five centra. These laminae were small as were the centra they overlay. The centra of coccygeal vertebrae 7-10 were largest, then the size decreased (Fig. Sn19 and Sn20). By 44 days (C.R. 84 mm.) the laminae of the first six vertebrae were seen above the centra but now there could be seen caudally projecting spicules on the dorsum of the centra 7-9 (Fig. Sn22). All these observations were made on lateral plates. On dorso/ventral viewing only the laminae of the first three coccygeal vertebrae could be seen. Caudal to this, they overlay the centra and were masked by that image (Fig. Sn21). The vertebral elements continued to increase in size (Fig. Sn31).

Alizarin red staining of foetus.

The centra of the coccygeal vertebrae were stained throughout the period and had a cylindrical shape with narrowing of the central position (Fig. AZ46). They increased in length from the first to the eighth and ninth and then regressed toward the distal tip of the tail. The laminae were apparent over the first 3-4 centra with a space existing between them. However, from the fourth to the eighth or ninth, the laminae were present attached to the dorsum of the centra as laterally placed dorsal projections (Fig. AZ50). This gave the centra a U-shaped appearance on cross-section (Fig. AZ52). The free laminae were vertical plates with their dorsal extremities inclining toward midline. The attached laminae were more pointed with a caudal prolongation. In a foetus of 44 days (C.R. 85 mm.) there were seen lying caudal and ventral to the centra of vertebrae six to nine, minute stained specks, lying in pairs. There was also one lying in a similar position relative to the first coccygeal vertebra. These structures were present in succeeding litters, and were not consistent in number but when they did appear they lay between the sixth to ninth coccygeal vertebrae.

Period of gestation 51-60 days.

Radiography of foetus.

The centra increased in size during this period with the longest lying in the eighth and ninth position. The laminae were present in some form in approximately the first eight coccygeal vertebrae but their form varied from, plate-like laminae in the cranial three or four to narrow spicules in the latter four or five. These spicules were directed caudally (Fig. X9).

Radiography of foetus impregnated with silver nitrate.

At 51 days (C.R. 105 mm.) the first three coccygeal vertebrae had pairs of laminae with their image separated from that of the centrum. The succeeding five vertebrae had laminae apparently merging with the centrum. The former three pairs were almost square but with an angled cranial border. The succeeding five pairs had dorsal eminences with caudally projecting spicules. The dorsal eminences diminished in size in the latter few leaving only the spicules. These observations were on lateral projection (Fig. Sn32). There appeared ventral to the caudal vertebrae, at the intervertebral spaces, pairs of extremely small specks. The first appeared at 53 days (C.R. 108.3 mm.) where three pairs were present between the eighth and eleventh coccygeal vertebrae. A 54 day foetus (C.R. 112 mm.) had six pairs from the eighth to the fourteenth coccygeal vertebrae but another foetus of 54 days (C.R. 113 mm.) lacked any. These were seen on lateral exposures. They were present in variable numbers in succeeding foetuses of the period (Fig. Sn44) but it was not until 58 days (C.R. 130 mm.) that they were seen on a dorso/ventral plate. By 56 days (C.R. 121 mm.) the laminae of the first three coccygeal vertebrae had narrowed to give a more rectangular outline with the longitudinal axis dorso/ventral and tilted slightly caudally (Fig. Sn44).

Alizarin red staining of foetus.

At 51 days (C.R. 105 mm.) the first three coccygeal vertebrae had small plate-like laminae with their greatest length dorso/ventral and a slight caudal angulation. The succeeding five vertebrae had dorsal projections from the centrum, the projection being raised cranially and having a thin prolongation caudally. The remaining vertebrae consisted of centra which were cylindrical with narrowed centres (Fig. AZ63). There were present also minute stained specks lying in pairs ventral to the centra and between succeeding pairs. The numbers and constancy of these centres varied with each litter (Fig. AZ106) but the common sites were at the first and second inter-coccygeal spaces and the eighth to twelth spaces (Fig. AZ73). One variation occurred in a foetus of 56 days (C.R. 121 mm.) when two additional centres were seen lying, one on each side of midline, ventro/lateral to the centrum of the first coccygeal vertebra. These centres were similar to the centres related to the sacral vertebrae.

Period of gestation 61 days onward.

Radiography of foetus.

The first three coccygeal vertebrae bore laminae separate from the centra while the succeeding four to five had dorsal eminences of the centra. There was no evidence of any separate centres lying ventral to the centra (Fig. X10).

Radiography of foetus impregnated with silver nitrate.

On dorso/ventral examination in the third, fourth and fifth coccygeal vertebrae, the caudally directed spicules could be seen extending beyond the caudal edge of the centrum. At the fifth to ninth intervertebral spaces pairs of small centres could be seen both on dorso/ventral and lateral viewing (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The laminae of the first three coccygeal vertebrae were separate from their centra although the third was closely applied. The succeeding five had dorsal elements of decreasing size with caudal projections. The eighth had merely the form of two dorsal spicules. There were small stained specks in pairs situated ventrally between the centra in the four foetuses examined but the numbers and positions varied, being found between the fourth and ninth coccygeal vertebrae (Fig. AZ114).

Conclusions.

The coccygeal vertebrae differed in their foetal development from the other vertebrae as the more caudal of the group developed from only one centre of ossification, that being for the centrum.

The cranial three coccygeal vertebrae developed from three centres i.e., one for the centrum and two for the laminae. The succeeding five vertebrae produced from the centrum dorsal projections of varying dgeree which remained attached to the centrum. The most caudal of the group remained cartilaginous at birth.

These findings agree with the comments of Crouch (1969) in his description of the various types and divisions of the coccygeal vertebrae. They also concur with Lesbre's (1897) observation that the last two or three coccygeal vertebrae bore cartilaginous centra at birth. The appearance of two small centres, ventral to the centra of some of the coccygeal vertebrae would indicate the development of the chevron bones of Crouch (1969) and the ossa arcus haemalis of Frewein (1970).

The centra of the coccygeal vertebrae appeared from 36 days (C.R. 49 mm.) in alizarin red stained specimens, from 34 days (C.R. 43 mm.) in radiographs of silver nitrate subjects and from 38 days (C.R. 58 mm.) in radiographs of unprepared foetuses. Those laminae which developed were apparent at 40 days (C.R. 66 mm.) when stained with alizarin red and also radiographically when impregnated with silver nitrate, a day later in unprepared foetuses. The ventral or haemal arch centres were observed first in the alizarin specimens at 44 days (C.R. 84 mm.) but were not apparent radiographically unless impregnation with silver nitrate had occurred and even then not until 53 days (C.R. 108.3 mm.).

Costae.

Strauss-Durckheim (1845) and Jayne (1898) both describe two principal centres for the ribs, one for the diaphysis and the other for the proximal head. The latter author also mentions an additional centre for the tubercle present on the first ten pairs of ribs. Mivart (1881) declares that in the developing vertebral column the cartilages also extend down in each ventral lamina as the cartilaginous predecessors of the ribs, and that those of the thorax, by their median fusion in the mid-ventral line, lay the foundation of the sternum. Lesbre (1897) states that the ribs begin to ossify very early, even before the vertebrae, but their ossification is always incomplete since they remain cartilaginous at their distal extremities.

Variations in the number of ribs seen in the cat, using radiography, are described by Boyd and Lindsay (1968) when anomalies occurring in individuals and litters are listed including some seen in foetal life.

Period of gestation 31-40 days.

Histology.

The cartilaginous models of the ribs were composed at their middle portions of degenerating cartilage cells and the peripheral collar was calcified by 31 days (C.R. 35 mm.) so that by 33 days (C.R. 39 mm.) invasion of the centre of the model by osteogenic cells and vascular tissue was seen.

Radiography of foetus.

The first indication of the presence of the ribs was seen in a foetus of a litter of 33 days (C.R. 38 mm.) (Figs. X1 and X2). In this case the outlines of the ribs were indistinct but there was a striped appearance of the thoracic wall provided by the presence of approximately six pairs of ribs. These findings were seen on a lateral exposure. Foetuses of two litters of 34 days (C.R. 43 mm.) were examined and in one there was a faint indication of approximately five pairs of ribs but the other litter was negative for such findings. The foetus of 35 days (C.R. 44.2 mm.) had eight pairs of ribs showing both on a lateral and dorso/ventral exposure. These were seen as narrow strands running across the thoracic wall. By 36 days (C.R. 49 mm.) the outline of the rib cage was much more distinct and all thirteen pairs of ribs could be seen on both a lateral and dorso/ventral view. On the lateral exposure, the ribs extended from vertebral level to approximately half way down the thoracic wall. The ribs five to ten were of greater length compared to the others. The ribs were constant in their presence from this age onwards and increased slightly in length over the period and by the end of the period extended more than half-way down the thoracic wall (Figs. X3, X4 and X5).

Radiography of the foetus impregnated with silver nitrate.

In a foetus of 31 days (C.R 35 mm.) ten pairs of ribs were evident as narrow shafts running in the thoracic wall (Figs. Sn4 and Sn5). On a dorso/ventral exposure the proximal ends were considerably removed from midline and on lateral viewing the ribs barely extended through the dorsal half of the thoracic wall. Further changes were in the manner described under radiography (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

In the foetuses of 31 days (C.R. 35 mm.) the number of ribs varied from six to eleven pairs (Fig. AZ10). Of this series, the length was greatest in the central ribs and diminished towards the ribs at either end. The shafts were curved with the convexity lateral in direction and the diameter of the shaft was fairly uniform. The foetuses of 33 and 34 days (C.R. 39 and 43 mm.) had eleven pairs of ribs and the range of length of shaft was similar to the previous range.(Fig. AZ15). By 35 days (C.R. 44.2 mm.) the number of pairs had increased to 12 and the shafts were altering in shape (Fig. AZ18). The more proximal length of the shaft was thickening and was more compressed in a cranio/caudal direction whereas the distal end was flattening, the compression being lateral in direction. This gave a somewhat spiralling appearance to the mid-shaft region. These changes were more marked in the longer ribs. One of the foetuses of 36 days (C.R. 49 mm.) had 13 ribs on the left and fourteen ribs on the right side, the extra one being caudal in position. The last ribs normally to appear were the first pair. The ribs continued to increase in length and by 40 days (C.R. 66 mm.) the proximal ends bore on their dorsal surfaces a raised protuberance (Fig. AZ33).

Period of gestation 41-50 days.

Radiography of foetus.

The ribs retained their general shape during this period but increased in total length. All thirteen pairs were evident. The flattening of the distal ends became more obvious as the ribs enlarged (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The ribs increased in size during the period. The flattening of the distal end became increasingly accentuated (Figs. Sn19, Sn20, Sn31 and Sn32). The proximal end of the first ten ribs began to flatten on their dorsal curvature so that a head was beginning to differentiate for each rib and also a raised eminence was produced on the dorsal curvature of the proximal section. This was seen to be occurring in the second half of this period (Fig. Sn27).

Alizarin red staining of foetus.

The ribs were compressed laterally at the distal ends and cranio-caudally at their proximal ends. At the latter extremity, there was a hook-like appearance with a medial curving of the most proximal end and a dorsal eminence appeared on the greater curvature of the "hook". This appearance was accentuated as the ribs increased in length and diameter (Fig. AZ50).

Period of gestation 51-60 days.

Radiography of foetus.

The ribs increased in size during the period. The distal ends remained flattened whilst the proximal ends became more closely related to the thoracic vertebrae and by 54 days (C.R. 112 mm.) on a dorso/ventral plate, the images of the first ten ribs appeared to be in apposition to the images of the thoracic vertebrae. The remaining ribs remained detached. This situation peristed throughout the remainder of the period (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The shaping of the proximal end was evident at 52 days (Fig. Sn37) and by now the proximal end of the ribs appeared closely approximated to the vertebral column on a dorso/ventral plate (Sn35). The first ten ribs were related to the cranio/lateral portion of each vertebra but the caudal three were opposite their corresponding vertebrae (Fig. Sn47). These latter ribs did not appear to have the developing tubercle.

Alizarin red staining of foetus.

The distal end of the ribs were flattened laterally (Fig. AZ73) and the proximal ends were strongly curved with a flattening of the dorsal surface of this curvature (Fig. AZ75). The head of the rib was ventral to the lamina of the first ten thoracic vertebrae (Fig. AZ75). The remaining three ribs remained further separated from their appropriate vertebrae. The flattened dorsal curvature had developed a roughened raised area becoming prominent at 57 days (C.R. 125 mm.) (Fig. AZ100).

Period of gestation 61 days onward.

Radiography of foetus.

The caudal three ribs appeared to be relatively closer to their appropriate thoracic vertebrae (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

The raised and flattened dorsal curvature of the proximal end was obvious in the foetus examined giving an appearance of a narrowed proximal head and then an expanded proximal dorsal curvature (Fig. Sn56).

Alizarin red staining of foetus.

The proximal end of the ribs was now beneath the transverse projections or processes and the dorsal curvature was opposite the extremity of the transverse projection (Fig. AZ117).

Conclusions.

The first indications of the presence of the ribs were seen in alizarin red stained foetuses at 31 days (C.R. 35 mm.) and again radiographically at the same date using silver nitrate impregnation of the foetus. However, the radiographic images in the fresh specimens were not seen until 33 days (C.R. 39 mm.) and it was not until the 41-50 day period that the full complement of ribs was consistently evident. The ribs during this latter period altered in shape with flattening of the distal end and curving of the proximal segment.

Histologically, there was primary calcification present in the ribs of 31 day (C.R. 35 mm.) foetuses and a centre of ossification by 33 days (C.R. 38 mm.). Lesbre's (1897) statement that the ribs begin to ossify very early, even before the vertebrae, appears to be borne out although the time between the ribs and vertebrae is up to 3 days. Histologically, there is an earlier date of true ossification in the ribs compared to the vertebrae.

There would seem to be only a diaphyseal centre present in foetal life which is as described by Strauss-Durckheim (1845) and Jayne (1898) but these authors also give another centre, described as that for the proximal head of the rib but they do not relate a time of appearance for it.

In the foetuses examined which had ribs in evidence, there were found to be some anomalies in the number of ribs. This was observed in four litters and affected nine individuals. The incidence of these supernumcrary ribs in littermates is also of note. The variations in rib numbers are listed in Table 3 which gives details of concommitant anomalies in the vertebral column and sternum.

Sternum.

Strauss-Durckheim (1845) and Jayne (1898) both state that the sternebrae appear to be developed from single centres of ossification, but the latter author qualifies this statement by narrating that there are grounds for believing that these centres are derived from paired primary centres. Mivart (1881) adds little information save that the cartilaginous predecessors of the ribs fuse ventrally in the median plane and lay the foundation of the sternum, which appears first as two strips of cartilaginous tissue on which the first ribs of each series attach. The strips of half-sternum, placed laterally, move towards each other and unite from before backwards into a single median sternum. His description continues that the sternum develops by successive centres placed in the intervals of articulation with the ribs, centres which remain double i.e. two centres lying laterally keep their primitive appearance as two hemi-sternebrae. These may remain distinct throughout life. Lesbre (1897) further states that although the sternebral complement is usually eight in the cat, sometimes nine may be present and he describes their appearance as little cylindrical pieces hollowed out in the middle.

Period of gestation 31-40 days.

Histology.

By 33 days (C.R. 38 mm.) on histological section, the cartilaginous precursors of the sternal centres were exhibiting degenerative changes in the cartilage cells. At 35 days (C.R. 44.2 mm.) there were swollen and degenerating cells in the sternal bodies with calcification of the ground substance. Further examination of a 39 day (C.R. 63 mm.) foetus revealed penetration of the bodies by osteogenic cells from the surrounding layer of now periosteum. The sternal bodies appeared to develop from single centres in the foetuses examined.

Radiography of foetus.

Two litters of 38 days (C.R. 58 and 60 mm.) were examined and in a foetus from one of them (C.R. 60 mm.) three sternebrae could just be discerned ventrally in the caudal thoracic region. Such structures were not evident in the 39 day (C.R. 63 mm.) foetus but at 40 days (C.R. 66 mm.) sternal bodies could be seen on both lateral and dorso/ventral exposures. On the latter plates eight sternal segments could be observed. They were present as extremely short, single and unpaired rods.

Radiography of foetus impregnated with silver nitrate.

The bodies of the sternebrae were not observed using this method until the foetus of 37 days (C.R. 56.5 mm.) when the sixth and seventh sternebrae, as judged by rib count, were seen as small spots lying ventrally in the thoracic region (Fig. Sn12). The foetus of 39 days (C.R. 63 mm.) demonstrated a similar picture but by 40 days (C.R. 67 mm.) all eight sternebrae were evident. The first was still small but the others were seen as short rods except for the last segment which was flattened, elongated and tapering toward its caudal end (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

In the foetus of 36 days (C.R. 49 mm.) the bodies of three sternebrae could be seen (Fig. AZ22). These appeared to be sternebrae five, six and seven. They had the form of short rods, lying in the ventral thoracic region. The number present at 37 days (C.R. 56.5 mm.) was similar but by 38 days (C.R. 58 mm.) five bodies had appeared of which the first and last were the recent additions. At 39 days (C.R. 63 mm.) there were six bodies present, the first element being the smallest (Fig. AZ32). At 40 days (C.R. 66 mm.) there were seven elements apparent, the ultimate being elongated and narrow compared to the short rods of the others (Fig. AZ33).

<u>Period of gestation 41-50 days.</u>

<u>Radiography of foetus.</u>

The bodies of the sternebrae were all evident throughout this period and were observed to greatest advantage on a lateral plate, as on the dorso/ventral exposure the vertebrae tended to overlay them. The last sternebra was wedge-shaped whilst the remainder were rod-shaped. The length of these rods increased during the period, at first fairly evenly but, by 45 days (C.R. 86 mm.) the first and penultimate sternebrae were shorter than the others, which were of increased length with the middle group being the largest (Figs. X3 and X7).

<u>Radiography of foetus impregnated with silver nitrate.</u>

The eight rod-like bodies of the sternebrae were seen throughout this period (Figs. Sn19, Sn20 and Sn31). The first and penultimate were the smallest and the last body was elongated with a tapered caudal end. In a foetus of 47 days (C.R. 92 mm.), the penultimate element was much smaller than the other bodies of that foetus and the bodies of sternebrae of foetuses of closely related ages (Fig. Sn30).

Alizarin red staining of foetus.

The sternebrae were cylindrical in shape with narrow central portions except for the last element. It was elongated and wedge-shaped with dorso/ventral flattening of its caudal end. The penultimate element was consistently shorter than the elements two to six but its size did vary in individuals i.e., in no chronological order. The first element was also shorter than the succeeding 5 sternebrae (Figs. AZ35, AZ49 and AZ51).

Period of gestation 51-60 days.

Radiography of foetus.

The rod-like shape of the sternebrae was maintained during this period but a gradual increase in size was appreciated. The penultimate body was the shortest and this was constant even in the cases where seven or nine sternebrae were present. The last body was wedge-shaped and elongated (Fig. X9).

Radiography of foetus impregnated with silver nitrate.

The rod-like appearance of the sternebrae could be seen throughout the period. The last sternebra was wedge-shaped but flattened at both ends. In a foetus of 53 days (C.R. 108.3 mm.) the number of sternebrae was seven but the third last body was irregular in shape and longer than the others, giving the appearance of an amalgamation of two sternebrae. The 60 day (C.R. 136 mm.) foetus also demonstrated a small penultimate sternebra (Figs. Sn51 and Sn52).

Alizarin red staining of foetus.

The bodies of the sternebrae were cylindrical with narrowing of their central portions. The first body had a somewhat pointed cranial extremity as did the penultimate body at its caudal tip. The last body was narrowest at its caudal end coming to a blunt termination (Figs. AZ73 and AZ108).

Period of gestation 61 days onward.

Radiography of foetus.

The sternebrae remained generally cylindrical in shape with the penultimate the shortest and the last, wedge-shaped (Fig. X10). In the litter of 61 days (C.R. 140 mm.) one foetus had only six elements present but the fourth and fifth of this series were irregular in outline and the fourth gave the impression of being a composite of three elements when viewed laterally.

Radiography of foetus impregnated with silver nitrate.

Again the penultimate element was the shortest cylinder but still retained the narrow centre whilst the last element was longest and wedge-shaped (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The caudal extremities of the first to the seventh sternebrae were flattened and had small facets on their lateral edges (Fig. AZ115).

Conclusions.

The mode of ossification was endochondral and the development of each sternal segment appeared to be from a single separate centre. Histologically the process of calcification was commencing by 35 days (C.R. 44.2 mm.) with a centre of ossification present by 39 days (C.R. 63 mm.). Alizarin red staining revealed the earliest sternal segments by 36 days (C.R. 49 mm.) with the full number being evident by 40 days (C.R. 66 mm.). Radiography tallied closely with these dates being between 37 and 40 days (C.R. 56.5 and 67 mm.) for the appearance in silver nitrate impregnated foetuses and 38 to 40 days (C.R. 58 to 66 mm.) in fresh specimens. The common number of sternal segments was eight but variations did occur and are recorded on Table 3.

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Maxilla.

Mivart (1881) places the ossification of the maxilla and premaxilla (os incisivum) as following that of the mandible which latter structure is said to be the first to appear. The maxilla is said to be formed by ossification in the membrane investing the maxillary process. Lesbre (1897) assigns it a membranous form of ossification and classifies it as ossified in a skull of a near-term foetus. Drews (1933) describes it as visible in a foetus of C.R. 46 mm. or 28 days and describes the body and palatine process as clearly distinguishable in the fifth week of gestation.

Period of gestation 21-30 days.

Radiography of foetus.

There was no evidence of the maxillae in the foetuses examined thus during this period.

Radiography of foetus impregnated with silver nitrate.

The maxillae were first evident in foetuses of 30 days (C.R. 29.1 mm.) when they were seen as strips lying dorsal to the mandibulae, with the rostral ends expanded and more dorsal than the pointed and more ventrally placed caudal ends. These observations were on lateral plates (Fig. Sn3).

Alizarin red staining of foetus.

The first foetuses to exhibit the presence of a stained maxilla were two of 28 days (C.R. 25; 26 mm.) (Fig. AZ1). In these foetuses the outline of the maxilla was of a triangle with a long base ventrally and extending from it a thin rostrally and dorsally directed process. The other foetus of 28 days failed to reveal such structures. Three foetuses of 39 days were subjected to this process but one failed to reveal a maxilla. The other two demonstrated maxillae to varying degrees. The foetus of C.R. 29 mm. had small stained triangular structures while the foetus of C.R. 29.1 mm. had a similar triangle, and adjoining and continuous with the rostral aspect of this a second triangular structure with a more irregular outline (Fig. AZ4).

Period of gestation 31-40 days.

Radiography of foetus.

At 31 days (C.R. 35 mm.) there were indistinct outlines of the maxillae present in foetuses of two of the three examined. They continued to be present from this day on, as irregularly triangular outlines above the mandible (Figs. X1 and X2). It was not until 36 days (C.R. 49 mm.) that the maxillary outline became distinct. It appeared on a lateral plate as a triangular structure with a pointed extension caudally (Figs. X3 and X5). On dorso-ventral viewing it was evident forming the most lateral portion of the face of the foetus (Fig. X4).

Radiography of foetus impregnated with silver nitrate.

The 31 day (C.R. 35 mm.) foetus had a triangular outline of the maxillary centre when viewed laterally. On dorso-ventral plates the centre formed the most lateral, longitudinal outline of the face with the os zygomaticus lying caudal and lateral. The countour was of a curved line with a step-like appearance of the centre of the line (Figs. Sn4, Sn5, Sn6 and Sn7). The centre continued to increase in size particularly in a dorsal direction so that at 40 days (C.R. 67 mm.) there was a rectangular shaped plate extending dorsally toward midline, filling in the outline of the face (Figs. Sn15 and Sn16).

Alizarin red staining of foetus.

The 31 day foetus (C.R. 35 mm.) had a development in the maxillary area resembling two continuous triangles, one lying rostral to the other (Figs, AZ6 and AZ9). The more rostral triangle became rounded off dorsally and began to extend dorsally and medially by 33 days (C.R. 39 mm.) (Fig. AZ18). The medial extension was approximately at right angles to the original development (Figs. AZ16). The space dorsally between the two triangles was being converted into a foramen but was not completely encircled until 35 days (C.R. 44.2 mm.) when it appeared as a round foramen (Fig. AZ19). This was the origin of the foramen infra orbitale. The double triangular appearance was now eliminated while the medial extension had increased in area. The 37 day (C.R. 56.5 mm.) foetus demonstrated the increasing dorsal encroachment of the facial region by the maxillary centre to approximate with the nasal bones (Figs. AZ24 and AZ25). The increase in the area of the centre continued throughout the period.

Period of gestation 41-50 days.

Radiography of foetus.

The centres continued to expand in area with dorsal encroachment when viewed laterally. The dorso-ventral image was difficult to interpret in definition of outline due to the developing frontal centres (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

Each maxillary centre made extensive growth in this period with enlargement of the vertical plate forming the lateral wall of the facial region whilst the horizontal shelf was growing medially from the inner aspect of the vertical plate (Figs. Sn23, Sn24, Sn26 and Sn28).

Alizarin red staining of foetus.

The medially projecting extensions of the centres for the maxillae were meeting in midline leaving only a narrow line between them. The outline of the two centres was like an outstretched butterfly when viewed ventrally due to the progressive extension of the more lateral and caudal projections which were closely related to the palatine centres (Fig. AZ40). These lateral extensions were separated from the more vertically placed lateral tissue of the maxillary centres by a hollowed cavity which was as yet unroofed at 43 days (C.R. 82.5 mm.) (Fig. AZ41). By 47 days (C.R. 92 mm.) the medially projecting centres were more extensive in area and there was a narrowing space between them and the incisive centres (Fig. AZ58). The hollowed cavity was commencing to develop a stained roof of tissue (Fig. AZ54) and within the cavity was seen a small irregular mass of stained tissue (Fig. AZ55). The lateral i.e., more vertical, plates of the maxillae were increasing in size during this period and the large foramen was an obvious feature at 43 days (C.R. 82.5 mm.) being directed laterally (Fig. AZ41). However, with growth, the direction of the foramen became more rostral by 47 days (C.R. 92 mm.) onward (Fig. AZ59).

Period of gestation 51-60 days.

Radiography of foetus.

On lateral plates of foetuses of 52 days (C.R. 108 mm.) the outline of the ventral border of the maxillae demonstrated pointed projections in the middle portion of the developing oral cavity. The projections were more pronounced in later foetuses and there was a general increase in size of the centres. By the end of the period, the ventral projections could be seen as individually formed conical papillae lying within and projecting from maxillary centres (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The growth of the horizontal plate was proceeding throughout this period and by the end the maxillary plate was related closely to the palatine and incisive centres. By 53 days (C.R. 108.3 mm.) there were apparent at the ventral border, when viewed laterally, conical projections in the structure of the maxilla (Fig. Sn37). These, having made themselves apparent, became more pronounced in definition and size (Fig. Sn54).

Alizarin red staining of foetus.

The medial horizontal plates were being overlapped caudally by the maxillary processes of the palatine centres (Fig. AZ70 and AZ71) and by the second half of this period the line of junction between the maxillary and palatine centres was filled in at this area (Fig. AZ95). The hollowed depression at the lateral edge was roofing over (Figs. AZ94 and AZ96) and within the cavity the developing teeth could be seen (Fig. AZ95). Also a fossa was developing rostral to this to accommodate the canine primordia. By 57 days (C.R. 125 mm.) a further rarefied area was appearing between this fossa and the hollowed depression. On the ventral surface a V-shaped ridge was arising with the point directed rostrally (Fig. AZ95). The extent of the maxillary centres continued to increase generally during this period (Figs. AZ73 and AZ100).

Period of gestation 61 days onward.

Radiography of foetus.

The outlines of the conical projections were distinct and the centres themselves were extensive on the lateral aspect of the face and projected medially on dorso/ventral viewing (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The maxillary centres were now extensive and still increasing in area (Fig. Sn56).

Alizarin red staining of foetus.

The V-ridge on theventral surface was increasing in prominence and was continued into the palatine centres (Fig. AZ112). The rostro-caudal length of the maxillary plates which had increased considerably over the latter days of the preceding period continued to alter from the 61st. day (C.R. 140 mm.) onward and this was accompanied by an overall increase in size.

Conclusions.

Histologically, the centres for the maxilla were seen to develop in membrane. There appeared to be two principal centres, one for the maxilla of each side. The centres first stained with alizarin red in foetuses of 28 days, repeating the finding of Drews (1933) as relating to the stated day of gestation but not repeating his finding of C.R. length; his figure was 46 mm. compared to these findings of 25 and 26 mm. However, his statement that the body and palatine process were clearly distinguishable in the fifth week of gestation would seem to correspond closely with these findings. The initial radiographic appearance was at 30 days (C.R. 29 mm.) with silver nitrate impregnation and 31 days (C.R. 35 mm.) in unprepared specimens. On each side the foramen infraorbitale was developing at the beginning of the 31-40 day phase to become enclosed by 35 days (C.R. 44.2 mm.) and the maxillary sinus was becoming evident as a cavity in the centre by 43 days (C.R. 82.5 mm.). The presence of the primordia of the teeth became evident in the 51-60 day period.

Os incisivum.

This is described by Mivart (1881) as arising from ossification of the cartilage of the naso-frontal process but appearing concurrently with the maxilla, following the emergence of the mandible. Jayne (1898) attributes to it a single centre of ossification and describes it as ossified in a skull close to birth. The incisivum in the work of Drews (1933) is given a single centre of ossification and is seen in a foetus of 46 mm. or 28 days.

Period of gestation 21-30 days.

Radiography of foetus.

No evidence of the presence of this structure was seen in foetuses of this period.

Radiography of foetus impregnated with silver nitrate.

The foetus of 30 days (C.R. 29.1 mm.) revealed minute specks which indicated the presence of the incisive bones. These were placed rostral to and in the same plane as the base of the maxillae when seen on a lateral plate. They were also visible on dorso-ventral viewing, again as small specks, one to either side of midline (Figs. Sn1 and Sn2).

Alizarin red staining of foetus.

Of the three foetuses of 28 days examined using this method only one (C.R. 26 mm.) revealed the presence of stained incisive bones. There were two small stained centres placed most rostrally, one to either side of midline, but in close proximity to each other. Of the foetuses of 30 days only one

(C.R. 29.1 mm.) revealed centres for the incisive bones. Here there was considerable development with two crescent-shaped structures lying rostrally with their long axes running in a sagittal plane and the convexity lateral. Their rostral ends were in extremely close proximity at midline (Figs. AZ4 and AZ5).

Period of gestation 31-40 days.

Radiography of foetus.

The outline of this centre could not be definitely identified until 33 days (C.R. 38 mm.) and even then its outline was indistinct but was visible on lateral viewing (Fig. X1). On dorso-ventral projection two small centres could be seen close to and on either side of midline (Fig. X2). By 36 days (C.R. 49 mm.) the outline although irregular was more distinct but was only visible on a lateral projection. On a true dorso-ventral plate the developing centres of the cranium masked the incisive centres. The centres increased in size and appeared as longitudinally placed flattened strips situated rostral to the maxillae to which they were closely relating by 40 days (C.R. 66 mm.).

Radiography of foetus impregnated with silver nitrate.

At 31 days (C.R. 35 mm.) the centres for these bones were present but only as short lines situated rostrally in the lateral views and as two small dots to either side of midline on dorso-ventral plates (Figs. Sn6 and Sn7). By 34 days (C.R. 43 mm.) the lateral appearance was triangular in outline but still small and irregular on dorso-ventral projection (Figs. Sn8 and Sn9). In the 39 day (C.R. 63 mm.) foetus, there could be seen two thin lines lying to each side of midline and arising from the triangular incisive centres when viewed dorso/ventrally (Fig. Sn16). The 40 day (C.R. 66 mm.) appearance was of a larger triangular centre situated rostrally in the nasal region (Fig. Sn17).

Alizarin red staining of foetus.

At 31 days (C.R. 35 mm.) the two centres were stained as crescentic structures, one to either side of midline and placed most rostrally in the head region. From the caudo-lateral extremity of the centre arose dorsal projections (Fig. AZ6). By 33 days (C.R. 39 mm.) the centres were widening medially to form a shelf-like area projecting caudally, whilst the dorsal prolongation was still evident at the caudo-lateral extremity (Figs. AZ13, AZ15 and AZ16). The centres continued to increase in size with a wider flattening of the shelf and more dorsal encroachment of the caudo-lateral projection. There was also formed at 33 days a thin medial line projecting caudally from the medial end of the crescent and parallel to midline. This persisted and thickened being apparent at the caudal and medial edge of the extending shelf of stained tissue as palatine processes (Fig. AZ29).

Period of gestation 41-50 days.

Radiography of foetus.

At the commencement of this period the centres could be seen both on dorso/ventral and lateral plates. The lateral view was approximately triangular and increased gradually in size but on the dorso/ventral plates the centres were observed as having a crescentic lateral portion joined with a straight medial border, the medial border of each flanking the midline

(Figs. X3, X4 and X5). This development was not fully observed till the 45 day (C.R. 86 mm.) stage (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The triangular shape was somewhat lost by expansion of the more rostral part of the centres and the addition of the lines running near midline (Fig. Sn24). On dorso/ventral viewing the centres were crescentic with a lateral peak and broader rostrally (Fig. Sn23). These developments were seen by 44 days (C.R. 84 mm.) and were accompanied by increase in size which continued throughout the remaining period.

Alizarin red staining of foetus.

The centres of the incisive bones gave the appearance of a rostral arc which was placed in a frontal plane and composed of two halves separated by a narrow division in midline. Caudally from this division a projection rose dorsally from each half forming two parallel sheets directed dorsally but lying in a saggital plane (Fig. AZ40). Laterally, from the dorsal surface of the arc, on each side of the face, there was arising a plate directed dorsally toward the nasal and maxillary centres (Fig. AZ50). By mid-period the ventral surface of the rostral arc was becoming indented to form a depression parallel with the rostral rim (Fig. AZ55). During the latter part of this period the lateral plate was becoming closely related to the nasal and maxillary centres on the lateral aspect of the facial region (Figs. AZ54 and AZ56).

Radiography of foetus.

By 52 days (C.R. 108 mm.) there could be seen on dorso/ventral projection, the appearance of a crescentic row of darkening spots running parallel with the rostral edge. These became clearer in definition by 54 days (C.R. 112 mm.) and remained throughout the period on dorso/ventral plates. The centres increased in size during this period (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The centres increased in size but there appeared by 53 days (C.R. 108.3 mm.) a series of areas of reduced opacity forming a crescentic arcade parallel to the rostral rim (Fig. Sn39). This was the view on dorso/ventral plates at 53 days (C.R. 108.3 mm.) and again at 54 days (C.R. 112 mm.) (Fig. Sn41) whilst on lateral viewing there was also seen an area of reduced opacity. By 54 days (C.R. 112 mm.) the lateral plates indicated an increasing degree of vertical growth of the centre (Fig. Sn40). These features followed through to the finish of this period (Fig. Sn54).

Alizarin red staining of foetus.

The excavation of the rostral depression continued during this period with rarefaction of the stained tissue leaving only a thin plate of tissue forming its rostral wall (Figs. AZ71 and AZ95). The other areas continued to increase in size and by the end of this phase, the line of junction of the incisivum with the maxillary centre on the lateral facial region was minimal in width and difficult to discern (Fig. AZ100).

Period of gestation 61 days onward.

Radiography of foetus.

The outline of the centre was clearly defined with the row of darkened areas forming a rostral arc on dorso/ventral viewing. The darker areas could also be appreciated on lateral viewing (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The crescent of reduced opacity was distinct and widening in this period being regular in outline when seen dorso/ventrally (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The rostral depression was seen to contain the developing incisor teeth, appearing as compact stained tissue within the arc shaped hollow (Fig. AZ112),which was showing evidence of division into alveoli.

Conclusions.

Histologically, the os incisivum developed in membrane. The development was from two centres, one for the bone of each side, placed rostrally and to each side of midline. These centres appeared at the same time as those of the maxillae being first evident as alizarin red stained structures in a foetus of 28 days (C.R. 25 mm.). Drews (1933) also gives the day of appearance as 28 but attributes a C.R. length of 46 mm. to this as compared to 26 mm. as detected in these findings. Radiographically, the centres were seen at 30 days (C.R. 29.1 mm.) in the silver nitrate preparations and 33 days (C.R. 38 mm.) in fresh specimens. The proccessus palatinus of each side was seen developing in the later part of the 31-40 day period as was the processus nasalis. The primordia of the incisor teeth were not in evidence till after 60 days (C.R. 138 mm.) but the arcus alveolus was seen developing in the 51 to 60 day period.

Os palatinum

Mivart (1881) indicates that the os palatinum arises from cartilage at the same time as the basi and exoccipitals, alisphenoids, basi-, orbito- and presphenoids and pterygoids. Jayne (1898) relates that it appears to have a single centre of ossification and shortly before birth he describes it as ossified. Drews (1933) tells of the presence of the palatine centres in a foetus of 46 mm. or 28 days.

Period of gestation 21-30 days.

Radiography of foetus.

There was no indication of ossification of these centres in foetuses of this group.

Radiography of foetus impregnated with silver nitrate.

The centres for the palatines were present in radiographs of the 30 day foetuses (C.R. 29 mm.) They were seen on lateral exposures as irregularly shaped sheets of impregnated tissue lying slightly caudo/dorsal to the os zygomaticum. There appeared to be a rostrally projecting pointed process when viewed laterally. On dorso/ventral exposure the structures appeared crescentic and lay one to either side of midline just within the image of the maxillae (Figs. Sn1 and Sn2).

Alizarin red staining of foetus.

The only foetus in which the stained palatine centres were seen was one of 30 days (C.R. 29.1 mm.). In this case the centres appeared as narrow curved strips of stained tissue with their convex border placed laterally and their long axis dorso/ventrally (Fig. AZ6). They lay medial and slightly caudal to the developing orbit (Fig. AZ5).

Period of gestation 31-40 days.

Radiography of foetus.

In the foetus of a litter of 33 days (C.R. 39.8 mm.) there appeared on lateral viewing a narrow strip of increased opacity caudal to the maxillary centre and on confirming its presence on dorso/ventral projection, two C-shaped centres could be seen to either side of midline, with their extremities directed medially (Figs. X1 and X2). This appearance was confirmed in the foetus of 36 days (C.R. 49 mm.) when the C-shaped structures enclosed the vomer centre. The lateral appearance at this stage was larger and more complex in outline with a rostrally directed projection coming from the ventral and rostral angle of the strip. The increase in size continued gradually and, on dorso/ventral plates, the ventral extremity of the C-shape appeared to project closer to midline.

Radiography of foetus impregnated with silver nitrate.

The centres appeared on dorso/ventral viewing as small traingular areas lying within the corpora mandibulae and were seen in the foetuses of 31 days (C.R. 35 mm.) (Figs. Sn4, Sn5, Sn6 and Sn7). The centres enlarged slightly during this period but still retained a triangular appearance with the base of the triangle laterally (Figs. Sn9 and Sn10). By 39 days (C.R. 63 mm.) their image was becoming slightly masked by overlying tissue (Figs. Sn15 and Sn16).

Alizarin red staining of foetus.

The two centres were producing, at their ventral ends, horizontal shelves which projected toward midline. These shelves were irregularly rectangular in shape and by 35 days (C.R. 44.2 mm.) had produced a small projection at the lateral edge rostrally (Figs. AZ18 and AZ19). There was also appearing, from the angle formed by the rostral and lateral borders, a projection directed forward. The vertical plates of the centres were still evident. By 38 days (C.R. 58 mm.) the projection on the lateral edge had developed to form a small wing attached to the lateral edge and bearing a foramen at its line of attachment. These wings protruded laterally. The caudal edge of the horizontal plate was now curved with the lateral angle being drawn out in a prolongation and becoming related to the pterygoid centre. Also the rostral edge was protruding more at its medial angle being here related to the maxillary centres (Fig. AZ29). The vertical plate was seen to bear on its outer surface at its rostral edge a small protuberance. Towards the end of this period the space in midline between the two horizontal plates was decreasing.

Period of gestation 41-50 days.

Radiography of foetus.

The C-shapes of these centres were visible at the beginning of this period on dorso/ventral plates and laterally the centres were seen as strips running horizontally, caudal to the maxillary centre (Figs. X3, X4 and X5). The dorsal border of the caudal half of the strip was expanding slightly during this period but on dorso/ventral observation, the centres became increasingly difficult to define (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The centres were increasing in size during this period and the triangular shape was being converted to a more rectangular outline with a caudo-lateral and rostro/lateral extension (Fig. Sn23). This alteration in shape was commencing at 44 days (C.R. 84 mm.) and distinct by the end of the period. The caudal end of the centre was being masked during this period by the developing praesphenoid centre (Fig. Sn28). These observations were on dorso/ventral projections.

Alizarin red staining of foetus.

The two horizontal plates were now closely related in midline. Their caudo/lateral angles were pointed, projecting caudally, and the lateral wings were present with foramina at their bases. The features were present throughout this period and increased with the overall extension in size (Figs. AZ40 and AZ55). The vertical plate had produced from its more rostral projection a dorsally elevated eminence separated from the remainder of the vertical plate by an incompletely closed foramen (Figs. AZ41 and AZ54). At 43 days this foramen was completely open dorsally but by 47 days (C.R. 92 mm.) the gap had narrowed (Fig. AZ54).

Period of gestation 51-60 days.

Radiography of foetus.

The dorsal expansion continued at the caudal end of the centre during this period and the dorso/ventral image was seen to be overlaid caudally by the image of the praesphenoid by 52 days (C.R. 108 mm.). The outlines became increasingly difficult to determine as the period progressed

(Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The extension of the centres continued and their approximation to midline was noted. The caudo-lateral extensions were markedly developed so that by 53 days (C.R. 108.3 mm.) the two centres when observed dorso/ventrally formed a rounded arc at the caudal border. These extensions at their caudal tips were, by 54 days (C.R. 112 mm.) in close proximation to the outlines of the pterygoid centres. By the end of this period, the centres were extensive and closely related to those of the maxilla. The overlying praesphenoid extensively masked the outline of the caudal end (Fig. Sn48).

Alizarin red staining of foetus.

The centres were increased in their area with widening and caudal extension of the horizontal plate. The midline gap was closing as was the relationship with the maxillary and pterygoid centres.

By 57 days (C.R. 125 mm.) the gap between the maxillary centre appeared partly closed but in fact this was found to be an overlapping of the edges (Fig. AZ95). The foramen at the base of the lateral wings in the 52 day foetus (C.R. 108 mm.) was wide and gave access to an extensive space, but it gradually decreased in diameter so that by the second half of this period it could be seen to lead into a canal which had an opening on the ventral surface of the horizontal plate (Fig. AZ96). This was the caudal opening of the palatine canal. The rostral opening was on the rostro-lateral border of the same plate (Fig. AZ71) but was not converted into a foramen, rostral foramen of palatine canal, until the gap between the palatine and maxillary edges was closed (Fig. AZ95). This was accomplished by filling in of the rostral curve between the lateral wing and the horizontal plate. On the ventral surface of the horizontal plate in its more rostral portion, there were appearing toward the end of this period, slightly raised ridges running divergently from the rostral border (Fig. AZ95). The vertical plate continued to increase in size and the opening in its rostral half still remained incomplete at the end of this period (AZ96). In the later phase of this period, the rostral border was indented by the approximation of the maxillary centre whilst the lateral border of the horizontal plate was smoother in outline, with the definition of the lateral wings being largely lost rostrally. The most caudal tip was truncated where it was immediately adjacent to the pterygoid centre.

Period of gestation 61 days onward.

Radiography of foetus.

The centres were largely masked on lateral viewing but on dorso/ventral plates could still be seen to be overshadowed by the praesphenoid caudally and to be related at their caudo/lateral borders to the pterygoids (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The centres were strongly defined on dorso/ventral plates with the praesphenoid overlying the caudal end. The pterygoids now lay immediate to the tip of the caudal extensions (Fig. Sn53).

Alizarin red staining of foetus.

The raised ridges on the ventral surface became increasingly prominent and were seen to be a continuation of similar ridges of the maxillary centres. The overlapping of these centres was obvious but they were still not united centres (Fig. AZ112). The centres were increasing in size and in the vertical plate the foramen remained open dorsally even after birth (Fig. AZ111).

Conclusions.

Histologically it was seen that the palatine centres of ossification were developed from membrane, being contrary to the description of Mivart (1881). In alizarin stained specimens the two centres were first seen at 30 days (C.R. 29.31 mm.) to either side of midline, compared to the figures of Drews (1933) of 28 days (C.R. 46 mm.). The initial radiographic appearance was seen at 30 days (C.R. 29.1 mm.) in silver nitrate impregnated foetuses and 33 days (C.R. 38 mm.) in fresh specimens. The development of the palatine canal was seen commencing in the first part of the 51-60 day period and the foramen sphenopalatinum was seen developing at the beginning of the 45-50 day period but remained incomplete throughout gestation.

Os zygomaticum

Mivart (1881) attributes the origins of this bone to membrane and groups it with the supra-occipital, parietals, interparietals, frontals squamosals, vomer, nasals and lachrymals. Jayne (1898) states that this bone develops from one centre of ossification and mentions the presence of a small tubercle representing the malar postorbital process in a skull shortly before birth. Drews (1933) shows this bone as a rhomboidal lamella at the begining of the fifth week, having been seen in a foetus of 46 mm. or 28 days. He further tells of the development of the processus maxillaris at the ventral edge and of the processus frontalis at the dorsal edge, all during intra-uterine life.

Period of gestation 21-30 days.

Radiography of foetus.

There was no trace of this bone in radiographs of the foetuses of this period.

Radiography of foetus impregnated with silver nitrate.

The foetuses of 30 days (C.R. 29.1 mm.) revealed the presence of this bone as a fine strip of impregnated tissue lying with its rostral half above and in close proximity to the caudal section of the maxilla. This was on lateral viewing whilst on a dorso/ventral plate the centres lay laterally on either side of the skull and appeared as small dots above the maxillae (Figs. Sn1 and Sn2).

Alizarin red staining of foetus.

In the foetuses of 28 days, only one (C.R. 26 mm.) had this structure stained. The centre appeared as a narrow triangular structure with the long base dorsally. Its rostral border was related to the caudal border of the corresponding maxilla of that side. One foetus of 30 days (29.1 mm.) had a similar stained structure (Fig. AZ4).

Period of gestation 31-40 days.

Radiography of foetus.

This centre was first positively seen in the foetus of 36 days (C.R. 49 mm.) when a fine line was observed running above and caudal to the maxilla. The outline became clearer in succeeding litters and by 40 days (C.R. 66 mm.) the sagittally directed line was identifiable running above the caudally directed process of the maxilla. These observations were made on lateral plates (Figs. X3 and X5). The images could also be seen on dorso-ventral viewing lying laterally on each side (Fig. X4).

Radiography of foetus impregnated with silver nitrate.

At 31 days (C.R. 35 mm.) on the lateral plate a strip could be seen running in the saggital plane, just caudal to the maxilla so that its rostral end was over-riding the caudal process of the maxilla. The dorso-ventral appearance was of a curved strip caudal to and outwith the maxillary image (Figs. Sn6 and Sn7). The lateral outline changed from a strip to a more triangular structure with the long base dorsally and this triangle increased in size during the remaining period (Fig. Sn15).

Alizarin red staining of foetus.

The centre had the form of a narrow strip of stained tissue with an extended point rostrally in the 31 day (C.R. 35 mm.) foetues (Fig. AZ8). The more central portion increased in size to produce a laterally flattened plate with a long pointed prolongation rostrally, overlying the process of the maxilla. This was evident by 35 days (Fig. AZ21) and over the following period there was produced from the caudal end of the plate a narrow projection directed caudally and curving somewhat medially to the temporal region. The foetus of 40 days (C.R. 66 mm.) had a centre with a flattened plate-like centre and both rostral and caudal projections (Fig. AZ33).

Period of gestation 41-50 days.

Radiography of foetus.

The centre continued to appear as a narrow line during this period but its overall length did increase.(Fig. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The centre enlarged during this period being broader on dorso/ ventral viewing. When viewed laterally, the triangular shape was altered by the appearance on the dorsal border, more caudally, of a raised point (Fig. Sn26). This appeared at 43 days (C.R. 82.5 mm.) and persisted throughout the period. The caudal and rostral narrow projections which had appeared at the appropriate angles of triangular centre at the start of this period elongated with the overall growth of the centre (Fig. Sn33).

Alizarin red staining of foetus.

The centre continued to increase in size with the ventral border becoming more intimately associated with the maxillae. The rostral projection lay above the maxillary centre whilst the caudal one became lodged below the rostral process of the temporal centre. At about two thirds of the way along the dorsal border there was seen developing a dorsal projection and the area between this and the most caudal tip was lacy in appearance at 43 days (C.R. 82.5 mm.). This projection became more obvious by 47 days (C.R. 92 mm.) with still a lace-like consistency (Fig. AZ56).

Period of gestation 51-60 days.

Radiography of foetus.

The linear image of this centre began to broaden during this period but it was 60 days (C.R. 136 mm.) before the outline of the centre was definite, having a wider central portion with caudal and rostral prolongations (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The growth of the centre continued and the lines of junction with the maxillary centre became increasingly difficult to define in the second phase of this period (Fig. Sn54).

Alizarin red staining of foetus.

The space between the dorsal prominence and caudal point gradually filled in and apparently shortened during this phase. The lines of attachment of the centre to both the maxillary and temporal centres intermingled more closely so that by 60 days (C.R. 136 mm.) the centre was apparently joined by sutural lines at these points. The dorsal curved border between the rostral tip and the dorsal point was deepening in its concavity and forming a ventral base for the developing orbit (Fig. AZ95).

Period of gestation 61 days onward.

Radiography of foetus.

The centre was associated with the maxillary centre rostrally and the rostral prolongation of the squamous temporal centre caudally (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The centre was widening and could be seen apparently forming the ventral border of the bony orbit (Fig. Sn56).

Alizarin red staining of foetus.

The dorsal curvature was accentuated by the prominence of the orbit and the points of overlap of the maxillary and temporal centres were attached by sutural lines (Fig. X114).

Conclusions.

Histologically the os zygomaticum was seen to develop from membrane and there were two primary centres, one for the bone of each side. The first appearance of the centres in the alizarin series of foetuses was in one of 28 days which corresponds to the day given by Drews (1933) but not to his C.R. length of 46 mm., compared to 26 mm. of this series.

The initial radiographic appearance was at 30 days (C.R. 29.1 mm.) in silver nitrate preparations but not till 36 days (C.R. 49 mm.) in fresh foetuses. The primordium of the processus frontalis became evident during the 41-50 day period, this following the description of Jayne (1898) and Drews (1933).

Mandibula.

Mivart (1881) states that Meckel's cartilage lays the cartilaginous foundation for the lower jaw and that a centre of ossification appears in each lateral moiety at an earlier period than in any other part of the skeleton. It is an ossification in the membrane investing Meckel's cartilage. Jayne (1898) relates that each half of the mandible develops from several centres of ossification which unite early. He recalls that the mandible is formed around the Meckel's cartilage from membrane. Lesbre (1897) also mentions this origin from the membrane of Meckel's cartilage. Drews (1933) indicates the mandibulae as present in a foetus of 46 mm. or 28 days where three rods of bone appear connected by small trabeculae. The most dorsal of these three rises towards the processus coronoideus, the central one towards the processus condyloideus and the ventral one stretches towards the angulus mandibulae.

Period of gestation 21-30 days.

Radiography of foetus.

There was no evidence of the mandibule on radiography of the foetuses of this range.

Radiography of foetus impregnated with silver nitrate.

There was no evidence of the mandibule until the foetuses of 30 days (C.R. 29.1 mm.). Of the three foetuses impregnated, the radiographs revealed the two corpora mandibulae. On a dorso-ventral plate the rostral ends were curved toward midline but not in apposition (Figs. Sn1, Sn2 and Sn3).

Alizarin red staining of foetus.

The earliest at which the mandibule was seen to be stained was in the foetuses of 28 days (C.R. 25 and 26 mm.) (Fig. AZ1). Here the corpora mandibulae were evident as bar-shaped structures with indented caudal ends and rostral ends which inclined towards each other and midline. The most rostral parts were slightly thickened and bore perforations on the dorsal surfaces. A further foetus of 28 days (C.R. 26 mm.) did not however reveal any stained structures. The foetuses of 30 days (C.R. 29 mm.) examined had corpora mandibulae of a similar appearance to that already described (Figs. AZ4 and AZ3).

Period of gestation 31-40 days.

Radiography of foetus.

The foetuses of 31 days (C.R. 35 mm.) bore faint traces of the bodies of the mandible. The two thin centres could be seen forming a V-shape, on a dorso/ventral plate but the lateral view was still indistinct in two out of the three litters examined. The foetuses of one litter revealed a strip lying most ventrally in the head region. These structures were present in succeeding foetuses (Figs. X1 and X2) and by 36 days (C.R. 49 mm.) the mandibular bodies could be seen to have widened on lateral viewing, particularly at their caudal ends. They continued to develop in size during the period and at 38 days (C.R. 58 mm.) and after they gave the impression of a less dense central portion apparent as a blacker strip running rostro-caudally in the body.

Radiography of foetus impregnated with silver nitrate.

The foetus of 31 days possessed centres for the two bodies of the mandible. On lateral viewing they were strap-like in appearance with an expanded caudal end and a slightly raised eminence on the dorsal surface of the rostral end. The dorso/ventral appearance was of two rods in V-formation but with a median gap existing between their rostral ends. (Figs. Sn4 and Sn5). The bodies increased in size during this period and the caudal expansion became more marked (Figs. Sn15 and Sn16).

Alizarin red staining of foetus.

In the 31 day (C.R. 35 mm.) foetus the body of the mandible was stained in its entire length and at the junction of the dorsal and caudal borders was a narrow projection directed caudally (Figs. AZ6, AZ8 and AZ9). The body continued to enlarge and there was particularly widening of the caudal end, becoming noticeable in the foetus of 33 days (Figs. AZ12 and AZ13). By 35 days (C.R. 44.2 mm.) from this widened end, there was forming a dorsal extension giving rise to the ramus (Fig. AZ18). By 37 days (C.R. 56.5 mm.) this extension had organised considerably to produce the precursor of the coronoid process dorsally, the condyloid process caudally and the angular process caudo-ventrally (Fig. AZ33).

At the rostral end of the pars molaris of each corpus mandibulae, there was seen at 33 days (C.R. 38 mm.) on the medial wall, a divergent offshoot, forming a V with the main body, with the point of the V directed rostrally. This offshoot then continued to grow caudally, parallel with the main body. The narrow space thus created between the new growth and the body was being floored ventrally, thus forming a channel with the developing offshoot as the most medial wall. By the end of this period, the channel thus formed extended almost to the caudal end of the corpus. By 38 and 39 days (C.R. 58 and 63 mm.) at the rostral end of the corpus i.e., rostral to this newly formed channel, a small cavity, with an incomplete lateral wall, was evident. These recent developments masked the appearance of the alveoli of the pars molaris and the alveolus of the canine tooth. These developments are best illustrated by a print of a later foetus referred to in the next period (Fig. AZ42).

Period of gestation 41-50 days.

Radiography of foetus.

At the commencement of this period there was becoming apparent the vertical growth of this centre from the dorsal region of the caudal end of the horizontally placed body. The vertical growth was directed dorso/caudally and, although present throughout the period, was not distinct in outline (Figs. X3, X4 and X5). However, it continued to increase in size. These were observations made on the lateral plates (Fig. X7). On dorso/ventral projection the darker line running through the V-shaped rami continued to be present (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

At 41 days (C.R. 73 mm.) there was commencing to appear the ramus of the mandible and by 43 days (C.R. 82.5 mm.) this was seen as a vertical plate with a rounded dorsal border (Fig. Sn20). This increased in size and definition during this period, developing a slight degree of caudal inclination. At the most caudal border of the body a caudal extension was produced giving rise to the origins of the coronoid, condyloid and angular processes which remained as a feature (Fig. Sn26). The body developed, on its dorsal surface, flask-shaped areas of reduced opacity, these becoming apparent at 44 days (C.R. 84 mm.). The rostral tip was irregular in outline with a roughened border (Figs. Sn24 and Sn26). All these observations were on lateral plates. On dorso/ventral viewing the central line of reduced opacity which was apparent at the beginning of the period became divided into discrete round areas by 45 days (C.R. 86 mm.) and also there was a similarly rounded area rostrally (Fig. Sn29).

Alizarin red staining of foetus.

By 43 days (C.R. 82.5 mm.) the newly formed channel on the medial aspect of the pars molaris of each corpus mandibulae was complete in its length extending from the level of the rostral edge of the ramus forward to the immediate area of the developing alveolus of the lower canine tooth (Fig. AZ42). There existed a short covered space between the channel and the alveolus at this rostral point (Fig. AZ43). There developed in this long trough and rostral cavity, small conical stained structures, two lying in the trough and one in the rostral cavity. They were first seen in the foetus of 46 days (C.R. 88 mm.) and then found in succeeding foetuses (Fig. AZ60). Where the new medial wall and the newly formed channel, was fused to the corpus ventrally there appeared to run a narrow groove, open medially and running parallel with the ramus (Fig. AZ43). The differentiation of the caudal end continued to progress and the vertical development was enlarged. On the caudal edge, a transverse ridge was developing beneath which was a short caudal projection. By the second phase of this period, these structures were distinct (Fig. AZ56). On the lateral wall of the vertical ramus a depression was developing, increasing in depth and extending during the period.

Period of gestation 51-60 days.

Radiography of foetus.

The ramus and corpus were visible and at the caudal border of the former was developing a small projection of increased density. The dorsal border of the corpus was ill defined and irregular at the beginning of this period but, by 60 days (C.R. 136 mm.) there were pointed conical projections seen directed dorsally from the pars molaris. At the junction caudally of the ramus and corpus there was formed at 60 days (C.R. 136 mm.) a small eminence. These findings were observed on lateral plates (Fig. X9).

The dorso/ventral plates revealed at first the darker centre of the line of the V image but, by the second half of this period, this had disappeared (Fig. X8).

Radiography of foetus impregnated with silver nitrate.

The vertical ramus was now distinct in outline and between it and the ventro/caudal eminence was seen developed by 53 days (C.R. 108.3 mm.) a strong white line (Figs. Sn37 and Sn54). The corpus was now rounded, smoother at its rostral tip and the whole centre had increased in size. These observations were made on lateral view but on both lateral and dorso/ ventral viewing there could be seen, in the semi-translucent areas of the pars molaris, rounder whiter structures with two being apparent in the central portion and one at the rostral end. There were also present small similar structures in the most rostral end of the corpus (Figs. Sn32, Sn43 and Sn54).

Alizarin red staining of foetus.

The rostral end of the corpus organised considerably during this period. At the 52 day day (C.R. 108 mm.) stage, its substance was of an open network with a cavity containing a conical structure but by 57 days (C.R. 125 mm.) this network had closed in and there were to be seen further small staining cones in an arc rostrally (Fig. AZ72). Also the open dorsal channel closed over centrally to form two cavities, the more caudal being the larger. Each cavity appeared to contain a cone of stained tissue. On the ventro/medial aspect of the pars molaris, the groove found there was developing a medial wall and by the second half of this period was a closed canal with a foramen opening into it at the base of the ramus marking the formation of the foramen mandibulae opening into the canalis mandibulae. The caudal extremity still bore a horizontal projection but this was more rounded in outline (Fig. AZ72).

Period of gestation 61 days onward.

Radiography of foetus.

The dorsal line of the pars molaris revealed a row of conical projections directed dorsally and just short of the rostral tip was seen a larger cone-like development directed more obliquely when viewed laterally. The entire outline of the mandible was clearer by now with a corresponding increase in size (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The outlines of the semi-lucent areas with their contained structures were increasingly distinct at this stage. The transverse white line on the caudal border, dorsal to the caudal eminence, was now evident as a rounded bar which was associated with the temporal centre (Fig. Sn56).

Alizarin red staining of foetus.

The mandibular outline was much more regular in contour with rounding off of the previously ragged projections. The most dorsal process of the ramus was round and smooth with a slight degree of caudal inclination. The angle formed by the junction of the caudal border of the ramus and the ventral border of the corpus was more pronounced and rounded. The conical structures in their cavities were easily recognised, there now being an arc of three at the rostral end of each corpus (Fig. AZ113).

Conclusions.

Histologically the mandible was seen to develop in membrane by the laying down of ossified tissue around a cartilaginous precursor. This development was similar to that described by Mivart (1881), Lesbre (1897) and Jayne (1898). The arrival of an alizarin red stained body of the mandible was first seen in a foetus of 28 days (C.R. 25 mm.) a similar finding to Drew (1933) as far as the day of gestation but this C.R. length of 26 mm. did not match his figure of 46 mm. Radiographically the first appearance was later, being 30 days (C.R. 29.1 mm.) in silver nitrate preparations and

31 days (C.R. 35 mm.) in unprepared specimens. The corpora of the mandibulae were the first to develop but the rami were appearing in the second phase of the 31-40 day period. The alveoli dentales were forming in this period also, by the growth of a separate medial wall but the primordia of the teeth were not in evidence till after 40 days (C.R. 66 mm). In fact those of the incisors did not appear till after 60 days (C.R. 136 mm.). The canalis mandibulae was seen developing during the 41-50 day phase and was converted to an enclosed canal by the second half of the 51-60 day period with the formation of the foramen mandibulae. The differentiation of the precursors of the processus coronoideus, processus condylaris and processus angularis was becoming noticeable at the end of the 31-40 day period which is close to the description of Drews (1933).

OSSA CRANII

Os occipitale.

Lesbre (1897) describes the occipital bone as arising from four centres i.e., a basilar part which he compared to the body of a vertebra, two lateral sections flanking the previous centre which in turn are compared to the two laminae of a vertebra and a superior covering plate bearing the occipital protuberance which he suggests is analogous with a spinous process. Jayne (1898) also describes four parts and names then supraoccipital, two exoccipitals and a basioccipital bone. In describing the skull shortly before birth, Jayne states that the four parts are separated by a strip of cartilage. The supraoccipital is oval, convex and smooth, the basioccipital is long, narrow and hexagonal and the exoccipitals are crescentic and have flattened condyles but no distinct paraoccipital processes. At birth the supraoccipital shows a faint lambdoidal crest; the paraoccipital processes (paracondylar processes) begin to appear. Mivart (1881) gives the origin of the basilar part of the occipital bone as the basicranial plate which he describes as a solid flattened mass of cartilage at the rostral end of the chorda dorsalis. He further describes two lateral upward growths of this cartilage which meet above and enclose the foramen magnum with a cartilaginous ring. He identifies the supraoccipital as arising from membrane whereas the basi- and exoccipitals are formed from ossifying cartilage. The supraoccipital is grouped with the arrival of the parietal, interparietal, frontal, squamosal, vomer, nasal, lachrymal and malar, whilst the basi- and exoccipitals are with the pre-. basi, ali- and orbitosphenoid and also the palatine and pterygoid. Drews (1933) confirms that the bone develops from four centres and details their appearance thus: basioccipital and exoccipital present in a foetus of 65 mm. or 32 days, and the supraoccipital present in a foetus of 71 mm. or 35 days. Crouch (1969) illustrates the four centres of the occipital bone as seen in a kitten skull showing the sutures formed between them.

Basioccipital.

Period of gestation 31-40 days.

Radiography of foetus.

In the 36 days (C.R. 55 mm.) foetuses the centre for the basi-occipital was discerned as a thickened line lying rostral and ventral to the exoccipitals. However the centre could not be observed on a dorso/ventral plate. It became apparent at 40 days (C.R. 66 mm.) when it could be seen as a cone-shaped structure with a rounded base, lying in midline and pointing rostrally (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

At 37 days (C.R. 56.5 mm.) a rod-like image could be seen extending rostrally, ventral to the exoccipital centres (Figs. Sn12 and Sn15). The rod was flattened at its caudal end. The dorso/ventral image was also rod-like but by 40 days it resembled an arrowhead with the tip pointing rostrally (Fig. Sn16). The lateral image was now more pointed rostrally with a slight dorsal curve in it (Fig. Sn17).

Alizarin red staining of foetus.

This centre was stained in the foetus of 33 days (C.R. 39 mm.) appearing as an oval area, ventral and rostral to the exoccipital centres (Figs. AZ12 and AZ14). The oval-shaped centre became more pointed rostrally giving an outline of an arrowhead by 35 days (C.R. 44.2 mm.). The size continued to increase in subsequent foetuses and the rostral projection became blunt (Figs. AZ28 and AZ29).

Period of gestation 41-50 days.

Radiography of foetus.

The centre increased in size during this period, the outlines becoming more clearly defined. The lateral image was thicker and there was a slight ventral curving of the rostral half. On dorso/ventral plates the centre was seen to develop a definite rostral neck leading into a rounded body (Fig. X6).

Radiography of foetus impregnated with silver nitrate.

The rostral neck of the centre i.e. the tip of the "arrowhead" was thinner during the early days of this period, later its connection with the main part of the centre rounded and widened to give a more pointed appearance to the whole structure (Figs. Sn23 and Sn24).

Alizarin red staining of foetus.

The caudal border of the centre demonstrated an indentation in the early part of the period and this remained till 50 days (C.R. 102 mm.) deepening somewhat during the period. The caudo/lateral borders were rounded at 43 days (C.R. 82.5 mm.) but began to flatten somewhat so that by 47 days (C.R. 92 mm.) there was a flatter caudo/lateral border leading to rounded lateral projections about halfway along the length of the centre (Fig. AZ54). The rostral projection was constant with its tip truncated (Figs. AZ58 and AZ59).

Period of gestation 51-60 days.

Radiography of foetus.

The growth of the centres continued and on lateral viewing the ventral end of the exoccipital centre appeared to overlap the caudal end of the basioccipital (Fig. X9). On D/V plates the caudal border of the centre appeared in the first two days of the period to develop an indentation which persisted throughout the remaining days of this period (Fig. X8).

Radiography of foetus impregnated with silver nitrate.

The centre increased in size and its relationship with the petrous centres of the temporal became closer, being noticeable by 54 days (C.R. 112 mm.) onwards (Figs. Sn40 and Sn42).

Alizarin red staining of foetus.

The caudal indentation was not as pronounced and there was expansion of the lateral edges of the broader region of the centre. The rostral projection appeared narrower on comparison. The increase in size continued and the angulation of the centre altered with the rostral tip being more dorsal than its opposite end (Figs. AZ70, AZ71, AZ95 and AZ96).

Period of gestation 61 days onward.

Radiography of foetus.

The centre exhibited no obvious changes (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

There were no immediate changes in this centre.

Alizarin red staining of foetus.

The rostral extremity was narrow and elongated to approximate with the body of the basisphenoid while the more ventrally placed caudal end was broad and had largely lost its indented caudal border (Fig. AZ112).

Exoccipital.

Period of gestation 31-40 days.

Radiography of foetus.

The foetuses of 36 days (C.R. 49 mm.) were the first to reveal the exoccipital centres. They were seen both on dorso/ventral and lateral exposures. On the former they appeared as two divergent ovals, one to either side of midline just rostral to the alae of the first cervical vertebra. On lateral viewing the image was one of an oval centre lying between the supraoccipital and basioccipital centres. The centres increased in size during this period (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The 37 day (C.R. 56.5 mm.) foetus revealed on dorso/ventral examination two oval centres one to either side of midline (Fig. Sn16) and these could also be seen on lateral projection (Fig. Sn12 and Sn15). They increased in size during this period and at 40 days (C.R. 67 mm.) the lateral appearance was still oval but on dorso/ventral projection the outline was more triangular with the image of the supraoccipital apparently lying between the two centres (Figs. Sn17 and Sn18).

Alizarin red staining of foetus.

A foetus of 33 days (C.R. 39 mm.) first exhibited the two centres for this bone (Fig. AZ12) They were rounded stained areas placed to either side of midline, rostral to the developing alae of the atlas (Fig. AZ14). The other foetus of 33 days (C.R. 39.8 mm.) did not exhibit such areas. The areas appeared at subsequent ages and by 35 days (C.R. 44.2 mm.) were more oval in outline (Fig. AZ18) being flat plates placed laterally with their flattened inner surfaces facing each other (Figs. AZ27 and AZ29). The size of the centres continued to increase slowly over the remaining period (Figs. AZ30 and AZ31).

Period of gestation 41-50 days.

Radiography of foetus.

The centres increased in size and the lateral oval image was closing ventrally with the basioccipital. The dorso/ventral outline was of two triangular shapes to either side of midline (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

There was a general increase in size of these centres which lay to either side of the centre for the supraoccipital when viewed dorso/ventrally (Figs. Sn19, Sn20, Sn31 and Sn32).

Alizarin red staining of foetus.

The two oval centres were developing ridges on the caudal surface of their lateral and medial borders which rose in prominence in succeeding foetuses to become obvious by 45 days (C.R. 86 mm.). The medial borders were becoming concave as opposed to convex lateral borders (Fig. AZ59). There was a slight indentation in the caudal or ventral border and on the inner surface, i.e., rostral face of the centre, a truncated projection was developing in the second part of this phase being distinct by 47 days (C.R. 92 mm.). This projection was directed rostro-ventrally. The overall size of the centres increased during this period (Fig. AZ58).

Period of gestation 51-60 days.

Radiography of foetus.

The oval centre when viewed laterally was overlying the basi-occipital image and on both exposures the increase in size was noted. By the end of this period, the oval centres were closer to the developing first cervical vertebrae and the dorso/ventral outline was altered by the formation of lateral projections from the cranio/lateral border (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The overall shape on dorso/ventral plates was triangular but by 52 days (C.R. 108 mm.) there were apparent two rounded eminences, one for each centre on the rostral surface (Fig. Sn39) and this was maintained during this period (Fig. Sn49). On lateral viewing (Fig. Sn37) the ovate shape persisted with the dorsal end having a wider rounded edge leading to a narrower ventral end (Fig. Sn54).

Alizarin red staining of foetus.

The centres continued to increase in size but with particular expansion of the lateral border, in a more ventral direction (Fig. AZ97). The two ridges increased in prominence emphasising the deepening depression between them (Fig. AZ71). The medial ridges, one on each centre, were more prominent in the latter half of this period. The inner projection on the inner surface (rostral face) lengthened accordingly as the period progressed.

Period of gestation 61 days onward.

Radiography of foetus.

The lateral image lay immediately rostral to the first cervical vertebra and was somewhat flattened in outline caudally (Fig. X10). The dorso/ventral view indicated the increasing growth of the lateral projection from each of the two centres (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

There was little change in the centres during this phase (Fig. Sn56).

Alizarin red staining of foetus.

The centres were now closely related to the supra and basioccipital centres (Fig. AZ100) producing an encirclement in midline marking the foramen magnum. The medial ridge of each centre on the caudal surface was broad and thickened while the lateral expansion was noticeable with a marked prominence developing as a lateral and ventral point on each centre.

Supraoccipital.

Period of gestation 31-40 days.

Radiography of foetus.

This centre was first visible as a thickened line, caudal to the os interparietale, on lateral plates of 36 day (C.R. 49 mm.) foetuses but was not seen on dorso/ventral viewing. It was present thereafter on lateral exposures but it was not until 40 days (C.R. 66 mm.) that its outline was seen on dorso/ventral plates. There it appeared as a bilobed structure with a narrowed junction in midline (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The first evidence was in the foetus of 34 days' (C.R. 43 mm.) when a short, fine line was seen on the lateral plate, running caudal to the interparietal centre (Fig. Sn8). There was no corresponding evidence seen on the dorso/ventral plate. By 37 days (C.R. 56.5 mm.) the line was thicker (Fig. Sn12) and by now the dorso/ventral plate exhibited a bilobed area with a median union of the lobes. This occurred rostral to the exo-ccipital centres. At 40 days (C.R. 67 mm.) this dorso/ventral appearance had lost its bilobed nature and was now oval in shape, extending across mid-line with a more flattened border caudally (Fig. Sn18). The lateral outline had widened particularly at its central portion and its rostral edge was slightly overlapping the caudal extremity of the interparietal centre (Fig. Sn17).

Alizarin red staining of foetus.

The 31 day (C.R. 35 mm.) lacked any staining of this centre but in all the 33 day (C.R. 39 mm.) foetuses there was present a centre with two narrow lateral wings joined by a median strip of stained tissue (Fig. AZ12). By 36 days (C.R. 49 mm.) the two lateral wings were extending caudally, still joined by the median isthmus (Fig. AZ20). However, due to increase in the width of this latter strip and the caudal extension of the lateral wings, the centre by 39 days (C.R. 63 mm.) had the form of a circular plate with a narrow segment missing in the centre of the margin (Fig. AZ30).

Period of gestation 41-50 days.

Radiography of foetus.

The centre continued to increase in size with its caudo-lateral margins coming to overly the exoccipital centres by the end of this period. The linear image presented on lateral plates broadened during this period (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

There was an increase in size in both the lateral and dorso-ventral images during this period (Figs. Sn20 and Sn33).

Alizarin red staining of foetus.

The centre was almost circular with an indentation in its mid-caudal section (Fig. AZ36) and leading from this was a fine fissure of short length. The dorsal or rostral border was slightly overlapped by the interparietal centre. By the second half of this period, a central vertical ridge was developing, producing slight depressions in the lower two quarters of the circle (Fig. AZ54). The dorsal or rostral edge was now flattened against the caudal edge of the interparietal centre, both centres being of similar breadth (Fig. AZ70).

Period of gestation 51-60 days.

Radiography of foetus.

The centre continued to increase in size during this period (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The centre maintained its rate of growth relative to surrounding centres during this period (Figs. Sn36, Sn39, Sn49 and Sn50).

Alizarin red staining of foetus.

The central ridge remained in evidence as did the slight depressions. The size of the centre increased overall during this period (Fig. AZ96).

Period of gestation 61 days onward.

Radiography of foetus.

There was no obvious alteration to the centre during this period (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The centre retained its position and size during this phase (Figs. Sn55 and Sn56).

Alizarin red staining of foetus.

The final centre was approximated closely with the overlying triangular interparietal centre (Fig. AZ111).

Conclusions.

The histological findings indicated that the original centres for this bone developed in cartilage. There were four centres, one each for the base and supraoccipital and two for the paired exoccipitals. This description matched the findings of Lesbre (1897), Jayne (1898) and Drews (1933) but not those of Mivart (1881). The first appearance of the centres was in the foetuses of 33 days (C.R. 39 mm.) when they were stained by alizarin red. The date given by Drews of 32 days for the basi and exoccipital and 35 days for the supraoccipital approximately fits the finding but his C.R. length of 65 and 71 mm. respectively, greatly exceed these findings of 38 and 39 mm. The initial radiographic appearance was in the foetuses of 36 and 39 days (C.R. 49 and 63 mm.) although in this case the earlier date was in untreated specimens except for the supraoccipital which was evident at 34 days (C.R. 43 mm.) with silver nitrate impregnation. The precursor of each condylus occipitalis was becoming evident by the second half of the 41 to 50 period being seen as a thickening of the exoccipital centres.

Os interpatietale.

Mivart (1881) describes the interparietals as developing from membrane and ossifying at the same time as the supraoccipital, parietal, frontals, squamosals, vomer, nasals, lachrymals and malars. He designates them as pleural but is not specific about exact number of segments. In Lesbre's (1897) treatise this bone is said to be formed from two plates which fuse very early and Jayne (1898) tells of a similar form of development. In his description of the skull shortly before birth, the interparietal is well ossified and larger than the supraoccipital. Drews (1933) describes two centres for this bone and indicates their initial presence in a foetus of 65.5 mm. or 32 days. He illustrates the bone with the two centres united in a foetus of 84 mm. but states in the text that in contrast to the dog the os interparietale remains an independent bone for years. Crouch (1969) illustrates the bone as a single structure still separated from its neighbour by sutures. This is in a drawing of a kitten skull.

Period of gestation 31-40 days.

Radiography of foetus.

This bone made its appearance on the lateral plates of the foetuses of 36 days (C.R. 49 mm.) when it was observed as a line rostral to the supra-occipital bone. The line was slightly curved with the convexity dorsal. There was no corresponding image visible on dorso/ventral viewing. By 40 days (C.R. 66 mm.) the lateral image was distinct and now was rostrally closely related to the parietal image but a narrow gap still intervened (Figs. X3 and X5). Only now was there a corresponding image on the dorso/ventral plates when a faint "heart-shaped" outline was discerned in midline.

Radiography of foetus impregnated with silver nitrate.

The 34 day (C.R. 43 mm.) foetus had an image present representing the centre for the interparietal when viewed laterally, appearing as a short line on the dorsal border of the caudal part of the skull region (Fig. Sn8). Its image was not clear on dorso-ventral projection. The line widened gradually and by 40 days (C.R. 67 mm.) the lateral view was of an extended line which slightly under-ran the rostral edge of the supraoccipital centre. The dorso-ventral view was now clear being somewhat heart-shaped with the apex pointing rostrally (Fig. Sn17 and Sn18).

Alizarin red staining of foetus.

The centres for the interparietal bones were not evident until the foetus of 33 days (C.R. 39 mm.) when they were seen as two faintly staining triangles placed to either side of midline between the parietal centres and that of the supraoccipital (Fig. AZ12). The centres were separated by a narrow space in midline (Fig. AZ14). By 35 days (C.R. 44.2 mm.) the two centres were uniting but still a fine line of division could be seen. However, by 36 days (C.R. 49 mm.) this line was being overgrown so the centre was attaining the appearance of a single structure which was approximately oval in shape, with its long axis transverse and with a small notch in its caudal border (Figs. AZ27, AZ30 and AZ41). This shape was continued through to 40 days (C.R. 66 mm.) with a gradual increase in overall size.

Period of gestation 41-50 days.

Radiography of foetus.

The centre increased in area during this period retaining its previous outline except that on lateral viewing the line was thickening (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The centre increased in area during this period and the separating line of demarcation from the pariteal centres diminished (Fig. Sn21 and Sn22).

Alizarin red staining of foetus.

The triangular shape of this centre appeared as one unit for the remaining length of gestation (Fig. AZ36). In the 43 day (C.R. 82.5 mm.) foetus it was wider than the centre for the supraoccipital and overlapped the latter centre's dorsal border. However, by 47 days (C.R. 92 mm.) the supraoccipital centre had enlarged to almost equate with the interparietal in width (Fig. AZ54).

Period of gestation 51-60 days.

Radiography of foetus.

The growth of the centres was maintained during this period so that by 52 days (C.R. 108 mm.) on the lateral plate, the rostral border of the centre appeared immediate to the parietal centre and by 54 days (C.R. 112 mm.) seemed to be touching it. The caudal border was by now apparent closely applied to the supraoccipital centre (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The centre appeared to increase gradually throughout this period and its relationship with the parietal centre was increasingly difficult to differentiate (Figs. Sn37, Sn39, Sn51 and Sn52).

Alizarin red staining of foetus.

The centre continued to increase in size, still retaining its triangular shape. By the later part of the period there was developing a close relationship between the internal crest of the temporal centres and the dorsal rim of the interparietal (Figs. AZ94 and AZ97). The most lateral point of the triangle demonstrated small projections in the later foetuses and this projection extended marginally beyond the underlying supraoccipital centre.

Period of gestation 61 days onward.

Radiography of foetus.

There was little change in the centre during this period (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

There was no significant change apparent in this centre.

Alizarin red staining of foetus.

There was developing a crest running from the apex to the base bisecting the triangle. The intimate approximation of the temporal and interparietal centres was intensifying during the last days of gestation (Fig. AZ111).

Conclusions.

Histologically the interparietal bone was seen to be preceded by cartilage which later ossified. The first evidence of bone was the appearance of two centres stained with alizarin red in foetus of 33 days (C.R. 39 mm.) followed by signs of union of the centres by 35 days (C.R. 44.2 mm). The presence of two centres fusing early is as described by Lesbre (1897) and Jayne (1898) but Mivart (1881) states that the centres arise in membrane. Drews (1933) also names two centres and gives an almost similar day of appearance of 32 days but his C.R. length figure of 65 mm. exceeds these findings of 39 mm. He illustrates the centres as united at 84 mm. C.R. length which again exceeds these findings of 44.2 mm.

The first radiographic appearance was later, at 34 days (C.R. 43 mm.) with silver nitrate impregnation, and 36 days (C.R. 49 mm.) in fresh specimens. As the dorso/ventral image was not clear until the end of the 31-40 day period, radiography did not readily define the original development from two centres.

Os sphenoidale.

Mivart (1881) declares that at an early period the sphenoid bone consists of eight distinct and significant parts: the bulk of the body or basisphenoid; the front part of the body or presphenoid; the greater wings or alisphenoids; the lesser wings or orbitosphenoids and the true pterygoid bones. These develop from cartilaginous ossification. Lesbre (1897) describes the ossification as from cartilage made of two principal pieces named as presphenoid and basisphenoid. These two eventually unite. Jayne's (1898) description is also of eight elements, two orbitosphenoids, two alisphenoids, two pterygoids, the presphenoid and the basisphenoid. At birth the orbitosphenoids have joined the presphenoid and the alisphenoids have coalesced with the basisphenoid. The pterygoid however are still partially distinct elements, the separating sutures dividing the external pterygoid fossae from end to end. He describes the sphenoid shortly before birth as well formed in bone and exhibiting all its parts. The rostral is distinct from the caudal. The presphenoid has united with the orbitosphenoid. The basisphenoid is separated from the alisphenoid and the pterygoids. The tip of the orbitosphenoid is truncated. At birth on the under surface of the sphenoid there are still distinct traces of the pterygo-alisphenoidal sutures. Drews (1933) states that the basi and presphenoidal structure develops from two ossification points each. The alisphenoid is already considerably developed at 71 mm. C.R. or 35 days and there is a centre on both sides of midline. The basisphenoid is already in its definitive form at 101 mm. or 47 days indicating by a lighter coloured band that it originated from two centres. The orbitosphenoid first occurred in the embryo of 84 mm. C.R. or 41 days. The presphenoid has joined this at 101 mm. C.R. or 47 days in the form of two triangles. The basi-and presphenoid are separated in a one day kitten whilst the cartilaginous connection of the orbito- with the apisphenoid could no longer be seen with the alizarin method. The pterygoids were developed in the form of two triangles, and completely merged with their neighbours during intra-uterine life. Crouch (1969) illustrates a presphenoid with two lateral orbitosphenoids and a basispehenoid with two alisphenoids. He describes the pterygoid processes of the alisphenoids and does not list a separate os pterygoideum.

Os basisphenoid.

Period of gestation 31-40 days.

Radiography of foetus.

In the foetus of the litter of 36 days (C.R. 49 mm.) the alae were evident on a dorso/ventral view where they appeared as two irregular divergent lines running laterally from the palatine centres. The lateral appearance was indistinct but the faint outline was discernible dorsal to the most caudal point of the mandible. The 37 day and 38 day (C.R. 56.5 mm.and 58 mm.) foetuses were positive for these centres and the lateral view was now of a rounded area in the region previously described while on dorso/ventral plates the images were more triangular in form. The remaining litters illustrated these centres with a gradual increase in size being apparent. (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The foetus of 31 days (C.R. 35 mm.) did not reveal these centres but in the 34 day (C.R. 43 mm.) foetus there was evident on the lateral exposures a small plate of impregnated tissue situated dorsal and caudal to the caudal extremity of the mandible and above the level of the pterygoids (Fig. Sn8). The dorso/ventral impression was of a small area merging with the image of the mandible at its caudal limit (Fig. Sn10). The 37 day (C.R. 56.5 mm.) foetus revealed a similar small plate on dorso/ventral viewing but the lateral impression was now of a larger, more irregular plate just dorsal to the image of the zygomatic process of the temporal bone (Fig. Sn12). The 39 day (C.R. 63 mm.) foetus revealed enlargement in both views of these centres and on the dorso/ventral projection the centres were seen as irregular plates with a darkened foramen most laterally and positioned between the ectotympanic ring caudally, the mandibular image laterally and the pterygoid medially (Figs. Sn15 and Sn16).

Alizarin red staining of foetus.

The centres for the alae of this bone appeared in the foetus of 35 days (C.R. 44.2 mm.) as stained plates, placed to either side of midline within the temporal region (Fig. AZ18). These plates were trifid in shape and in the more caudal edge was an unclosed foramen, i.e., foramen ovale (Fig. AZ19). They were angled obliquely with their ventral ends closer to midline. By 36 days (C.R. 49 mm.) these centres were approximating closely with the pterygoid centres which were placed ventro-medial to them. They continued to increase in size extending in a wider field dorso-laterally (Figs. AZ28 and AZ29). By now there were two closed foramina, foramen rotundum and foramen ovale, present in the more dorso-lateral expansions of the alae. At 40 days (C.R. 66 mm.) there appeared between them, in midline, a centre for the body of this bone. This had a rounded central portion with two expanded projections protruding laterally.

Period of gestation 41-50 days.

Radiography of foetus.

The alae of the basisphenoid could be seen as small patches lying rostral to and within the temporal centres on lateral plates whilst, on dorso-ventral projection, two small oval spots could be seen to either side of midline and lying within the temporal centres. They increased in size during this period (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The alae of the basisphenoid continued to increase in area during this period and there appeared by 44 days (C.R. 84 mm.) a centre lying in midline between the alae (Fig. Sn33). It was bilobed in appearance and still fairly faint. This centre increased in size and produced, at 45 days (C.R. 86 mm.) a pair of short lateral protrusions (Fig. Sn28).

Alizarin red staining of foetus.

The alae of this bone continued to extend in width during this period and by 44 days (C.R. 85 mm.) were closely related laterally with the temporal centres (Fig. AZ54). The two foramina in each ala were a constant feature (Fig. AZ41) and the bases of the centres were closely related to the pterygoid centres (Fig. AZ55). The body also increased in size with a central portion with a bilobed appearance having a narrow blunt ended projection extending laterally on both sides (Figs. AZ54 and AZ55). The most rostral part of the body produced, during the second half of this period, a small foramen in midline representing the canalis craniopharyngeus and this continued to be seen throughout the rest of this time (Fig. AZ55). By 50 days (C.R. 102 mm.) the lateral projections had extended to make contact with the alae (Fig. AZ59).

Period of gestation 51-60 days.

Radiography of foetus.

The alae were visible on lateral viewing (Fig. X9) but by now the dorso/ventral plates revealed, lying between the two previously observed spots (the alae), a centre for the basiphenoidal body. This structure was rod-like with a lateral bud-like expansion on each lateral face. It lay rostral to the basioccipital centre to which it became more closely related as the period progressed. The alae also increased in size, relating to the body centrally and the temporal centres laterally (Fig. X8).

Radiography of foetus impregnated with silver nitrate.

The growth of the alae was continual and they came into apparent close association with the body toward the end of this period. The lateral projections of the central body were clearer in definition during this period and by 57 days (C.R. 125 mm.) the basisphenoidal and presphenoid centres were apparently in fairly close approximation at their rostral and caudal borders respectively (Figs. Sn48 and Sn53).

Alizarin red staining of foetus.

The central body was broadening during this period and the small foramen was still apparent at the rostral end. The lateral projections were widening at their tips and extending caudally (Fig. AZ71) decreasing the gap between them and the centres for the alae (Fig. AZ96). The alae increased rapidly in size during the first half of this period becoming intimately related to the dorsal edge of the centre for the squamous part of the temporal bone. The two foramina remained patent in each of the two alae (Fig. AZ96). Ventrally the alae were extending rostrally toward the perpendicular plate of the palatines, to which they were constantly related during the second half of this period (Fig. AZ95). It was to these rostral projections of the alae that the centres for the pterygoid bones were fusing by the second half of this period.

Period of gestation 61 days onward.

Radiography of foetus.

Laterally the structural outline was difficult to discern but on dorso/ventral projection the body and alae were clearly defined during this phase (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The centre was seen consisting of widely developed alae related to temporal centres and the body of the basisphenoid in midline. The latter itself was in close association with the praesphenoid.

Alizarin red staining of foetus.

The enlarging centre in midline was now closely associated with the alae, there being only a fine line of unstained tissue separating them. The rostral border still maintained a gap between it and the praesphenoid. The alae were extensive and closely associated with the temporal centres (Figs. AZ111 and AZ112).

Os praesphenoidale.

Period of gestation 31-40 days.

Radiography of foetus.

In the foetuses of 40 days (C.R. 66 mm.) there was apparent a faint strip above the palatine centres which was taken to represent the beginning of the praesphenoid centres. The outline was indistinct.

Radiography of foetus impregnated with silver nitrate.

In the foetus of 39 days (C.R. 63 mm.) there was appearing over the image of the palatine centres at their caudal ends a rather poorly defined layer of impregnated tissue which tended to mask the palatine outline (Fig. Sn16).

Alizarin red staining of foetus.

The centres for the praesphenoid did not make an appearance until a foetus of 38 days (C.R. 58 mm.) when they were seen as two small crescentic areas lying medial to the centres of the wings of the basisphenoids. The two centres lay to either side of midline (Fig. AZ28). They had increased in size by 40 days (C.R. 66 mm.) and the greater curvature, which was lateral, was more irregular in outline.

Period of gestation 41-50 days.

Radiography of foetus.

In the foetuses at the commencement of this period there were present on lateral plates faint short strips lying above the palatine centres

(Figs. X3 and X5). The strip became slightly curved with its convexity dorsal, and by 45 days (C.R. 86 mm.) was clearer in outline with a small darker invagination on its ventral border at its central point (Fig. X7).

Dorso-ventral viewing did not give a clear picture of the centre during this period.

Radiography of foetus impregnated with silver nitrate.

By 44 days (C.R. 84 mm.) there had appeared, one to either side of midline, a pair of small crescentic centres lying just caudal to the inter-palatine midline (Fig. Sn23) and by 45 days (C.R. 86 mm.) these small centres were joining with the larger area of tissue immediately lateral to them and overlying the caudal palatine borders. The appearance at 46 days (C.R. 88 mm.) was one of two circles of tissue, one on either side of midline, partly over the caudal border of the palatine centres (Fig. Sn28). These circles were gradually seen to amalgamate in midline.

Alizarin red staining of foetus.

The centres for the alae of the praesphenoid were squarer rostrally by 43 days (C.R. 82.5 mm.) and gave the appearance of two commas, one on either side of midline, with the convexity placed laterally. At this stage there also appeared two small strips of stained tissue at the termination of the tails of the commas (Fig. AZ41). By 44 days (C.R. 84 mm.) each strip had become incorporated with the ala of that side and also the two halves had united in midline giving a rather butterfly-like appearance. The union of the strips and the wings had created a foramen on each half of the ultimate centre.

The rostral segments of the alae began to project forward at 47 days (C.R. 92 mm.) and by 50 days (C.R. 102 mm.) there were two distinct rostral projections, one placed to either side of midline (Figs. AZ54 and AZ59). The foramina persisted throughout the period.

Period of gestation 51-60 days.

Radiography of foetus.

The dorso/ventral image became clarified at the beginning of this period being seen as a structure resembling a butterfly with outstretched wings and bearing on each wing a darkened spot. The size of this image increased during this period and also the space existing between the two wings rostrally was gradually narrowing from the central point forward so that by 60 days (C.R. 136 mm.) the gap was partially closed (Fig. X8). The image improved in definition in the first half of the period with the darker area on the ventral border being converted to a spot within the centre itself. However in the second half of the period the lateral picture became less distinct due to the development of overlying centres (Fig. X9).

Radiography of foetus impregnated with silver nitrate.

By 54 days (C.R. 112 mm.) the two circles had unified to give a structure like a butterfly with outspread wings which lay over the caudal end of the palatine centres and just rostral to the pterygoids (Fig. Sn42). This structure continued to increase in size, the one foramen on each wing remaining as a darker cicle (Fig. Sn48).

Alizarin red staining of foetus.

The rostral projections of the united centre were extending further forward (Fig. AZ70), and the midline gap between them was narrowing so that by 57 days (C.R. 125 mm.) the more rostral half of the projection was separated only by a thin line (Fig. AZ96 and AZ98). The large foramen in each lateral section of the centre was still present (Fig. AZ98).

Period of gestation 61 days onward.

Radiography of foetus.

The dorso/ventral image was clearly seen overlying the palatine image rostrally and related caudally to the pterygoids at the lateral angles, i.e., to either side of midline and the body of the basisphenoid (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

The centre still retained its "outspread" appearance with the dark foramina persisting. Beneath the centre could be seen the palatine caudal projection running to meet the pterygoids.

Alizarin red staining of foetus.

The narrow gap found rostrally in the previous period was closed leaving only a wedge-shaped invagination at the most rostral border in midline for receiving the precursors of the ethmoid (Fig. AZ111). The rostral margins were in close contact with the frontal centres.

Os sphenoidale.

Conclusions.

Histologically the development of the os spheniodale was seen to be by ossification of existing cartilage. There were two main areas of development i.e., the area for the praesphenoid and that for the basisphenoid. The former involved four separate centres, developing as two placed apart to either side of midline initially, followed by two further centres placed at midline and between the two initial centres. The two centres at midline united almost immediately forming a single structure. Thus from this point, the development was from three regions of ossification, the single midline structure, and two more laterally placed centres. This description does not match those of the named authors except that of Drews (1933). The time of appearance of these centres was, in alizarin specimens at 38 days (C.R. 58 mm.) for the most lateral centres and at 43 days (C.R. 82.5 mm) for those closest to midline. Those latter centres fused almost immediately to give a single area on midline. The corresponding days given by Drews (1933) are 41 days (C.R. 84 mm.) and 47 days (101 mm.) do not compare with these findings of 60 mm. and 83.5 mm. respectively. The merging of the lateral centres with the midline structures resulted in the formation of the canales optici, this occurring in the middle of the 41-50 day period. Radiographically the centres were first seen at 39 days (C.R. 63 mm.) (silver nitrate preparations) and 40 days (C.R. 66 mm.) (fresh specimens) for the lateral centres and 44 days (C.R. 84 mm.) (silver nitrate preparations) for those closer to midline.

The second main area for the development was formed of two laterally placed centres for the alae of the basisphenoid which were placed one to either side of midline and a centre for the body of the basisphenoid. This disposition of centres concurs with the descriptions of Mivart (1881) and Jayne (1898). The centres for the alae were apparent in alizarin red stained specimens by 35 days (C.R. 44.2 mm.) followed by the centre for the body at 40 days (C.R. 66 mm.). The time given by Drews (1933) when the alae were present is 35 days which he gives a C.R. length of 71 mm. as compared with these findings of 44 mm. There were seen developing in the alae two foramina for each side, being seen as early as the end of the 31-40 day period. They were the foramen rotundum and foramen ovale. Radiographically the centres were first seen at 31 days (C.R. 35 mm.) (silver nitrate preparations) and 36 days (C.R. 49 mm.) (fresh specimens) when the alae were present and at 44 days (C.R. 84 mm.) (silver nitrate preparations) and 51 days (C.R. 105 mm.) (fresh specimens) when they were joined by the centre for the body.

Os pterygoideum.

Mivart (1881) declares that the origin of the bone is from cartilage and develops along with the basi- and exoccipitals, ali-, basi-, orbito- and presphenoids and palatines. He refers to them as the true pterygoid bones in his description of the appearance of the sphenoid bone. Lesbre (1897), having related the form of development in man as an internal wing of the apophisis pterygoid of the sphenoid bone which is taken to be the processus pterygoideus, and united with it in early development, states that in the domestic mammals, it remains distinct during life or during the major part of it. Jayne (1898) attributes two centres to the pterygoids but compartments them with the development of the sphenoid bone. In the late prenatal skull they are mentioned as ossified but separated from the basisphenoid, and again at birth there are still distinct traces of the pterygo-alisphenoidal sutures. Drews (1933) however is of the view that the pterygoids, having developed from two triangular centres and been observed in a foetus of 46 mm., which he ages 35 days, are completely merged with their neighbouring bones during the intra-uterine life of the cat. Couch (1969) in his illustration of a kitten skull shows the pterygoid as the pterygoid process of the alisphenoid.

Period of gestation 31-40 days.

Radiography of foetus.

The foetuses of the litter of 37 days (C.R. 56.5 mm.) were the first to reveal the presence of the centres for these bones. They appeared as two small spots, one to either side of midline caudal to the presphenoidal alae, when viewed dorso-ventrally (Fig. X4). The succeeding foetuses had present such centres during the remainder of the period.

Radiography of foetus impregnated with silver nitrate.

The two centres were visible as rounded dots, placed one to either side of midline and caudal to the palatine centres when seen on dorso-ventral viewing in the 31 day (C.R. 35 mm.) foetus (Fig. Sn5). The lateral view was also positive for these centres (Fig. Sn4). They increased in size during this period and by 39 days (C.R. 63 mm.) were oval in shape and apparent on the dorso-ventral plates, lying medial to the centres of the alae of the basisphenoids (Fig. Sn16). On a lateral view, they were in the region immediately dorsal to the caudal limits of the developing mandible This was still the appearance at 40 days (C.R. 67 mm.) (Figs. Sn17).

Alizarin red staining of foetus.

In the foetus of 31 days (C.R. 35 mm.) two small dots of stained tissue were visible, caudal to the palatine centres (Fig. AZ7). These small centres became cone-shaped with the base of the cone placed dorsally (Fig. AZ11) and by 35 days (C.R. 44.2 mm.) there was a slight curvature of the length with the points directed more caudally. These centres now became closely related to the centres of the alae of the basisphenoids by 36 days (C.R. 49 mm.) and continued to enlarge in these positions (Fig. AZ29).

Period of gestation 41-50 days.

Radiography of foetus.

The centres were still seen on dorso-ventral viewing as triangular structures lying rostro-caudally, related to the palatine centres rostrally and lying to either side of the basisphenoidal centrum. Lateral views were less clear in definition (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The centres increased fractionally in apparent length during this period and with the appearance of the body of the basisphenoid by 44 days (C.R. 84 mm.) were seen to lie to either side of it and somewhat rostrally (Fig. Sn23).

Alizarin red staining of foetus.

The two centres increased in size remaining as rather claw-like projections related to the base of the alae of the basisphenoids (Fig. AZ40), and projecting caudally (Fig. AZ55). The caudal projections of the palatine centres were related rostrally to the pterygoids (Fig. AZ58).

Period of gestation 51-60 days.

Radiography of foetus.

The centres continued to be observed on dorso-ventral plates (Fig. X8).

Radiography of foetus impregnated with silver nitrate.

The centres increased in apparent length and their relation to the palatine centres became increasingly closer, so that by the end of the period, they appeared as prolongations of the palatine extensions. They were, however, still separated by an intervening line. These observations were on dorso-ventral plates (Fig. Sn48).

Alizarin red staining of foetus.

The centres were gradually increasing in size to occupy a position with the base applied to the alae of the basisphenoid dorsally and the palatine centres rostrally, while the pointed apices were directed caudo-ventrally (Fig. AZ95).

Period of gestation 61 days onward.

Radiography of foetus.

The structures were still visible to either side of midline and related to the palatine centres (Fig. X11).

Radiography of foetus impregnated with silver nitrate.

The centres could be seen as prolongations of the palatine centres but still separate from them.

Alizarin red staining of foetus.

The centres were now attached to the alae of the basisphenoid, there being only a thin line demarcating the junction. Rostrally the perpendicular laminae processes of the palatine centres were lying against the pterygoids (Fig. AZ112).

Conclusions.

The histological picture was of ossification from a cartilaginous precursor, there being two centres, one for the bone of each side. The first appearance, using alizarin red staining, was at 31 days (C.R. 35 mm.) compared to 28 days which appears in the version given by Drews (1933). Comparing the C.R. lengths, there is a discrepancy between 46 mm. for Drews (1933) and 35 mm. for these findings. The description of Mivart (1881) is similar to these findings in that he describes separate centres for the pterygoids, developing from cartilage but while Lesbre (1897) states that the centres appear to remain distinct and separate in all the domestic animals, the findings are that in the feline the centres close with the alae of the basisphenoids around the end of the gestation period and remain separated from the palatine by a fine sutural line, producing a developmental situation individual to the feline. This situation is intermediate between the findings of Jayne (1898) and Drews (1933) but would justify the illustration of a kitten skull by Crouch (1969) which demonstrated the pterygoid as just a process of the alisphenoid (ala of the basisphenoid).

Os temporale.

Mivart (1881) describes the temporal bone as arising from many distinct centres and consisting for a time of several distinct bones. He lists these as squamosal, the tympanic parts and the tympanohyal. The bone forming the inner and larger chamber of the tympanic cavity is not apparent at a fortnight post-partum. Three other areas of ossification present themselves in the primitive cartilaginous auditory capsule, spreading and coalescing to form the petrous and mastoid portions of the temporal bone. These three are the pre-otic, forming part of the petrous and part of the mastoid, the opisthotic forming the lower part of the petrous bone and the epiotic forming the mastoid process. Lesbre (1897) reports three principal pieces, the squamous, the tympanic portion and the petrous portion.. The first two are said to be from membranous origin and the latter preceded by cartilage. The petrous is formed from three points, epiotic, opisthotic and pro-otic. The mastoid portion is more or less cartilaginous at birth. Jayne (1898) confesses that the details of the development of the temporal bone has not been satisfactorily investigated. He does confirm his finding of four distinct elements naming them the squamous, the petro-mastoid, the ectotympanic and entotympanic. In the skull shortly before birth he describes the squamous as ossified (from membrane) but not united to the petrous or tympanic. The ectotympanic is a delicate ring of bone. The anterior portion of the petrous is entirely ossified except near rhe apex but the mastoid portion is cartilaginous. At birth he tells of the mastoid portion as being visible and club-shaped. The ectotympanic ring is stouter in appearance. Drews (1933) notes the first appearance of the temporal bone as the arrival of the squamosal bone and annulus tympanicus. This is in a foetus of 63 mm. or 31 days. He continues by saying that during the intra-uterine period, the petrous also develops whereas the mastoid does not appear until after birth.

Period of gestation 31-40 days.

Radiography of foetus.

The 36 day litter (C.R. 55 mm.) had foetuses with a thin line running caudal and slightly dorsal to the mandible. The direction of its length was almost parallel with the mandibular body. This zygomatic process was seen in all the succeeding foetuses and by 40 days (C.R. 66 mm.) had thickened considerably. In the foetus of 38 days (C.R. 58 mm.) this centre was joined by the ectotympanic ring which was an incomplete ring placed ventral and slightly caudal to the squamosal centre (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The foetus of 34 days (C.R. 43 mm.) demonstrated both on lateral and dorso-ventral projection a centre for the zygomatic process of the squamosal part of this bone. The lateral view was of a fine line running caudally from above the caudal end of the mandible and approximately parallel to it (Fig. Sn8). On the dorso-ventral plate there again was a fine line running in a lateral situation on either side of the head, caudal to the mandible and basisphenoid (Fig. Sn9). The image was crossed by that of the parietal bones on true dorsal-ventral projection. There was also early evidence of the development of the ectotympanic ring but this was only seen on the lateral plate as a semicircle lying between the previously described centre (Fig. Sn8). The ring had increased in size and definition in the foetus of 37 days (C.R. 56.5 mm.) and was visible on both lateral and dorso-ventral viewing. There also has appeared a small dot at the most ventral end of the ring, but separated from it when seen laterally, at 37 days (C.R. 56.6 mm.) (Fig. Sn12). On dorso-ventral projection the dot, the image of the malleus, appeared within the semicircular image in a foetus of 39 days (C.R. 63 mm.) (Fig. Sn16). This foetus of 37 days (C.R. 56.5 mm.) also illustrated on lateral plates, the increase in size which had occurred in the squamosal centre and by now the line had thickened and was confluent with a small plate of impregnated tissue which had developed at its caudal end (Figs. Sn12 and Sn15). The 39 day (C.R. 63 mm.) foetus on dorso-ventral viewing showed the line of the squamosal centre as thickened and also having a rostro-medial projection approximately halfway along its length (Fig. Sn16).

Alizarin red staining of foetus.

In the foetuses of 31 days (C.R. 35 mm.) there was seen on the lateral aspect of the head, caudal to the mandibulae, a thin line of stained tissue. This line was dorsal to, but in the same plane as, the mandibulae (Fig. AZ8). At the caudal end of the line and confluent with it, was a small area just commencing to stain and by 33 days (C.R. 39 mm.) this was more extensive. There also appeared at this stage a faint crescent of staining tissue lying ventral to the development described previously but having at its medial end a separate dot of stained tissue (Fig. AZ15). This crescent increased in length to become semicircular by 35 days (C.R. 44.2 mm.) By this time the line was extending both dorsally and medially producing a rectangular shape when viewed laterally (Fig. AZ18). The area at 37 days (C.R. 56.5 mm.) was still enlarging and the ring was now virtually complete, forming 2/3rds. of a circle with the gap facing laterally. From 38 days (C.R. 58 mm.) there was forming a trough between the rostrally projecting bar and the more vertical plate of tissue (Fig. AZ30). Dorsally the centre was becoming closely related to the extending parietal centre and its caudal border was almost vertical in direction. This border was continued ventrally to form a pointed caudal projection at the caudo-ventral angle (Fig. AZ33). The smallest centre at the end of the semicircle was no longer just a dot and by 37 days (C.R. 56.5 mm.) showed more definite form being approximately comma shape with a flattened head and thinner tail.

Thus by the end of this period there were present 3 centres in the developing temporal region of each side of the head, i.e., one for the pars squamosa, the ectotympanic ring and a small centre for the malleus.

Period of gestation 41-50 days.

Radiography of foetus.

On lateral plates the horizontally running process remained evident and thickened during this period. There was added to its caudal end by 45 days (C.R. 86 mm.) an expanding plate which remained present, increasing slightly in area. On dorso-ventral viewing, the process was seen as a curved line placed laterally. The ring of tissue, ventral to the previous development was observed throughout the period on the lateral plates (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

From the caudo-ventral angle of the plate of the pars squamosa there was seen by 43 days (C.R. 82.5 mm.) a hook-like projection which remained present thereafter. It was seen on lateral viewing. At 44 and 45 days (C.R. 84 and 86 mm.) there appeared on the same aspect, a small dot of tissue placed at the caudal end of the ring but there was no further development except in increase in size of the more dorsal areas of the centre. The long rostral projection, approximated with the zygomatic centre, was broadening during this period (Fig. Sn26).

Alizarin red staining of foetus.

The definition of the centre at the rostral end of the circle of tissue clarified at the beginning of this period with the hammer-like appearance of the malleus developing. By 44 days (C.R. 84 mm.) a small rod of stained tissue appeared on each side of the laterally expanded portion of the basi-occipital bone and somewhat dorsal to it. There was no further development evident until the foetus of 47 days (C.R. 92 mm.) when these rods could be seen to have elongated with a pointed end directed medially and an expanded lateral section (Fig. AZ54). This was to form the caudal wall of the petrous portion of the bone. Adjacent to the lateral end was a further downward growth of stained tissue. Two other centres had appeared in the region of each developing temporal bone. A short rod of tissue was lying adjacent to the ala of the sphenoid bone (Fig. AZ54) and this and the previous two new centres were to form the dorsal and caudal walls of the petrous portion incorporating the internal acoustic meatus and fossa cerebellaris. A new crescent of tissue lay just within and above the circle of the ectotympanic ring which was most ventrally placed. This circle had increased in its circumference and appeared to be immediate to the squamous centre (Figs. AZ54 and AZ55). By 48 days (C.R. 94 mm.) the new centres were increasing in size and area and there had appeared a further short rod between the two centres previously described as lying adjacent to the basioccipital and to the sphenoidal alae. The crescentic centre relating to the ossifying ring was becoming broader but remained crescentic (Figs. AZ50 and AZ59) commencing the formation of the promontory of the pyramid. The squamous centre enlarged during the period and the trough-like depression between the vertical plate and the rostral narrow projection deepened with growth (Figs. AZ43 and AZ56). The medial aspect of the vertical plate increased its inter-relationship with the alae of the basisphenoid (Fig. AZ59).

Period of gestation 51-60 days

Radiography of foetus.

In the foetuses at the commencement of this period, the previously described structures were becoming more clearly visible and the ring of tissue could be seen on dorso-ventral plates. By 54 days (C.R. 112 mm.) there was now an addition as a new image appeared in plates of both projections. Laterally this was seen as a crescentic structure placed at the caudal end of the semicircular image of the ectotympanic ring. On dorso-ventral projection it appeared as an oval structure lying within the caudal end of the ring. These shapes increased in size and the dorso-ventral image apparently had two darker spots centrally placed within these shapes by 60 days (C.R. 136 mm.) representing the internal acoustic foramen and the fossa cerebellaris. The crescentic shape of the lateral image was lost being now a diffuse area lying above the caudal end of the semicircular ring (Figs. X8 and X9). This was the appearance of the petrous portion of the bone.

Radiography of foetus impregnated with silver nitrate.

In the first few days of this period, the small area adjacent to the caudal end of the ring began to increase in size and by 53 days (C.R. 108.3 mm.) was a small crescentic shape (Fig. Sn37). On dorso-ventral plates at the same age there was appearing within and slightly caudal to the squamosal vertical plate a rounded area of impregnated tissue, not showing strongly, but lying to the side of the "neck" of the basioccipital centre (Fig. Sn42), marking the early formation of the pars petrosa. This area continued to expand and by 57 days (C.R. 125 mm.) appeared to have contained the centre which was lying at the caudal end of the ring (Fig. Sn48). There still remained at the end of this period a space between the temporal centres and the interparietals, the parietals, the suproccipitals and the exoccipital centres when seen on a lateral plate (Fig. Sn54).

Alizarin red staining of foetus.

The centres continued to expand and increase in complexity. By 52 days (C.R. 108 mm.) the more caudal centres related to the basioccipital bone and were producing a rather tubular structure which curved strongly with its convexity medially (Figs. AZ70 and AZ71). The other two centres adjacent to it were becoming involved and by 57 days (C.R. 125 mm.) they had amalgamated to produce a round tubular structure with an apparent aperture centrally, the internal acoustic meatus and deficiency in the wall more dorsally. From the dorso-caudal aspect a finger like projection was observed. The centre lying more ventrally, related to the ectotympanic ring, was increasing in area and forming a round "bowl shaped"structure with an aperture directed laterally (Figs. AZ95, AZ96, AZ97 and AZ98) thus producing the round window on the rounded promontory of the pyramid. The ectotympanic ring was increasing in thickness and caudally it was blunter ended at the termination of this period.

Period of gestation 61 days onward.

Radiography of foetus.

The centres both on lateral and dorso-ventral plates were distinct, consisting of the three main components, i.e., squamous, tympanic and petrous, grouped closely together (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The space between the supra and exoccipital centres and the squamous and tympanic temporal centres still remained (Fig. Sn56) although into it could be seen projecting a small area of tissue from the temporal centres.

Alizarin red staining of foetus.

The rounded tube-like development appeared to be more complete in its contour but retained an apparent central opening, internal acoustic meatus, and a dorsally placed aperture, the fossa cerebellaris. It lay lateral to and above the basi-occipital centre and was related rostrally to the basisphenoids (Figs. AZ111 and AZ112). Ventrally the bowl-like structure of the promontory was extensive in area but there remained an area devoid of stained tissue between the temporal tissue and the centre of the exoccipital bones (Fig. AZ112). Through this area could be seen extending in the foetus at term two finger-like projections which were from the dorso-caudal border described in the period 51-60 days. This was apparently calcified areas of the semicircular canals.

Conclusions.

The nature of the development of the centres for this bone was both endochondral and intramembranous when viewed histologically. A single centre each for the squamous part of the temporal bone the ectotympanic ring and the malleus appeared to develop in membrane appearing earlier than the other temporal centres. They were seen as alizarin red stained structures at 31 days (C.R. 35 mm.) for the squamous primordia and 33 days (C.R. 39 mm.) for the ring at which time a separate centre for the malleus appeared. Radiographically, their initial appearance was at 34 and 36 days (C.R. 43 and 49 mm.) for the squamous portion and 34 and 38 days (C.R. 43 and 58 mm.) for the ectotympanic ring. The earliest of these dates was in radiographs of foetuses impregnated with silver nitrate and the latest in fresh specimens. A corresponding date for the separate centre for the malleus when impregnated with silver was 37 days (C.R. 56.5 mm.).

The centres formed from cartilage were involved in the development of the petrous portion of the bone. There were 4 such centres for each temporal bone, appearing first in alizarin stained specimens at between 44 and 48 days (C.R. 84 and 94 mm.). The most ventrally placed centre continued to develop to produce the promontory of the pyramid with the round window in evidence, the centres above it becoming confluent to form the petrous section of the temporal bone. The internal acoustic meatus was seen on the dorsal surface at 57 days (C.R. 125 mm.). Radiographically, these centres began to make their appearances from 44 days (C.R. 84 mm.) (silver nitrate impregnated foetuses) and 54 days (C.R. 112 mm.) (fresh foetuses), being apparent but indistinct by the end of the 51-60 day period. The gap between the squamous and tympanic centres and the exoccipital centres was still evident at birth.

There is general agreement that the os temporale develops in three portions, i.e., petrous, squamous and tympanic, and the observations of Lesbre (1897) regarding their type of development would match these findings. The description of Jayne (1898) of the state of development shortly before birth is similar to that of Drews (1933) which also resembles these findings. Drew's figure for the arrival of the squamous bone and annulus tympanicus at 31 days concurs with these findings but the C.R. length of 63 mm. differs markedly from the observed one of 35 mm. No development of the processus mastoideus of the pars petrosa was observed during foetal development. This finds agreement with the reports of Lesbre (1897), Jayne (1898) and Drews (1933).

Auditory ossicles.

Mivart (1881) states that the auditory ossicles are formed in part at least by ossification of the proximal ends of the cartilages of the first and second visceral arches, the first giving the body of the malleus and the second, the body of the long crus of the incus. The stapes differs as it is a small part of the rostral wall which has grown out, become separated and secondarily connected with the upper part of the second arch. Lesbre (1897) relates that the ossicles ossify very early in the embryo before the end of the first half of gestation. Jayne's (1898) description is similar in that he describes the malleus and incus as developed from the upper part of the primative lower jaw i.e., Meckel's cartilage whilst the stapes is developed from the cartilage surrounding the fenestra ovalis. Drews (1933) indicates that the malleus and incus are first seen in a foetus of 115 mm. or 49 days, the former appearing pear-shaped. In a foetus of 130 mm. or 53 days, the stapes was observed. At birth the manubrium mallei was also ossified in its definitive form but this would appear to have happened independently.

No detailed study was made of the auditory ossicles during this investigation.

Os parietale.

Mivart (1881) describes the development from membrane of the parietals along with the supraoccipital, interparietal, frontals, squamosals, vomer, nasals, lachrymals and malars. Lesbre (1897) tells of two primary centres of ossification which develop almost simultaneously with those of the frontals and the description of Jayne (1898) is also of two centres. He continues with a description of a skull shortly before birth where the parietals are externally strongly convex and internally they bear narrow curved plates representing the tentorial processes. Drews (1933) tells of the first sign of the parietals in a foetus of 46 mm. or 28 days, and relates that ossification continues in the fifth week of gestation as a result of the occurrence of two centres.

Period of gestation 31-40 days.

Radiography of foetus.

The parietal centres became evident at the 38 day (C.R. 58 mm.) stage but even then there was only a faint line to be seen following the dorsal line of the dome of the cranium when viewed laterally. On dorso-ventral viewing the lateral outline of the cranium contained the images of the parietal centres. By 40 days (C.R. 66 mm.) the density of the image had increased so that the caudal part of the dome of the cranium was demarcated by the parietal outline. A gap existed between the frontal and parietal outlines (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

The centres for the parietal bones were not obvious until the foetus of 37 days (C.R. 56.5 mm.) when a fine lattice-work was seen to extend over the caudal half of the dome of the cranium (Fig. Sn12). The opacity of the area increased and by 40 days (C.R. 67 mm.) the area involved reached rostrally to border on the frontal area, ventrally to the temporal region and caudally to the interparietal centre. There was also, caudal and ventral to the latter centre, an extensive radiolucent area between the parietal centre and the developing occipital bones (Fig. Sn17 and Sn18).

Alizarin red staining of foetus.

Of the three foetuses of 31 days (C.R. 35 mm.) examined by this method, two revealed areas of stained parietal centres. These were two faint sheets of tissue placed on either side of the head, caudal to the frontal centres. They had a lace-like appearance. These areas increased in extent and by 33 days (C.R. 39 mm.) were enlarging in a ventral direction (Fig. AZ15). At 35 days (C.R. 44.2 mm.) the area of extension was involving an increase in the rostro-caudal dimension of the more dorsal part (Fig. AZ18) so that by 36 days (C.R. 49 mm.) the area was of such proportion as to approximate with the temporal central ventrally and the frontal centre rostrally (Fig. AZ21). This latter junction was of a close nature with the lacy framework of both centres apparently touching. There still remained an unstained area on the vertex of the cranium (Fig. AZ22) but the caudal border was related to the interparietal centres (Fig. AZ20).

Period of gestation 41-50 days.

Radiography of foetus.

The centre continued to increase in area during this period and its increased density was noticeable (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The centre continued to increase in area during this period and its increased density was noted (Figs. Sn20 and Sn32).

Alizarin red staining of foetus.

The extension of these centres continued with the overall increase in skull size. There still remained throughout this period a gap of unstained tissue between the parietal and frontal centres dorsally (Fig. AZ36). The periphery of these centres elsewhere was closely related to or overlapping their neighbours, except the temporal centres. On the internal surface there was developing a ridge of increased thickness which ran close to and parallel with the caudal border of the centre. This ridge increased in prominence during the period. The position of this ridge can be seen on the exterior in Fig. AZ61.

Period of gestation 51-60 days.

Radiography of foetus.

At the beginning of this period the dorsal and caudal borders increased in radiopacity, as was apparent at 52 days (C.R. 108 mm.). In addition, another line of denser bone was shown, parallel to the caudal border and running ventrally. By 54 days (C.R. 112 mm.) these structures were clear in position and remained throughout the period. The entire centre continued to increase in size (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

By 53 days (C.R. 108.3 mm.) on a lateral plate, the region immediate to the caudal border was denser than the remaining parietal tissue (Fig. Sn37) and this appearance continued throughout the period (Fig. Sn54).

Alizarin red staining of foetus.

The extent of increase in the centres was in step with the increase in the bones of the neurocranium. The inner ridge was becoming more massive and closely related to the interparietal centre which had a flattened border to accomodate it (Fig. AZ67). There still existed at the end of this phase, a dorsal gap in the tissue and there were still spaces separating these centres and the temporal centres (Figs. AZ97 and AZ98).

Period of gestation 61 days onward.

Radiography of foetus.

The whiter region at the rostro-dorsal angle was now triangular in shape with its apex directed rostro-ventrally and the white lines were still present. These observations were on lateral plates (Fig. X10).

Radiography of foetus impregnated with silver nitrate.

The denser area at the caudo-dorsal region of these centres was apparent laterally and also on a dorso-ventral view a similar line could be seen paralleling the caudal border of these centres (Fig. Sn53).

Alizarin red staining of foetus.

The inner caudal ridge was now extensively projecting forward into the interior with the ridges of both centres producing a V-shaped formation.

Conclusions.

Histologically the centres were seen to develop from membrane thus bearing out the description of Mivart (1881). The development was from two primary centres, one for each side, and their arrival in alizarin red stained specimens was first marked by the presence of two stained areas in the foetus of 31 days (C.R. 35 mm.) which is later than the 28 day foetus of the series described by Drews (1933). Also the C.R. length of 35 mm. differed from the length given by Drews of 46 mm. However, his description of ossification continuing in the fifth week of gestation is in approximate agreement. The initial radiographic appearance was at 37 days and 38 days (C.R. 56.5 mm. and 58 mm.) the earlier time being with silver nitrate impregnation of the foetus. The development of the processus tentoricus was seen in the alizarin stained foetus in the 41-50 day period and radiographically from 52 days (C.R. 108 mm.) onward. This development resulted in a structure similar to that described by Jayne (1898).

Os frontale.

Mivart (1881) states that the centre for this bone arises from membrane along with the supraoccipital, parietals, interparietal, frontals, squamosals, vomer, nasals, lachrymals and malars. Lesbre (1897) describes the frontal bones as developing from two single primary centres almost simultaneously with the parietals. Jayne (1898) describes the frontal bone in a skull shortly before birth as very convex and there are as yet, no frontal sinuses, but the frontal postorbital processes are small tubercles. Drews (1933) first describes the frontal in a foetus of 46 mm. or 28 days and relates that it ossifies during the fifth week.

Period of gestation 21-30 days.

Radiography of foetus.

This structure was not apparent in any of the radiographs of the foetuses of this period.

Radiography of foetus impregnated with silver nitrate.

The foetuses of 30 days (C.R. 29.1 mm.) all had a small somewhat rectangular patch of impregnated tissue apparent above the orbital region on lateral viewing. On dorso-ventral exposure the two strips could be seen lying laterally on either side of the developing skull (Figs. Sn1 and Sn3).

Alizarin red staining of foetus.

Of the foetuses of 28 days, two (C.R. 25 and 26 mm.) had stained tissue of the os frontale (Fig. AZ1). The foetus of C.R. 26 mm. had small rectangular sheets, one above each of the orbits, whilst the other foetus had more extensive areas staining with small spicules radiating out from the dorsal border of the sheets giving them an irregular rounded appearance. The 30 day (C.R. 32 mm.) foetuses had bilateral stained sheets over the orbit with a similar radiating pattern at the dorsal border (Fig. AZ4).

Period of gestation 31-40 days.

Radiography of foetus.

The frontals were not positively identified until 33 days (C.R. 38 mm.) when they were best observed on the dorso-ventral projection as faint areas of opacity dorsal to the orbits and extending dorso-laterally. The lateral view was of a faint area placed immediately above the developing orbit (Figs. X1 and X2). By 36 days (C.R. 49 mm.) the areas had increased in size and improved in definition. On dorso-ventral projection they were semi-circular areas situated above the orbits; on lateral viewing the areas were fainter. The extension of the frontal bone was increasingly evident as this period progressed and by 38 days (C.R. 58 mm.) the dorsal line of the head was paralleled by the outline of the frontal bones when seen laterally. On dorso-ventral exposure the rostral line of the dome of the cranium was formed by the frontal centres. By 40 days (C.R. 66 mm.) the area of the frontal development extended on lateral plates from the middle of the cranium into and rostral to the dorsal part of the orbit (Figs. X3, X4 and X5).

Radiography of foetus impregnated with silver nitrate.

In the 31 day (C.R. 35 mm.) foetus there was an area of increased opacity above the developing orbit as seen on lateral exposure, while on dorso-ventral viewing the most rostral outline of the cranium was formed of the developing frontal centres (Figs. Sn4 and Sn5). By 34 days (C.R. 43 mm.) the area of opacity had extended caudally and dorsally in the region of the cranium. Rostrally a projection was seen running ventrally toward the maxilla. These were observations on a lateral plate (Fig. Sn8). The structures were seen on a dorso-ventral exposure as a line extending around the lateral and rostro-lateral boundaries of the cranium. There was also an area of increased opacity present over the orbit and towards midline with a prolongation running down the medial aspect of the orbit (Fig. Sn9). By 39 days (C.R. 63 mm.) the extension of the area was marked so that by 40 days (C.R. 67 mm.) the centre extended rostrally to the maxilla, caudally to the parietal, caudo-ventrally to the developing temporal region as well as providing most of the medial wall of the orbit (Figs. Sn15 and Sn17).

Alizarin red staining of foetus.

In the 31 day (C.R. 35 mm.) foetus the stained area extended over the orbital region with a convex border and a more densely staining basal line dorsal to the orbit (Fig. AZ6). The 33 day (C.R. 39 mm.) foetus exhibited a larger stained area dorsally (Fig. AZ12) and the denser line was bifurcating rostrally with one branch curving round the rostral aspect of the orbit and the more dorsal also running rostrally (Fig. AZ13). By 35 days (C.R. 44.2 mm.) this bifurcation had created a notched appearance of the rostral border into which the maxilla would eventually fit and there was developing from these centres a dorso-medial wall to the orbit (Fig. AZ18). These later changes increased in size in the subsequent foetuses and by 38 days

(C.R. 58 mm.) the dorsal extension of the stained area was such as to approximate with the parietal caudally and the opposite frontal rostro-dorsally (Fig. AZ25). However there remained an open area at the most dorsal point of the crown where there was no stained tissue.

Period of gestation 41-50 days.

Radiography of foetus.

The area of coverage of the frontal centres increased during this period. Rostrally there was an extension of the dorsal line of the lateral image, being the point of junction with the maxillary and nasal centres. This produced a slight concavity of the dorsal line at its rostral end. Just dorsal to this concavity could be seen a faint dorsally arched line running caudally above the developing orbit. By the end of this period, the arched line was longer and more clearly discerned. (Fig. X7).

Radiography of foetus impregnated with silver nitrate.

The field of the centres continued to increase with extension continuing in the orbital region. Observed laterally, a fine line appeared above the orbit by 43 days (C.R. 82.5 mm.) signifying the dorsal rim of that structure (Figs. Sn20 and Sn33).

Alizarin red staining of foetus.

The centres continued to enlarge and there was particular extension of the medial wall of the orbit during the second phase of this period (Fig. AZ56). The rostral notch was commencing to roof over with a curved open network of stained tissue, being evident at the commencement of this period (Fig. AZ35) and by 47 days (C.R. 92 mm.) showing considerable progress rostrally. (Fig. AZ57).

Period of gestation 51-60 days.

Radiography of foetus.

By 52 days (C.R. 108 mm.) the rostral prolongation was somewhat in the shape of an inverted V and the arch above the orbit was increasing in definition. The whole centre increased in size to correspond with the enlargement of the head.

Radiography of foetus impregnated with silver nitrate.

The centra continued to enlarge during this period. The line above the orbit was apparent throughout the period and by 57 days (C.R. 125 mm.) a local thickening appeared just in front of the rostral end (Fig. Sn46).

Alizarin red staining of foetus.

There was an increase in size and the plate forming the medial wall of the orbit was extending ventrally. During this period, the line marking the dorsal rim of the orbit was more deeply stained signifying the formation of a ridge (Fig. AZ73 and AZ97) and by the end of the period at the caudal end of the ridge an eminence was appearing.

Period of gestation 61 days onward.

Radiography of foetus.

The V formation rostrally was filling in by this time and the dorsal arched line was a distinct white line running round above the orbit.

Radiography of foetus impregnated with silver nitrate.

The thickening on the dorsal orbital rim was developing into a slight eminence which appeared to be directed slightly ventrally when viewed on a lateral plate (Fig. Sn56).

Alizarin red staining of foetus.

The eminence at the caudal end of the ridge over the orbit was pronounced at birth. (Fig. AZ 112).

Conclusions.

Histologically the ossa frontale were seen to develop in membrane agreeing with the findings of Mivart (1881) but several days in advance of the appearance of the parietal centres. There were two centres, one for each side, and their first appearance was detected in the alizarin red stained specimens, being evident at 28 days (C.R. 25 mm.) which matches the day of gestation given by Drews (1933) but does not tally with his C.R. length, his being 46 mm. as compared to these findings of 25 and 26 mm. The first radiographic appearance was not until 30 days (C.R. 29.1 mm.) in the silver nitrate impregnated foetus and 33 days (C.R. 38 mm.) in the fresh specimens. The supraorbital process as described by Jayne (1898) became evident in the latter part of the 51 to 60 day period.

Os ethmoidale.

Mivart (1881) describes this bone as developing from the ethmovomerine cartilage with the median ethmoid and cribriform plate ossifying late. Lesbre (1897) also adds that there is a cartilaginous precursor whilst Jayne (1898) gives greater detail of the ethmoids in his description of the skull close to birth. He describes the lateral as consisting of a few folds of cartilage in which have appeared several bony nodules at the rostral end of the future fourth piece and a small nodule in the medial part of the sixth piece. The mesethmoid and cribriform plate are represented by cartilage. At birth these ossified nodules in the lateral ethmoid at the end of the terminal medial part of the fourth scroll have extended laterally and upward along the caudal boundary of the ethmoidal cleft and also slightly upward into the rostral ends of the first and second pieces. The sixth piece had increased ossification and a new centre had appeared in the seventh piece whilst the fifth was still cartilaginous. Drews (1933) reports that shortly before birth 130 mm. or 53 days, the oral ends of the endo-turbinals begin to ossify but it is not until after birth that ossification occurs in the ectoturbinal, lamina cribriosa and the lamina perpendicularis. Crouch (1969) illustrates the ethmoid bone of a kitten and shows a horizontal or cribriform plate and the perpendicular plate.

Ewer (1973) describes the skull of Canoidea as having turbinals comprising a single maxillary, a nasal and a primary series of ethmoturbinals, the latter differentiating originally from the median nasal septum. These are sometimes collectively referred to as endoturbinals. They are supplemented by later developing outgrowths from the side walls of the nasal passages, forming an ectoturbinal series.

In a foetus from a litter obtained at birth, there was evidence of alizarin red staining of the primary series of the endoturbinalia.(Fig. AZ 111).

Ossa turbinalia.

Both Mivart (1881) and Lesbre (1897) indicate cartilaginous precursors for these bones and Lesbre (1897) describes the maxillary turbinate as having one centre of ossification. Drews (1933) states that the start of ossification of the turbinates cannot be established until just before birth.

In a foetus from a litter obtained at birth, there was evidence of alizarin red staining of the ventral conchae (maxillary or ventral turbinalia). This is similar to the findings of Drews (1933). (Fig. AZ 111).

Os lacrimale.

Mivart (1881) describes this bone as arising from membrane with the supraoccipitals, parietals, interparietals, frontals, squamosals, vomer, nasals and malars. Jayne (1898) states that there is one centre of ossification for this bone and that in the skull shortly before birth only a narrow line of ossification can be seen along its rostral border and at birth the ossification of the lacrymal has increased to a narrow crescentic band. Drews (1933) shows the lacrymal to be present in a foetus of 46 mm. or 28 days, in the form of a punctate spot in the orbital region.

Period of gestation 31-40 days.

Radiography of foetus

There was no radiographic evidence of the appearance of this centre.

Radiography of foetus impregnated with silver nirate.

There was no evidence of this centre in radiographs of impregnated foetuses.

Alizarin red staining of foetus.

Of the three litters of 31 days (C.R. 35 mm.) only one contained a foetus revealing a small centre of stained tissue lying medial to the dorsal border of the maxillary centre. This was in the form of a small crescent of tissue. The foetuses of 33 days (C.R. 39 mm.) onward, all demonstrated a centre at this point (Fig. AZ15 and AZ16) by 36 days (C.R. 49 mm.) the dorsal half had expanded to be approximately triangular in shape with a narrow strip ventrally, terminating in a slightly expanded end. The centre continued to increase in size and became more lace-like in form by 39 days (C.R. 63 mm.) onward (Fig. AZ33).

Period of gestation 41-50 days.

Radiography of foetus.

The centre was observed as a faint line when seen on a lateral plate of the foetuses of 45 days (C.R. 86 mm.). It was slightly curved with its concavity facing into the orbit. The image of the centre remained faint throughout the remainder of the period.

Radiography of foetus impregnated with silver nitrate.

The centre was first identified in a foetus of 43 days (C.R. 82.5 mm.) and described an indefinite V-shape on a lateral plate (Fig. Sn20), lying on the rostral surface of the orbit dorsal to the main substance of the developing maxilla. It was repeatedly observed in later plates but increased little in size, remaining similar in outline.

Alizarin red staining of foetus.

The centre became more triangular in form during this period and increased slightly in size (Fig. AZ41).

Period of gestation 51-60 days.

Radiography of foetus.

The centre remained visible throughout the period as a fine line with some widening at the base. By 60 days (C.R. 136 mm.) it was difficult to determine it as a separate structure (Fig. X9).

Radiography of foetus impregnated with silver nitrate.

The centre was discerned on lateral plates as an approximately V-shaped centre but remained small throughout (Figs. Sn32 and Sn54).

Alizarin red staining of foetus.

The centre extended more laterally as an angled projection but still retained a triangular shape.

Period of gestation 61 days onward.

Radiography of foetus.

The density of the image had increased but its differentiation from neighbouring centres was difficult (Fig. X10).

Radiography of foetus impregnated with silver nitrate.

The centre could not be discerned as a separate structure.

Alizarin red staining of foetus.

There was a narrow dorsal prolongation appearing at this stage but the centre still remained small in comparison to its neighbours.

Conclusions.

The centre developed from membrane as was observed histologically, but although it was seen stained by alizarin red at 31 days (C.R. 35 mm.) it did not appear radiographically till 43 days (C.R. 82.5 mm.) in silver nitrate preparations and 45 days (C.R. 86 mm.) in fresh specimens. The day of appearance of the alizarin stained centre was later than that given by Drews (1933) who quotes 28 days and also the C.R. length which he gives of 46 mm. is far removed from this finding of 35 mm. The description of the centre at birth given by Jayne (1898) resembles that found here.

Os nasale.

Mivart (1881) reports that the nasal bones develop from membrane along with the supra-occipitals, the parietals, interparietals, frontals squamosa, vomer, lachrimals and malars. Jayne (1898) accords one centre of ossification to this bone and states that it is ossified in a skull close to birth. Drews (1933) notes the nasals as present in a foetus of 63 mm. or 31 days and apparent as two ossified centres.

Period of gestation 31-40 days.

Radiography of foetus.

The first evidence of the presence of these centres was in the foetus of 36 days (C.R. 49 mm.) when a faint line was seen running rostro-caudally in the most dorsal part of the face. This line was more clearly defined in the litter of 38 days (C.R. 58 mm.) when it could be seen lying rostral to the frontal centres (Figs. X3 and X5).

Radiography of foetus impregnated with silver nitrate.

The presence of the centre of this bone was indefinite at 31 days (C.R. 35 mm.) but by 34 days (C.R. 43 mm.) on a lateral plate, two strips could be seen overlying each other running parallel to the nasal profile of the foetus (Fig. Sn8). They were also obvious on the dorso-ventral plate as slightly diverging short strips (Fig. Sn9). The size of the centres increased and by 40 days (C.R. 67 mm.) the lateral view was of a V-shaped structure with the point of the V directed at the frontal region (Fig. Sn17). On dorso-ventral plates the centres appeared crescentic, one to either side of midline (Fig. Sn16).

Alizarin red staining of foetus.

At 31 days (C.R. 35 mm.) the centres were seen as horse-shoe shaped structures, one to either side of midline with the convexity dorso/caudally (Fig. AZ7). By 35 days (C.R. 44.2 mm.) the centres having increased in size, the areas contained within the horseshoe rings were commencing to stain (Fig. AZ19) so that by 37 days (C.R. 56.5 mm.) the centres were almost complete with stained tissue (Fig. AZ24). Thus the appearance at 40 days (C.R. 66 mm.) was of two isosceles triangles placed one to either side of midline and with their bases rostral (Fig. AZ32).

Period of gestation 41-50 days.

Radiography of foetus.

The lateral image remained as a thin line increasing in length during this period. On dorso-ventral plates, the outline was of two small centres lying to either side of midline most rostrally with a rounded caudal border, straight lateral and medial borders and a flattened rostral periphery. This latter image was not fully apparent till 45 days (C.R. 86 mm.) when it was still faint in outline. The centres increased in size during the remaining period (Figs. X6 and X7).

Radiography of foetus impregnated with silver nitrate.

The dorso-ventral appearance was of two centres with straight medial borders just to either side of midline and convex lateral borders containing faintly radiopaque tissue (Fig. Sn23). The opacity and extent of the tissue increased during this period and by 45 days (C.R. 86 mm.) the centres were of even density. The lateral view was originally irregularly

V-shaped (Fig. Sn24) but the area between the two levels became gradually radiopaque during this period (Fig. Sn32).

Alizarin red staining of foetus.

The bilateral centres continued to appear as two triangles to either side of midline but their dorsal surfaces were increasing in convexity giving the centre a scrolled appearance (Fig. AZ39).

Period of gestation 51-60 days.

Radiography of foetus.

The centre increased in size and definition during this period (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

The density of the centres increased as did their size (Fig. Sn39). On lateral viewing the profile became more pronounced as the rostral tips of the nasal centres protruded and were but slightly curved. This became noticeable by 53 days (C.R. 108.3 mm.) (Fig. Sn38) and was obvious at 57 days (Fig. Sn66).

Alizarin red staining of foetus.

The centres were pointed dorsally, with the point being at the most dorso-medial angle, so that the medial edges of the two centres were straight and close to each other in midline. The lateral borders were convex. The outer surface was strongly convex and, in the 52 day foetus (C.R. 108 mm.) the tissue was then lacy in appearance (Fig. AZ70). However, as the period progressed, the density of the centres increased and by 57 days (C.R. 125 mm.) they were relatively opaque. The overall size had also increased (Fig. AZ101).

Period of gestation 61 days onward.

Radiography of foetus.

The outline of the centres was well defined in both lateral and dorso-ventral exposures (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The outline of the nasal centres was clear (Fig. Sn55) and the profile well defined on lateral viewing (Fig. Sn56).

Alizarin red staining of foetus.

The ventral border at its region of union with the lateral border was beginning to project rostrally and ventrally to give at birth a short pointed extension at this area.

Conclusions.

Histologically the centres were seen to develop in membrane. There were two primary centres, one for the bone of each side. The alizarin red stained foetuses gave first positive identification of the centres at 31 days (C.R. 35 mm.) which matches the day given by Drews (1933) but his C.R. length figure of 63 mm. is in excess of these findings of 35 mm. Radiographically the centres were first seen at 34 days and 36 days (C.R. 43 mm. and 49 mm.) the earlier date being in the silver nitrate specimens.

Vomer.

Mivart (1881) describes this bone as arising from membrane at the same time as the supra-occipitals, interparietals, frontals, squamosals, nasals, lachrymals and malars. He identifies it as having a single centre being an ossification of the membrane investing laterally the lowest part of the ethmo-vomerine cartilage. Jayne (1898) however attributes its development to two centres. In the skull shortly before birth he states that the vomer is for the greatest part ossified. Drews (1933) finding agreement with the latter, states that the vomer is a paired structure appearing in a foetus of 46 mm. or 28 days.

Period of gestation 21-30 days.

Radiography of foetus.

There was no evidence of the presence of the vomer in the foetuses of this group.

Radiography of foetus impregnated with silver nitrate.

In one of the foetuses of 30 days (C.R. 31 mm.) the centre for the vomer could be seen on a lateral plate as a slight streak placed dorsal to the developing oral cavity and divided obliquely caudo-dorsally.

Alizarin red staining of foetus.

There was no evidence of staining of the vomer in the foetus of this group.

Period of gestation 31-40 days.

Radiography of foetus.

In the foetuses of 36 days there was an indication of the presence of the vomer in two of the litter of C.R. 55 mm. but not in the other litter (C.R. 49 mm.). The centre was double in one foetus, lying between the outline of the alae of the presphenoid and was only visible on the dorso-ventral plates. The other foetus in which the centre was present had a U-shaped structure in an identical position. The two litters of 38 days (C.R. 58 and 60 mm.) both had foetuses with the centre present but again in one litter it appeared double and in the other it was U-shaped. The subsequent litters demonstrated the centre (Fig. X5) but due to the lack of a true dorso-ventral projection it was difficult to evaluate the shape.

Radiography of foetus impregnated with silver nitrate.

In the foetus of 31 days (C.R. 35 mm.) the development of the vomer could be seen. It appeared on the lateral plate as a narrow line running caudo-dorsal from the caudal border of the maxilla, whilst on the dorso-ventral plate it had the form of a band running in midline from the rostral maxillary region (Figs. Sn6 and Sn7). The lateral appearance in the 34 day foetus (C.R. 43 mm.) was wider at its rostral end whilst the dorso-ventral form appeared divided longitudinally (Figs. Sn10 and Sn11). The vomer image was progressively masked by those of the maxilla and zygomaticum during the remaining period when viewed laterally (Fig. Sn15) but the dorso-ventral form was still recognisable lying in midline above the maxilla. It continued to have a divided appearance (Fig. Sn16).

Alizarin red staining of foetus.

The vomer was stained in the foetus of 31 days (C.R. 35 mm.) giving the appearance of two narrow wings diverging from a midline union rostrally and running caudo-dorsally (Fig. AZ6). This configuration resembled a plough shape. The size of the centre increased with age and the wings increased principally in length (Fig. AZ28). On the dorsal surface close to the caudal end there was appearing on each side a raised roughened eminence in the foetuses of 38 days (C.R. 58 mm.) onward.

Period of gestation 41-50 days.

Radiography of foetus.

Observation of the vomerine centres was largely obstructed by the development of overlying areas (Figs. X6 and X7). On dorso-ventral plates in a few individuals the V form of the centres could be seen.

Radiography of foetus impregnated with silver nitrate.

The V-fotmation of the centres was evident on dorso-ventral viewing (Fig. Sn23) but the centres were difficult to discern on lateral view (Fig. Sn22). There was an increase in size corresponding to the general growth of the region.

Alizarin red staining of foetus.

The length of the two wings of the vomer increased throughout the period, unification ventrally was still evident. The united body was evident through the space between the palatine and maxillary centres (Fig. AZ40) until the later part of this period when those gaps began to close (Fig. AZ58). There appeared also separated rostral extensions of the wings as they approached the vertical plates of the incisive centres. On the dorsal surface at about two thirds of the way along the length, there was seen developing at the commencement of this period a small truncated prominence which rose in height during the remaining period (Fig. AZ59). The caudal third of the wings were expanding vertically with a slight divergence of the extension of both sides (Fig. AZ54).

Period of gestation 51-60 days.

Radiography of foetus.

There was difficulty in outling the centre during this period but there was apparent increase in size (Figs. X8 and X9).

Radiography of foetus impregnated with silver nitrate.

There was difficulty in outling the centre during this period but there was some increase in size (Fig. Sn48).

Alizarin red staining of foetus.

The centre increased in size during this phase. The dorsal prominences were more noticeable and assumed a more transverse line in the second half of this phase (Fig. AZ70). The more caudal portion of the wings continued to expand in area. This area of extension was progressively covered by the rostral growth of the praesphenoid centres so that by 57 days (C.R. 125 mm.) the presphenoids extended rostrally to the level of the dorsal prominence of the vomer (Fig. AZ96).

Period of gestation 61 days onward.

Radiography of foetus.

The centres were not easily defined due to the overlying surrounding tissue (Figs. X10 and X11).

Radiography of foetus impregnated with silver nitrate.

The centres were not easily defined due to the overlying surrounding tissue (Figs. Sn53 and Sn54).

Alizarin red staining of foetus.

The final specimens revealed little of the growth of the vomer as the ethmoids were now covering the vomerine centres with staining tissue and the vomer appeared to have received little stain as a consequence of poor infiltration of the staining fluid. There was no evidence to suggest that any major alteration in development had occurred (Fig. AZ111).

Conclusions.

Histologically the vomer developed from membrane being constructed alongside the more caudo-ventral part of the cartilage of the nasal capsule which lay in midline. The alizarin red stained specimens demonstrated a centre which appeared to have two wings unified at midline and appearing first of all at 31 days (C.R. 35 mm.). The silver nitrate impregnated specimens were positive radiographically at 30 days (C.R. 29.1 mm.) but the centres of the treated foetuses in a number of the earlier foetuses appeared to be separated in midline but this may have been due to the finer parts being still relatively radiolucent although calcified. Drews found the centres to be paired appearing at 28 days but his C.R. length of 46 mm. is in excess of these findings of 35 mm. There was no histological or alizarin stained evidence of the pairing of the centres and this is similar to the findings of Mivart (1881). However both Jayne (1898) and Drews (1933) found them to be paired.

Os hyoideum

Mivart (1881) ascribes the origin of this apparatus to the second and third visceral arches. The epi-, cerato- and basihyals ossify from the lower end of the second arch while the thyrohyals are of the solitary ossifications of the third visceral arch. Drews (1933) states that the ossification of the hyoid starts in the cat after birth. The basi-, thyro-, kerato-, epi- and stylohyoid develop from one ossification core each.

No detailed study was made of the hyoid apparatus during this investigation.

SUMMATION OF FINDINGS

IN GROUP A.

The Skeleton as a Whole.

The times of development of the centres of ossification of the entire skeleton, excluding the visceral skeleton, are compiled in the table 4. The number of centres developing in foetal life and their times of appearance, as detected using the selected techniques, are recorded.

In Figs. G1-7 there is recorded in graph form, the state of development of the skeleton at all stages of gestation from 25 days or 20 mm. C.R. length onward until full term or 150 mm. C. R. length as detected on radiographs of fresh specimens. Using the graph, it is possible to take a specific day of gestation which is marked on the horizontal axis and by tracing vertically, to determine which bony elements would be present at that particular time. Conversely, if a specific C.R. length is taken on the vertical axis and a line drawn horizontally, then a determination of the state of development of the bony elements anticipated at that C.R. length can be made.

There was found to be a total of sixty-six types of centres of ossification developed during foetal life. This means that although a centre may be repeated to either side of midline e.g., skull or repeated serially e.g., vertebral column, the total of sixty-six represents only the sum of the various types e.g., there are thirteen thoracic vertebrae but only two types of centres are counted for this group i.e., one for the centrum and one for laminar development. All of these centres were investigated using alizarin red staining and radiography both with and without silver nitrate impregnation. Although all the centres were observed histologically, for their type of ossification only thirty-four were given times of appearance on a histological basis.

From the evidence presented on Table 4 it can be seen that of the sixty-six types of centres examined, forty-six were revealed earliest by alizarin red staining, with a further nine revealed as early as by either other technique. Using radiography of silver nitrate impregnated foetuses, five centres were revealed earliest, with a further seven as early as by either of the other methods. Radiography of fresh material was first to reveal a centre in only two cases, with an equal first for another two centres.

It would appear therefore that alizarin red staining is the most sensitive of these techniques for revealing the early presence of calcified material, with radiography of silver nitrate impregnated foetuses next and the radiography of fresh foetuses the slowest to reveal the developing centres. However the difference in time between the first detection of centres using alizarin red stain and silver nitrate impregnation was never great, Table 4, which is similar to the findings of O'Rahilly and Meyer (1956). The times for radiography of the fresh foetuses had more obvious disparities with the times for the other two methods.

As stated by O'Rahilly and Meyer (1956) histological examination proved to be the most critical method of examination for the developing centres, as it allowed assessment as to whether merely primary calcification was being observed or the presence of a true centre of ossification. From the Table 4 it can be seen that the techniques of alizarin red staining and silver nitrate impregnation were initially detecting the onset of primary calcification and the formation of a periosteal collar. A true centre of ossification did not usually occur until after several days. This was as found by Meyer and O'Rahilly (1958). See Appendix II

Study of the development of the structure of the formative centres was best carried out on alizarin red stained speciemens. The process of histological study although affording a more critical assay of the mode of development necessitated the examination of a large amount of material in order to build up a three dimensional image. The alizarin red method, on the other hand, offered a three dimensional structure which could be manipulated and was capable of being dissected to reveal underlying structures. This difficulty with histological preparations was most obvious when dealing with the developing skull where alizarin studies proved to be most valuable.

Radiography was a useful method for recording increase in growth and size of a centre providing sufficient care was excercised in obtaining accurate positioning of the foetus. For intricate knowledge of detail, radiography of fresh material was of limited value due to the lack of contrast with surrounding tissue and so impregnation with silver nitrate was necessary before detail could be studied. However, in the head region, as the silver salt increased the radiopacity of the centres, it was necessary to radiograph the skull in sections to gain clear images of the deeper structures.

THE RADIOGRAPHIC IDENTIFICATION OF THE VARIOUS STAGES OF PREGNANCY IN THE DOMESTIC CAT

The radiographic appearance of feline foetuses _in utero_ has not previously been reported before Boyd (1971). Joshua (1965) states that in pregnancy diagnosis foetal heads and outlines are palpable from 49 days (at which stage the skeleton is becoming radiographically visible). The radiographic appearance of the centres of ossification of the limb bones of feline foetuses _ex utero_ has been reported by Boyd (1968), using crown-rump (CR) measurements to assess foetal age; the earliest date at which ossification could be seen in the appendicular skeleton _ex utero_ was at 31 days of gestation.

The radiographs of the adult female cats were examined for the appearance, size and position of the uterus and for the presence of foetal skeletal elements. The chronological order of the appearance of the skeletal elements was recorded.

RESULTS.

25-35 days (C.R. 19-44.2 mm.). At this stage the uterus could be seen to be enlarged and more cranial in its position in the abdomen. Although centres of ossification for clavicle, mandible, maxilla, ribs, shaft of humerus, radius, ulna, femur and tibia were apparent on X-ray of the individual foetuses radiographed _ex utero_ from a litter of 34 days (C.R. 43 mm.) there was no evidence of such centres in the radiographs of pregnant mothers.

36 - 45 days (C.R. 49-86 mm.). In a radiograph of a pregnant cat calculated to be in its 38th day (C.R. 58 mm.) of gestation the uterus was cranial in position and enlarged. It was possible to observe ossification of the foetal mandible, the frontal, maxillary and parietal bones of the skull and the scapula, humerus and femur of the appendicular skeleton. The bodies of the vertebrae were visible, as were the ribs. At 41 days (C.R. 73 mm.) gestation the preceding findings were confirmed and the radius and ulna were also visible. Figure 1 illustrates those findings in litter 37. The radiographs of two litters of 43 days (C.R. 82.5 mm.) demonstrated the presence of the shafts of the tibia, ileum and ischium and the occipital bones of the skull.

46-55 days (C.R. 88-115 mm.). The previous findings were constant in litters of 47 days (C.R. 92 mm.) but by now the interparietal bones were visible. Figure 2 shows a lateral view of litter age 47 days (C.R. 92 mm.). At 50 days (C.R. 102 mm.) the metatarsal bones were in evidence. At 52 days (C.R. 108 mm.) the phalanges of the digits were seen, as was the sternum. This was constant in the two litters of this age. Three litters of 53 days (C.R. 108.3 mm.) were examined and, in all, the digits could be seen of both pectoral and pelvic limb. The fibular-tarsal bone was also observed in these litters. In the skull the outlines of the tympanic bullae were discernible.

56 days to parturition (C.R. 120-150 mm.). Figure 3 is a radiograph of litter 69 age 56 days (C.R. 120 mm.) and demonstrates the structures present at this stage. The previous findings were established in the litters

up to 58 days (C.R. 130 mm.) when there was added the appearance of molar teeth developing in the alveoli of the mandible and maxillae. The last litter to be examined, Fig. 4 was that of a cat in labour. Here again the teeth were visible within their alveoli and also the tibial-tarsal bone could now be identified.

CONCLUSIONS.

Using the CR length measurements to assess foetal age, a method of approximately estimating the various stages of pregnancy in cats using radiography was produced. It was seen that, although uterine enlargement and displacement was seen as early as the 25th. day (C.R. 19 mm.) the first signs of the foetal skeletal system were not apparent *in utero* until the 38th. day (C.R. 58 mm.). From this time a progressive pattern of appearance of ossified parts was noted which allowed a means of estimating the day of gestation.

GROUP B.

The litters removed by Caesarian section are listed in Table 2. The number of foetuses in each litter is given, as are the individual C.R. lengths and known days since coitus. The selection of techniques to which foetuses from each litter were subjected is also given.

The C.R. lengths of the foetuses of Group B were known as were the days since coitus. Using these C.R. lengths, a calculated age in days since coitus, was found for each litter using the method of calculation utilised with Group A. The true age was then compared with the calculated age and the results are shown in Table 5. Disparities arise in the relation between these two ages with the most marked differences being in the last ten days of gestation. The series Group A is a limited number only and therefore it would be wrong to discredit the method of calculation of age used by Farris.

To further test the accuracy of the findings of Group A, the foetuses of Group B were subjected, as numbers per litter permitted, to the same techniques for study as Group A. The observations made on a Group B foetus were then compared to those made on a foetus of comparable C.R. length from Group A. These observations were on the time of appearance of the centres of ossification of the appendicular and axial skeleton. The results of this comparison are given in Table 6.

It can be seen from these results that the observations on times of appearance of centres of ossification related to C.R. length, which were made in foetuses of Group A, closely resemble those made in foetuses in Group B and that no one technique differs markedly in efficacy in either group. There were only two marked variances in times of appearance of centres. The time of appearance of the centre of the body of the praesphenoid was recorded at 82 mm. in Group A and 60.1 mm. in Group B when stained by alizarin red. In the case of the first appearance of the centre for the ventral arch of the atlas this was evident in one foetus of 84.3 mm. and another of the litter of 85-91 mm. in Group B compared to 105 mm. in Group A, when impregnated with silver nitrate. This same centre appeared earlier on radiographs of fresh specimens in Group B i.e., 85-91 mm. compared to 105 mm. in Group A.

These results indicate that data of this nature could possibly be utilised for the following purposes:

(a) To identify the age and C.R. length of a foetus presented without these criteria e.g., a radiograph of an aborted foetus. The skeletal maturity of the unknown foetus is assessed and recorded. The results in Group A are then consulted and a similar point in skeletal maturity found. It is then reasonable to attribute the C.R. length of the foetus found to be at that point of maturity in Group A, to the unknown foetus. An approximate age could then be given using the scale described by Farris (1950) but there would appear to be a margin for correction in this.

(b) To assess whether a foetus of either known age or C.R. length has achieved a state of skeletal maturity commensurate with its age and C.R. length. This would be accomplished by comparing the state of skeletal maturity of the foetus in question directly with that recorded in observed foetuses of similar C.R. length and age. This would allow an opinion to be given as to the presence of foetal regression or deviation from the normal pattern of ossification.

In further studies in this field, I hope greatly to increase the numbers of litters in Group B and thus to increase the accuracy of ageing a feline foetus from a given C.R. length. With the pattern of ossification now described and assembled in a chronological order, I hope to project this work into the field of study of teratologies with regard to skeletal deformities *in utero* or in the neonate.

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TABLE 1.

GROUP A.

LIST OF LITTERS EXAMINED
AND TECHNIQUES USED

LITTER NUMBER	NUMBER OF INDIVIDUALS RECEIVED FROM LITTER	CROWN RUMP LENGTH mm	ESTIMATED AGE DAY OF GESTATION	X RAY FOETUS	FOETUS X RAY SILVER NITRATE	X RAY PREGNANT ♀	ALIZARIN	HISTOLOGY
1	3	17	24	+	+	+	−	+
2	3	17	24	+	−	−	−	+
3	3	17	24	+	−	−	−	+
4	3	18	24	+	−	−	−	+
5	3	19	25	+	−	+	−	+
6	2	22	26	+	−	−	−	−
7	3	23	27	+	−	−	−	+
8	4	23·2	27	+	+	−	+	+
9	2	25	28	+	−	−	+	+
10	2	26	28	+	−	−	+	+
11	4	26	28	+	+	+	+	−
12	2	29	30	+	−	−	+	+
13	6	29·1	30	+	+	+	+	−
14	2	31	30	+	+	+	−	−
15	2	31·2	30	+	+	+	−	−
16	2	32	30	+	−	−	+	+
17	3	32	30	+	+	−	+	−
18	3	35	31	+	−	−	+	+
19	2	35	31	+	−	−	+	+
20	4	35	31	+	+	+	+	+
21	2	38	33	+	−	−	+	+
22	4	39	33	+	−	−	+	+
23	2	39·8	33	+	+	−	+	+
24	2	43	34	+	+	+	+	−
25	3	44	34	+	−	−	−	+
26	2	44·2	35	+	−	+	+	+
27	3	49	36	+	+	−	+	+
28	2	55	36	+	−	−	+	+
29	3	56·5	37	+	+	−	+	−
30	2	58	38	+	−	+	+	+
31	2	60	38	+	−	−	+	−
32	4	63	39	+	+	+	+	+
33	3	65	39	+	+	+	+	−
34	2	66	40	+	−	−	+	+
35	7	67	40	+	+	−	+	−
36	5	68·9	40	+	+	−	+	+
37	3	73	41	+	+	+	−	−
38	2	75	41	+	−	−	+	−
39	4	75	41	+	−	−	−	+
40	3	78	42	+	−	+	−	−
41	2	80	42	+	−	−	+	+
42	5	82·5	43	+	+	+	+	−
43	5	83	43	+	−	+	+	−
44	4	84	44	+	+	+	+	−
45	6	85	44	+	+	−	+	−

LITTER NUMBER	NUMBER OF INDIVIDUALS RECEIVED FROM LITTER	CROWN RUMP LENGTHmm	ESTIMATED AGE DAY OF GESTATION	X RAY FOETUS	FOETUS X RAY SILVER NITRATE	X RAY PREGNANT ♀	ALIZARIN	HISTOLOGY
46	5	85	44	+	+	+	+	+
47	4	86	45	+	+	+	+	−
48	4	88	46	+	+	+	+	−
49	4	90	46	+	−	−	−	−
50	4	90	46	+	+	+	+	+
51	2	91	47	+	−	−	−	+
52	4	92	47	+	+	+	−	−
53	7	92	47	+	+	+	+	−
54	6	94	48	+	−	+	+	−
55	4	95	48	+	+	+	+	−
56	4	102	50	+	+	+	+	−
57	5	103	50	+	−	+	−	−
58	2	105	51	+	+	+	+	−
59	4	105·5	51	+	−	+	+	−
60	5	108	52	+	+	+	+	−
61	4	108·3	53	+	+	+	+	−
62	4	109	53	+	+	+	−	−
63	2	110	53	+	−	−	−	+
64	2	112	54	+	−	+	+	+
65	3	112	54	+	+	+	+	−
66	4	113	54	+	+	+	+	−
67	4	114	54	+	+	−	+	−
68	2	115	54	+	−	−	+	−
69	2	120	56	+	−	+	+	+
70	2	121	56	+	+	+	+	−
71	3	122	56	+	−	+	−	−
72	6	125	57	+	+	−	+	−
73	4	125	57	+	+	+	+	−
74	3	127	57	+	+	−	+	−
75	4	130	58	+	+	+	+	−
76	2	130	58	+	−	+	−	−
77	4	130	58	+	−	−	−	−
78	2	133	59	+	−	−	+	−
79	2	136	60	+	+	+	+	−
80	1	138	60	+	−	−	−	−
81	2	140	61	+	−	−	−	+
82	4	146	62	+	−	+	−	−
83	2		AT BIRTH	+	−	−	+	−
84	3		AT BIRTH	+	+	−	+	−
85	2		1 DAY P.P.	+	−	−	+	−
86	2		2 DAYS P.P.	+	−	−	+	−
87	2		2 " "	+	−	−	−	−
88	3		3 " "	+	−	−	−	+
89	1		3 " "	+	−	−	−	−
90	3		3 " "	+	−	−	+	−
TOTAL 90	TOTAL 288			TOTAL 90 LITTERS	TOTAL 42 LITTERS	TOTAL 43 LITTERS	TOTAL 62 LITTERS	TOTAL 35 LITTERS

TABLE 2.

GROUP B.

LIST OF LETTERS, AGES, C.R. LENGTHS
AND TECHNIQUES USED

TABLE 2

LITTER NUMBER	INDIVIDUALS	C.R. LENGTHS mm.	AGE DAYS SINCE COITUS	X-RAY FOETUS	X-RAY S.NITRATE	PREGNANT ♀	ALIZARIN	HISTOLOGY
I	6	29,29.2,31 32.1,32.6,33.2	31	+	+	+	+	+
II	1	40	34	+	+	+	-	-
III	1	41	38	+	-	+	+	-
IV	1	60.1	40	+	-	+	+	-
V	4	80,82.1, 84.3,84.3	45	+	+	+	+	+
VI	3	85,88,91	49	+	+	+	+	+
VII	2	110,110	56	+	+	+	+	-
VIII	3	116,116,123	60	+	+	+	+	+
IX	1	140	65	+	-	+	-	-
X	3	135.5,137,139	66	+	-	+	+	-

TABLE 3.

GROUP A.

NUMBERS OF INDIVIDUALS WITH VARIATIONS IN BONY ELEMENTS OF THORAX AND VERTEBRAL COLUMN

Litter	Estimated age (days)	Individuals	Number of ribs	Number of cervical vertebrae	Number of thoracic vertebrae	Number of lumbae vertebrae
42	46	a	14 : 14	7	13	7
		b	13 : 13	7	13	7
59	54	a	13 : 12	7	13	7
		b	13 : 12	7	13	7
65	57	a	14 : 14	7	13	7
		b	14 : 14	7	13	7
		c	14 : 14	7	13	7
70	61	a	14 : 14	7	14	7
		b	14 : 14	7	14	7

TABLE 4.

GROUP A.

LIST OF CENTRES NOTED AND THEIR TIMES OF APPEARANCE
WITH CORRESPONDING C.R. LENGTHS

OSSA MEMBRI THORACICI

Bone	Centre	Method	C.R. length mm.	Day of gestation
Clavicula	Corpus	R	35	31
		S	29	30
		A	25	28
		H	17	21
Scapula	Corpus	R	38	33
		S	31	30
		A	35	31
		H	35 : 38	31 : 33
Humerus	Corpus	R	35	31
		S	29	30
		A	25	28
		H	23 : 29	27 : 30
	Prox. Epiphysis	R		1 day post-partum
		S		Post-partum
		A		At birth
Radius	Corpus	R	38	33
		S	29	30
		A	25	28
		H	23 : 29	27 : 30
Ulna	Corpus	R	39	33
		S	29	30
		A	25	28
		H	23 : 29	27 : 30
Ossa Metacarpalia II III IV V	Corpus	R	49	36
		S	43	34
		A	38, 38, 38, 43	33, 33, 33, 34
		H	43 : 58	34 : 38
Metacarpus I (proximal element)		R	66	40
		S	82	43
		A	63	39
		H	63 : 84	39 : 44

contd. ...

TABLE - OSSA MEMBRI THORACICI (contd.):

Bone	Centre	Method	C.R. length mm.	Day of gestation
Ossa digit-		R	66, 66, 66, 66	40, 40, 40, 40
orum manus		S	66, 63, 66, 66	40, 39, 40, 40
II III IV V		A	63, 58, 63, 66	39, 38, 39, 40
Phalanx proxi- malis	Corpus	H	63 : 84	39 : 44
Phalanx media	Corpus	R	69, 69, 69, 80	40, 40, 40, 42
		S	82, 75, 82, 82	43, 41, 43, 43
		A	69, 69, 69, 82	40, 40, 40, 43
		H	63 : 84	39 : 44
Phalanx distalis	Corpus	R	49, 49, 49, 58	36, 36, 36, 38
		S	43, 43, 56, 56	34, 34, 37, 37
		A	38, 38, 38, 43	33, 33, 33, 34
		H	44 : 63	34 : 39
Ossa digit-		R	69	40
orum manus		S	82	43
I		A	82	42
Middle element	Corpus	H	63 : 84	39 : 44
Distal element	Corpus	R	49	36
		S	43	34
		A	39	33
		H	44 : 63	34 : 39

R = Radiography of foetus
S = Radiography of foetus impregnated with silver nitrate
A = Alizarin red staining of foetus
H = Histology

OSSA MEMBRI PELVINI.

	Centre	Method	C.R. length mm.	Day of géstation
Os ilium	Corpus	R	49	36
		S	43	34
		A	35	31
		H	38 : 44	33 : 35
Os ischii	Corpus	R	58	38
		S	56	37
		A	49	36
		H	63 : 66	39 : 40
Os pubis	Corpus	R	112	54
		S	112	54
		A	108	53
		H	112	54
Femur	Corpus	R	35	31
		S	29	30
		A	25	28
		H	29 : 38	30 : 33
Tibia	Corpus	R	35	31
		S	29	30
		A	25	28
		H	29 : 38	30 : 33
Fibula	Corpus	R	49	36
		S	29	30
		A	25	28
		H	29 : 38	30 : 33
Ossa tarsi		R	112	54
Talus	Corpus	S	112	54
		A	112	54
		H	112	54

contd. ...

TABLE - OSSA MEMBRI PELVINI (contd.):

Bone	Centre	Method	C.R. length mm.	Day of gestation
Calcaneus	Corpus	R	91	47
		S	84	44
		A	84	44
		H	85 : 90	44 : 46
Ossa metatarsalia		R	49	36
II - V	Corpus	S	56	37
		A	43	34
		H	44 : 58	34 : 38
Ossa digitorum		R	66, 66, 66, 73	40, 40, 40, 41
Pedis II III		S	73, 69, 69, 83	41, 40, 40, 43
IV V		A	69, 69, 69, 82	40, 40, 40, 43
Phalanx proximalis	Corpus	H	63 : 84	39 : 44
Phalanx media		R	73, 73, 73, 78	41, 41, 41, 42
		S	83, 73, 83, 83	43, 41, 43, 43
		A	82	43
		H	63 : 84	39 : 44
Phalanx distalis		R	66, 66, 66, 73	40, 40, 40, 41
		S	56	37
		A	49	36
		H	43 : 63	34 : 39

R = Radiography of foetus
S = Radiography of foetus impregnated with silver nitrate
A = Alizarin red staining of foetus
H = Histology

AXIAL SKELETON

Bone	Centre	Method	C.R. length mm.	Day of gestation
Vertebrae Cervicales III - VII	Centrum	R	49	36
		S	56	37
		A	39	33
		H	44 ; 63	35 : 39
	Laminae	R	49	36
		S	43 to 56	34 to 37
		A	44	35
		H	44 : 63	35 : 39
Atlas	Laminae	R	49	36
		S	43	34
		A	35	31
		H	44 : 63	35 : 39
	Ventral body (Arch)	R	105	51
		S	105	51
		A	92	47
		H	-	-
Axis	Laminac	R	49	36
		S	43	34
		A	39	33
		H	44 : 63	35 : 39
	Centrum	R	49	36
		S	56	37
		A	39	33
		H	44 : 63	35 : 39
	Rostral body (Dens)	R	84	44
		S	84	44
		A	82	43
		H	-	-
Vertebrae Thoracicae	Centrum	R	49	36
		S	43 to 56	34 to 37
		A	35 to 39	31 to 33
		H	44 : 63	35 : 39
	Laminae	R	49	36
		S	56	37
		A	39	33
		H	44 : 63	35 : 39

contd......

TABLE - AXIAL SKELETON (contd.):

Bone	Centre	Method	C.R. length mm.	Day of gestation
Vertebrae Lumbales	Centrum	R	49	36
		S	43 to 56	34 to 37
		A	39	33
		H	44 : 63	35 : 39
	Laminae	R	49	36
		S	56	37
		A	43	34
		H	44 : 63	35 : 39
Vertebrae Sacrales	Centrum	R	49 to 66	36 to 40
		S	56 to 67	37 to 40
		A	49 to 66	36 to 40
		H	44 : 63	35 : 39
	Laminae	R	49 to 66	36 to 40
		S	67	40
		A	66	40
		H	44 : 63	35 : 39
	Ventral body	R	130	58
		S	121	56
		A	108	52
		H	-	-
Vertebrae Caudales (Coccygeae)	Centrum	R	58	38
		S	43	34
		A	55	36
		H	-	-
	Laminae	R	73	41
		S	67	40
		A	66	40
		H	-	-
	Os Arcus Haemalis	R		Post-partum
		S	108	53
		A	84	44
		H	-	-

contd. ...

TABLE - AXIAL SEKELETON (contd.):

Bone	Centre	Method	C.R. length mm.	Day of gestation
Costae	Corpus	R	38 to 39	33 to 36
		S	35	31
		A	35	31
		H	35 : 38	31 : 33
Sternum	Corpus	R	58 to 66	38 to 40
		S	56 to 66	37 to 40
		A	49 to 66	36 to 40
		H	44 : 63	35 : 39

R = Radiography of foetus
S = Radiography of foetus impregnated with silver nitrate
A = Alizarin red staining of foetus
H = Histology

OSSA FACIEI

Bone	Centre	Method	C.R. length mm.	Day of gestation
Maxilla	Centre	R	35	31
		S	29	30
		A	25	28
Os Incisivum	Centre	R	38	33
		S	29	30
		A	26	28
Os Palatinum	Centre	R	39	33
		S	29	30
		A	29	30
Os Zygomaticum	Centre	R	49	36
		S	29	30
		A	26	28
Mandibula	Centre	R	35	31
		S	29	30
		A	25	28

R = Radiography of foetus
S = Radiography of foetus impregnated with silver nitrate
A = Alizarin red staining of foetus

OSSA CRANII

Bone	Centre	Method	C.R. length mm.	Day of gestation
Os Occipitale	Basioccipital	R	49	36
		S	56	37
		A	39	33
	Exoccipital	R	49	36
		S	56	37
		A	39	33
	Supraoccipital	R	49	36
		S	43	34
		A	39	33
Os Inter-parietale	Centre	R	49	36
		S	43	34
		A	39	33
Os Basi-sphenoidale	Corpus	R	105	51
		S	84	44
		A	66	40
	Ala	R	49	36
		S	43	34
		A	44	35
Os Prae-sphenoidale	Corpus	R	105	51
		S	84	44
		A	82	43
	Ala	R	66	40
		S	63	39
		A	58	38
Os pterygoideum	Centre	R	56	37
		S	35	31
		A	35	31

contd. ...

TABLE - OSSI CRANII (contd.):

Bone	Centre	Method	C.R. length mm.	Day of gestation
Os Temporale Pars Squamosa	Centre	R	49	36
		S	43	34
		A	35	31
Pars Tympanica	Ectotympanic	R	58	38
		S	43	34
		A	39	33
Pars Petrosa	4 Centres	R	112	54
		S	84	44
		A	84 to 94	44 to 48
Os Parietale	Centre	R	58	38
		S	56	37
		A	35	31
Os Frontale	Centre	R	38	33
		S	31	30
		A	25	28
Os Lacrimale	Centre	R	85	45
		S	84	43
		A	35	31
Os Nasale	Centre	R	49	36
		S	43	34
		A	35	31
Vomer	Centre	R	49	36
		S	31	30
		A	35	31

R = Radiography of foetus
S = Radiography of foetus impregnated with silver nitrate
A = Alizarin red staining of foetus

TABLE 5.

COMPARISON OF GROUPS A AND B FOR C.R. LENGTHS AND ESTIMATED AGE

TABLE 5

COMPARISON OF C.R.LENGTH, KNOWN AGE & ESTIMATED AGE USING C.R.LENGTHS.

LITTER	C.R. mm.	DAYS SINCE COITUS	ESTIMATED AGE (DAYS)
I	29 - 33.2	31	30
II	40	34	33
III	41	38	34
IV	60.1	40	38
V	80 - 84.3	45	42-44
VI	85 - 91	49	44-49
VII	110	56	53
VIII	116 -123	60	56
IX	140	65	61
X	135.5-139	66	61

TABLE 6.

COMPARISON OF GROUPS A AND B FOR TIMES OF APPEARANCE OF CENTRES OF OSSIFICATION

APPENDICULAR SKELETON

Ossa membri thoracici

Clavicula

No disparity detected
(N. D. D.)

Scapula

Corpus	Group A	C.R. 35 mm.	+ ve	Alizarin
Corpus	Group B	C.R. 29-32 mm.	+ ve	Alizarin
Corpus	Group A	C.R. 58 mm.	+ ve	X-Ray Pregnant Female
Corpus	Group B	C.R. 60.1 mm.	- ve	X-Ray Pregnant Female

Humerus

Corpus	Group A	C.R. 58 mm.	+ ve	X-Ray Pregnant Female
Corpus	Group B	C.R. 60.1 mm.	- ve	X-Ray Pregnant Female

Radius

N. D. D.

Ulna

N. D. D.

Carpus

N.D.D.

Metacarpus

Corpus V	Group A	C.R. 43 mm.	- ve	Alizarin
Corpus C	Group B	C.R. 41 mm.	+ ve	Alizarin

Manus Digits II-V.

Phalanx proximalis.

Corpus II, III and V	Group A	C.R. 63, 63,66 mm.	+ ve	Alizarin
Corpus II, III and V	Group B	C.R. 60.1 mm.	+ ve	Alizarin
Corpus II, III and IV	Group A	C.R. 66, 66, 66 mm.	+ ve	X-Ray
Corpus II, III and IV	Group B	C.R. 60.1 mm.	+ ve	X-Ray

Phalanx media

N. D. D.

Phalanx distalis

Corpus V	Group A	C.R. 43 mm.	+ ve	Alizarin
Corpus V	Group B	C.R. 41 mm.	+ ve	Alizarin

Manus Digit I.

N. D. D.

Ossa membri pelvini

Os ilium

Corpus	Group A	C.R. 43 mm.	+ ve	Silver Nitrate
Corpus	Group B	C.R. 40 mm.	+ ve	Silver Nitrate

Os ischium

Corpus	Group A	C.R. 58 mm.	+ ve	X-Ray
Corpus	Group B	C.R. 60.1 mm.	- ve	X-Ray

Os pubis

N. D. D.

Femur

Corpus	Group A	C.R. 58 mm.	+ ve	X-Ray Pregnant Female
Corpus	Group B	C.R. 60.1 mm.	+ ve	X-Ray Pregnant Female

Tibia

N. D. D.

Fibula

N. D. D.

Tarsus

Calcaneus

Corpus	Group A	C.R. 84 mm.	+ ve	Silver Nitrate
Corpus	Group B	C.R. 80·43 mm.	-ve + ve	Silver Nitrate
Calcaneus Body	Group A	C.R. 91 mm.	+ ve	X-Ray
Calcaneus Body	Group B	C.R. 85-91 mm.	- ve	X-Ray

Talus

N. D. D.

Metatarsus

Corpus	Group A	C.R. 43 mm.	+ ve	Alizarin
Corpus	Group B	C.R. 41 mm.	+ ve	Alizarin

Pes Digits II-V.

Phal. prox. et med.

N. D. D.

<u>Phalanx distalis</u>

Corpus II - V	Group A	C.R. 49 mm.	+ ve	Alizarin
Corpus	Group B	C.R. 41 mm.	+ ve	Alizarin

AXIAL SKELETON

Costae

Corpus	Group A	C.R. 35 mm.	+ ve Alizarin
Corpus	Group B	C.R. 29-32 mm.	+ ve Alizarin

Sternum

Corpus	Group A	C.R. 58 mm.	+ ve X-Ray
Corpus	Group B	C.R. 60.1 mm.	- ve X-Ray
Corpus	Group A	C.R. 109 mm.	+ ve X-Ray Pregnant Female
Corpus	Group B	C.R. 110 mm.	- ve X-Ray Pregnant Female

Vertebrae cervicales III - VII

N. D. D.

Atlas

Laminae	Group A	C.R. 43 mm.	+ ve Silver Nitrate
Laminae	Group B	C.R. 40 mm.	+ ve Silver Nitrate
Ventral Body (Arch)	Group A	C.R. 105 mm.	+ ve + ve Silver Nitrate
Ventral Body (Arch).	Group B	C.R. 80-84.3 mm.	+ve −ve Silver Nitrate (2 foetuses examined)
Ventral Body (Arch)	Group A	C.R. 105 mm.	+ ve Silver Nitrate
Ventral Body (Arch)	Group B	C.R. 85-91 mm.	+ ve Silver Nitrate
Ventral Body (Arch)	Group A	C.R. 105 mm.	+ ve X-Ray
Ventral Body (Arch)	Group B	C.R. 85-91 mm.	+ ve X-Ray

Vertebrae thoracicae, lumbales, sacrales et caudales.

N. D. D.

SKULL

Ossa Faciei

Maxilla

Centre	Group A	C.R. 58 mm.	+ ve	X-Ray Pregnant Female
Centre	Group B	C.R. 60.1 mm.	- ve	X-Ray Pregnant Female

Os incisivum

N. D. D.

Os palatinum

N. D. D.

Os zygomaticum

N. D. D.

Mandibula

Centre	Group A	C.R. 58 mm.	+ ve	X-Ray Pregnant Female
Centre	Group B	C.R. 60.1 mm.	- ve	X-Ray Pregnant Female

Ossa Cranii

Os occipitale

Basioccipital

Centre	Group A	C.R. 39 mm.	+ ve	Alizarin
Centre	Group B	C.R. 41 mm.	- ve	Alizarin

Exoccipital

N. D. D.

Supraoccipital

Centre	Group A	C. R. 39 mm.	+ ve	Alizarin
Centre	Group B	C.R. 41mm.	- ve	Alizarin

Os interparietal

N. D. D.

Os basisphenoidale

Corpus	Group A	C.R. 66 mm.	+ ve	Alizarin
Corpus	Group B	C.R. 60.1 mm.	+ ve	Alizarin
Alae	Group A	C.R. 44 mm.	+ ve	Alizarin
Alae	Group B	C.R. 41mm.	+ ve	Alizarin

Os praesphenoidale

Corpus	Group A	C.R. 82 mm.	+ ve	Alizarin
Corpus	Group B	C.R. 60.1 mm.	+ ve	Alizarin

Alae

N. D. D.

Os pterygoideum

Centre	Group A	C.R. 35 mm.	+ve	Alizarin
Centre	Group B	C.R. 24-32 mm.	+ ve	Alizarin

Os temporale

Pars squamosa

Centre	Group A	C.R. 35 mm.	+ ve	Alizarin
Centre	Group B	C.R. 29-32 mm.	+ ve	Alizarin

Pars tympanica

N. D. D.

Pars petrosa

4 Centres	Group A	C.R. 112 mm.	+ ve	X-Ray
4 Centres	Group B	C.R. 110 mm.	+ve	X-Ray

Os parietale

Centre	Group A	C.R. 58 mm.	+ ve	X-Ray Pregnant Female
Centre	Group B	C.R. 60.1 mm.	- ve	X-Ray Pregnant Female

Os Frontale

Centre	Group A	C.R. 58 mm.	+ ve	X-Ray Pregnant Female
Centre	Group B	C.R. 60.1 mm.	- ve	X-Ray Pregnant Female

Os lacrimale

N. D. D.

Os nasale

N. D. D.

Vomer

Centre	Group A	C.R. 35 mm.	+ ve	Alizarin
Centre	Group B	C.R. 29-32 mm.	+ ve	Alizarin

FIG. GI.

RADIOGRAPHY OF FOETUS

FORELIMB

In Figs. GI-7 there is recorded in chart form, the state of development of the skeleton at all stages of gestation from 25 days or 20 mm. C.R. length onward until full term or 150 mm. C. R. length as detected on radiographs of fresh specimens. Using the chart it is possible to take a specific day of gestation which is marked on the horizontal axis and by tracing vertically, to determine which bony elements would be present at that particular time. Conversely, if a specific C.R. length is taken on the vertical axis and a line drawn horizontally, then a determination of the state of development of the bony elements anticipated at that C.R. length can be made.

RADIOGRAPHY OF FOETUS FORELIMB

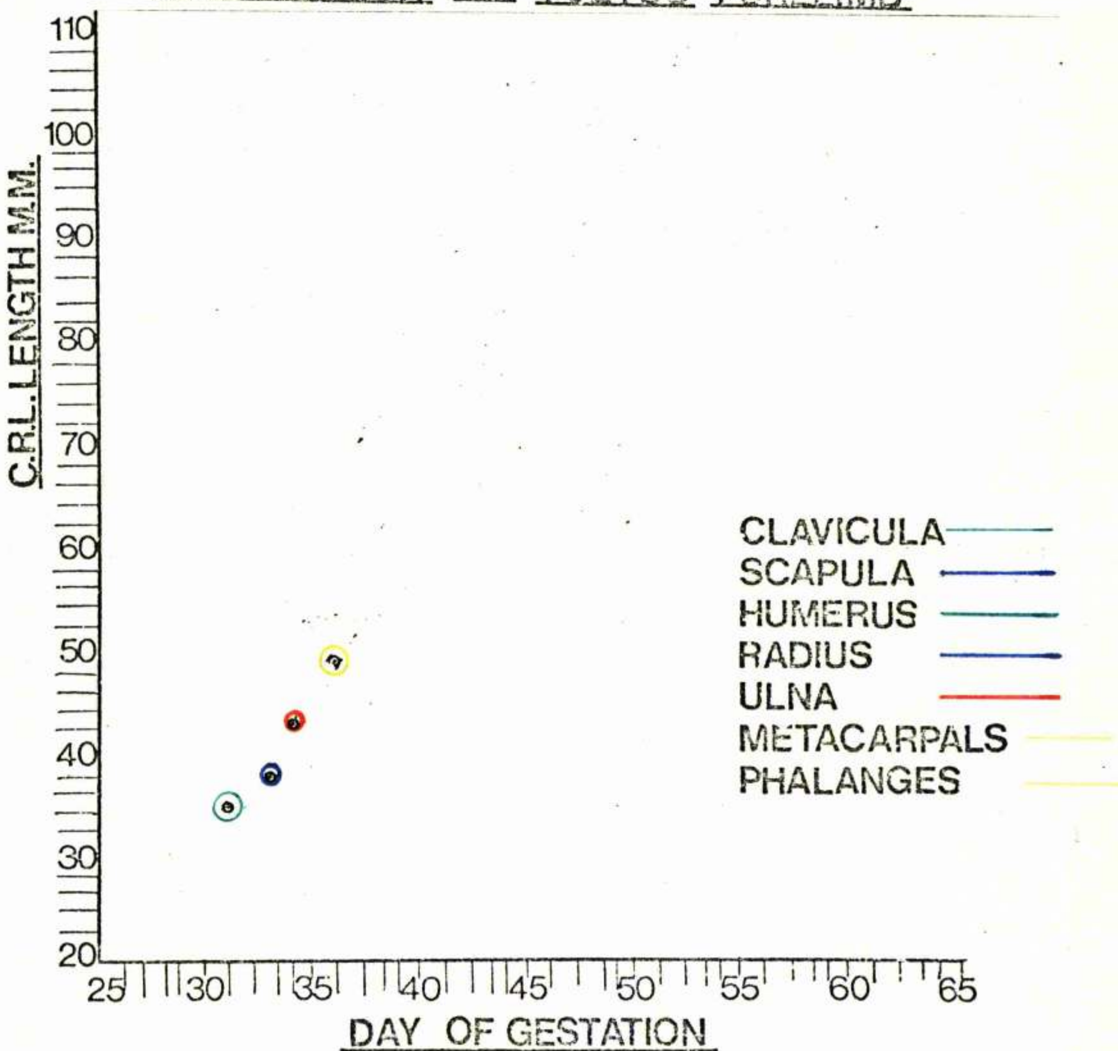
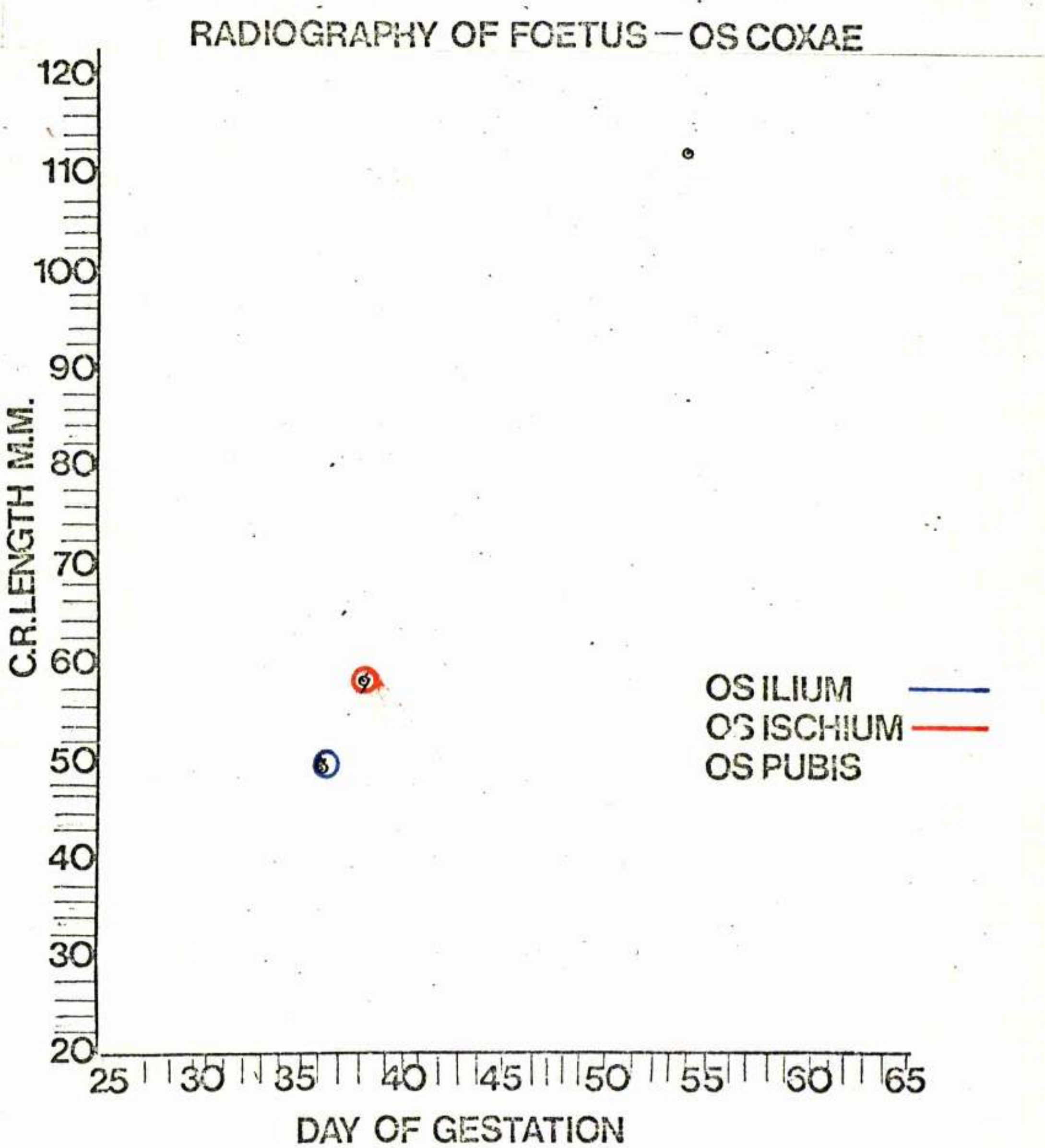


FIG. G2.

RADIOGRAPHY OF FOETUS

OS COXAE



RADIOGRAPHY OF FOETUS — OS COXAE
C.R.LENGTH M.M.
120
110
100
90
80
70
60
50
40
30
20
25
30
35
40
45
50
55
60
65
DAY OF GESTATION
OS ILIUM
OS ISCHIUM
OS PUBIS

FIG. G3.

RADIOGRAPHY OF FOETUS

HINDLIMB

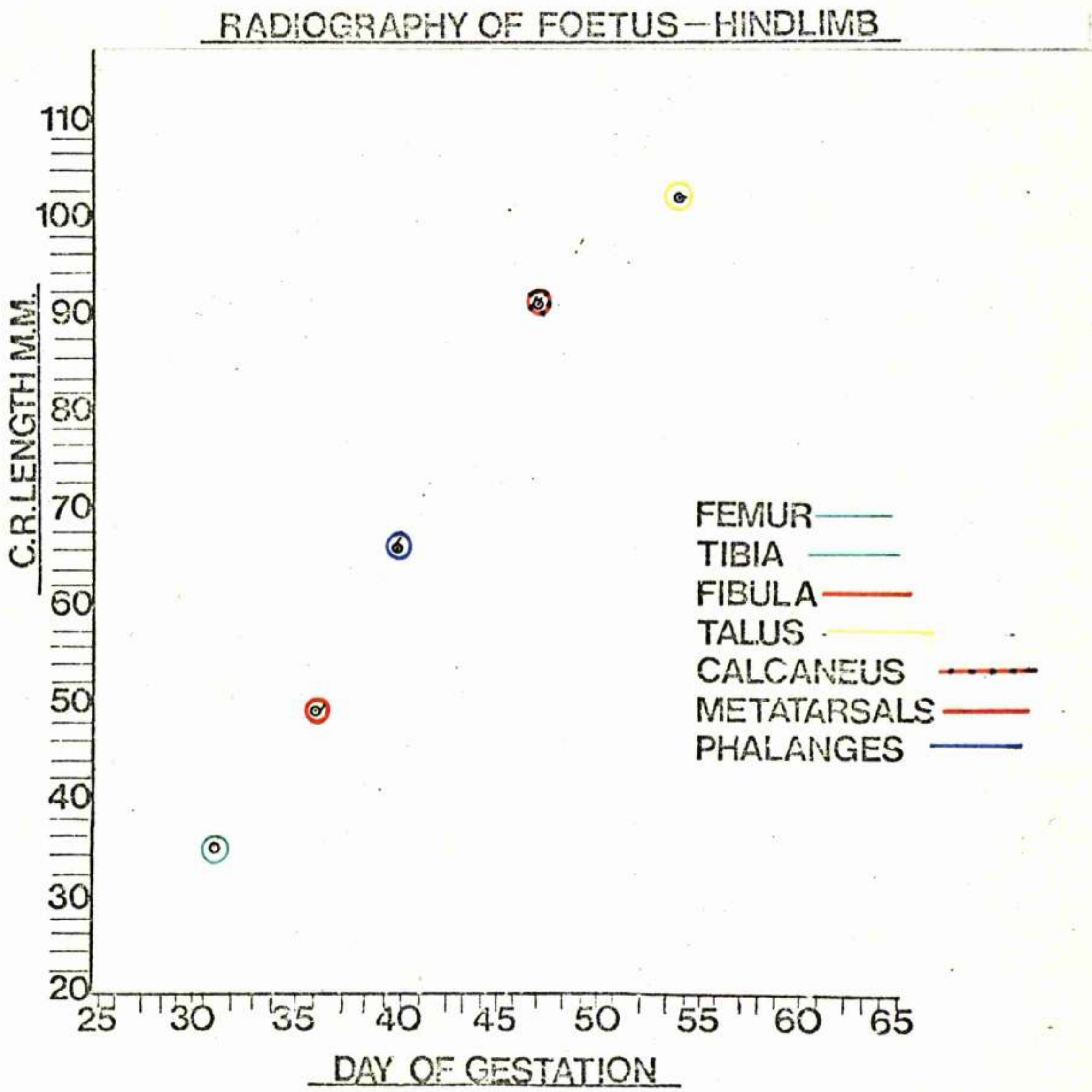

RADIOGRAPHY OF FOETUS—HINDLIMB
C.R.LENGTH M.M.
110
100
90
80
70
60
50
40
30
20
25
30
35
40
45
50
55
60
65
DAY OF GESTATION
FEMUR
TIBIA
FIBULA
TALUS
CALCANEUS
METATARSALS
PHALANGES

FIG. G4.

RADIOGRAPHY OF FOETUS

AXIAL SKELETON

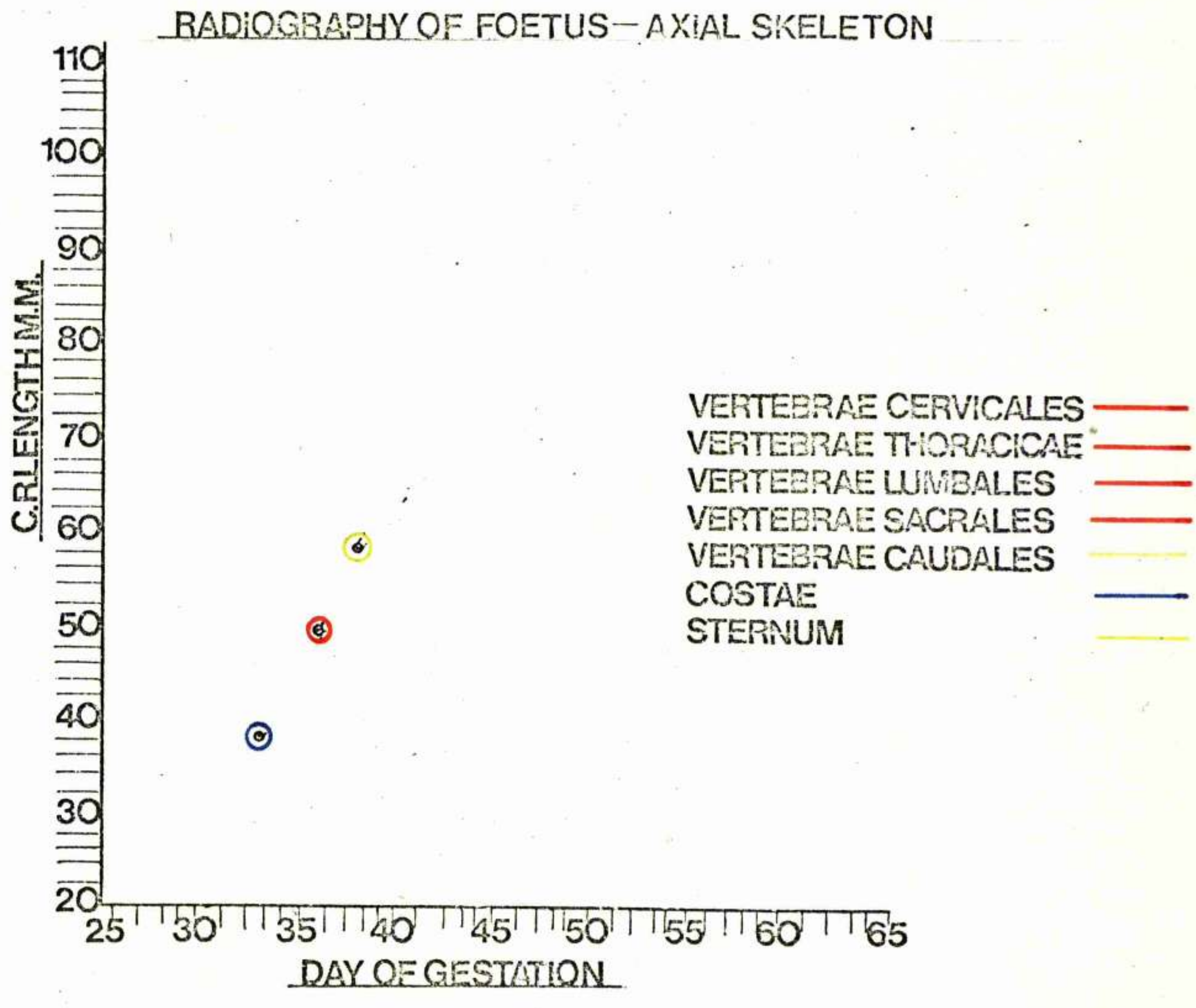
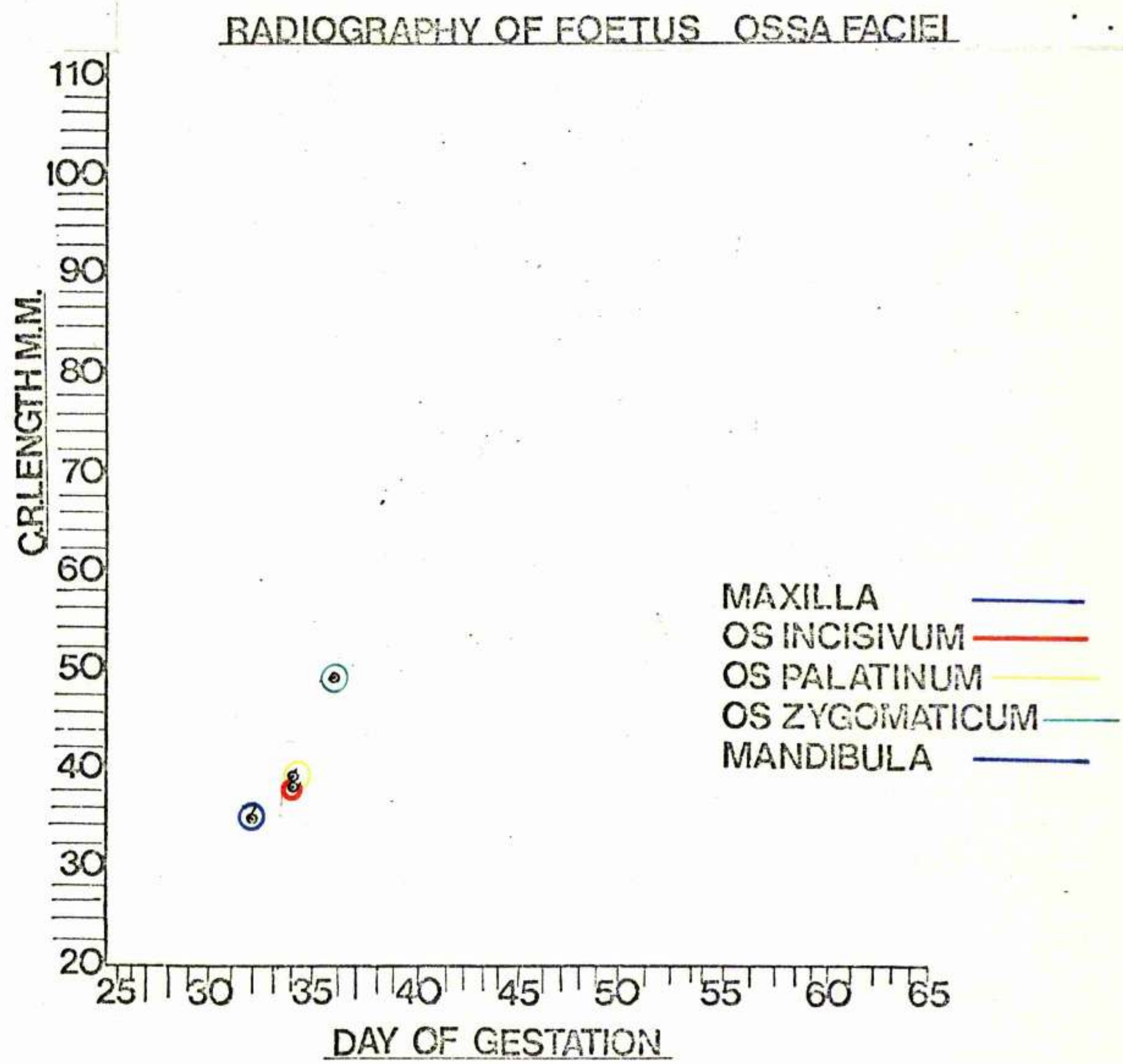

RADIOGRAPHY OF FOETUS—AXIAL SKELETON
C.R.LENGTH M.M.
110
100
90
80
70
60
50
40
30
20
25
30
35
40
45
50
55
60
65
DAY OF GESTATION
VERTEBRAE CERVICALES
VERTEBRAE THORACICAE
VERTEBRAE LUMBALES
VERTEBRAE SACRALES
VERTEBRAE CAUDALES
COSTAE
STERNUM

FIG. G5.

RADIOGRAPHY OF FOETUS

OSSA FACIEI



RADIOGRAPHY OF FOETUS OSSA FACIEI
C.R.LENGTH M.M.
110
100
90
80
70
60
50
40
30
20
25
30
35
40
45
50
55
60
65
DAY OF GESTATION
MAXILLA
OS INCISIVUM
OS PALATINUM
OS ZYGOMATICUM
MANDIBULA

FIG. G6.

RADIOGRAPHY OF FOETUS

OSSI CRANII

BRAIN CASE

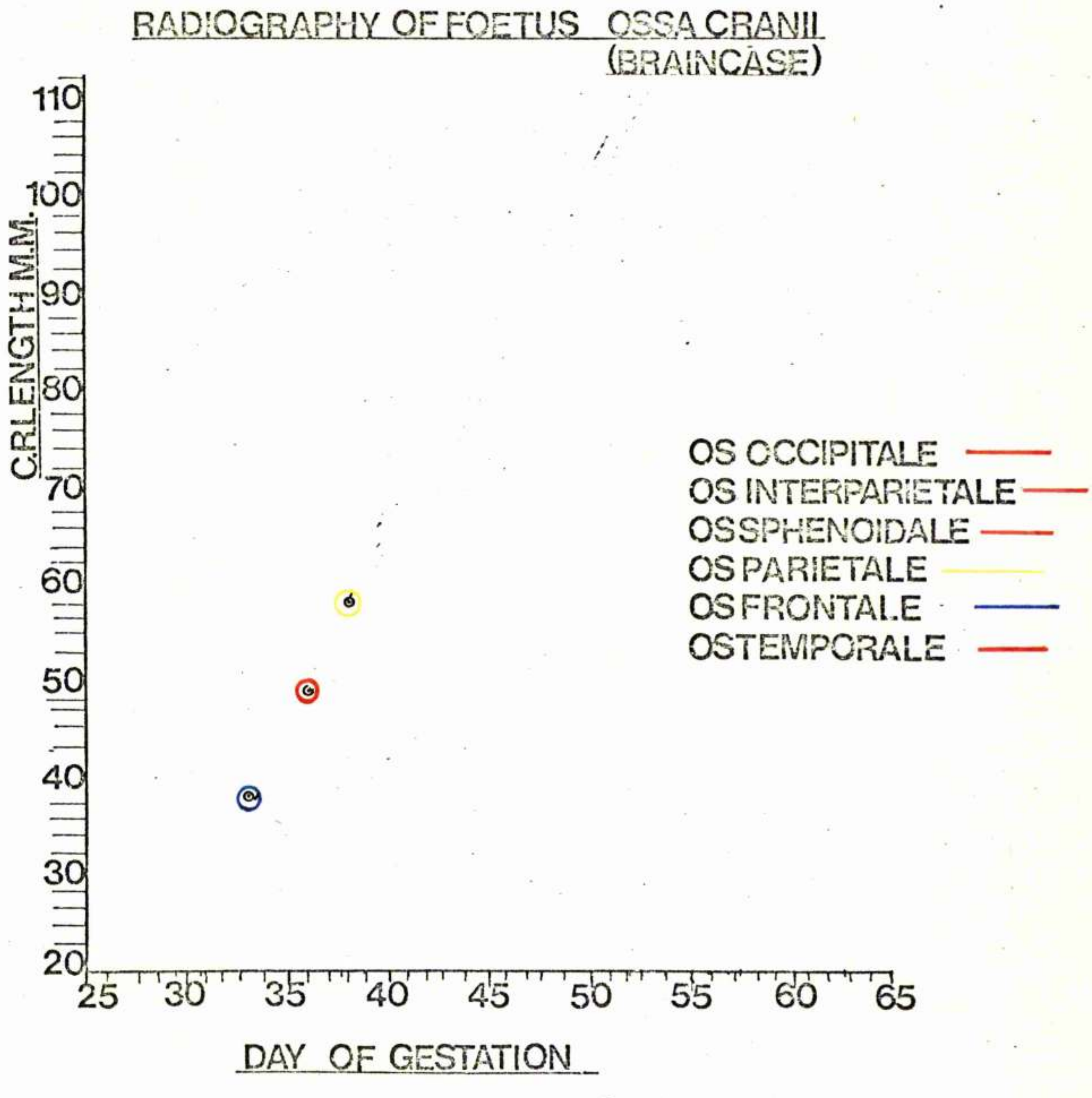
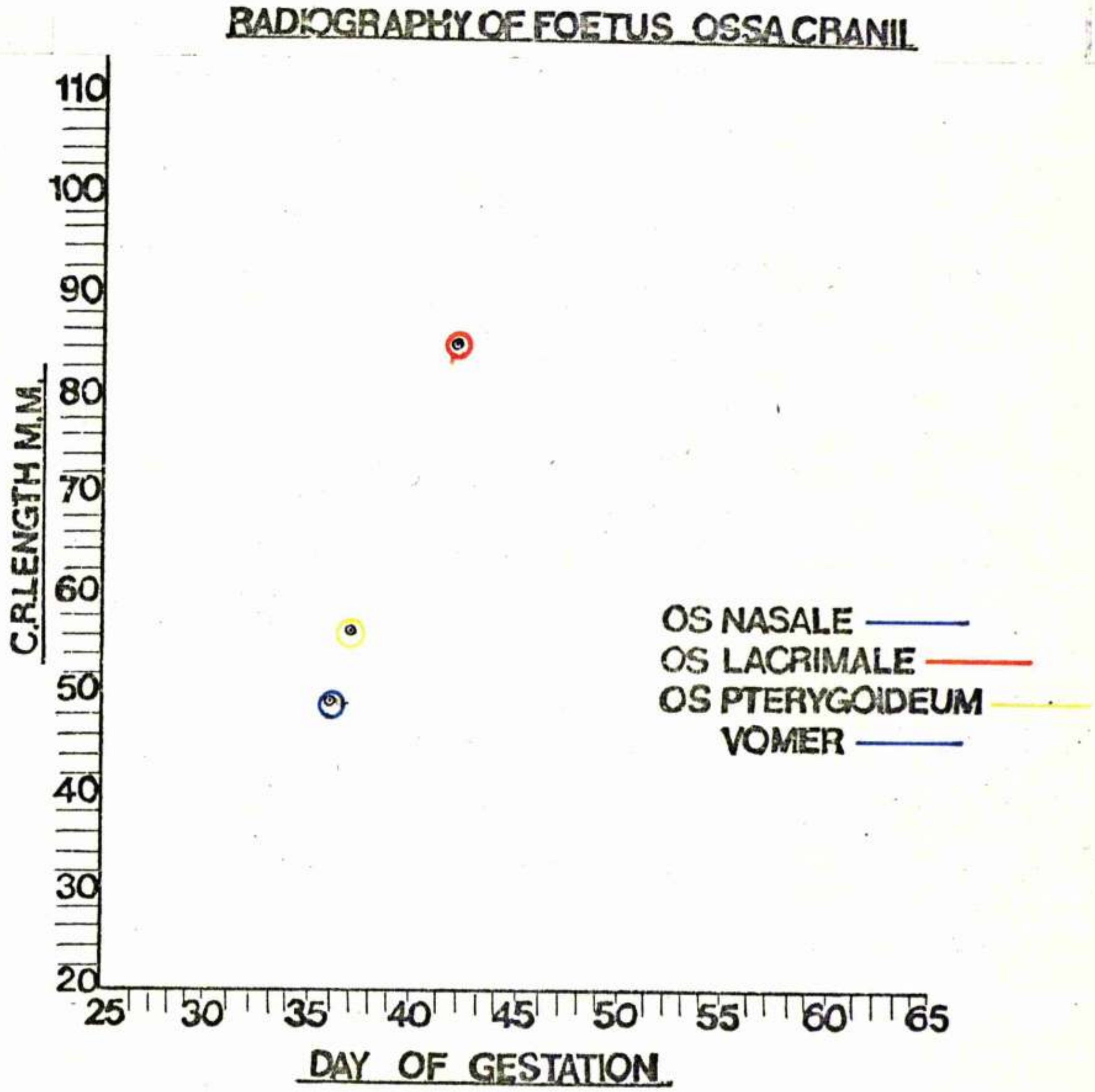

RADIOGRAPHY OF FOETUS OSSA CRANII
(BRAINCASE)
C.R.LENGTH M.M.
110
100
90
80
70
60
50
40
30
20
25
30
35
40
45
50
55
60
65
DAY OF GESTATION
OS OCCIPITALE
OS INTERPARIETALE
OS SPHENOIDALE
OS PARIETALE
OS FRONTALE
OS TEMPORALE

FIG. G7.

RADIOGRAPHY OF FOETUS

OSSI CRANII


RADIOGRAPHY OF FOETUS OSSA CRANII
C.R.LENGTH M.M.
110
100
90
80
70
60
50
40
30
20
25
30
35
40
45
50
55
60
65
DAY OF GESTATION
OS NASALE
OS LACRIMALE
OS PTERYGOIDEUM
VOMER

X - SERIES OF PLATES FOR RADIOGRAPHY OF FOETUSES

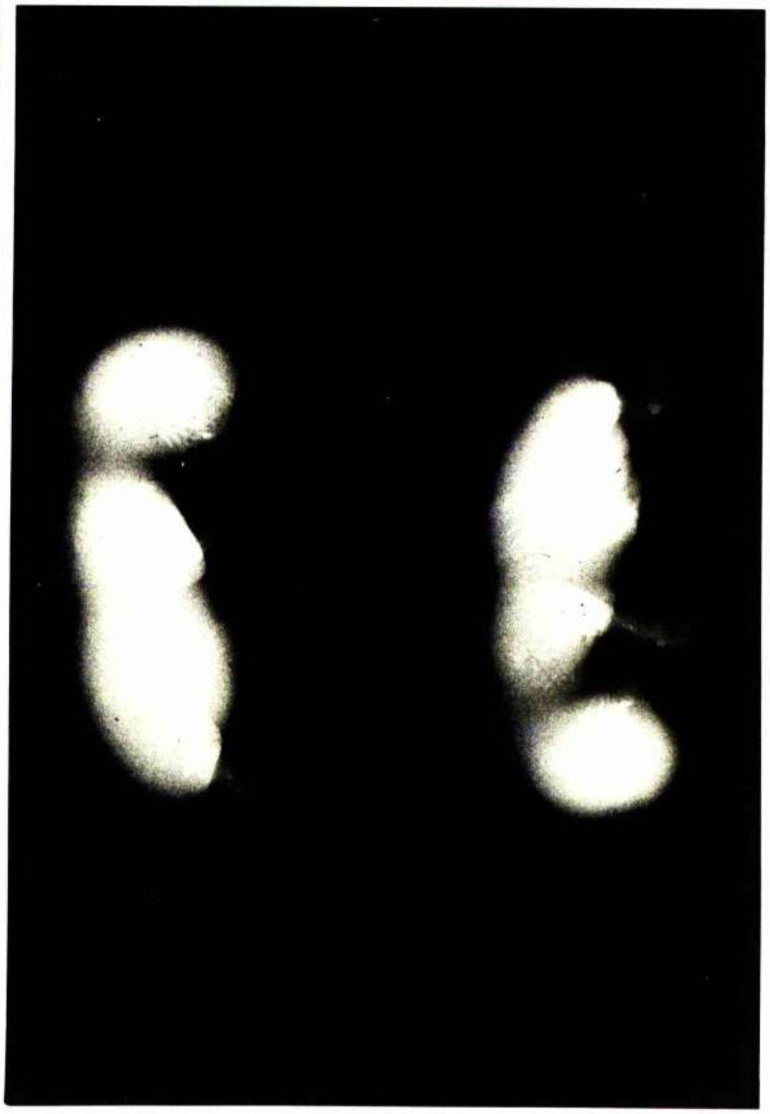


FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	LATERAL
XI	No.23	39.8mm.	33 days		

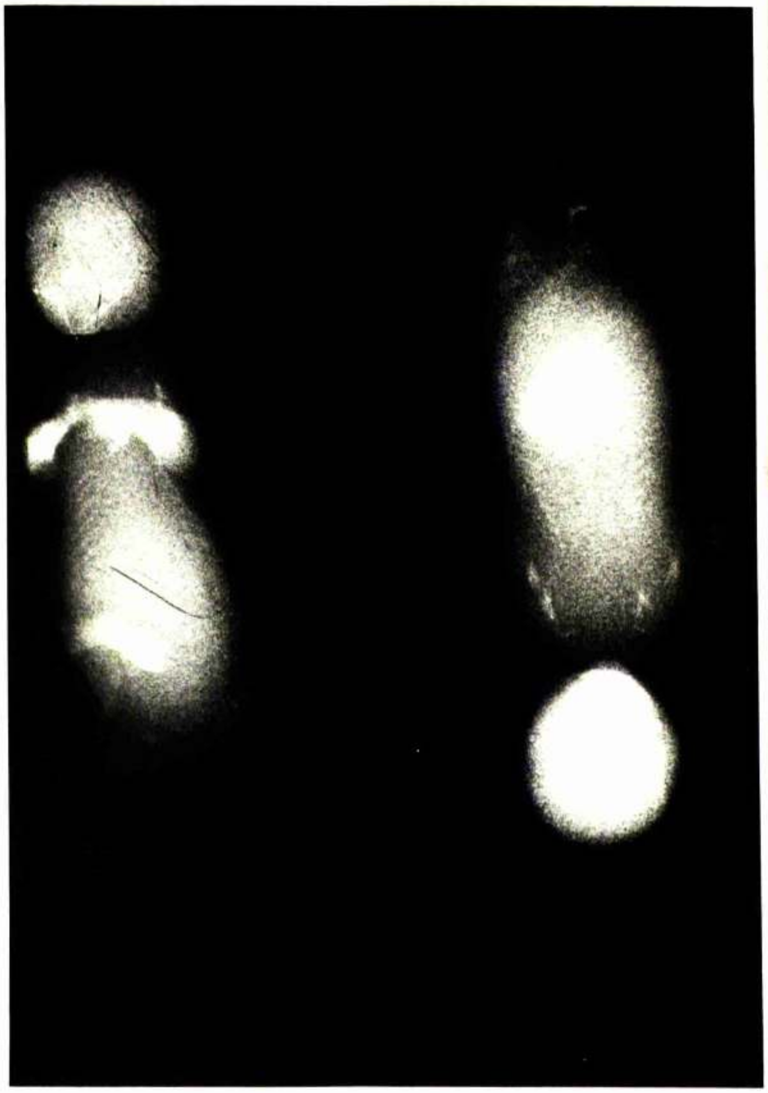


FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	DORSO VENTRAL
X2	No.23	39.8mm.	33 days		

FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	LATERAL
X3	No.37	73mm.	41 days		

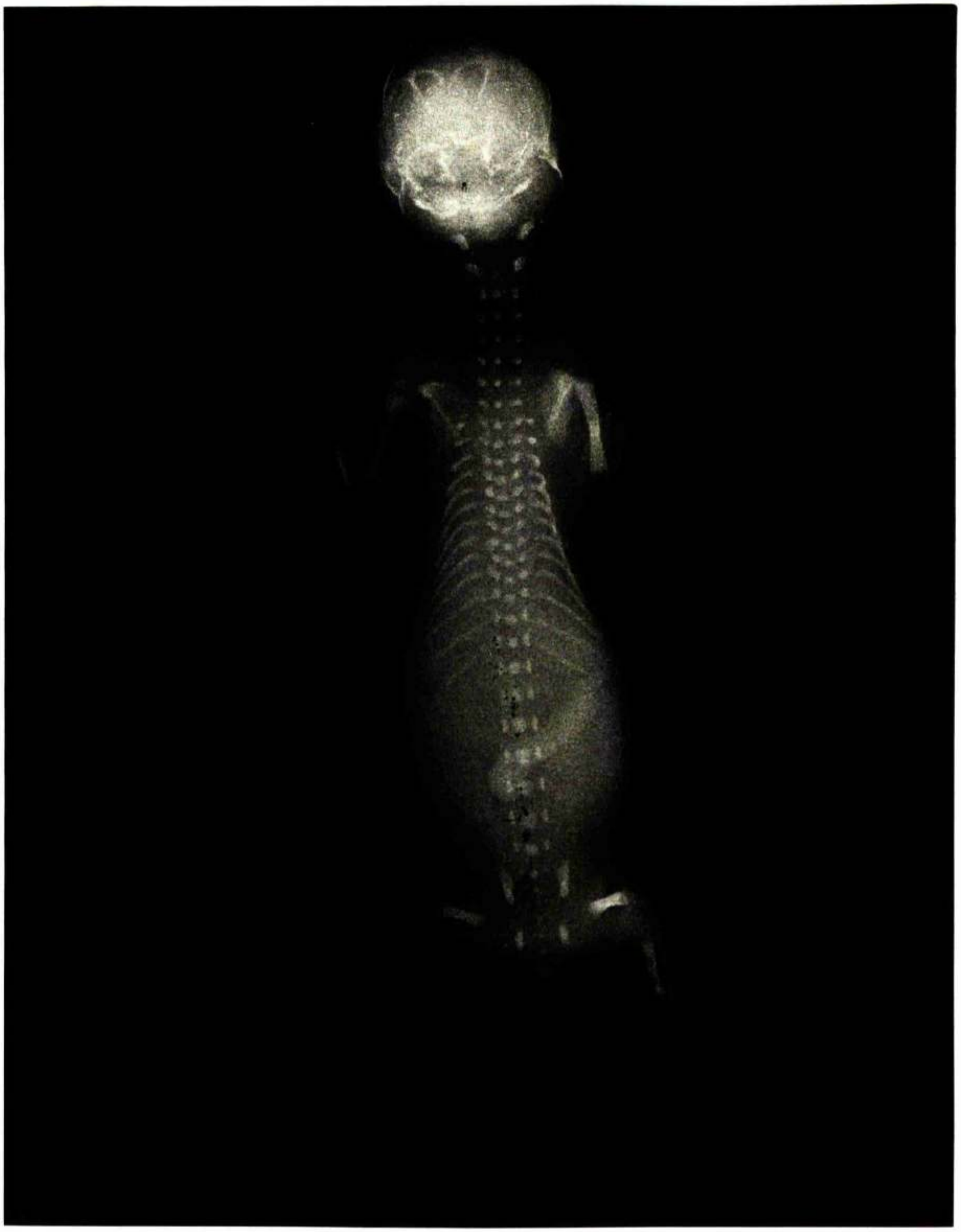


FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	DORSO VENTRAL
X4	No.37	73mm.	41 days		

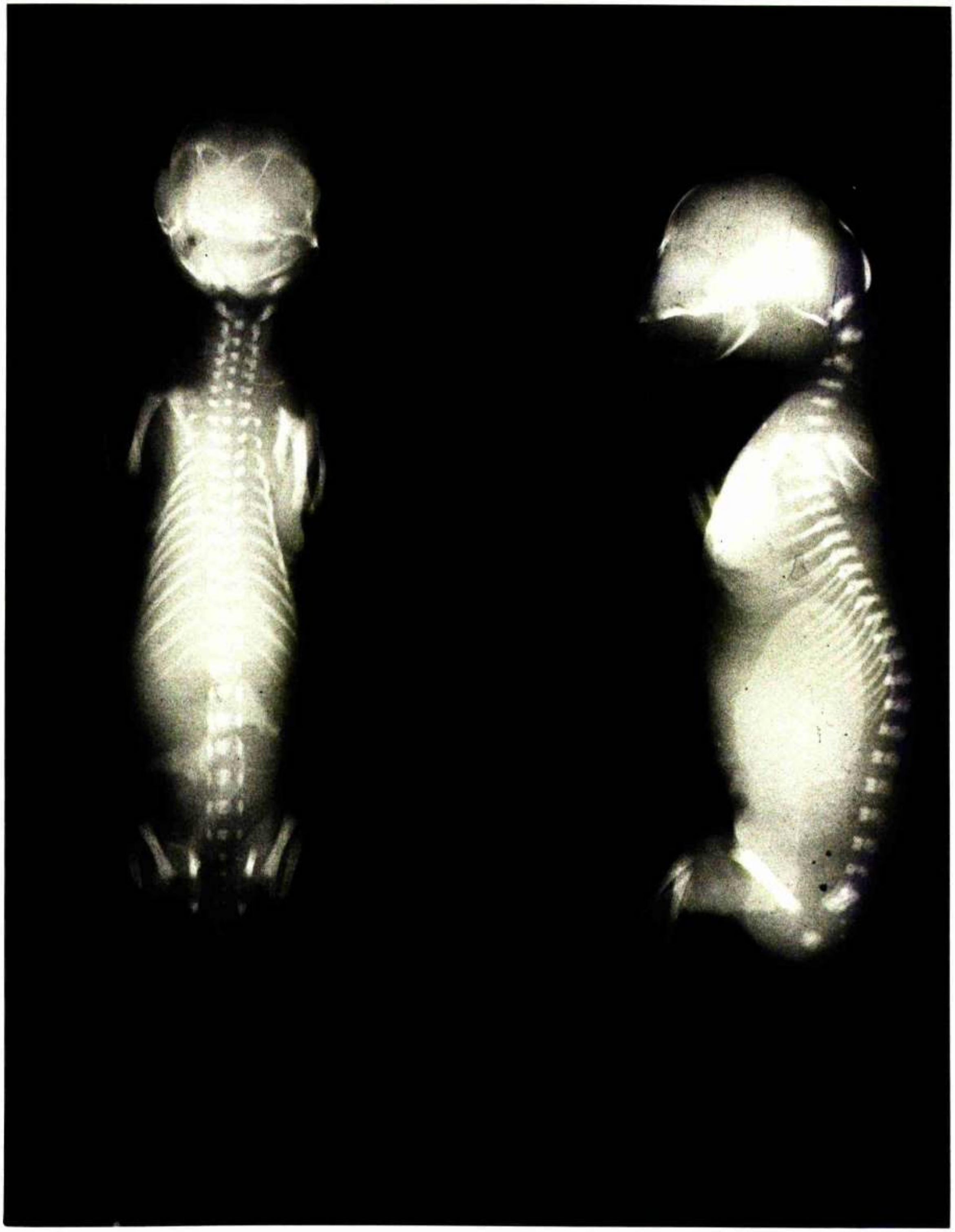


FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	LATERAL AND
X5	No.39	75mm.	41 days		DORSO VENTRAL

FIG. X6 — LITTER No.53 — C.R. 92mm. — ESTIMATED AGE 47 days — RADIOGRAPH — DORSO VENTRAL

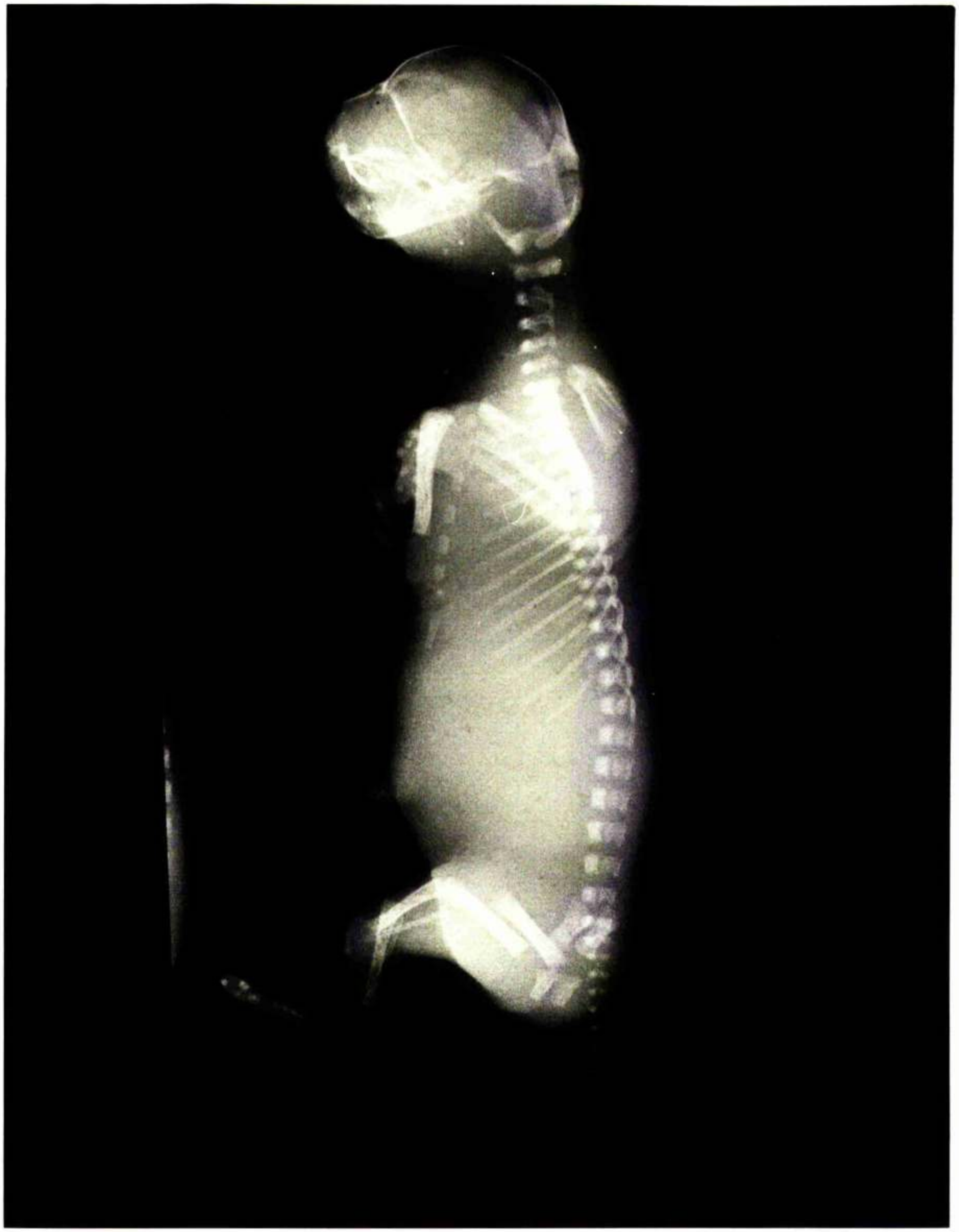


FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	LATERAL
X7	No.53	92mm.	47 days		

FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	DORSO VENTRAL
X8	No.78	133mm.	59 days		

FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	LATERAL
X9	No.78	133mm.	59 days		

FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	LATERAL
X10	No.84	——	at birth		

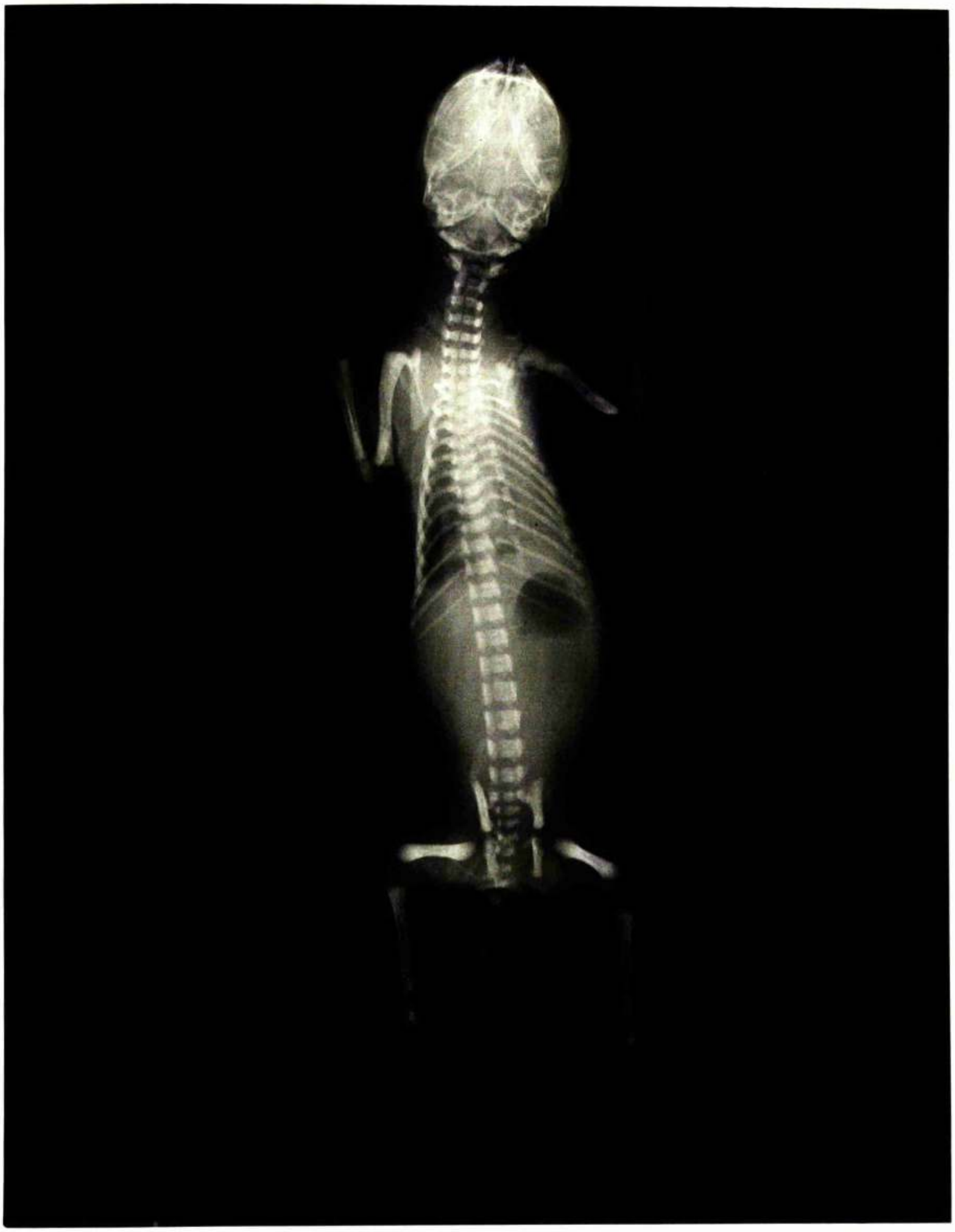


FIG.	LITTER	C.R.	ESTIMATED AGE	RADIOGRAPH	DORSO VENTRAL
Xll	No.84	-----	at birth		

Sn - SERIES OF PLATES FOR RADIOGRAPHY
OF FOETUSES IMPREGNATED WITH
SILVER NITRATE

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 1	No.13	29.1mm.	30 days	NITRATE	

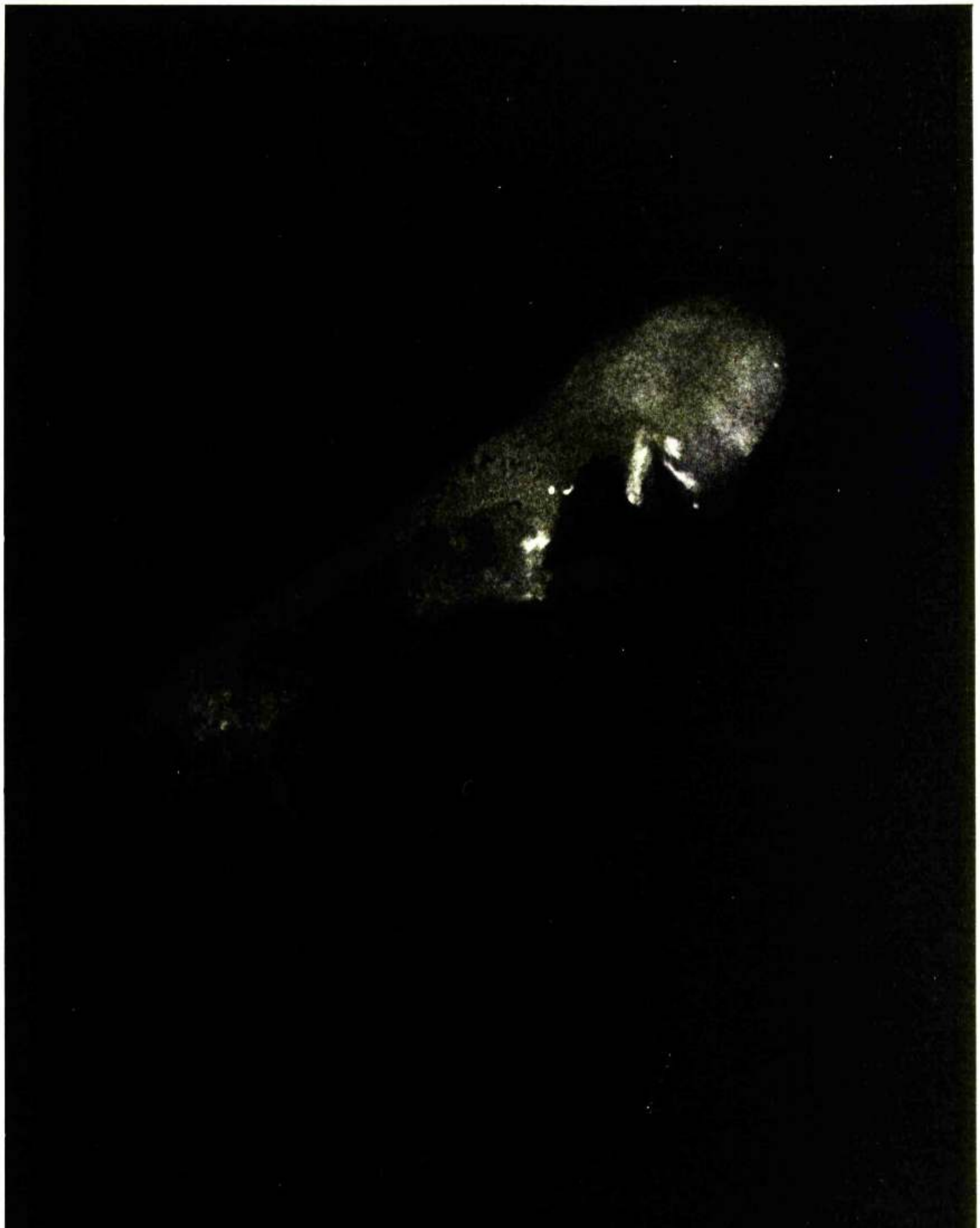


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 2	No.13	29.1mm.	30 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 3	No.15	31.2mm.	30 days	NITRATE	

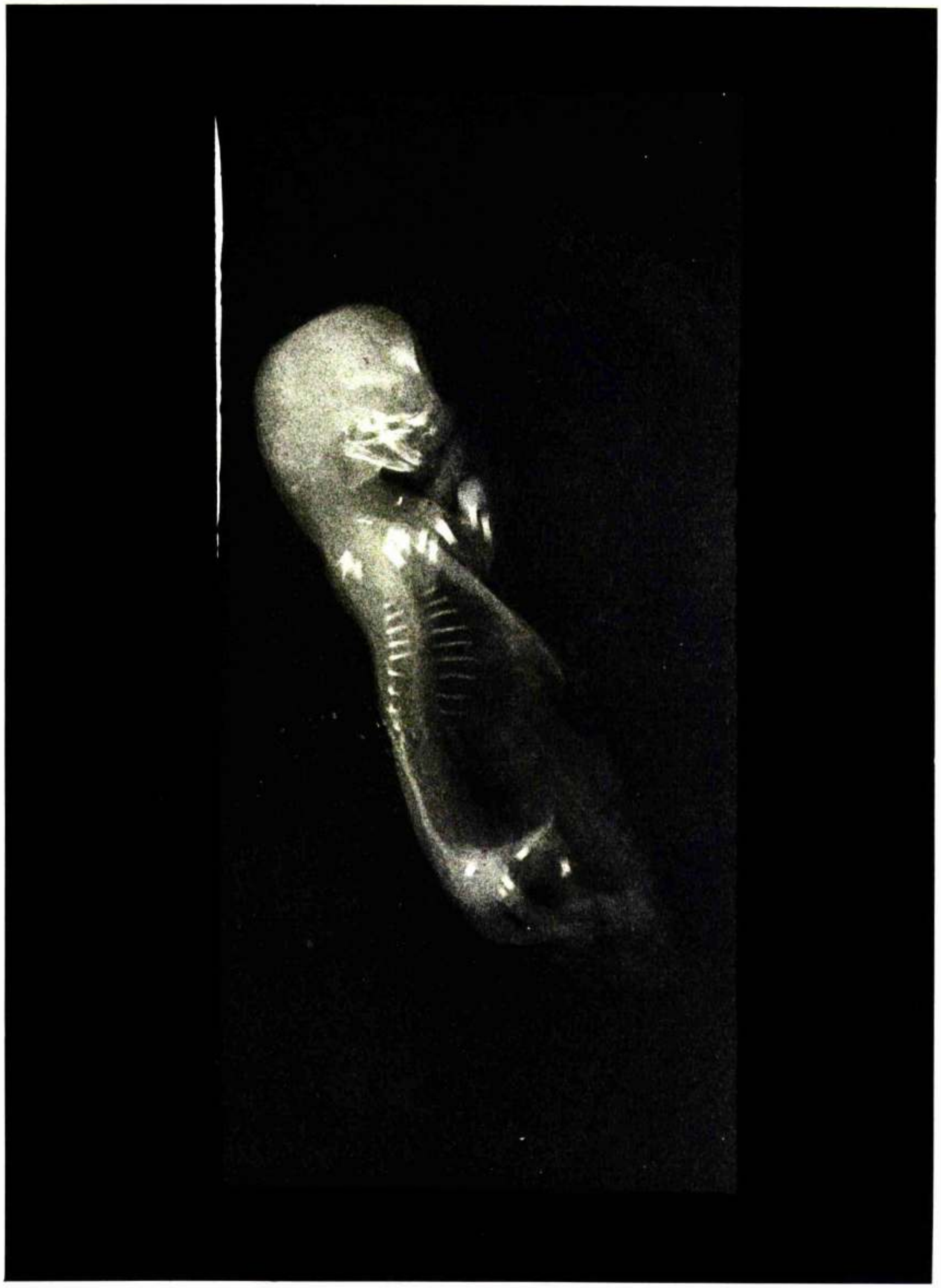


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 4	No.20	35mm.	31 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 5	No.20	35mm.	31 days	NITRATE	

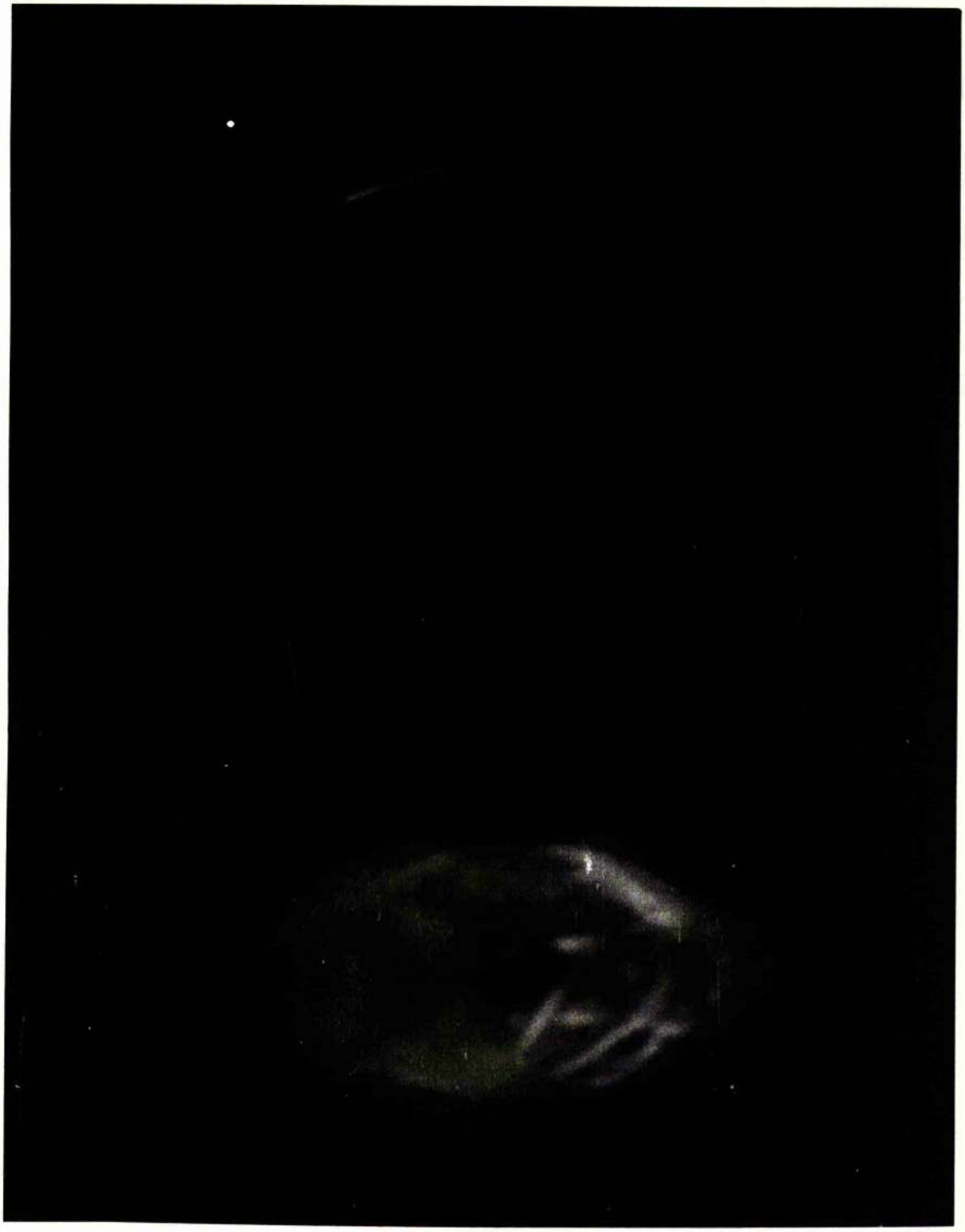


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 6	No.20	35mm.	31 days	NITRATE	HEAD

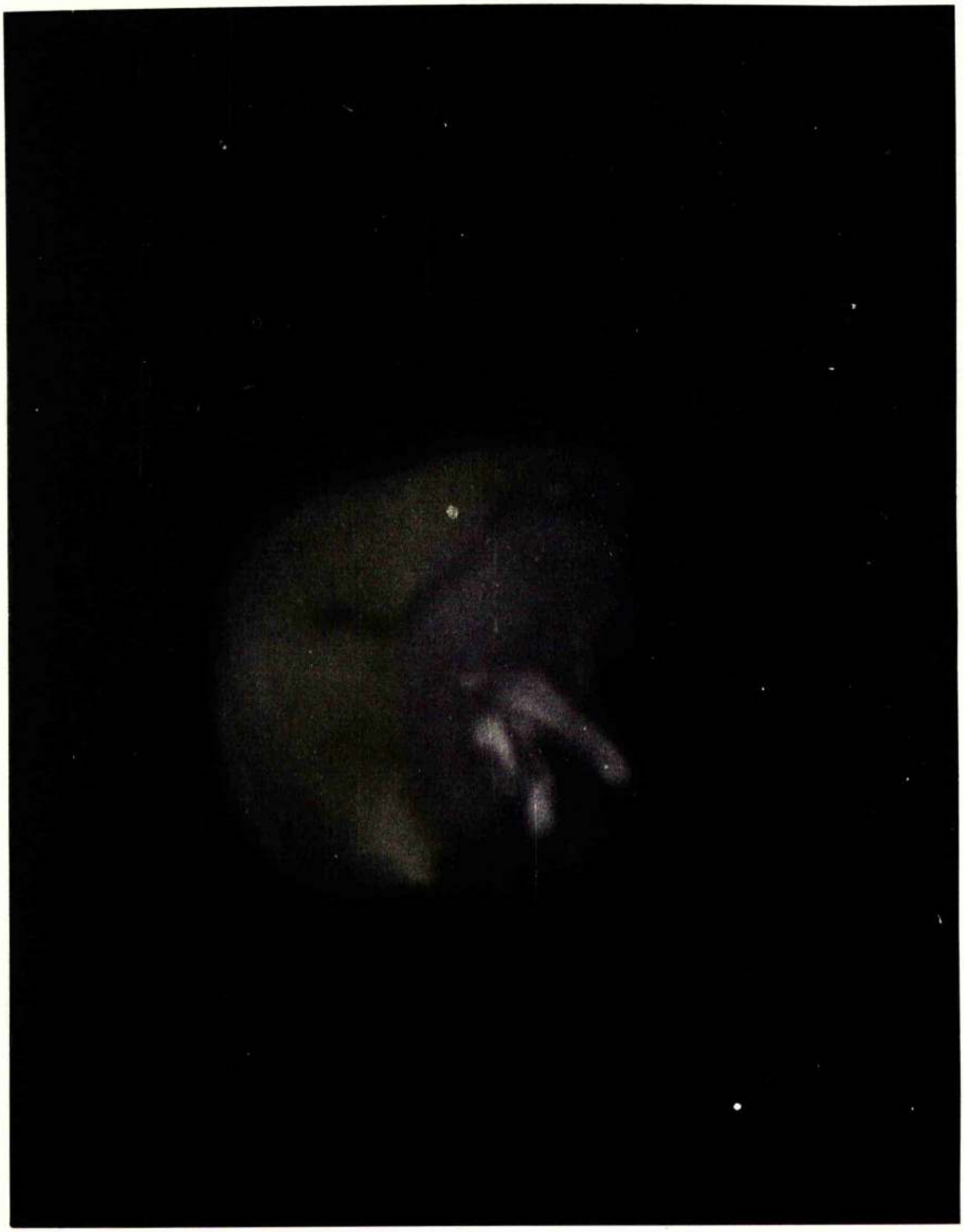


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 7	No.20	35mm.	31 days	NITRATE	HEAD

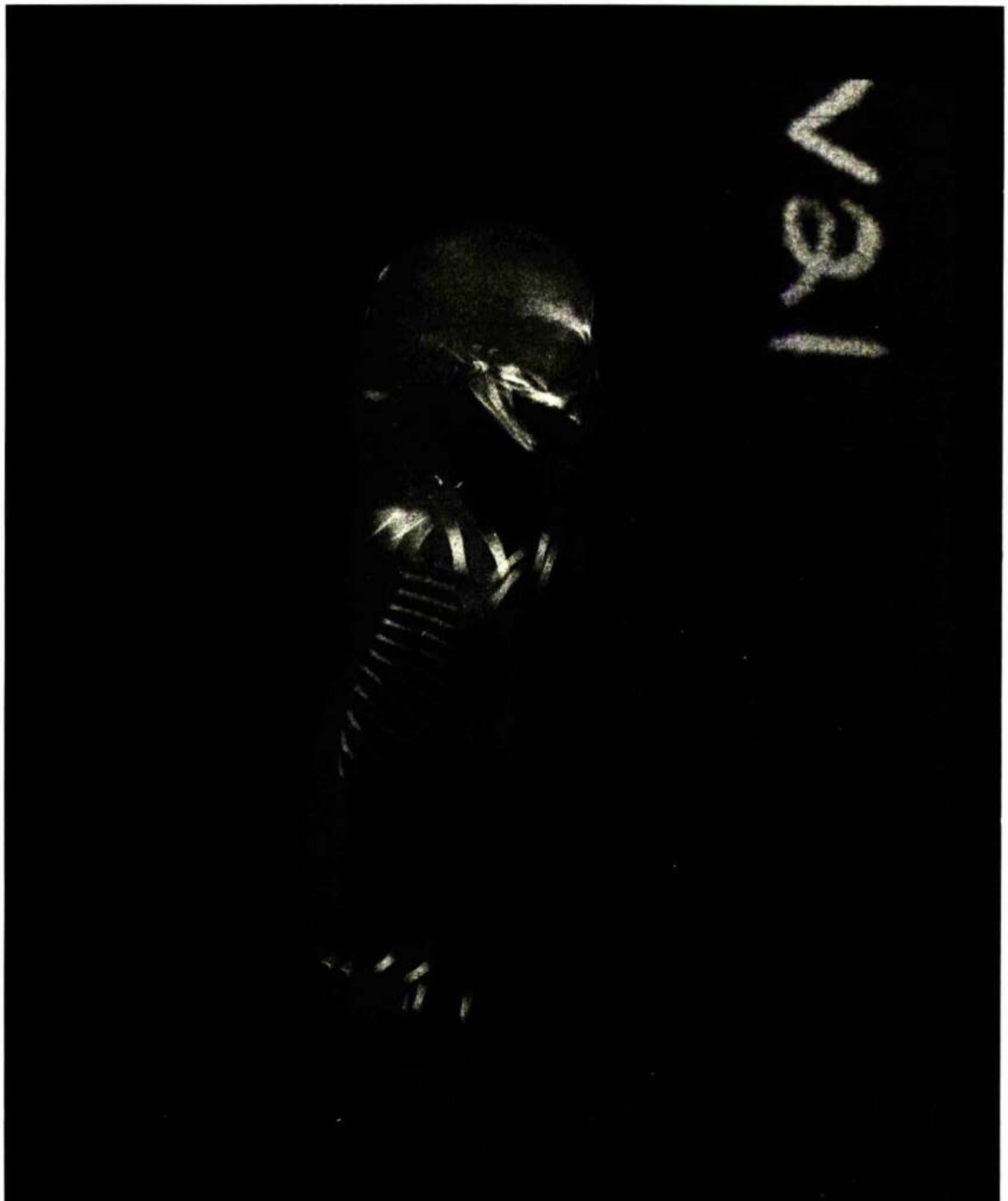


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 8	No.24	43mm.	34 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 9	No.24	43mm.	34 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 10	No.24	43mm.	34 days	NITRATE	HEAD

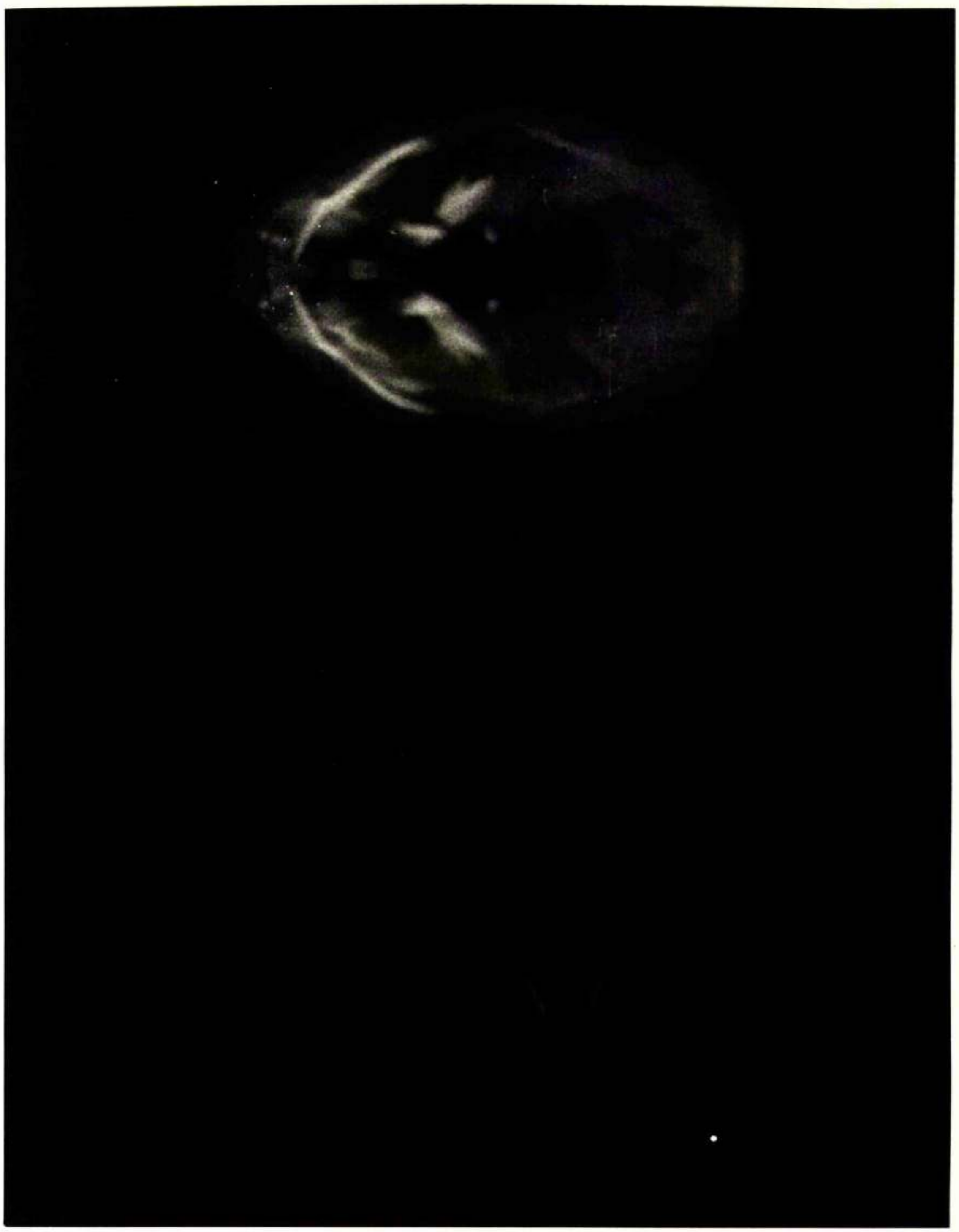


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
S·N 11	No.24	43mm.	34 days	NITRATE	HEAD & MANDIBLE

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 12	No.29	56.5mm.	37 days	NITRATE	

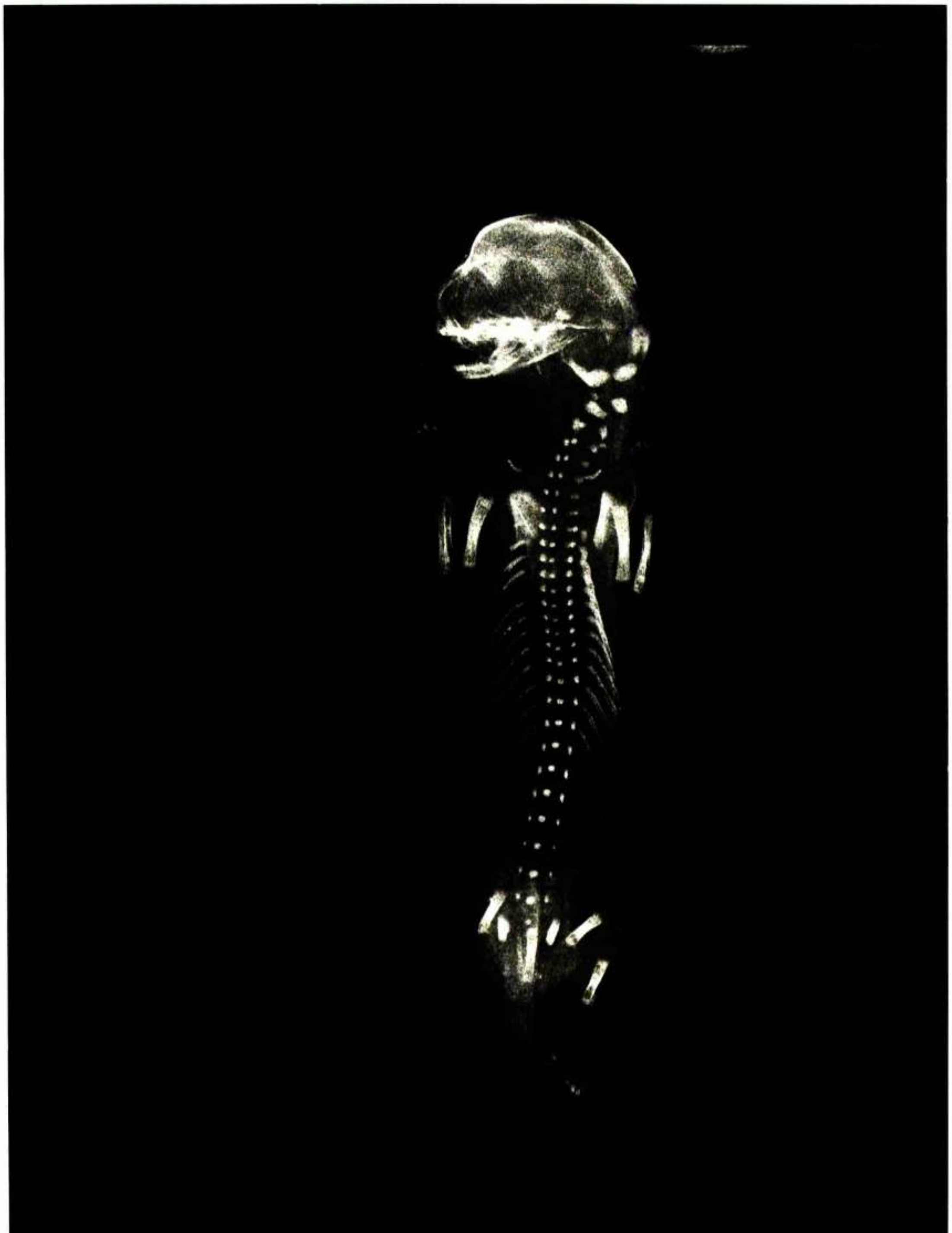


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 13	No.32	63mm.	39 days	NITRATE	

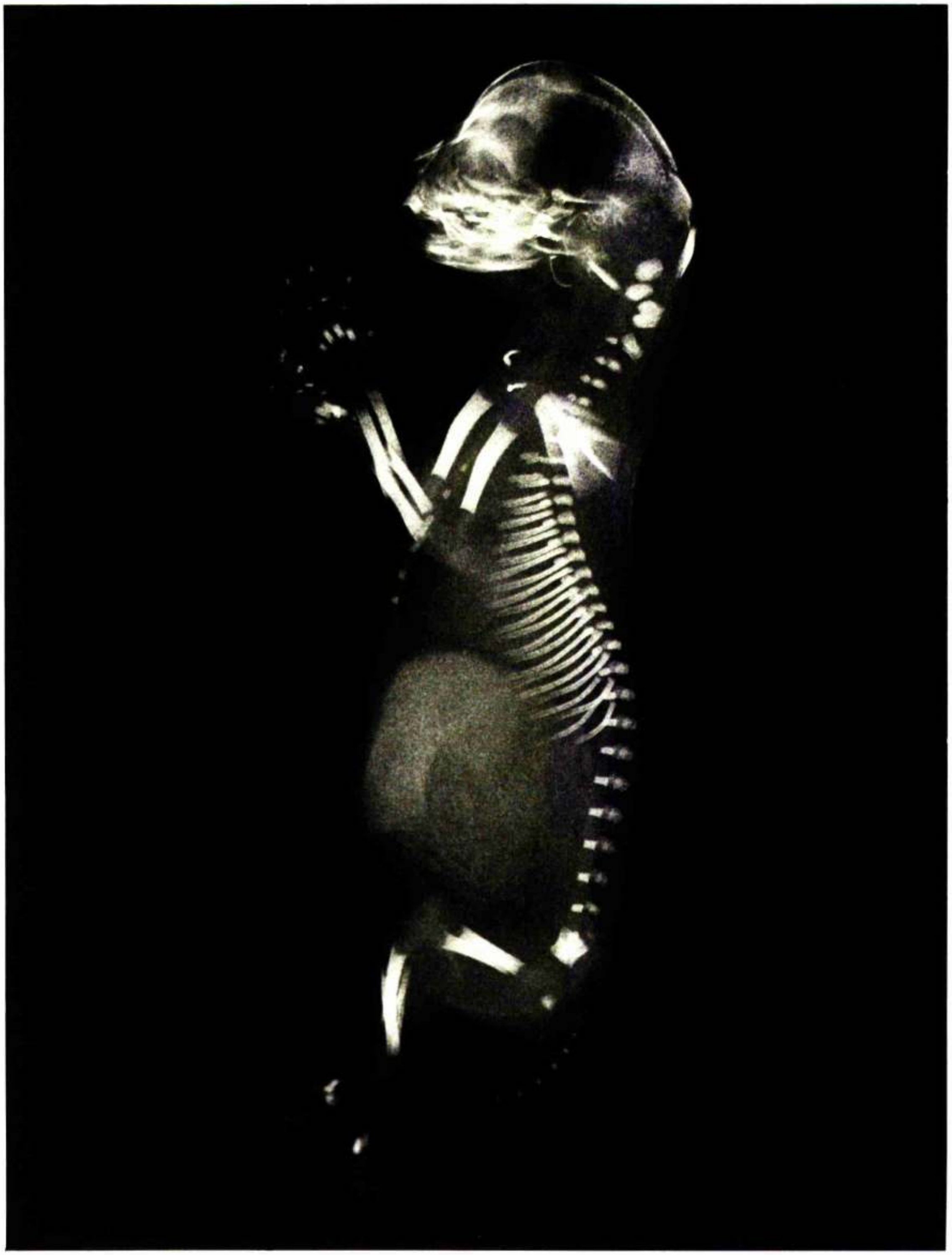


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 14	No.33	65mm.	39 days	NITRATE	

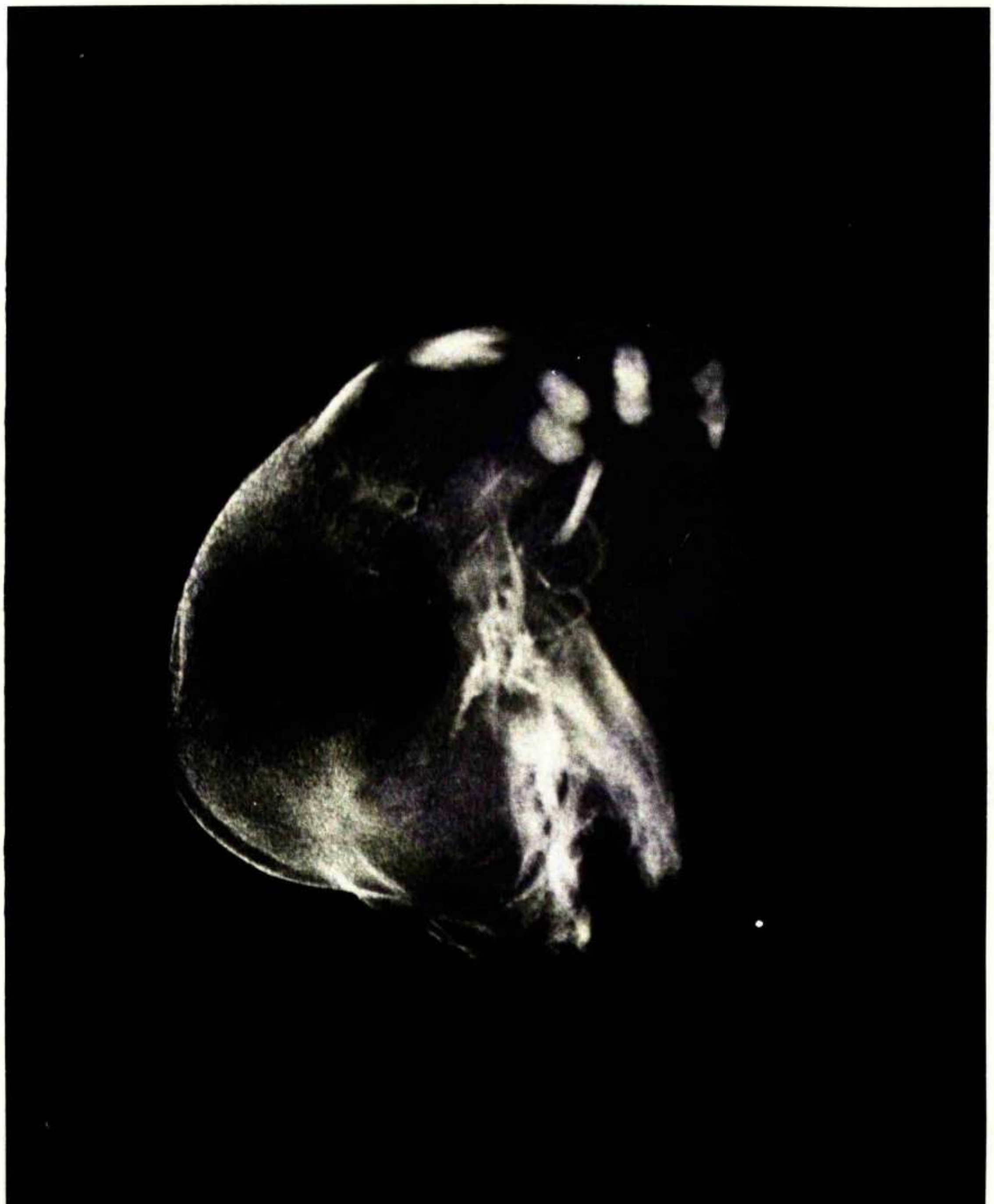


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL HEAD
SN 15	No.33	65mm.	39 days	NITRATE	

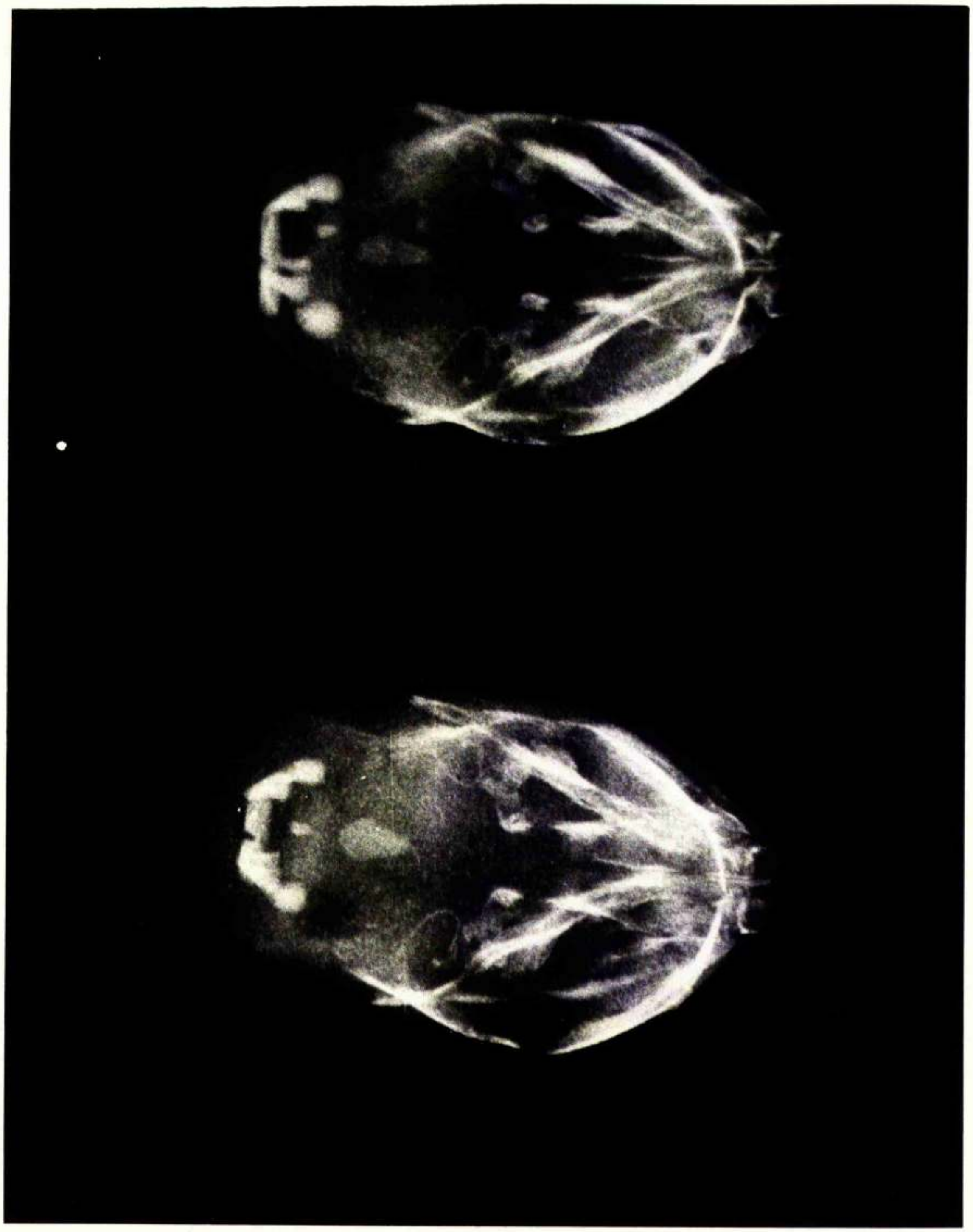


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 16	No.33	65mm.	39 days	NITRATE	HEAD

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 17	No.35	67mm.	40 days		

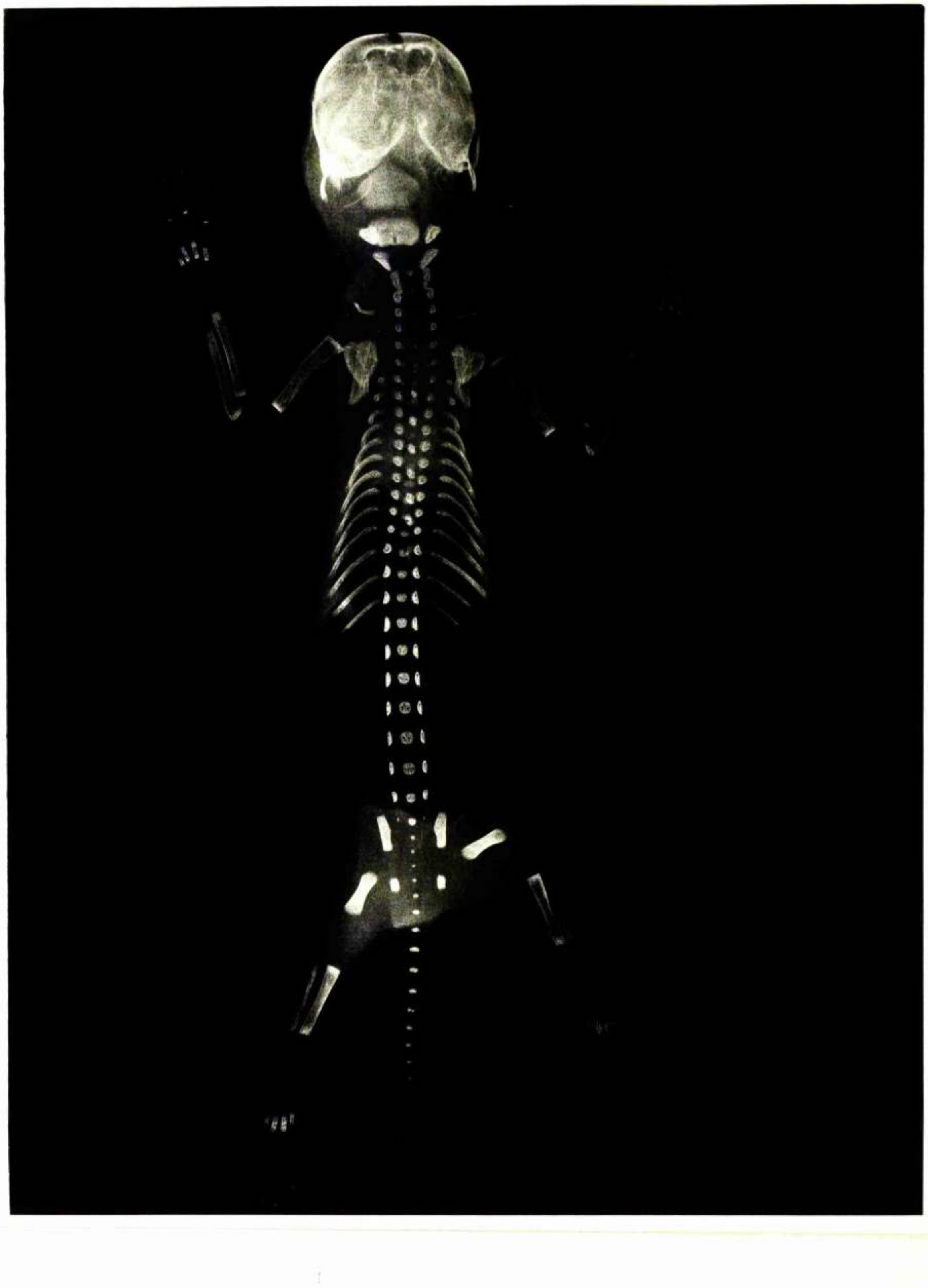


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 18	No.35	67mm.	40 days	NITRATE	

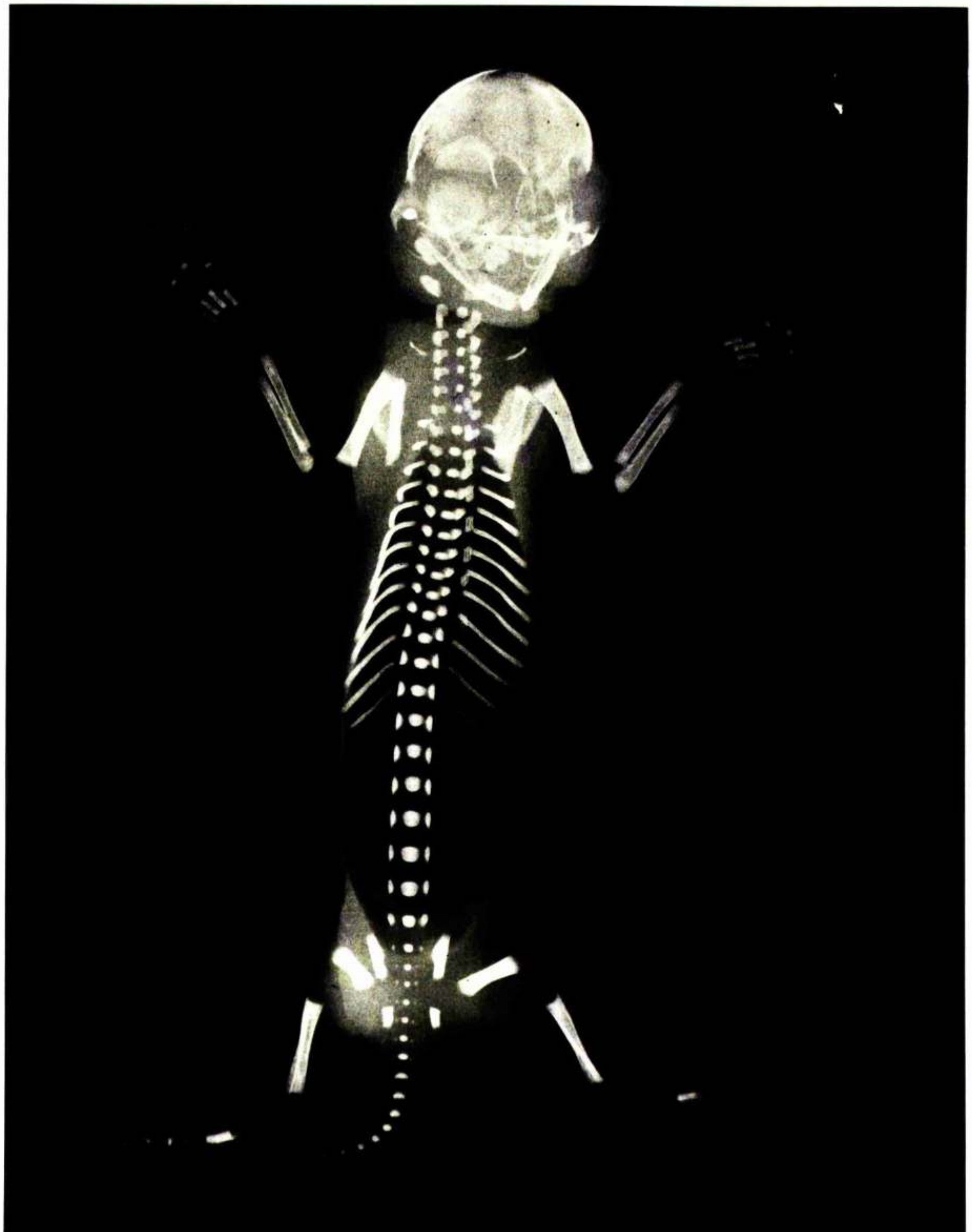


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 19	No.42	82.5	43 days	NITRATE	

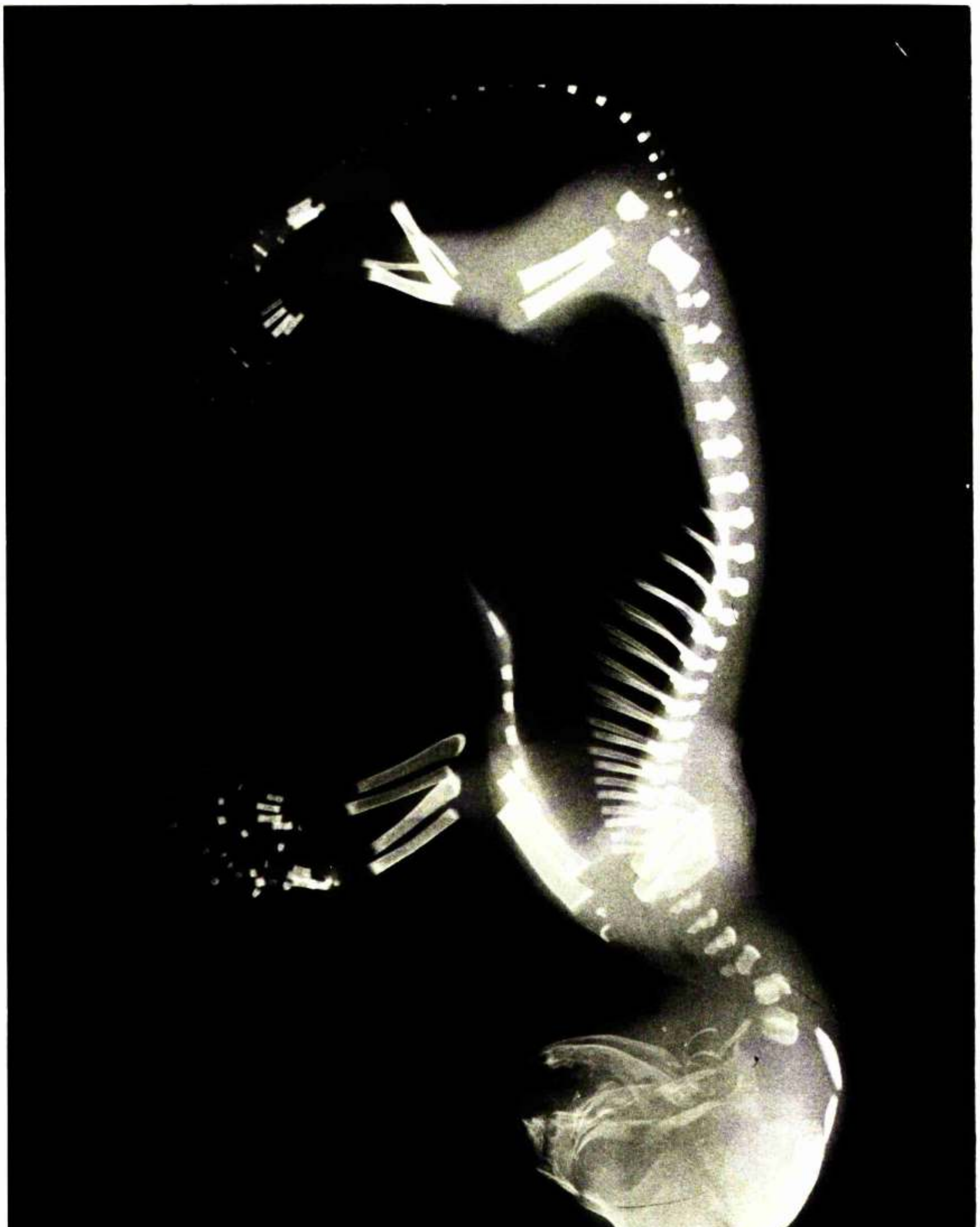


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 20	No.42	82.5	43 days	NITRATE	

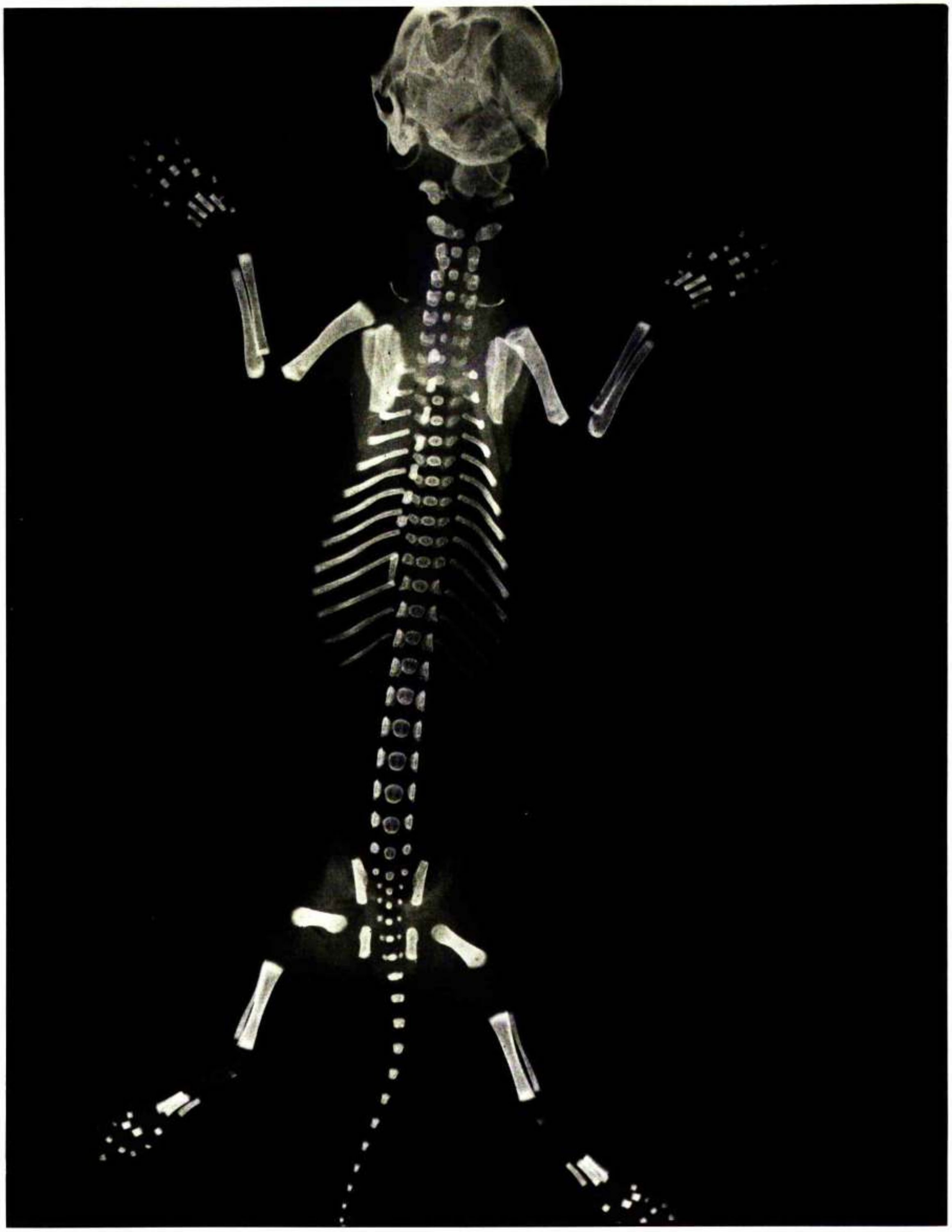


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 21	No.44	84mm.	44 days	NITRATE	

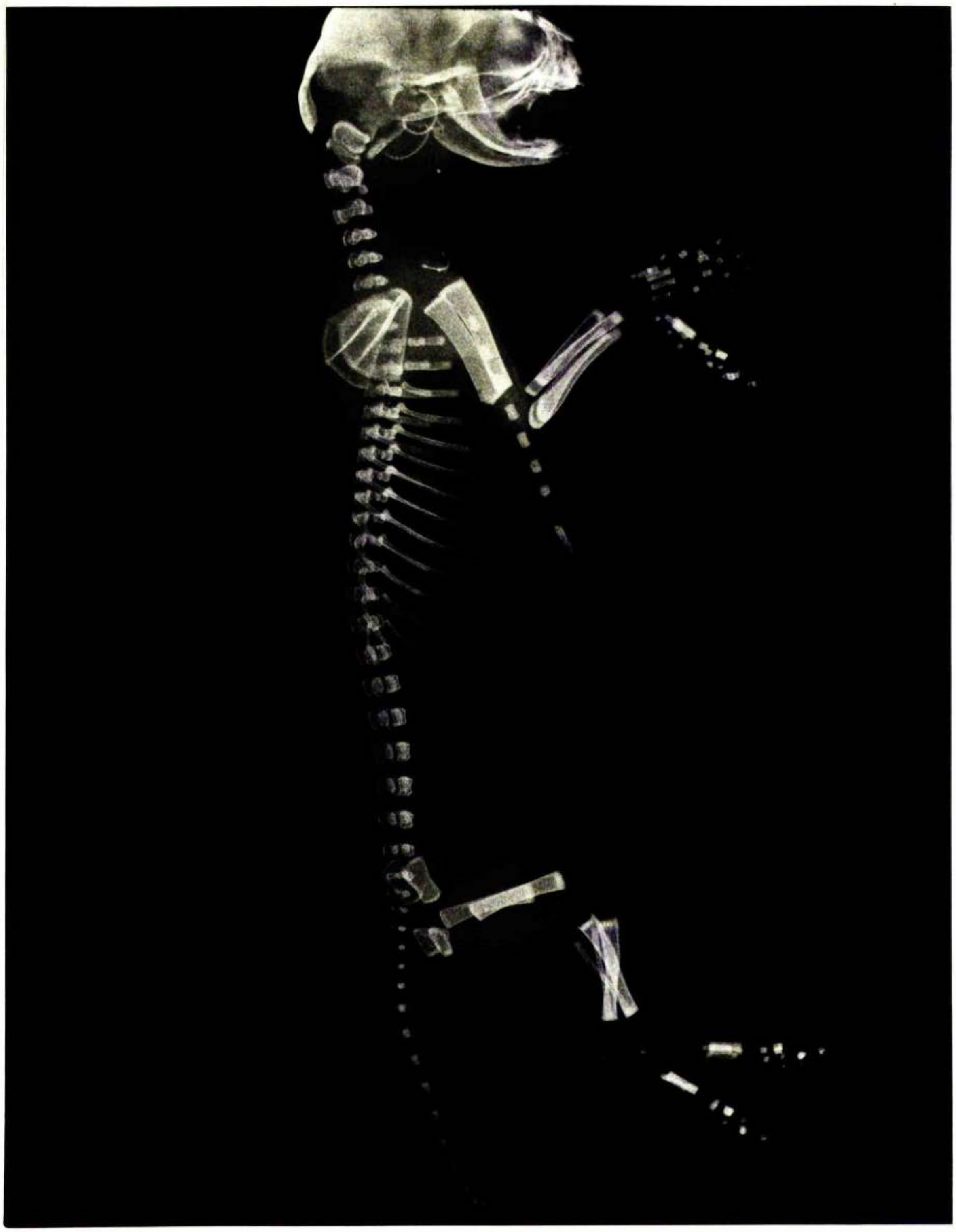


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 22	No.44	84mm.	44 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 23	No.44	84mm.	44 days	NITRATE	HEAD

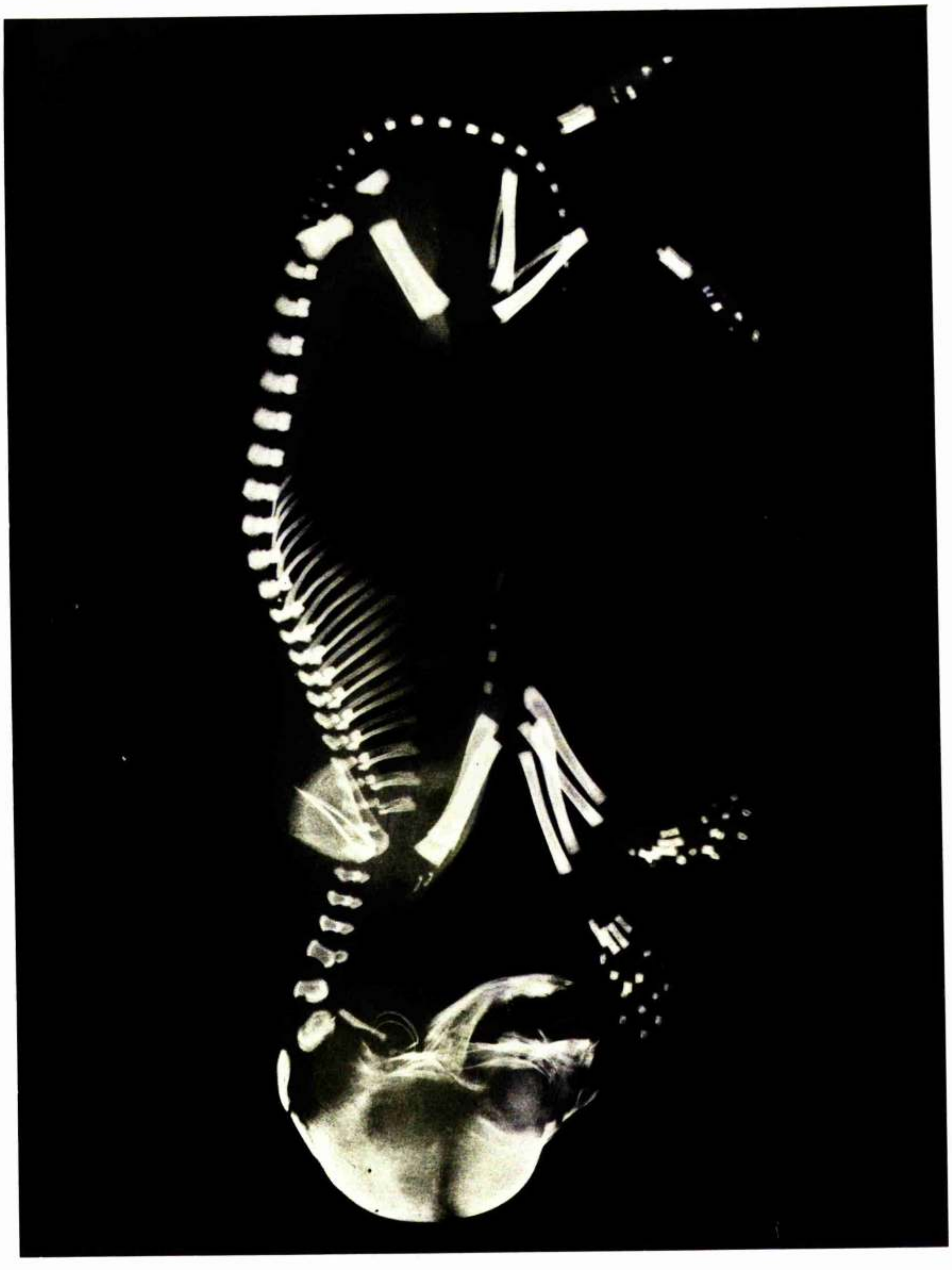


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 24	No.45	85mm.	44 days	NITRATE	

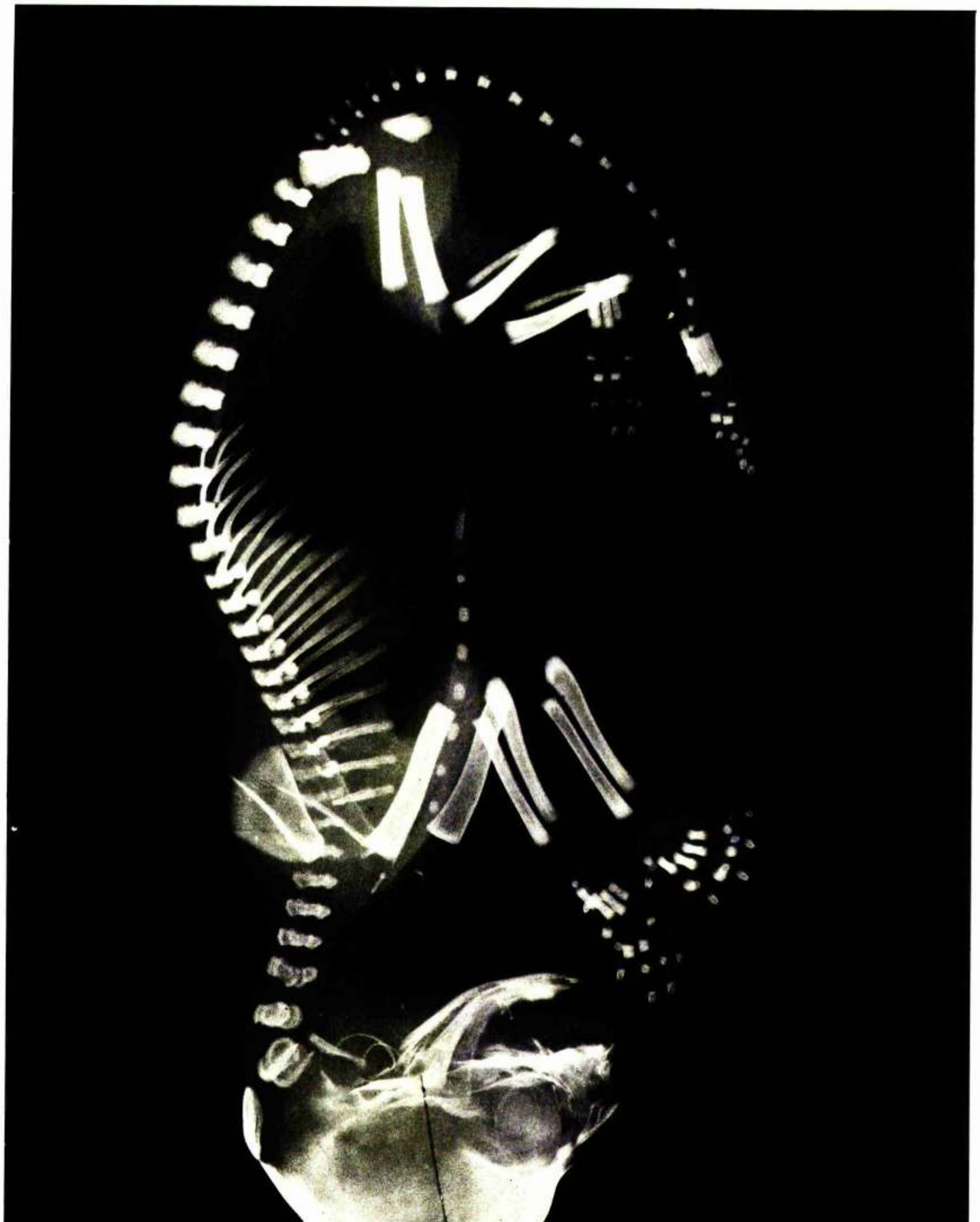


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 25	No.45	85mm.	44 days	NITRATE	

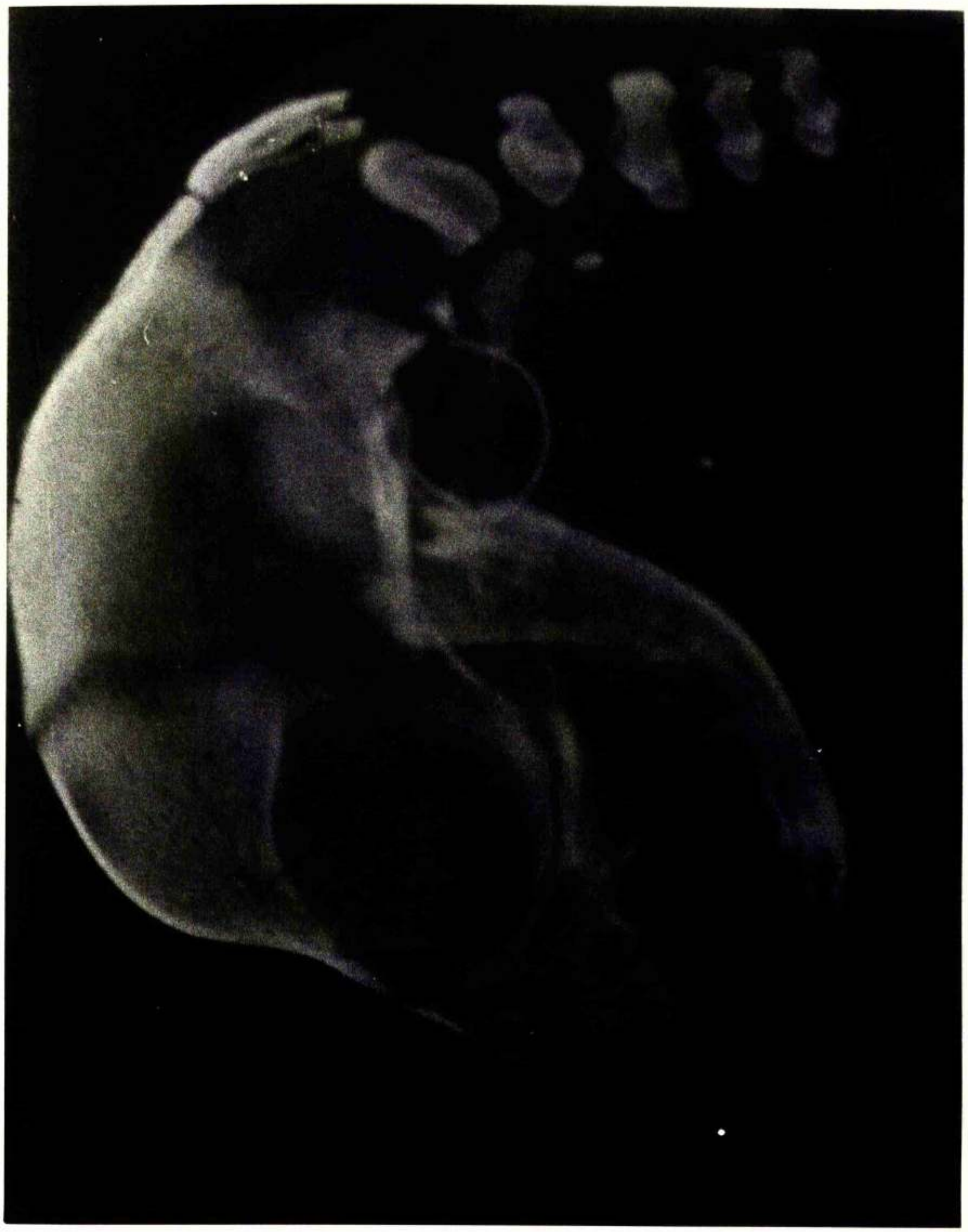


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL MEDIAN
SN 26	No.46	85mm.	44 days	NITRATE	SECTION HEAD

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 27	No.47	86mm.	45 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 28	No.48	88mm.	46 days	NITRATE	HEAD

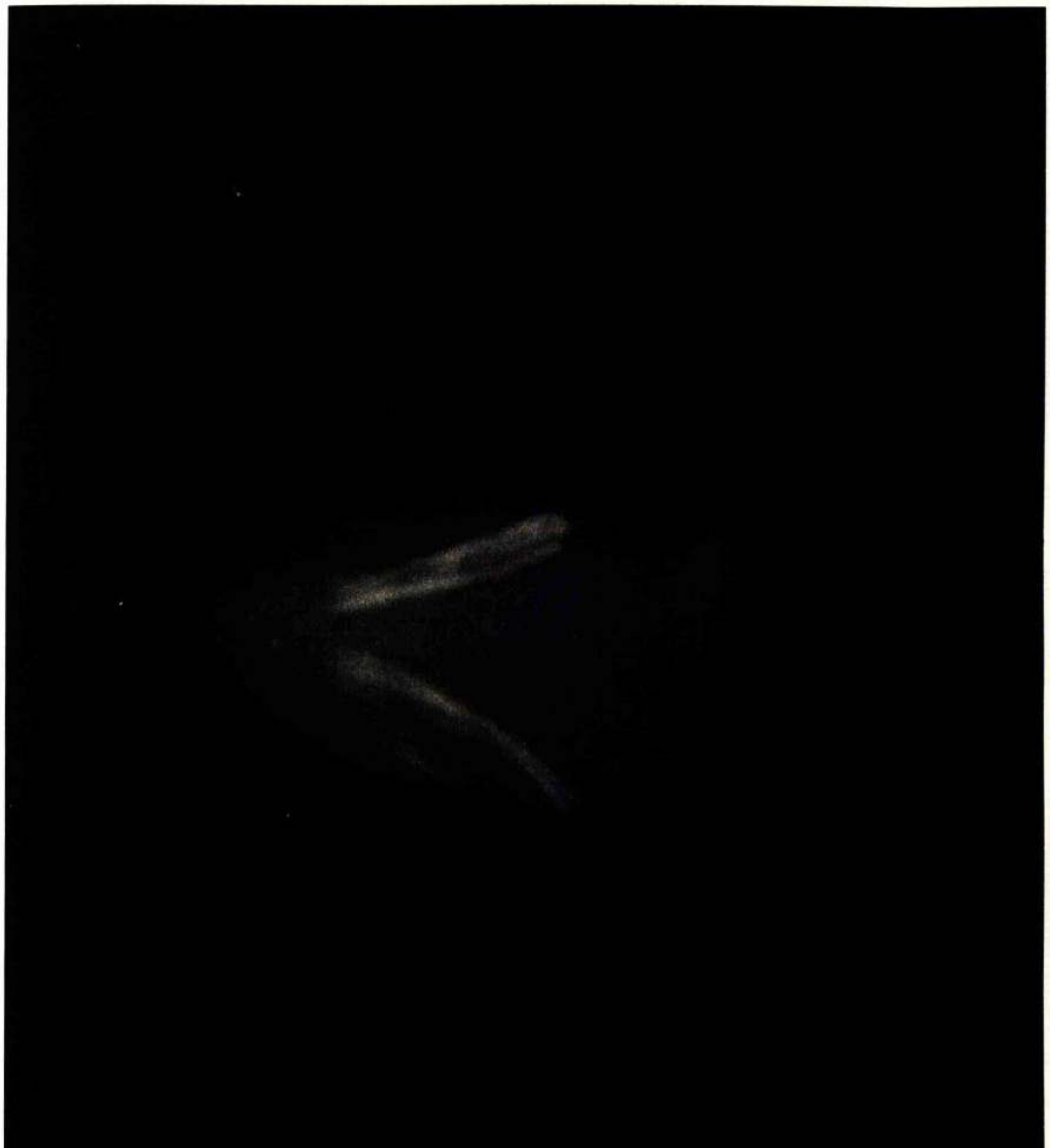


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	MANDIBLE
SN 29	No.48	88mm.	46 days	NITRATE	

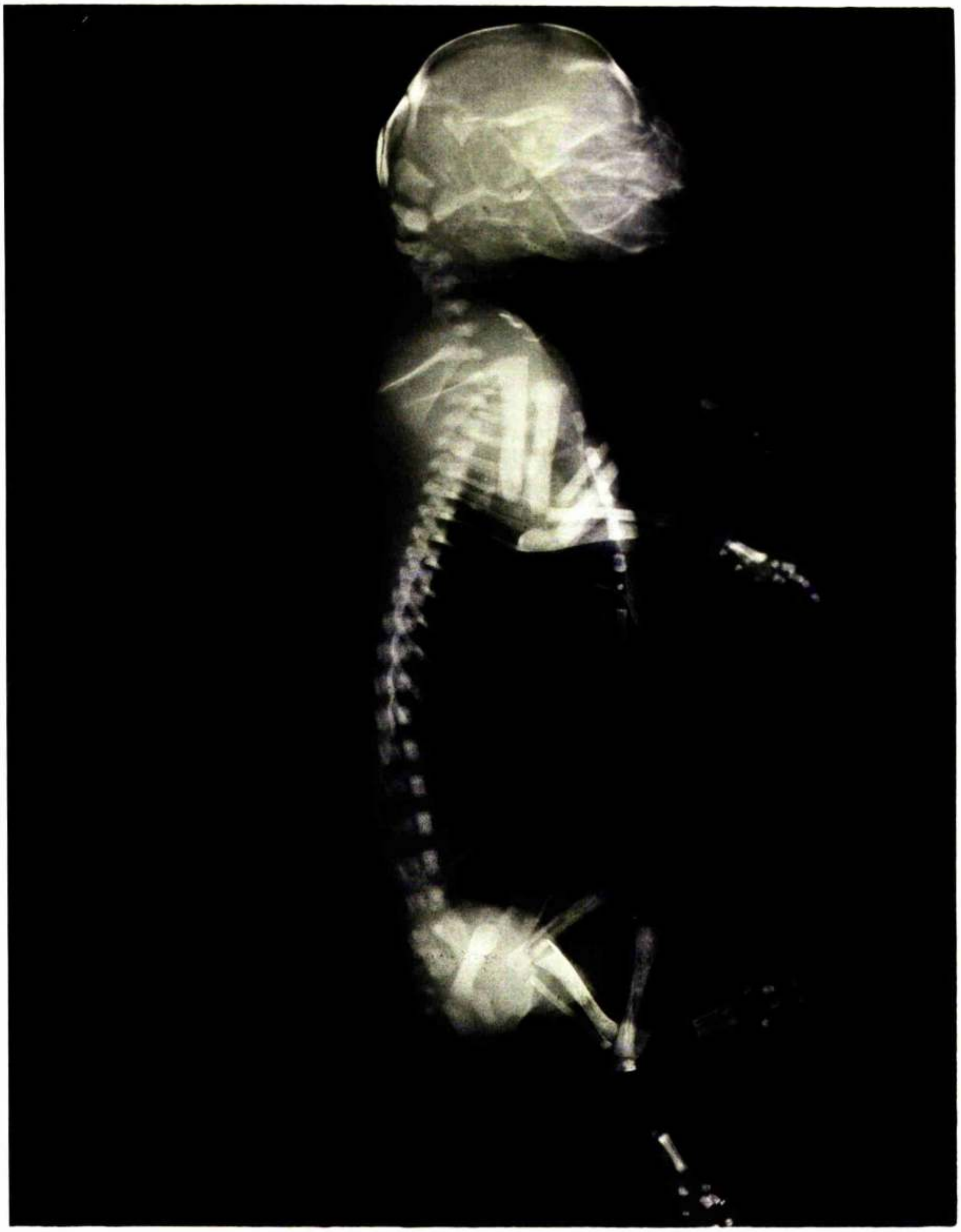


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 30	No.52	92mm.	47 days	NITRATE	

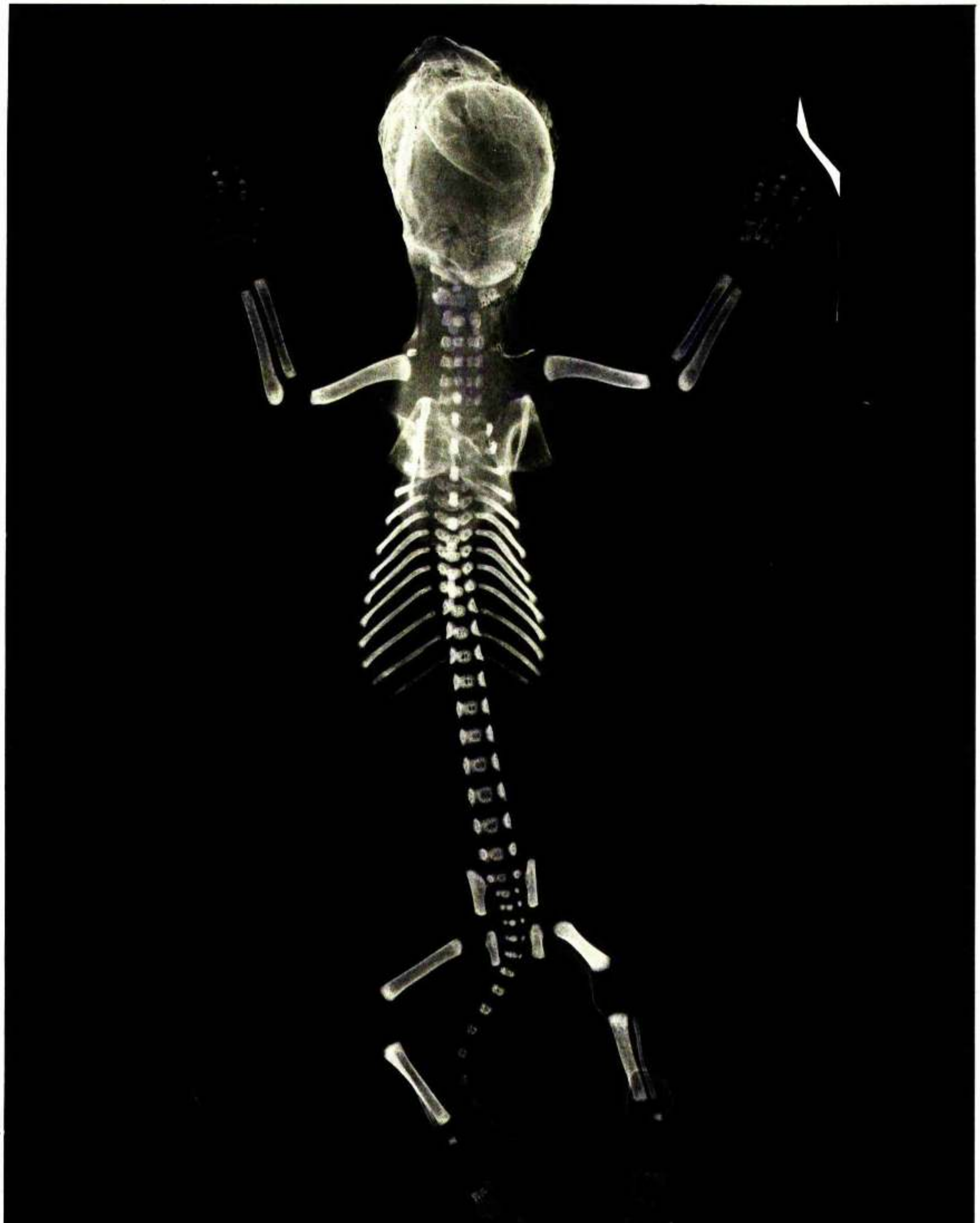


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 31	No.56	102mm.	50 days	NITRATE	

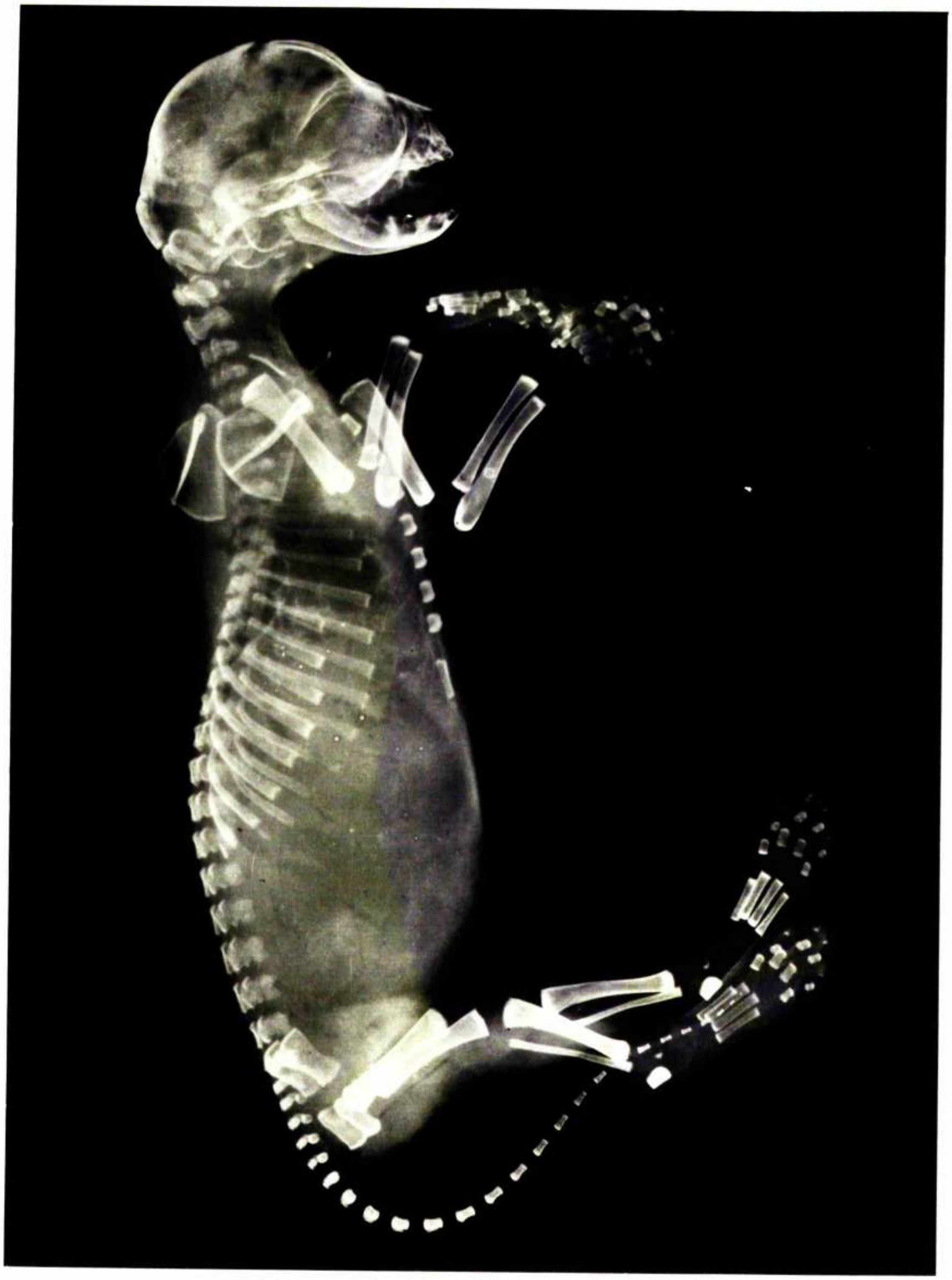


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 32	No.59	105.5mm.	51 days	NITRATE	

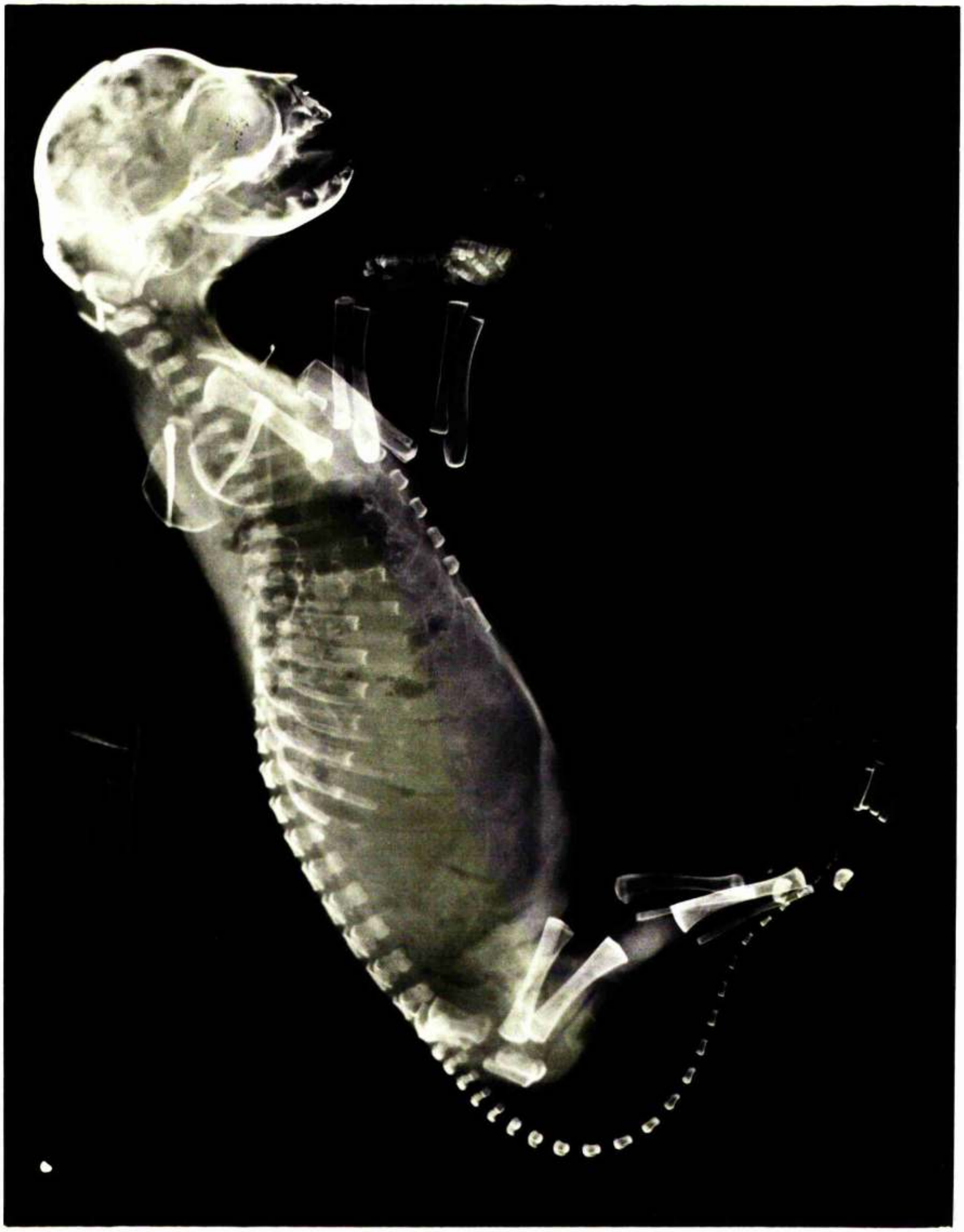


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 33	No.59	105.5mm.	51 days	NITRATE	

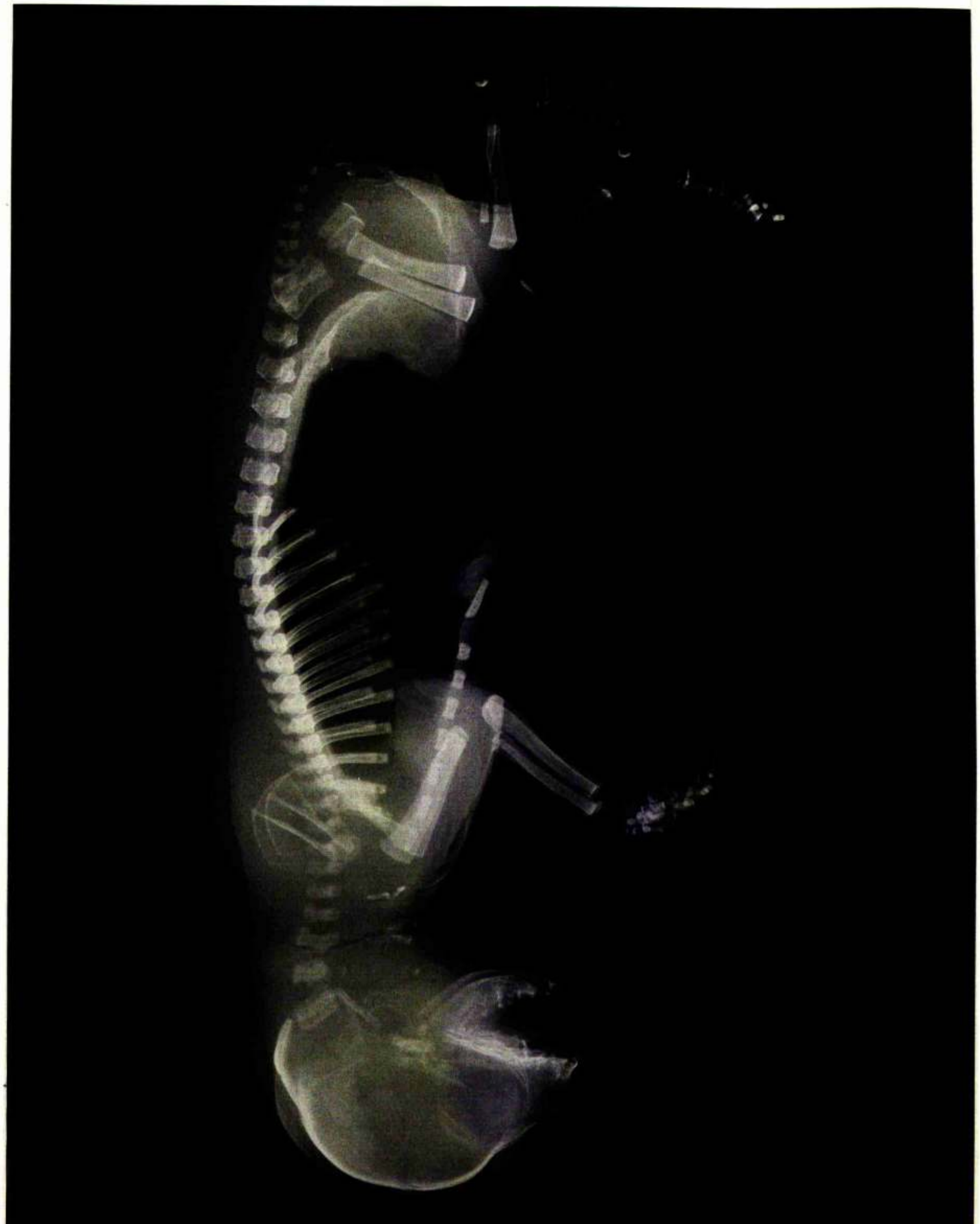


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 34	No.60	108mm.	52 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 35	No.60	108mm.	52 days	NITRATE	

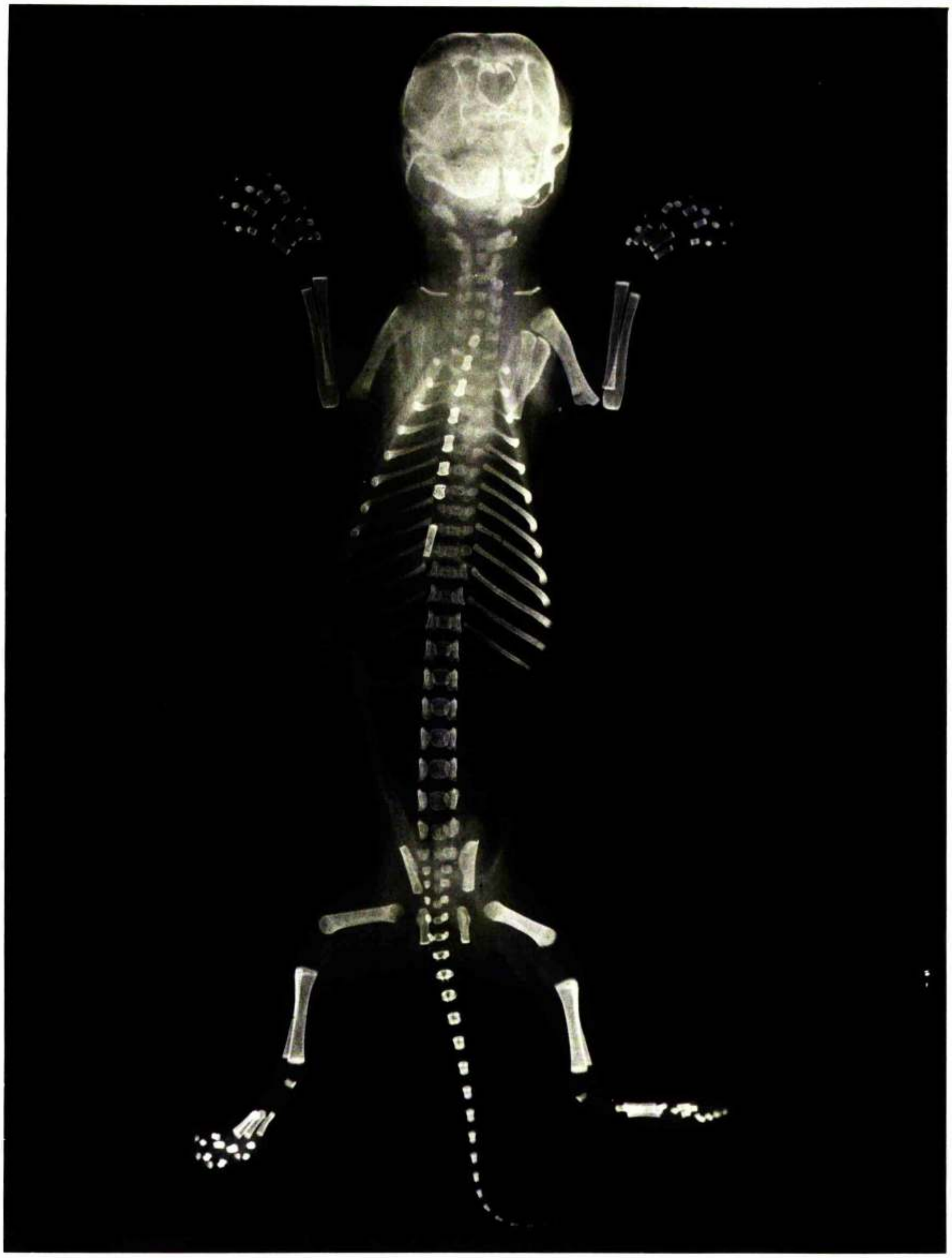


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 36	No.61	108.3mm.	53 days	NITRATE	

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 37	No.61	108.3mm.	53 days	NITRATE	

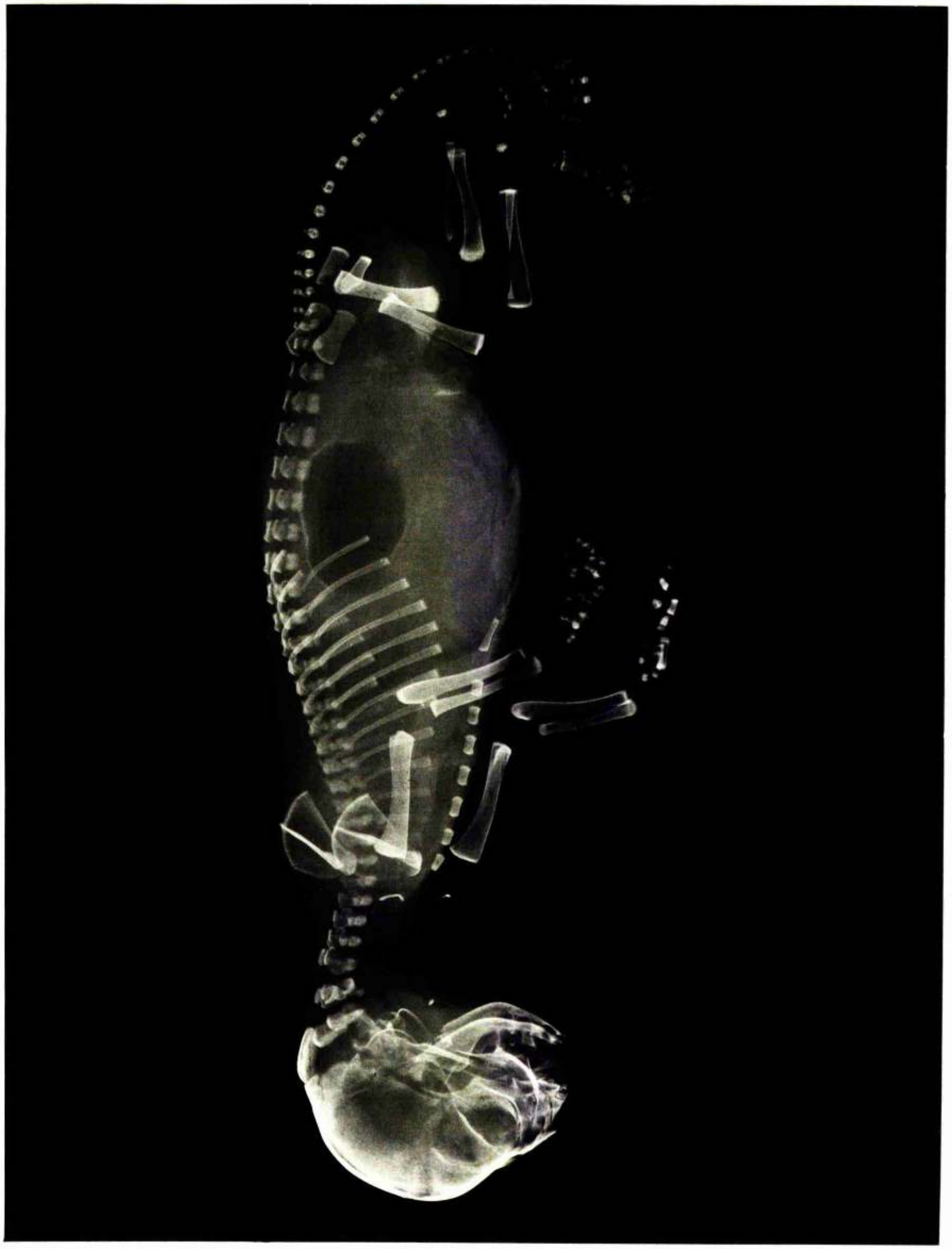


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 38	No.62	109mm.	53 days	NITRATE	

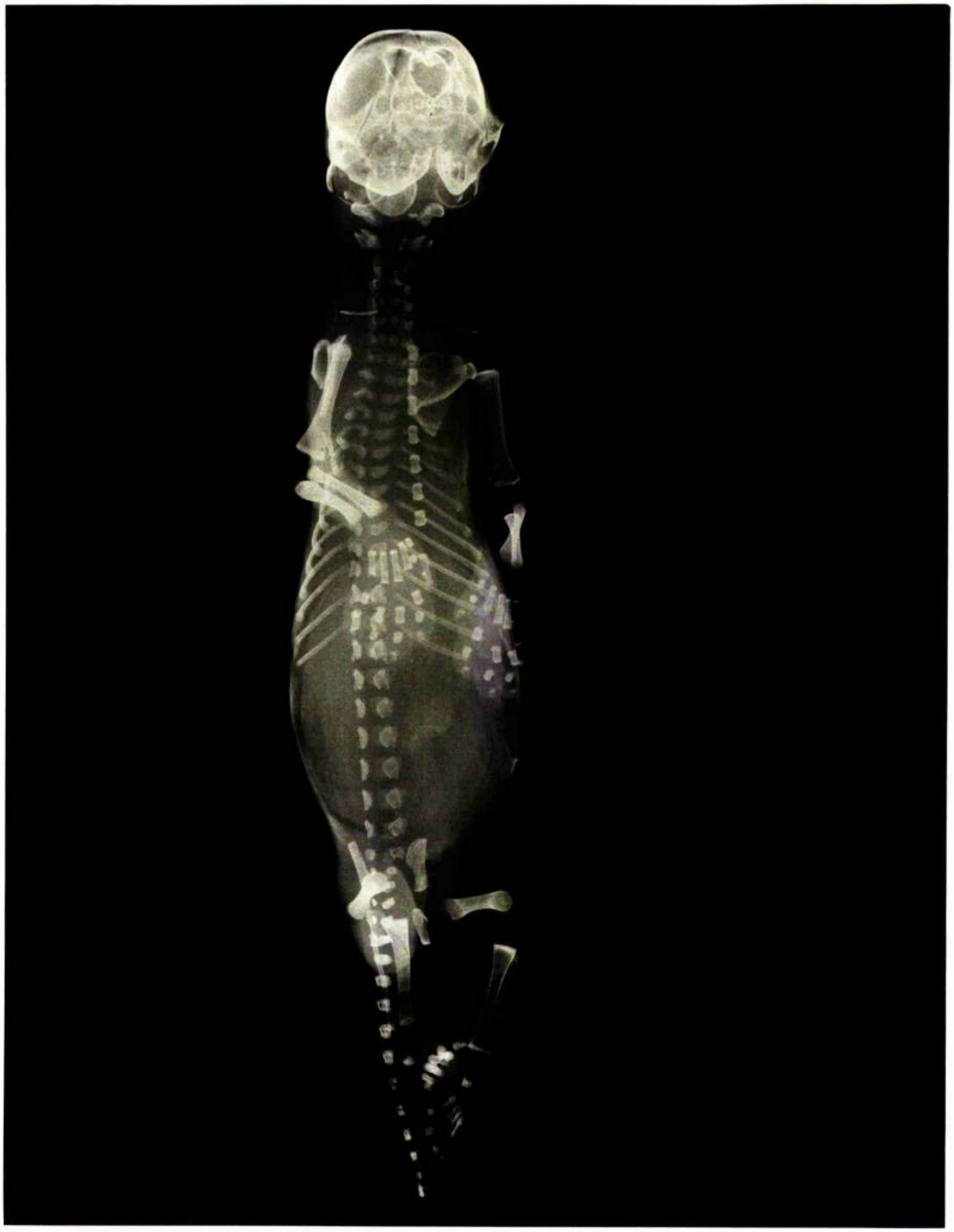


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 39	No.62	109mm.	53 days	NITRATE	

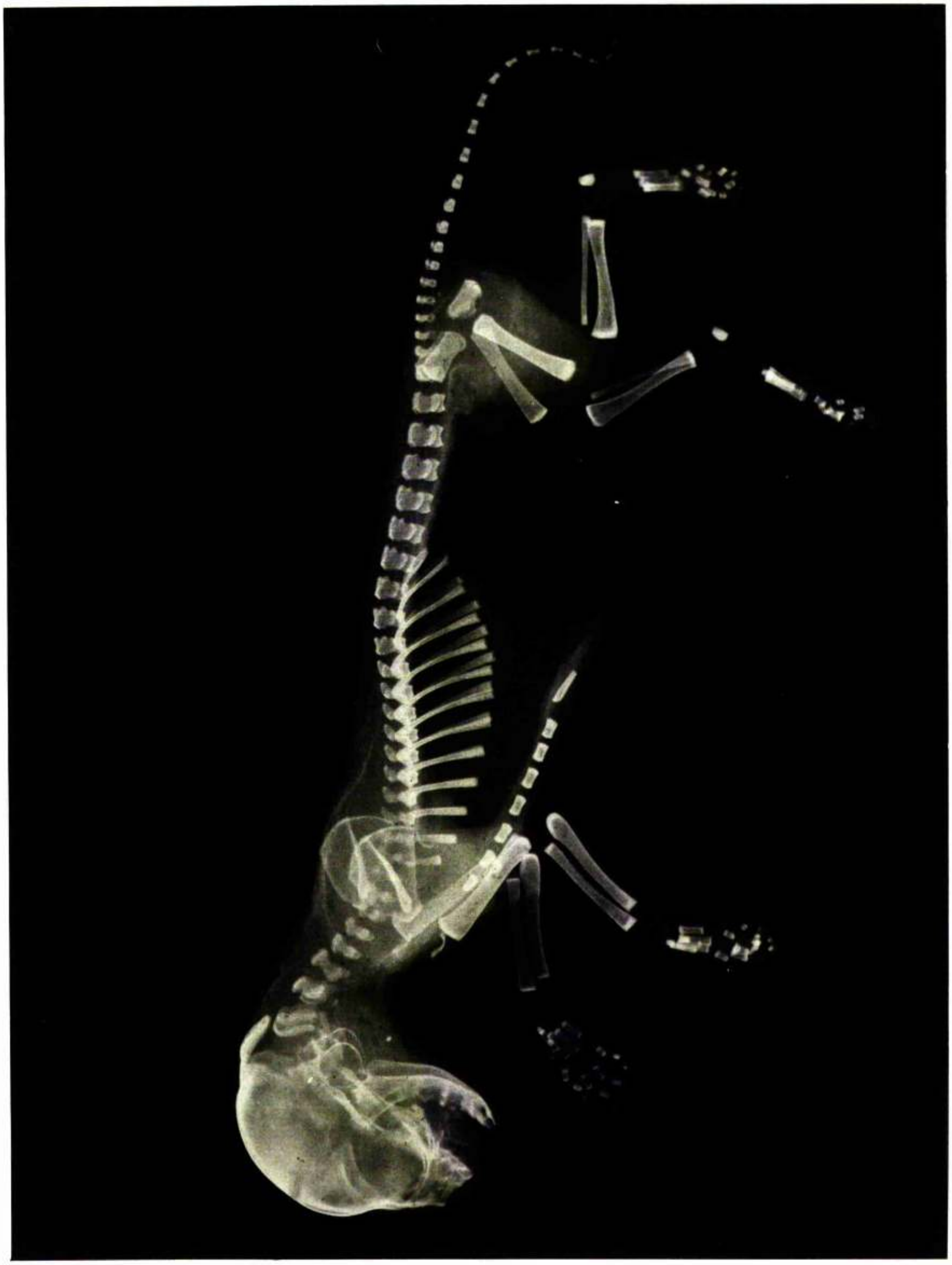


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 40	No.65	112mm.	54 days		

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 41	No.65	112mm.	54 days	NITRATE	

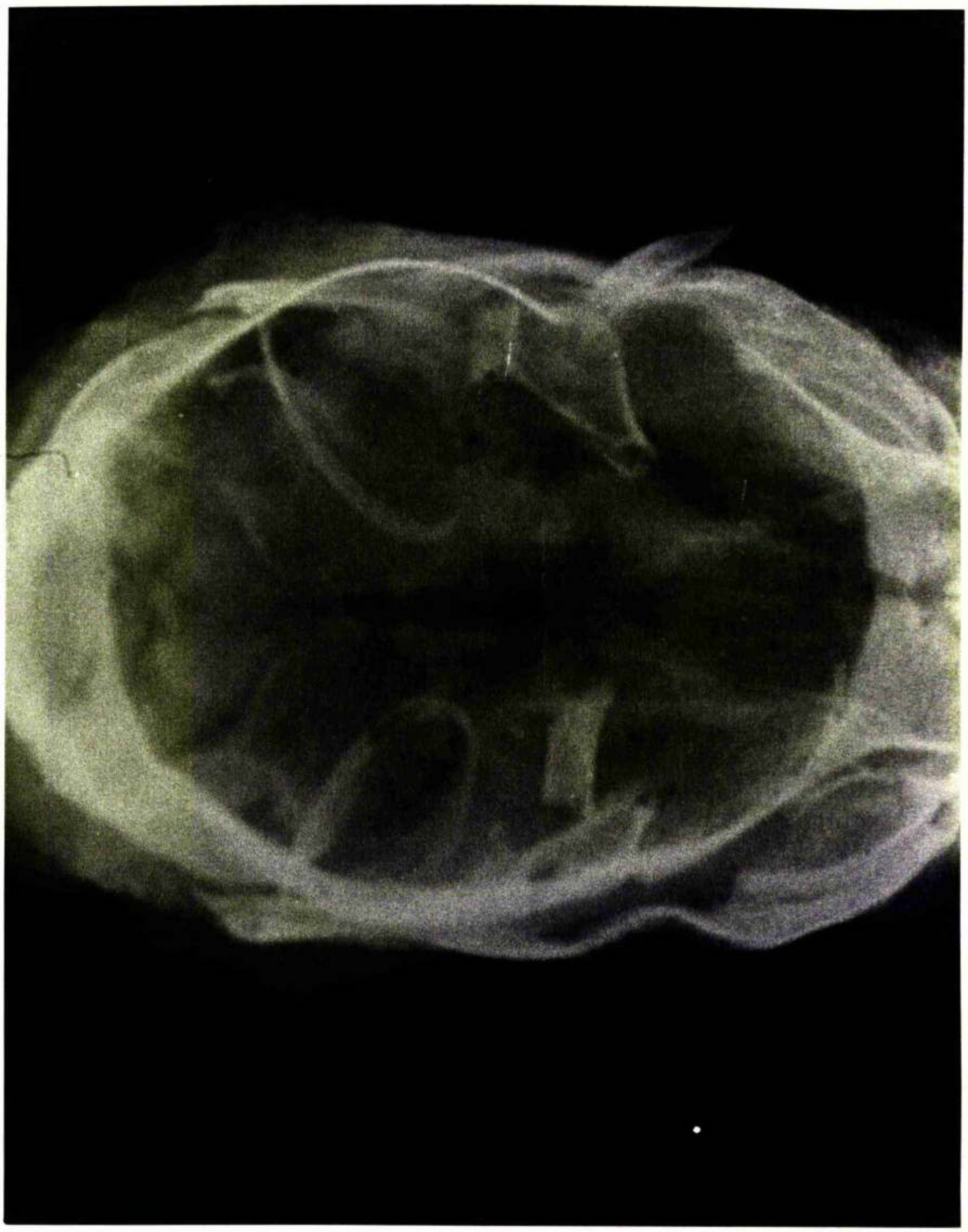


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 42	No.65	112mm.	54 days	NITRATE	HEAD

FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	MANDIBLE
SN 43	No.65	112mm.	54 days	NITRATE	

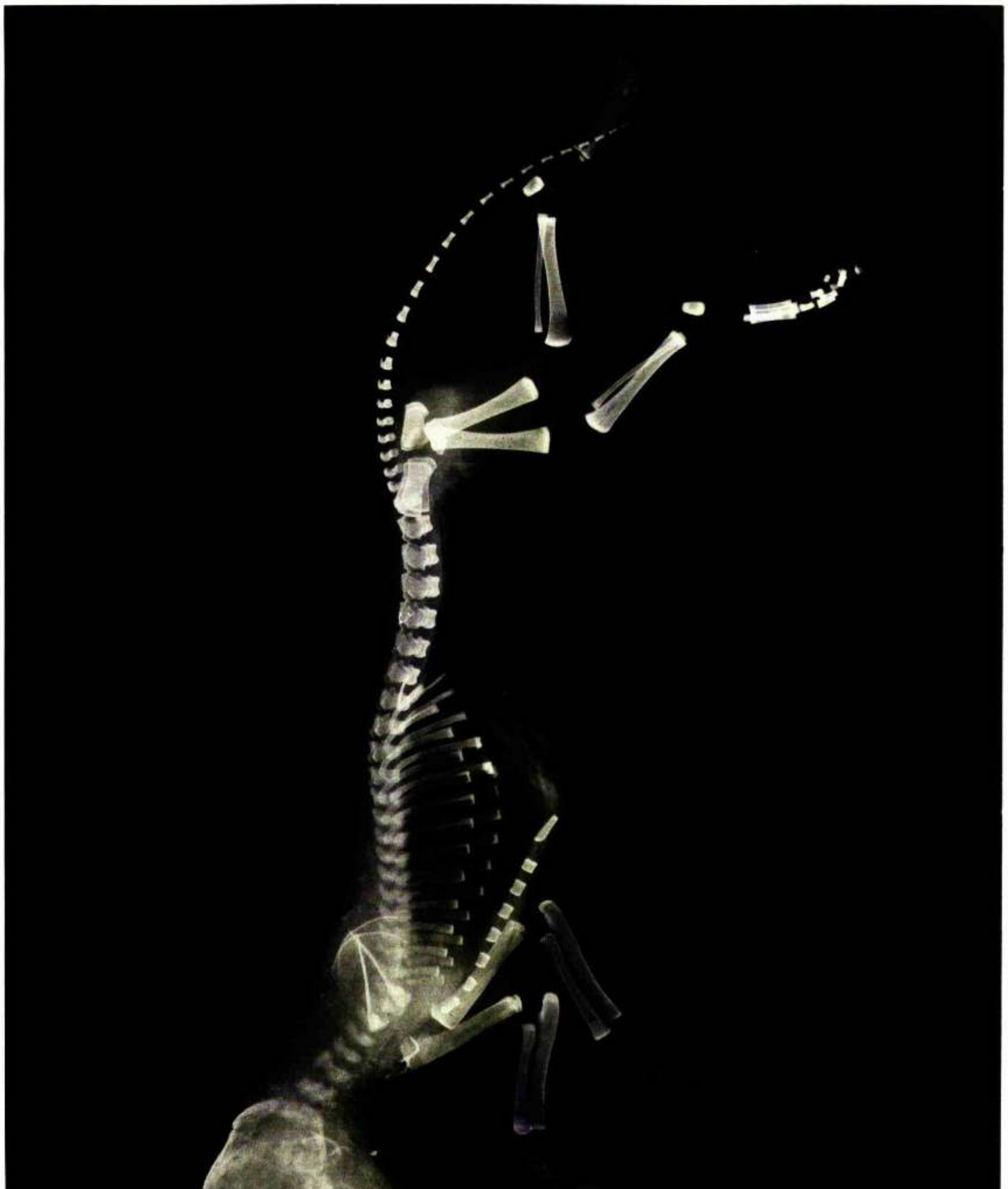


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 44	No.70	121mm.	56 days		

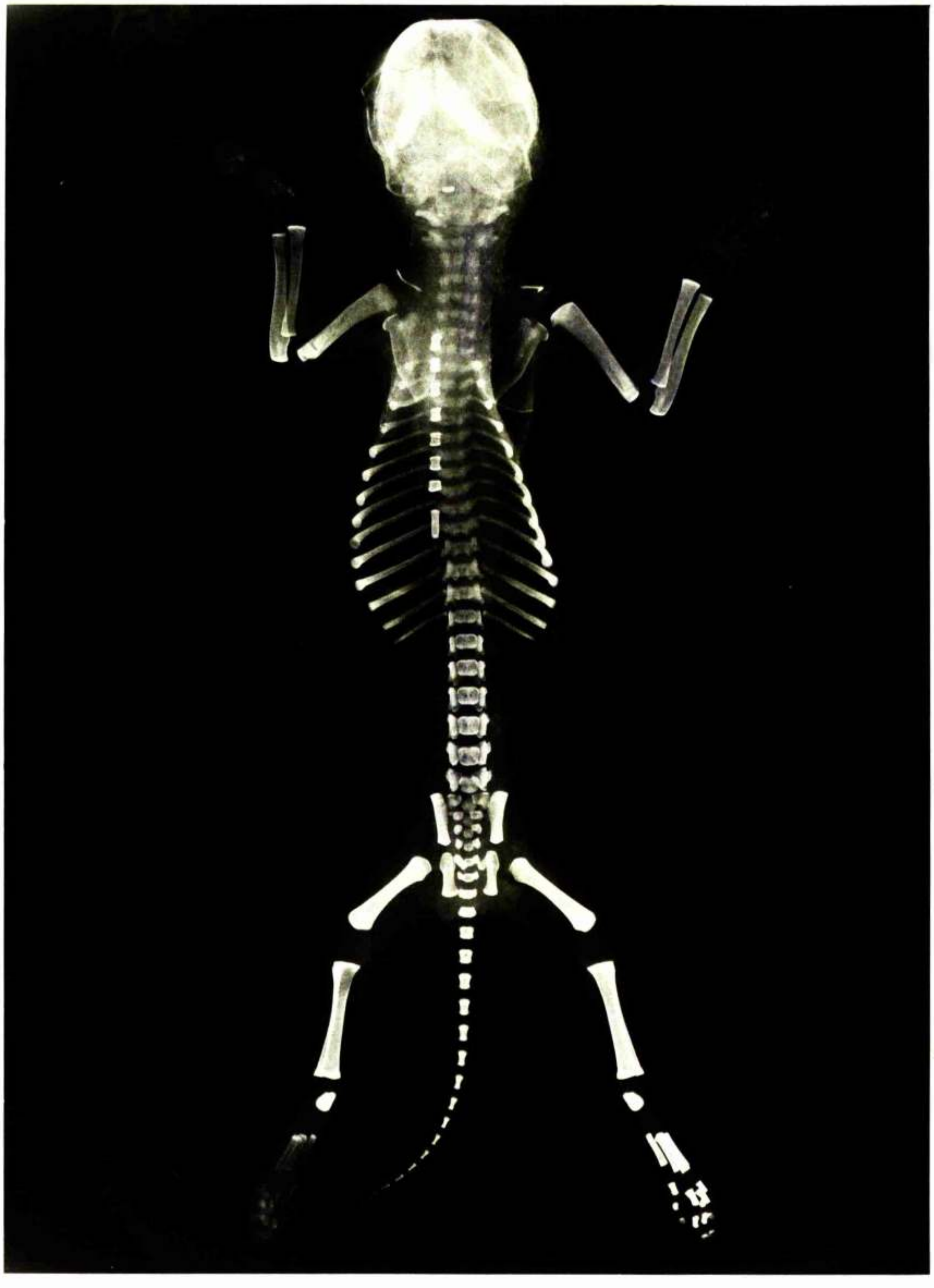


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 45	No.70	121mm.	56 days	NITRATE	

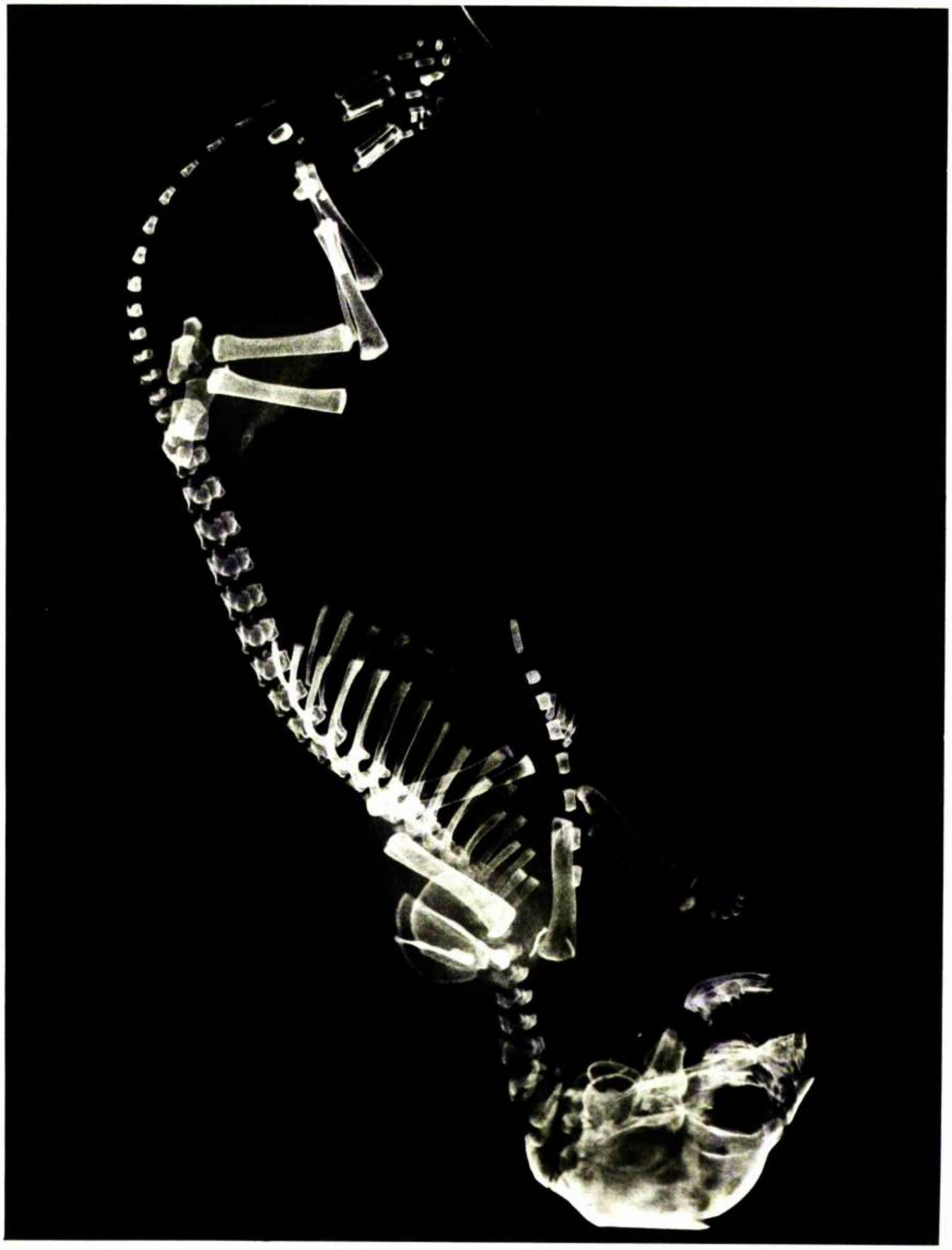


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 46	No.74	127mm.	57 days	NITRATE	

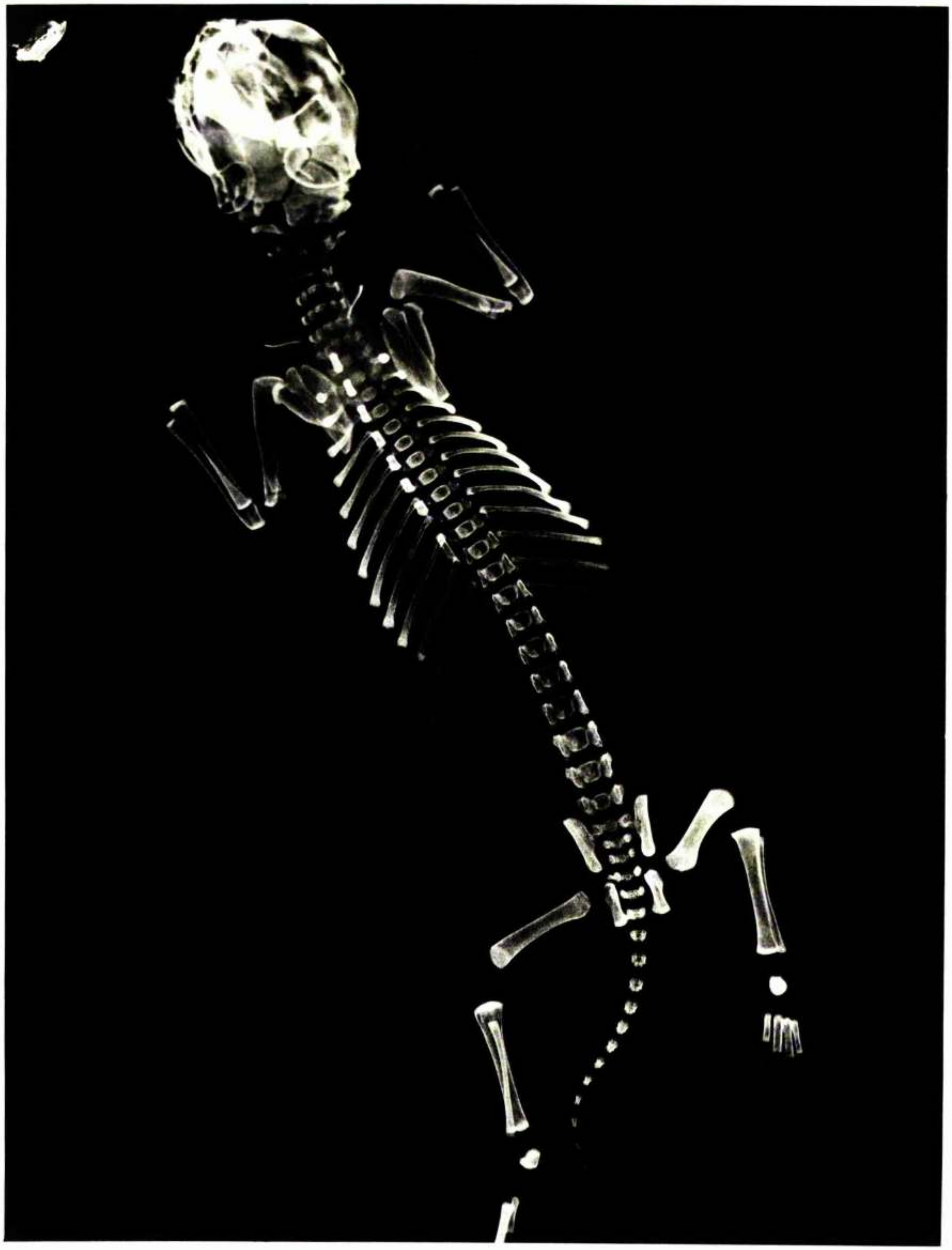


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 47	No.74	127mm.	57 days	NITRATE	

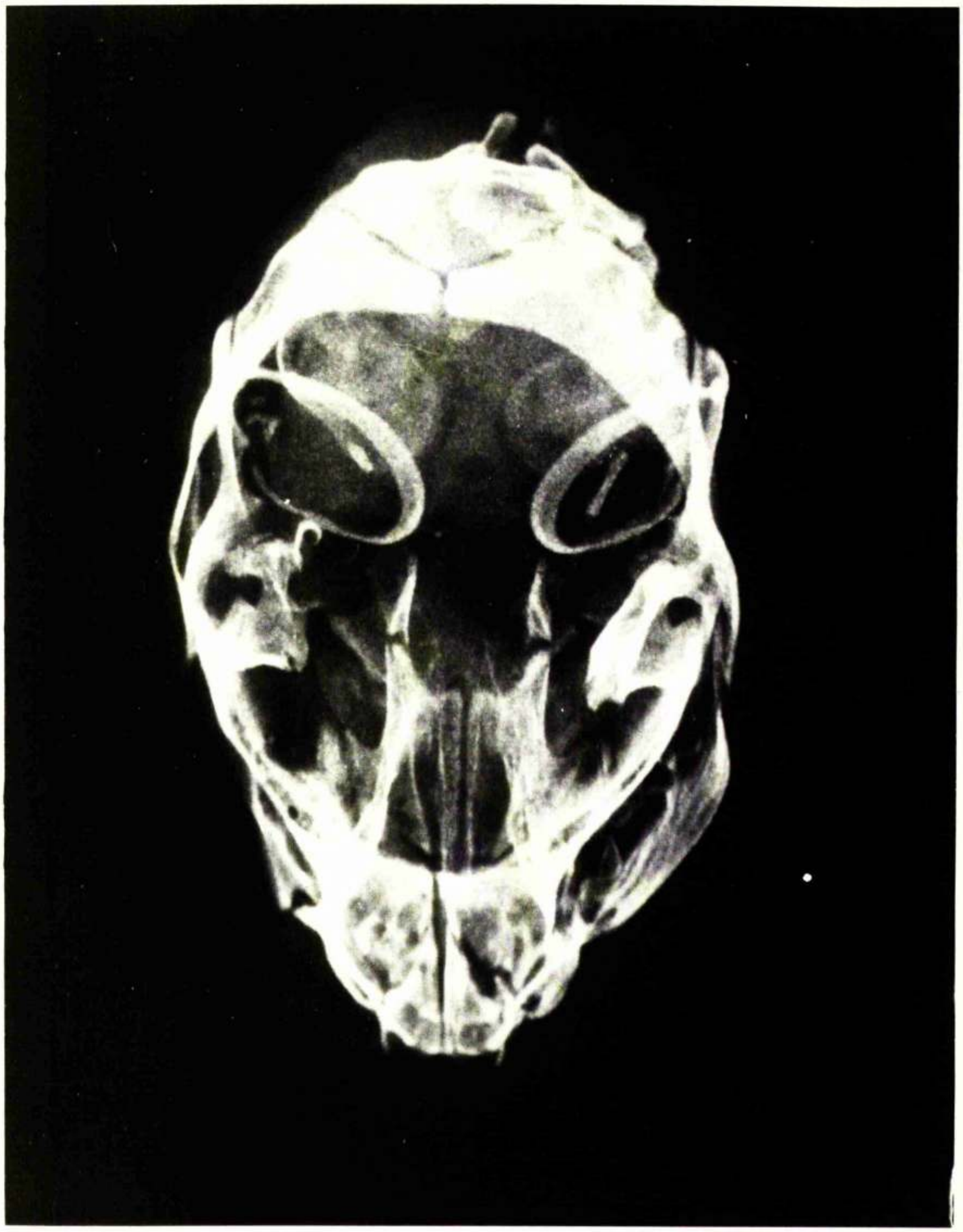


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 48	No.74	127mm.	57 days	NITRATE	HEAD

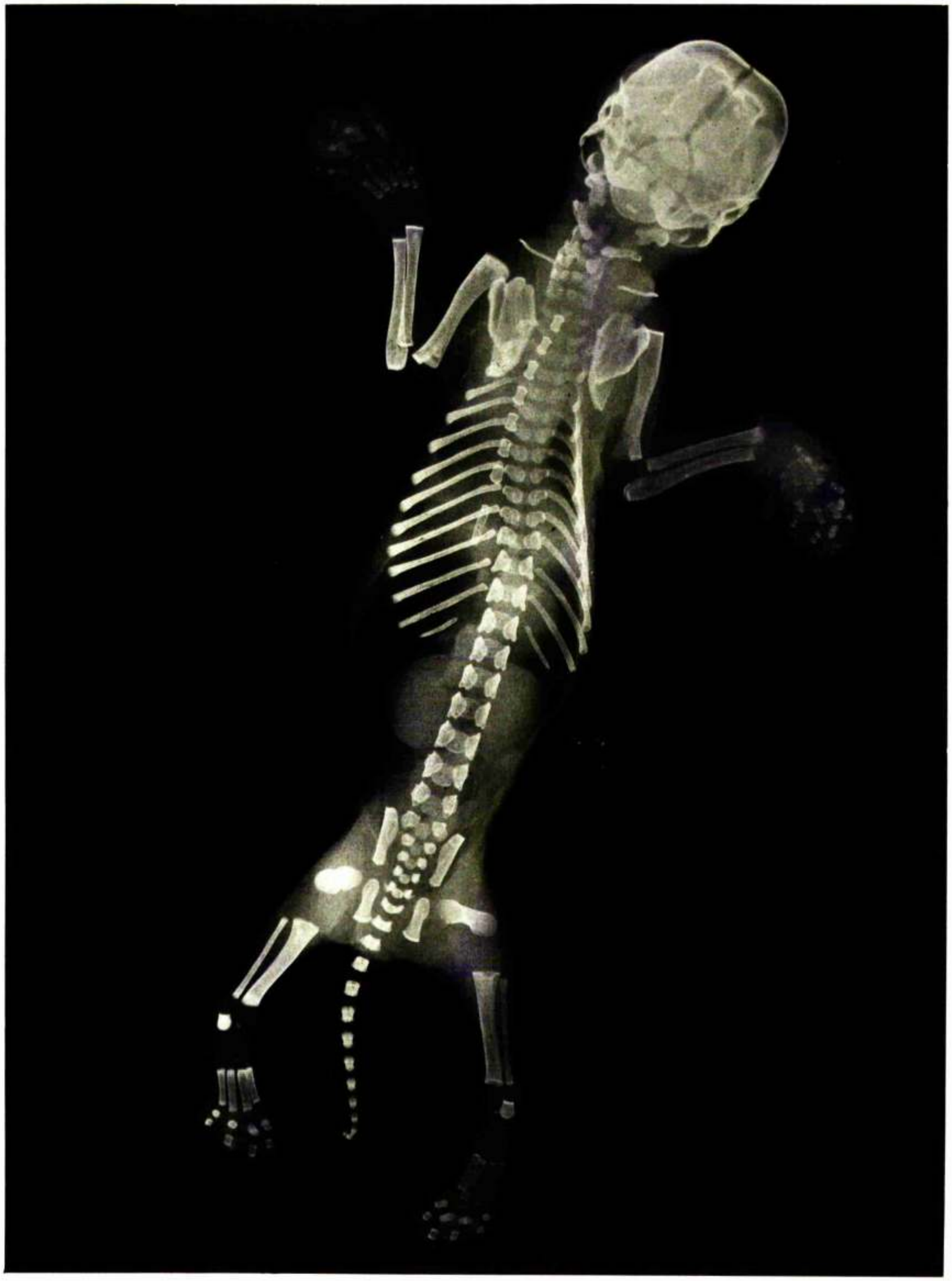


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 49	No.75	130mm.	58 days	NITRATE	

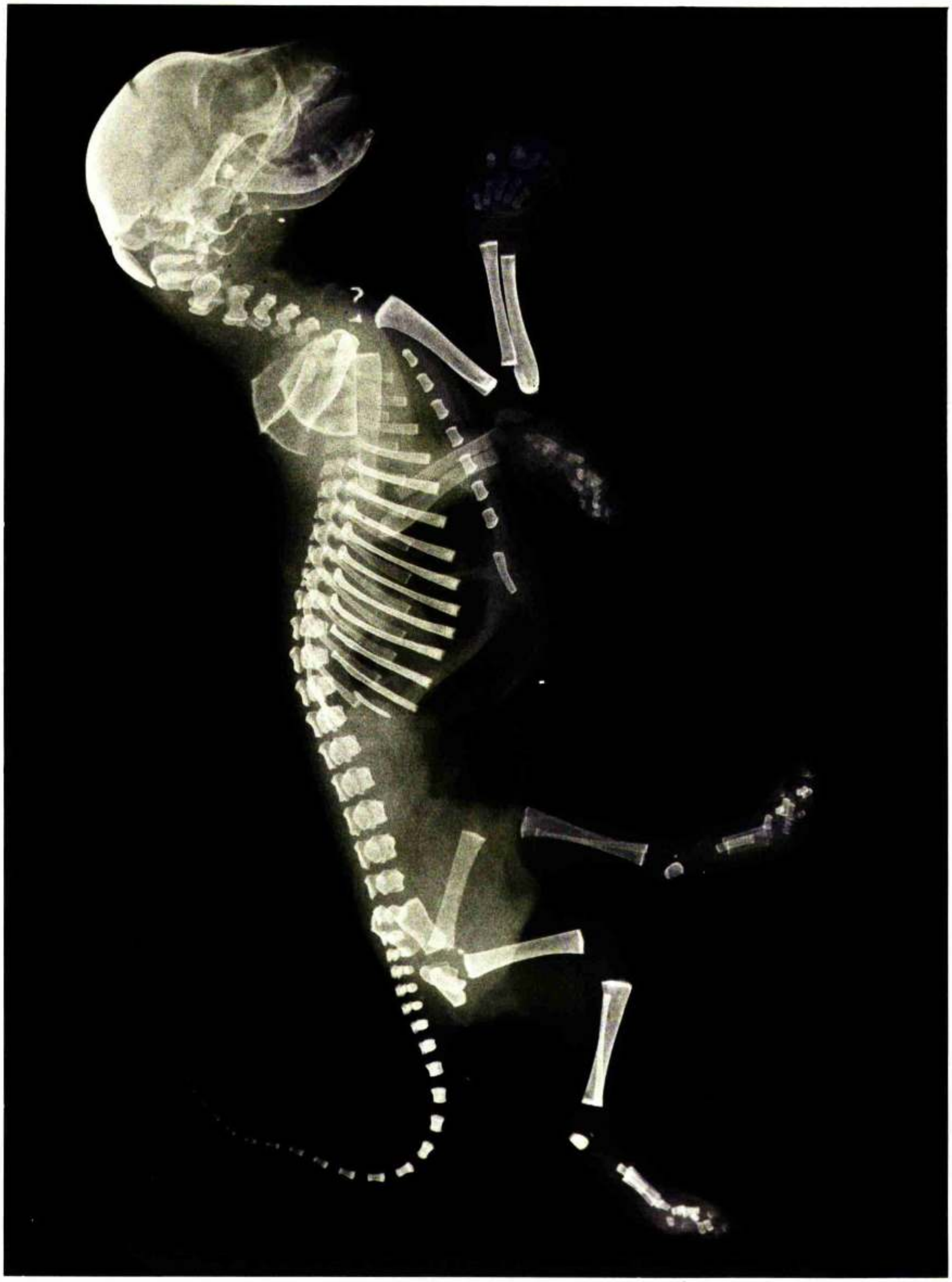


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 50	No.75	130mm.	58 days	NITRATE	

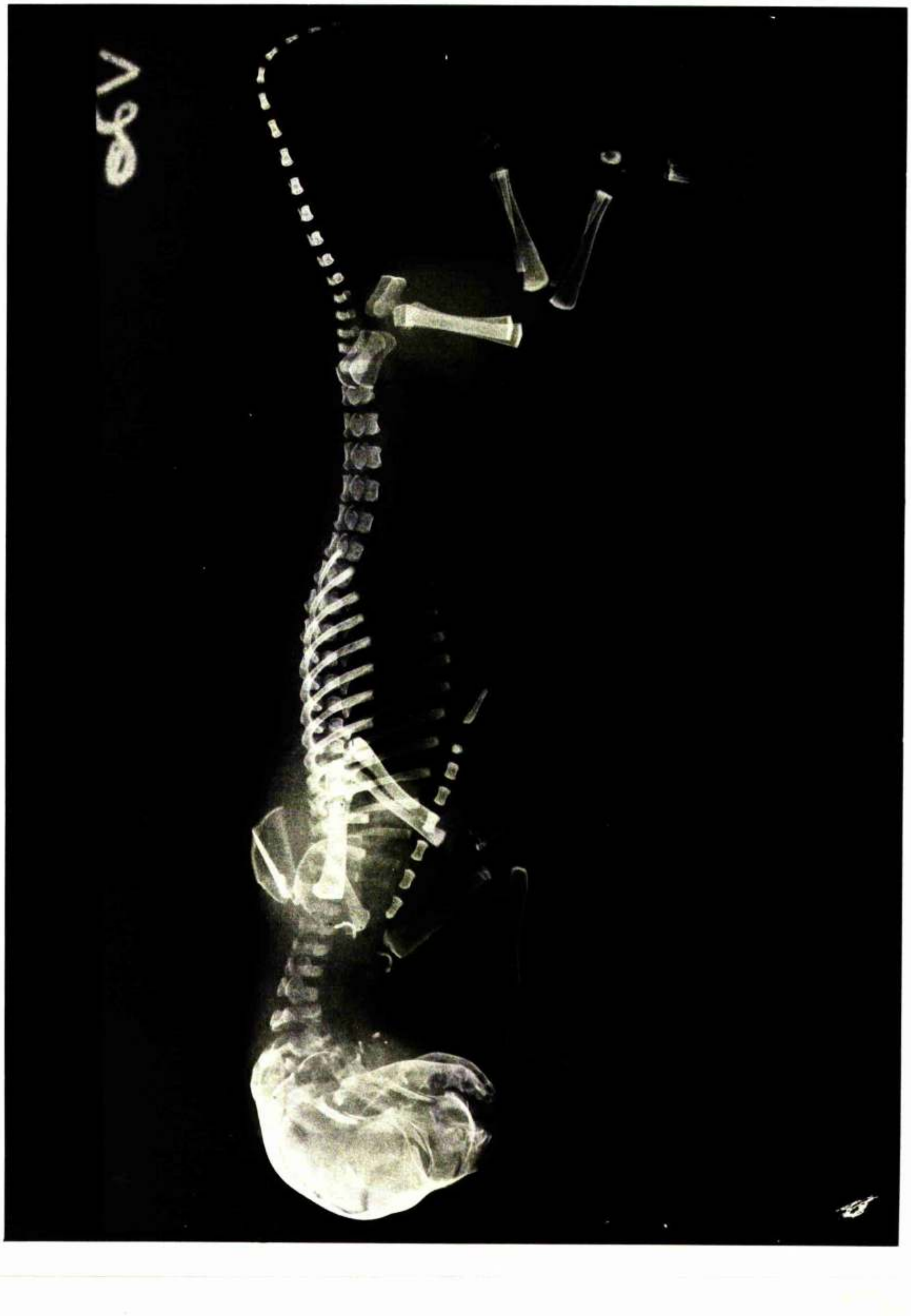


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 51	No.79	136mm.	60 days	NITRATE	

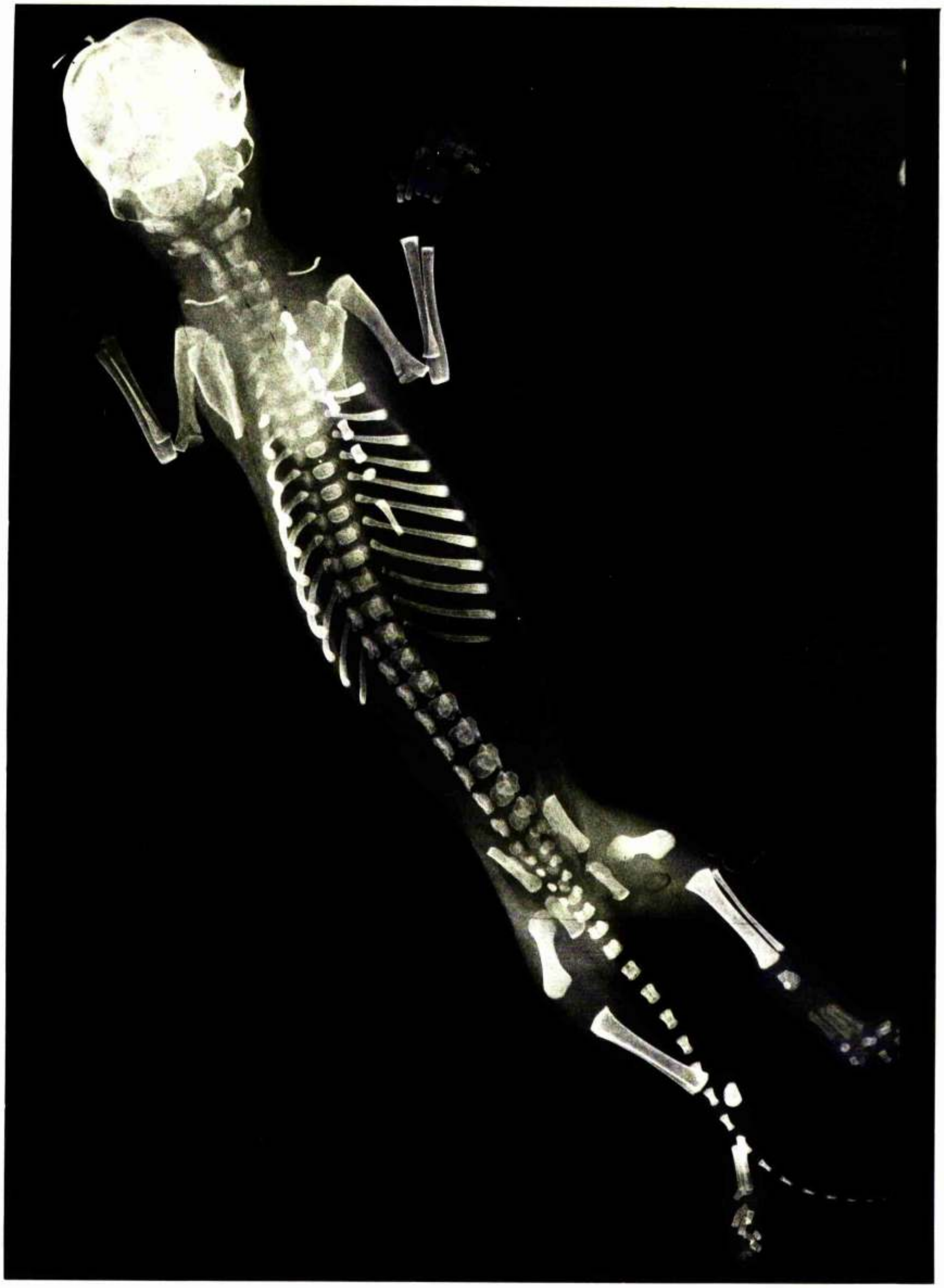


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 52	No.79	136mm.	60 days	NITRATE	

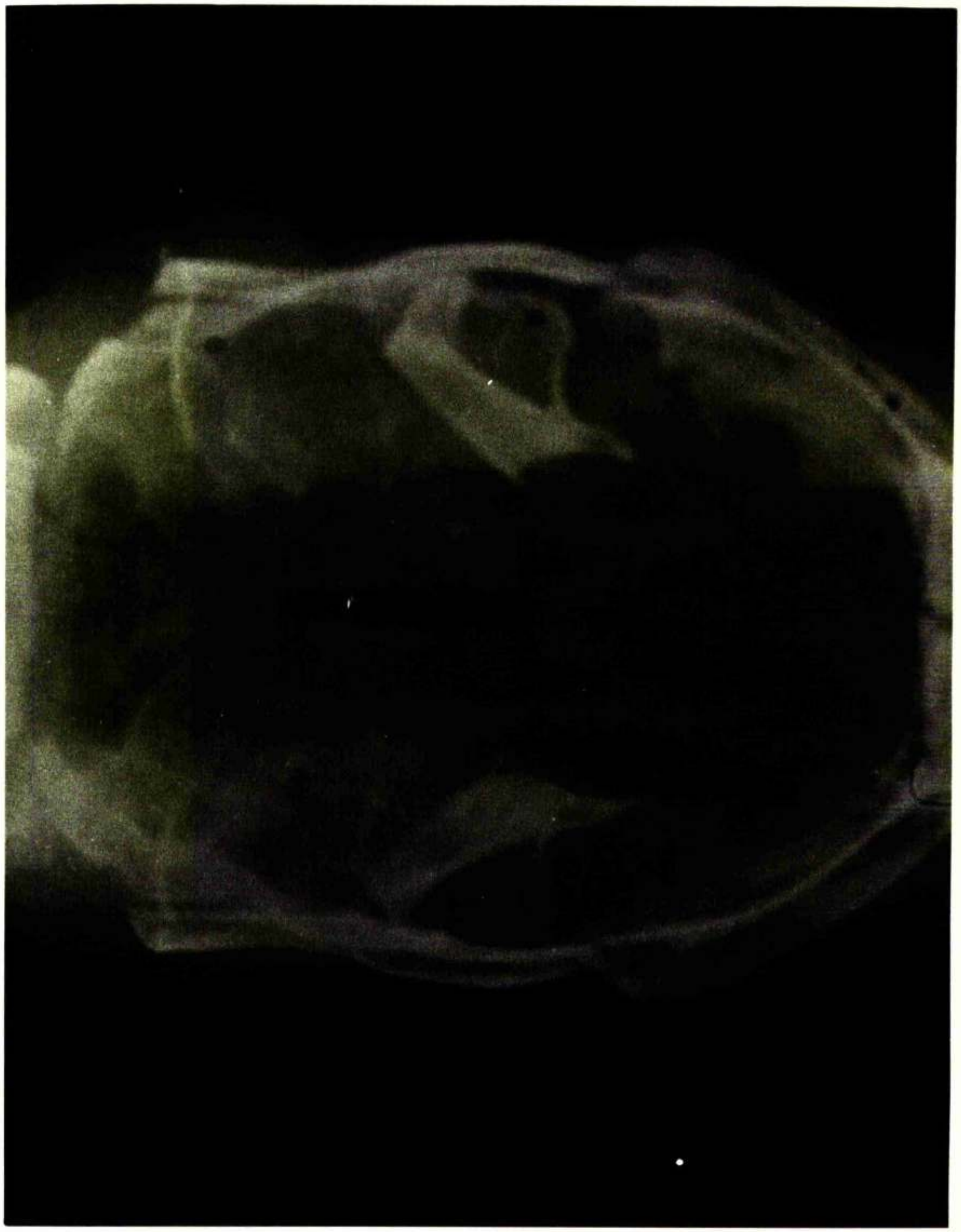


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	DORSO VENTRAL
SN 53	No.79	136mm.	60 days	NITRATE	HEAD

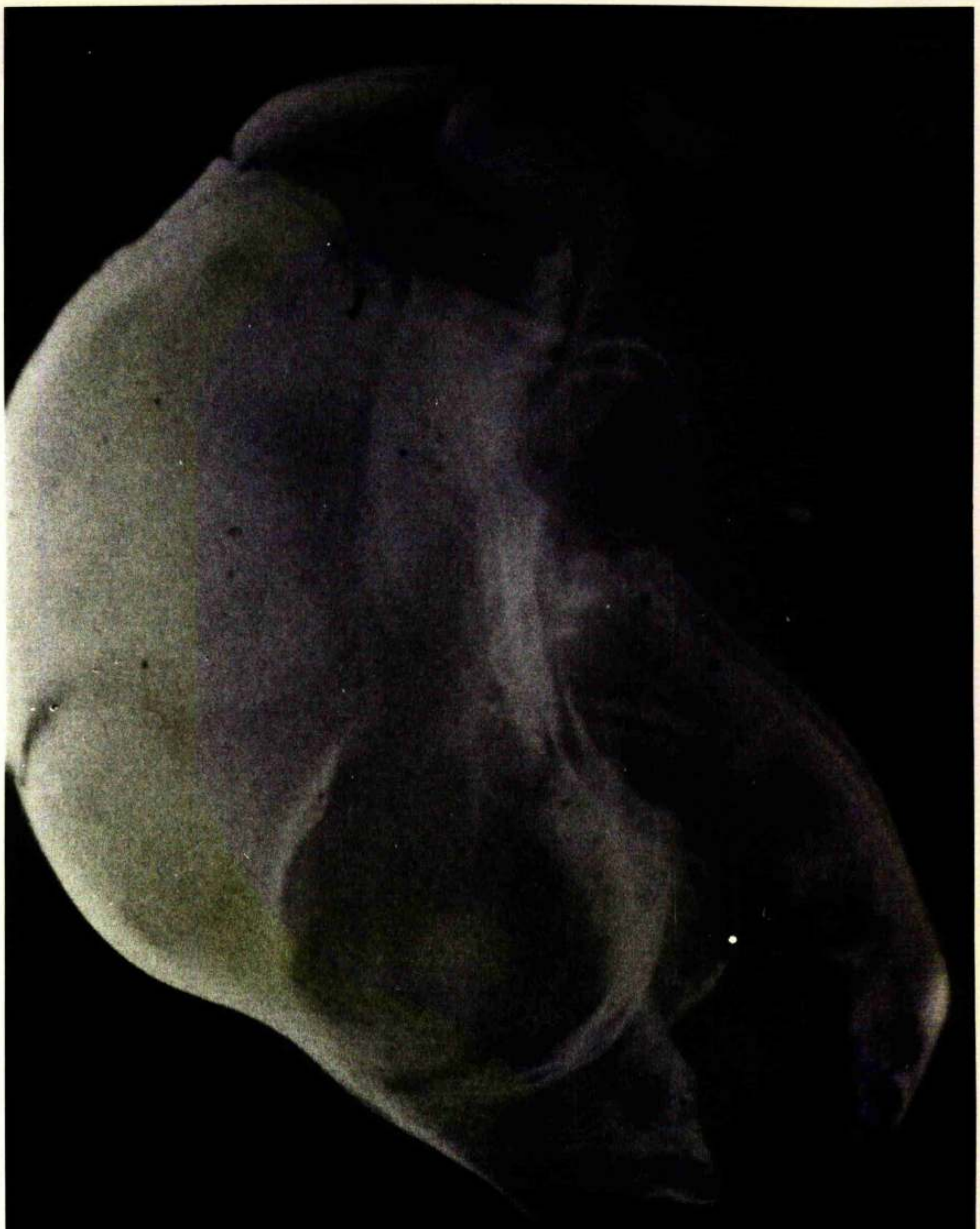


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 54	No.79	136mm.	60 days	NITRATE	HEAD

FIG. SN 55	LITTER No.84	C.R. ———	ESTIMATED AGE at birth	SILVER NITRATE	DORSO VENTRAL

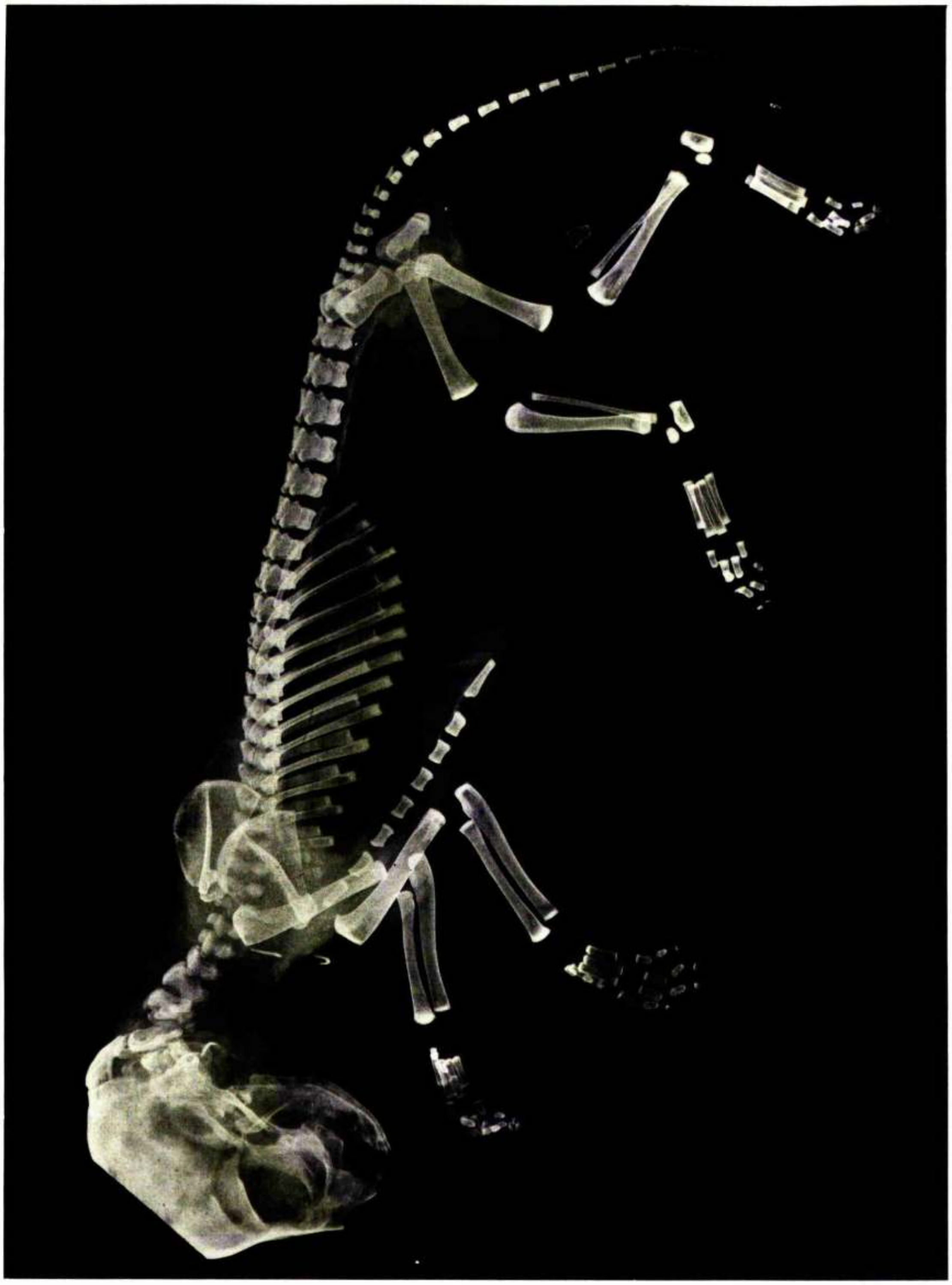
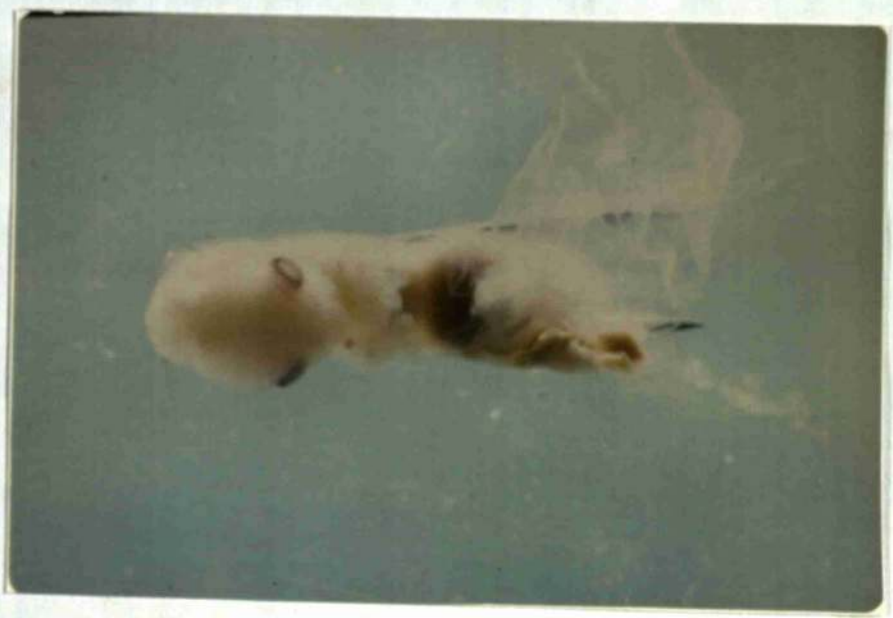


FIG.	LITTER	C.R.	ESTIMATED AGE	SILVER	LATERAL
SN 56	No.84	——	at birth	NITRATE	

AZ - SERIES OF PLATES FOR FOETUSES
STAINED WITH ALIZARIN RED

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
1	No.9	25mm.	28 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
2	No.10	26mm.	28 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
3	No.12	29mm.	30 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
4	No.13	29.1mm.	30 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
5	No.17	32mm.	30 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
6	No.18	35mm.	31 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
7	No.18	35mm.	31 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
8	No.18	35mm.	31 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
9	No.19	35mm.	31 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
10	No.20	35mm.	31 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
11	No.22	39mm.	33 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
12	No.22	39mm.	33 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
13	No.22	39mm.	33 days		

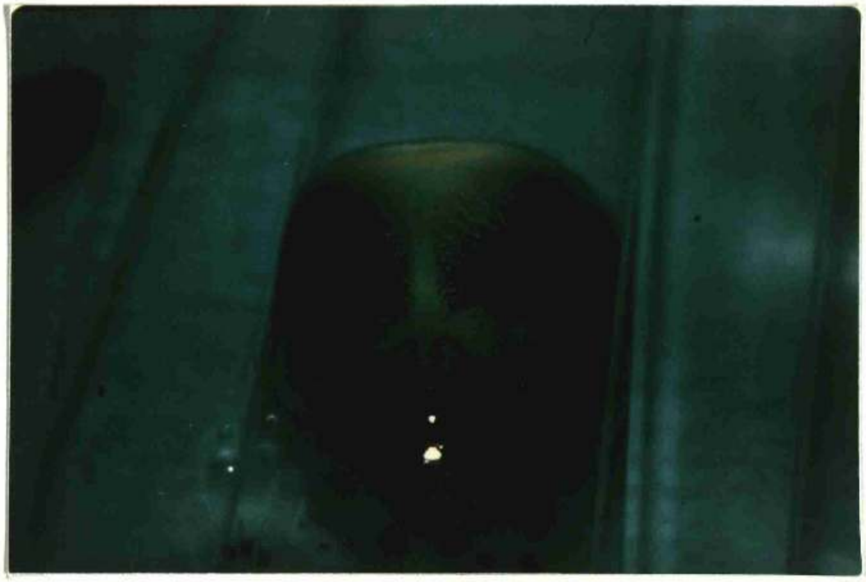
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	ROSTRAL HEAD
14	No.22	39mm.	33 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
15	No.23	39.8mm.	33 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL.
16	No.23	39.8mm.	33 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
17	No.26	44.2mm.	35 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
18	No.26	44.2mm.	35 days		



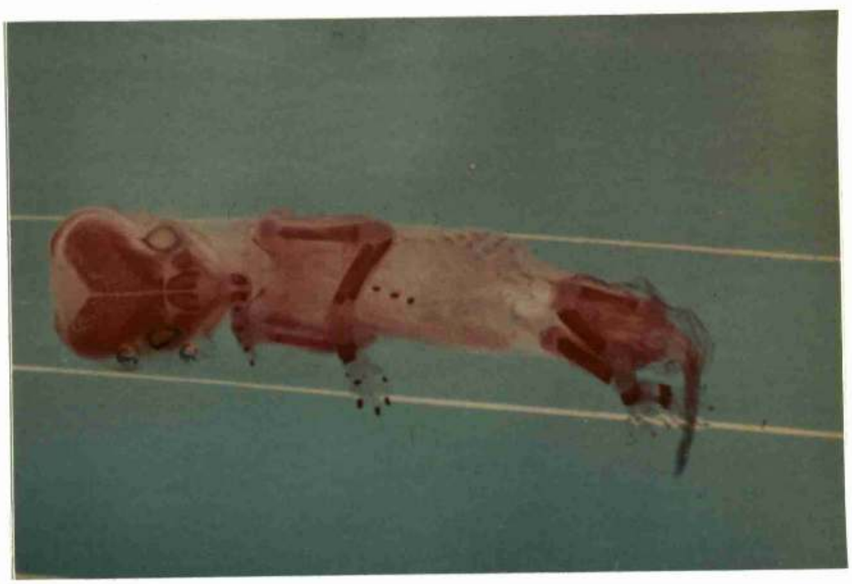
AZ LITTER C.R. ESTIMATED AGE ALIZARIN VENTRO DORSAL
19 No.26 44.2mm. 35 days

AZ LITTER C.R. ESTIMATED AGE ALIZARIN DORSO VENTRAL
20 No.27 49mm. 36 days

AZ 21 | LITTER No.27 | C.R. 49mm. | ESTIMATED AGE 36 days | ALIZARIN | LATERAL

AZ 22 | LITTER No.27 | C.R. 49mm. | ESTIMATED AGE 36 days | ALIZARIN | VENTRO DORSAL

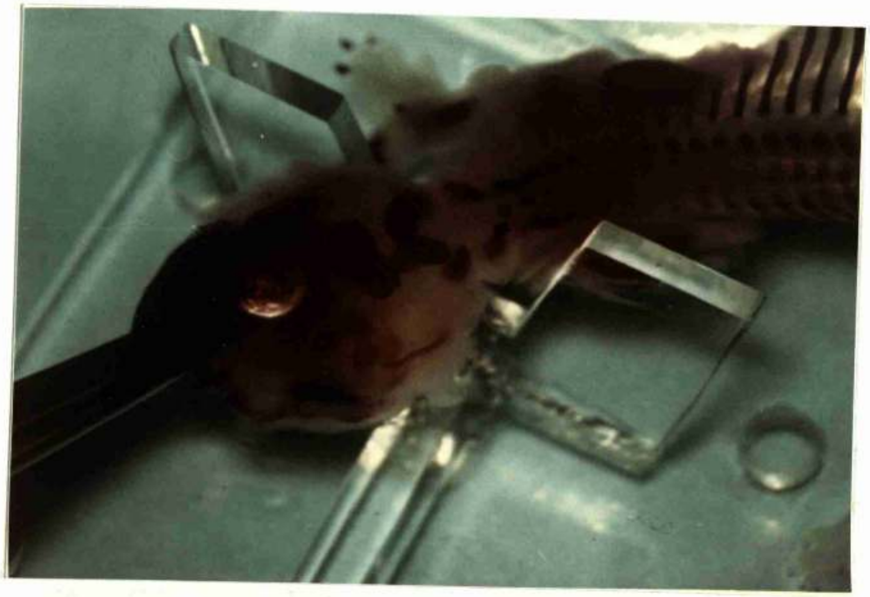
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
23	No.28	55mm.	36 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSO VENTRAL
24	No.29	56.5mm.	37 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
25	No.29	56.5mm.	37 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
26	No.30	58mm.	38 days		



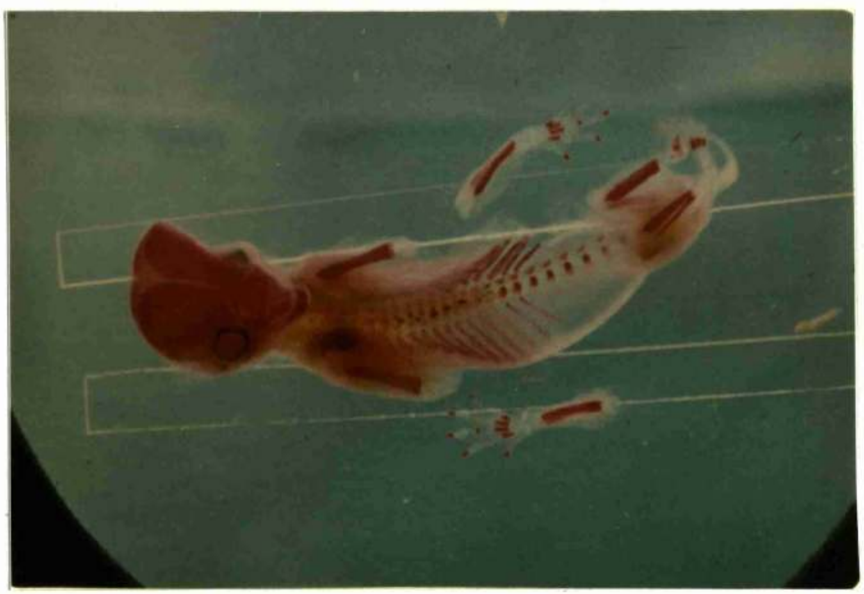
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSO VENTRAL
27	No.30	58mm.	38 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSO VENTRAL
28	No.30	58mm.	38 days		HEAD

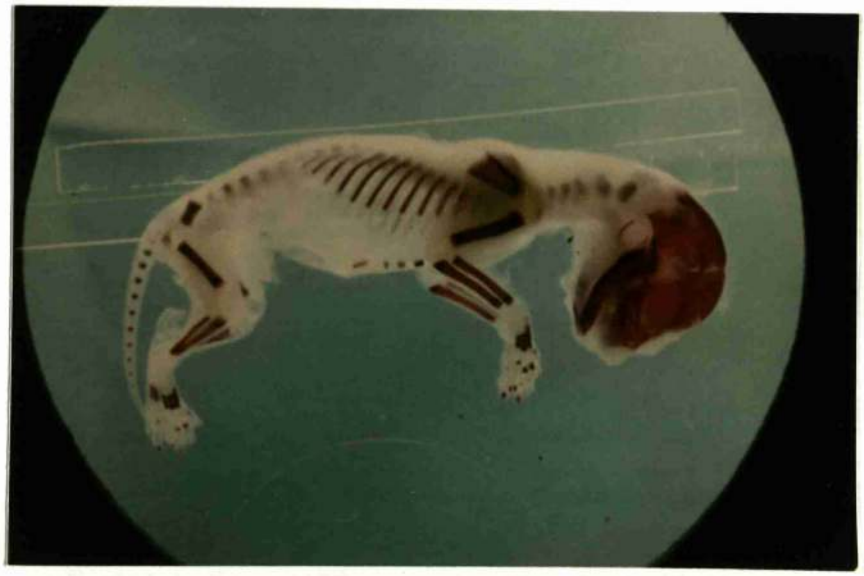
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD VENTRO DORSAL
29	No.30	58mm.	38 days		MANDIBLE REMOVED

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
30	No.32	63mm.	39 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSO VENTRAL
31	No.32	63mm.	39 days		

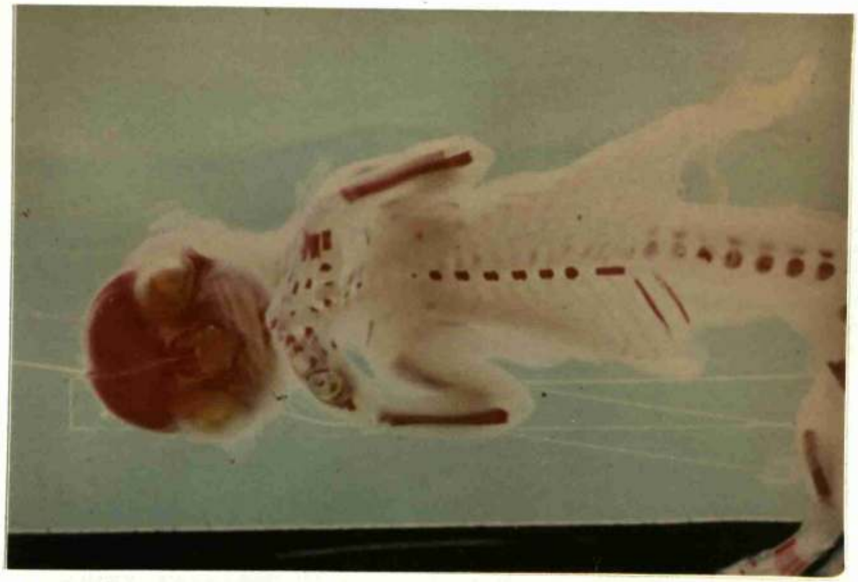


AZ.	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
32	No.32	63mm.	39 days		

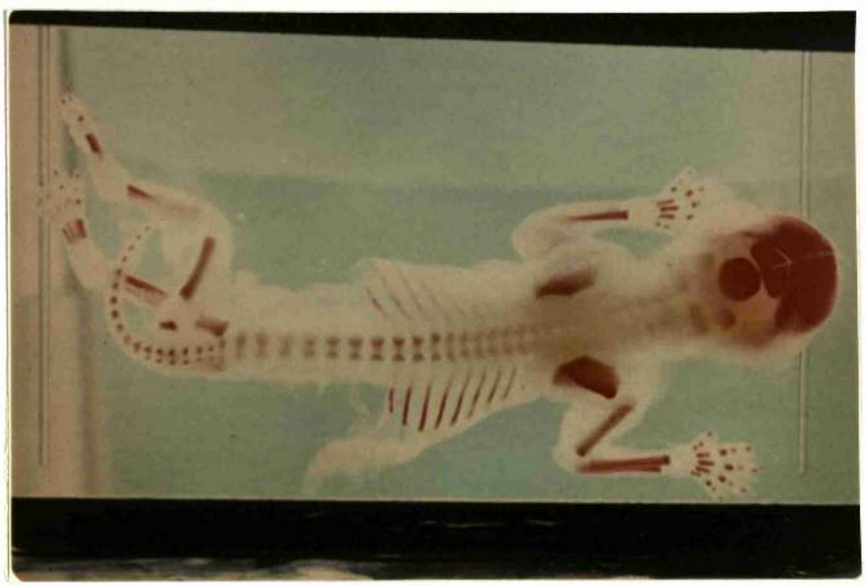


AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
33	No.34	66mm.	40 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	CRANIO LATERAL
34	No.36	68.9mm.	40 days		VIEW OF CAUDAL END



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
35	No.41	80mm.	42 days		

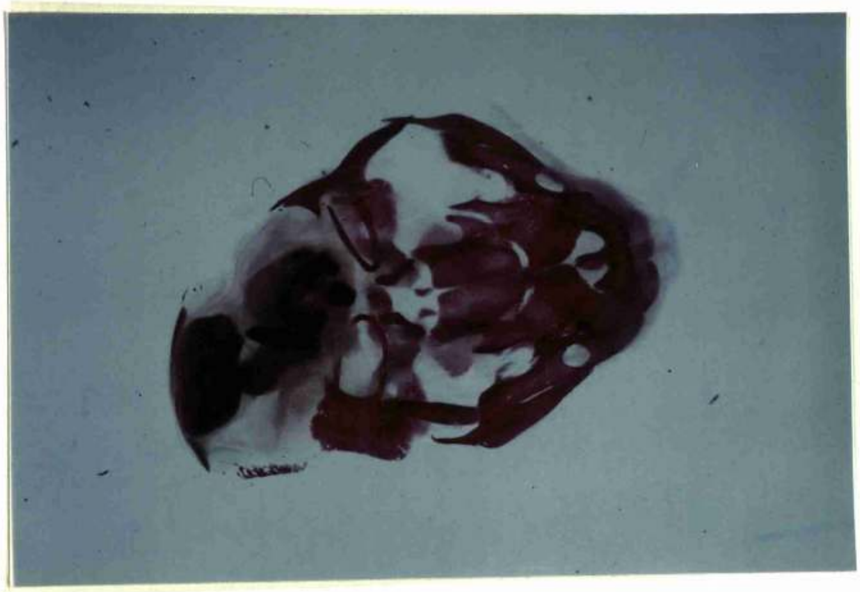


AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSO VENTRAL
36	No.41	80mm.	42 days		

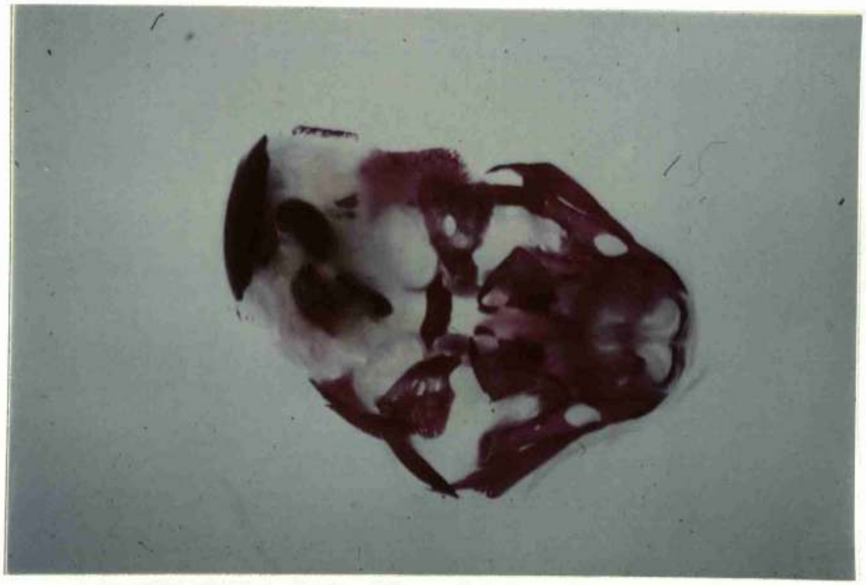
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
37	No.41	80mm.	42 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
38	No.42	82.5mm.	43 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	ROSTRAL VIEW
39	No.42	82.5mm.	43 days		OF HEAD



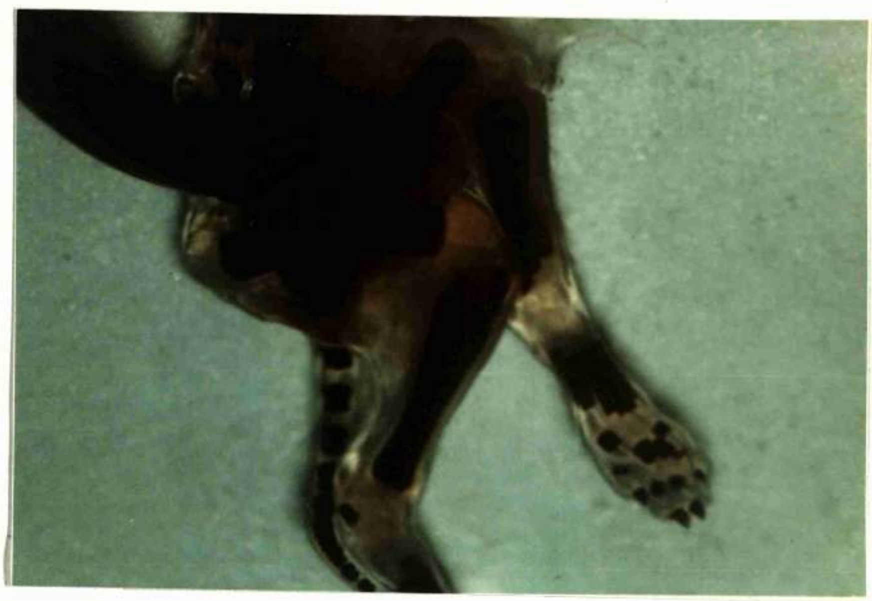
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
40	No.42	82.5mm.	43 days		VENTRO DORSAL



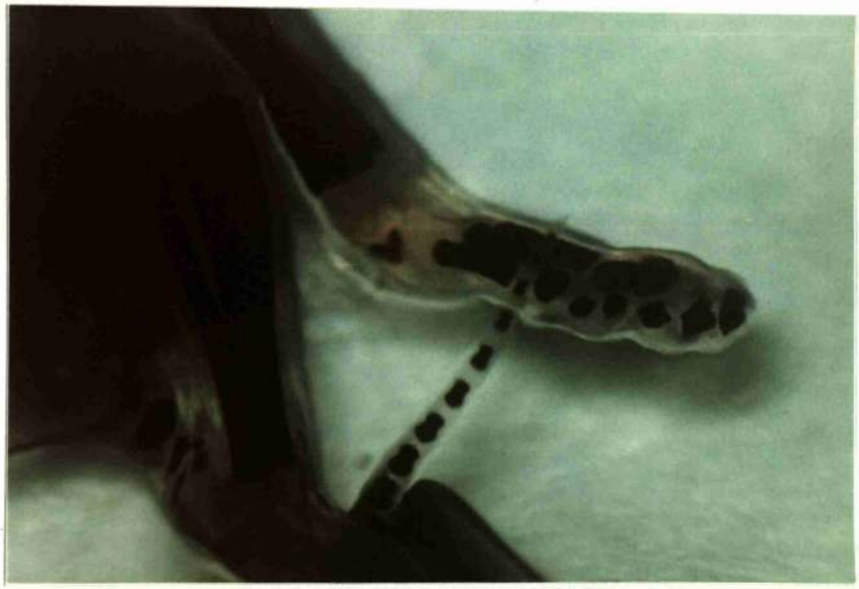
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
41	No.42	82.5mm.	43 days		DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	MANDIBULA
42	No.42	82.5mm.	43 days		

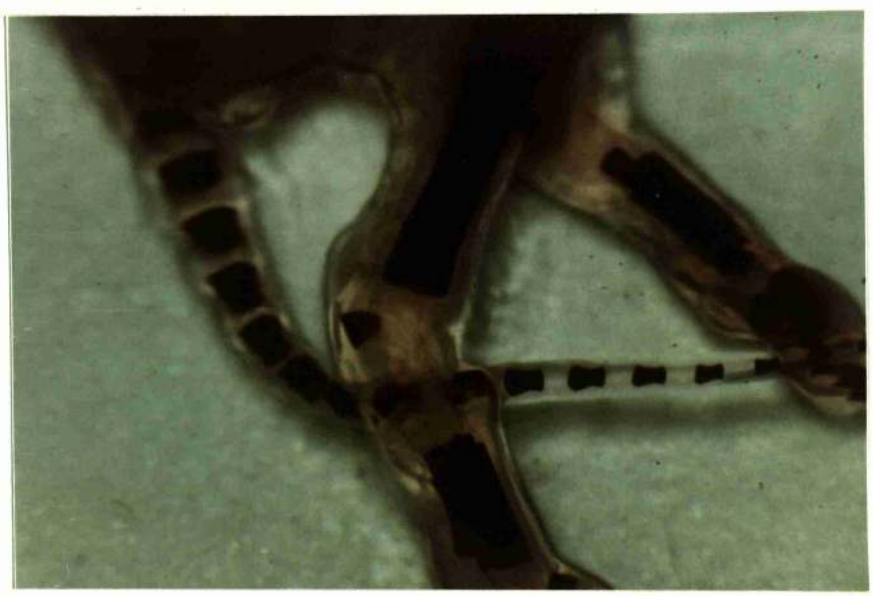
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
43	No.44	84mm.	44 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
44	No.44	84mm.	44 days		CAUDAL END



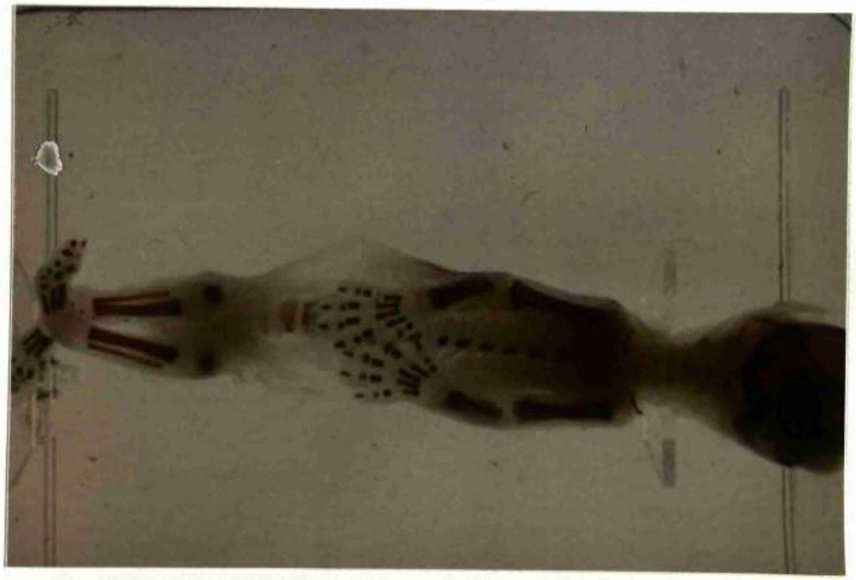
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
45	No.44	84mm.	44 days		PELVIC LIMB



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
46	No.44	84mm.	44 days		PELVIC LIMB

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
47	No.46	85mm.	44 days		

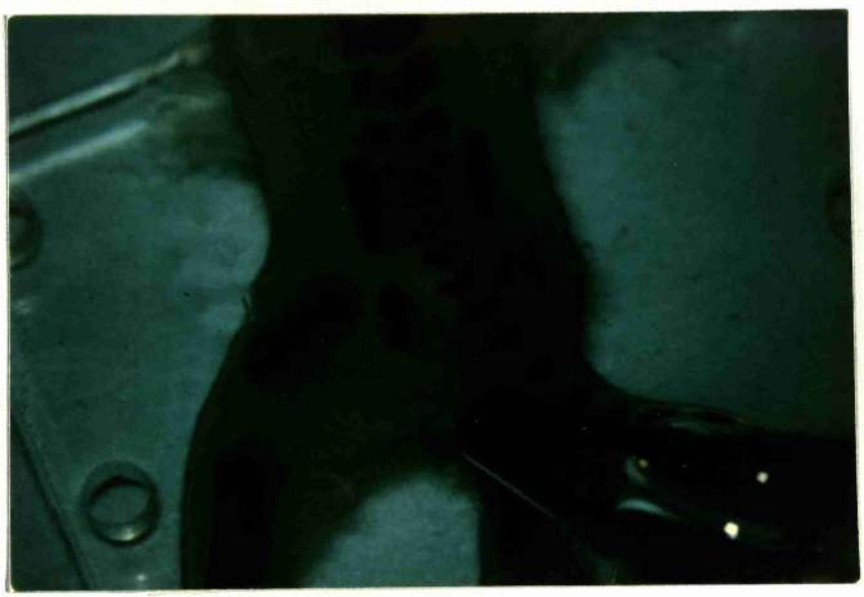
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
48	No.47	86mm.	45 days		PELVIS



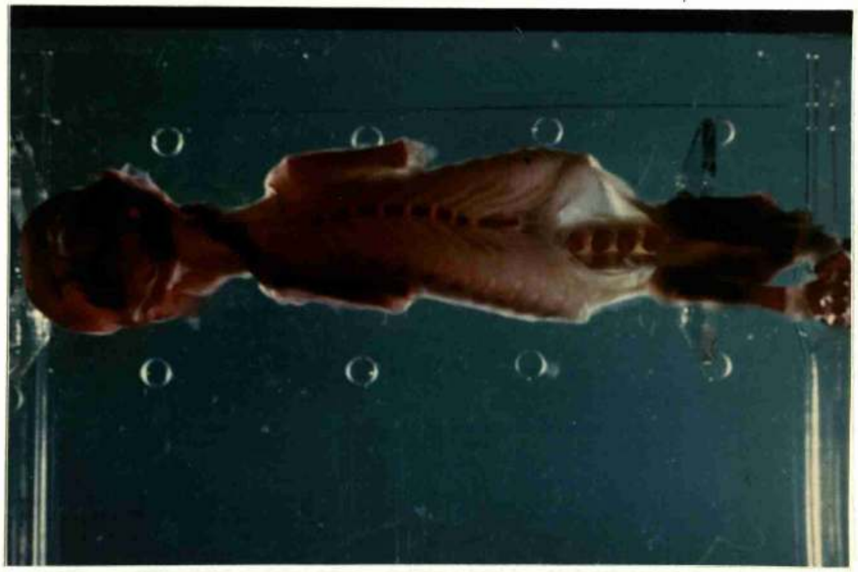
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
49	No.48	88mm.	46 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
50	No.48	88mm.	46 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
51	No.48	88mm.	46 days		THORAX



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSO VENTRAL
52	No.48	88mm.	46 days		CAUDAL END

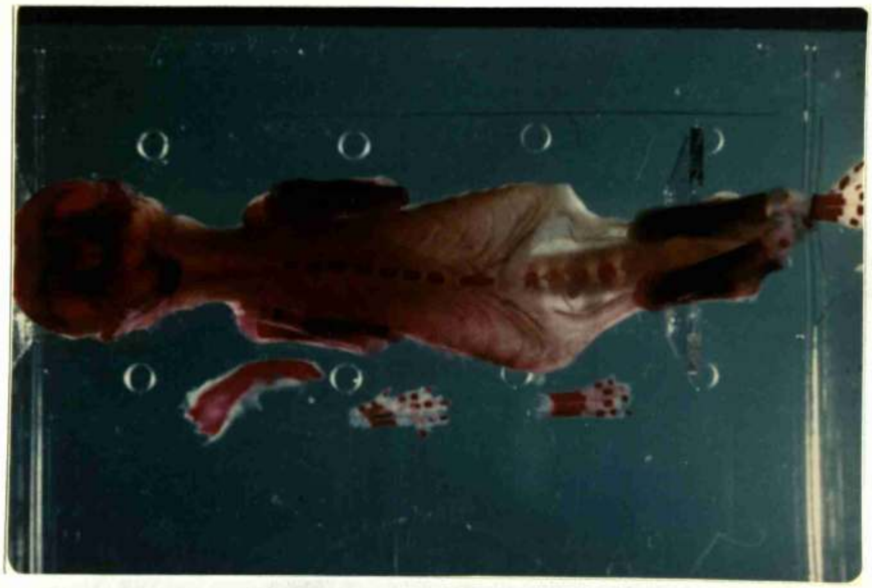


AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
53	No.53	92mm.	47 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
54	No.53	92mm.	47 days		DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
55	No.53	92mm.	47 days		VENTRO DORSAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
56	No.54	94mm.	48 days		



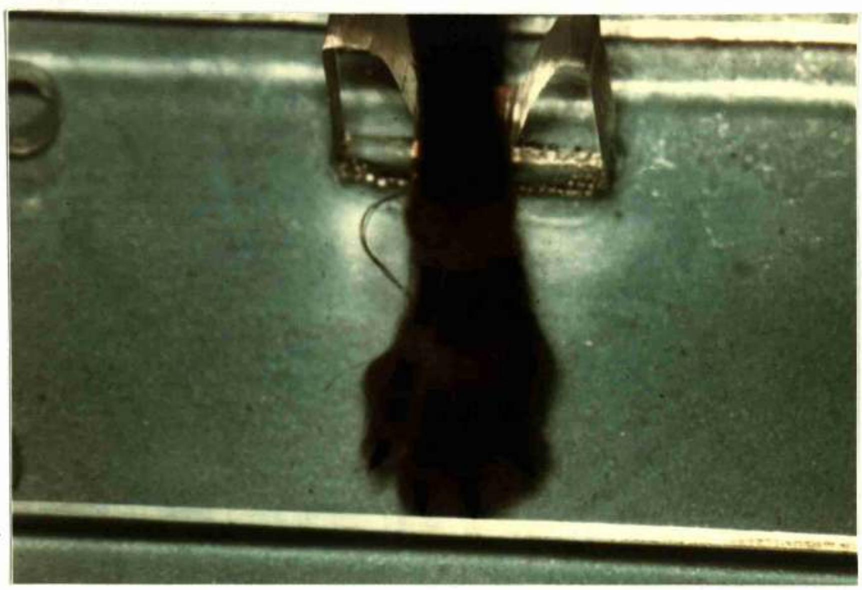
AZ 57 LITTER No.54 C.R. 94mm. ESTIMATED AGE 48 days ALIZARIN VENTRO DORSAL

AZ 58 LITTER No.55 C.R. 95mm. ESTIMATED AGE 48 days ALIZARIN HEAD VENTRO DORSAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
59	No.55	95mm.	48 days		DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	MANDIBULA
60	No.55	95mm.	48 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
61	No.56	102mm.	50 days		

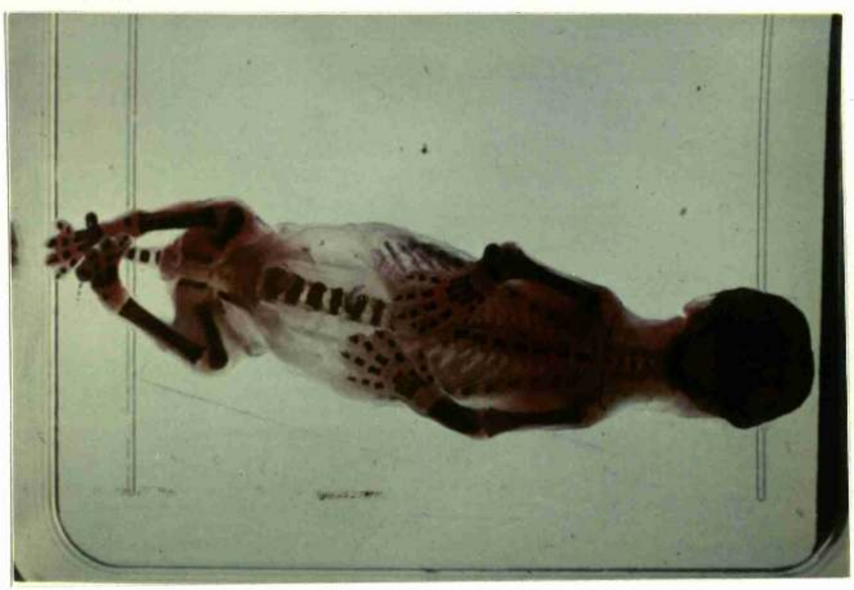


AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSUM OF MANUS
62	No.56	102mm.	50 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PECTORAL & PELVIC
63	No.58	105mm.	51 days		LIMBS. LATERAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	SACRO ILIAC REGION
64	No.58	105mm.	51 days		LATERAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	SACRO ILIAC REGION
65	No.58	105mm.	51 days		VENTRO LATERAL



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
66	No.59	105.5mm.	51 days		

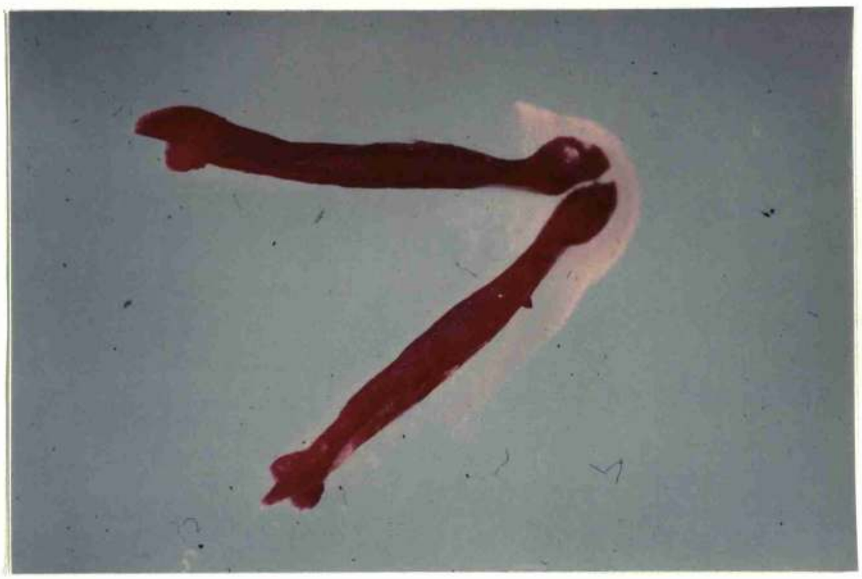
AZ 67 | LITTER No.60 | C.R. 108mm. | ESTIMATED AGE 52 days | ALIZARIN | DORSO VENTRAL

AZ 68 | LITTER No.60 | C.R. 108mm. | ESTIMATED AGE 52 days | ALIZARIN | PELVIC REGION VENTRO DORSAL

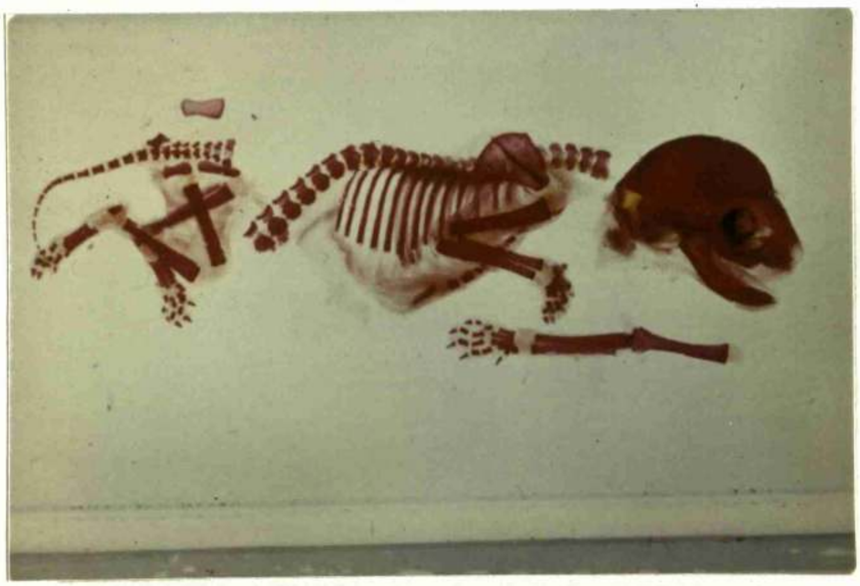
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PELVIC REGION
69	No.60	108mm.	52 days		DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
70	No.60	108mm.	52 days		DORSO VENTRAL

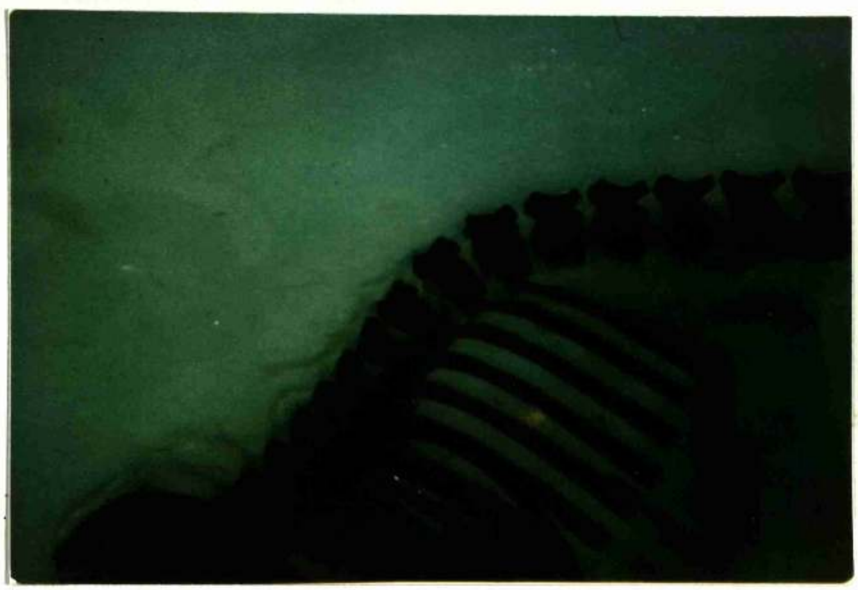
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
71	No.60	108mm.	52 days		VENTRO DORSAL



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	MANDIBULA
72	No.60	108mm.	52 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
73	No.61	108.3mm.	53 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	THORACO-LUMBAR
74	No.61	108.3mm.	53 days		REGION LATERAL

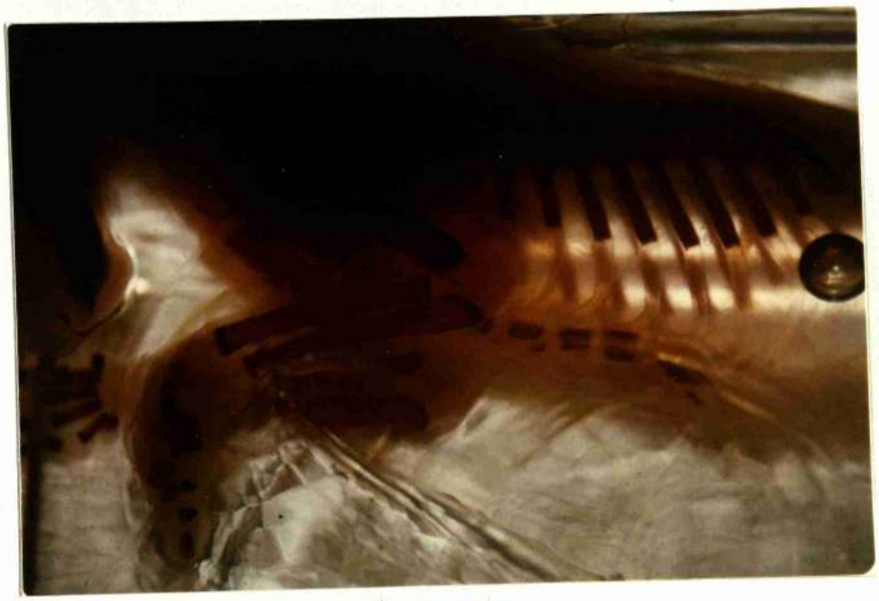
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	CERVICAL & THORACIC
75	No.61	108.3mm.	53 days		VERTEBRAE. LATERAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	FEMOROTIBIAL JOINT
76	No.61	108.3mm.	53 days		VIEW OF CRAN.ASPECT PELVIS IN BRIDGE.

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSUM OF PES.
77	No.61	108.3mm.	53 days		PROXIMAL EXTREMITY OF TIBIA, CAUDAL END

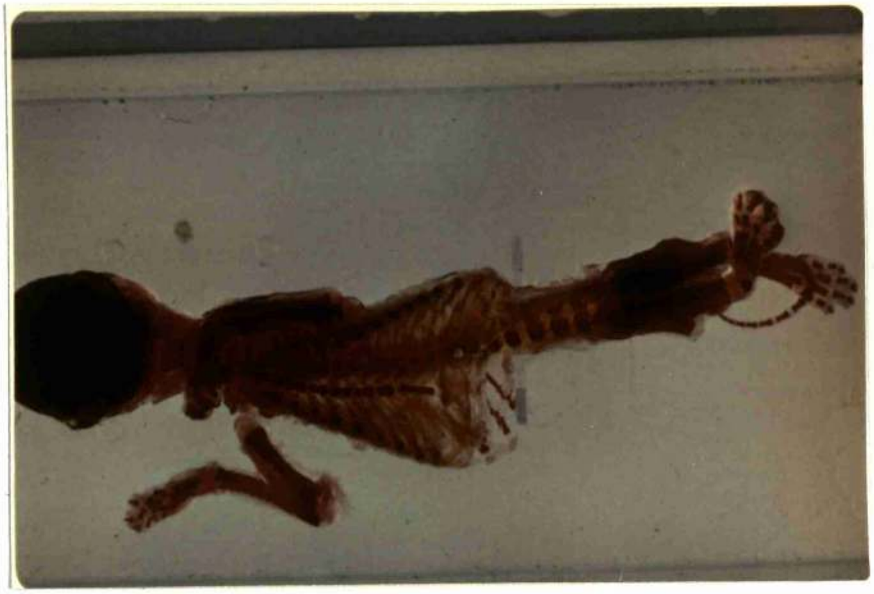
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
78	No.64	112mm.	54 days		

AZ 79 | LITTER No.64 | C.R. 112mm. | ESTIMATED AGE 54 days | ALIZARIN | CAUDAL END VENTRO DORSAL

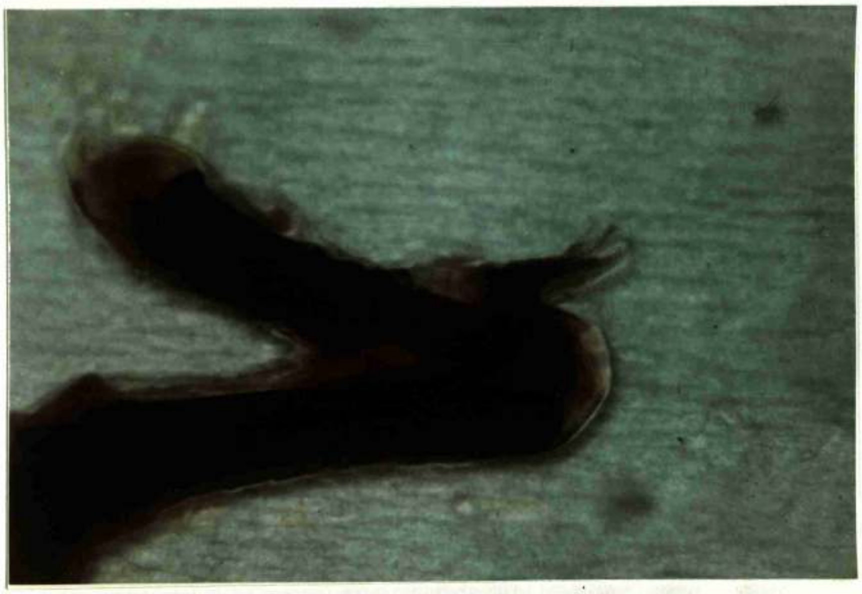


AZ 80 | LITTER No.64 | C.R. 112mm. | ESTIMATED AGE 54 days | ALIZARIN | LATERAL PECTORAL LIMB

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
81	No.65	112mm.	54 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
82	No.65	112mm.	54 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	MEDIAL ASPECT
83	No.65	112mm.	54 days		PECTORAL LIMB

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL ASPECT
84	No.65	112mm.	54 days		PECTORAL LIMB

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
85	No.65	112mm.	54 days		

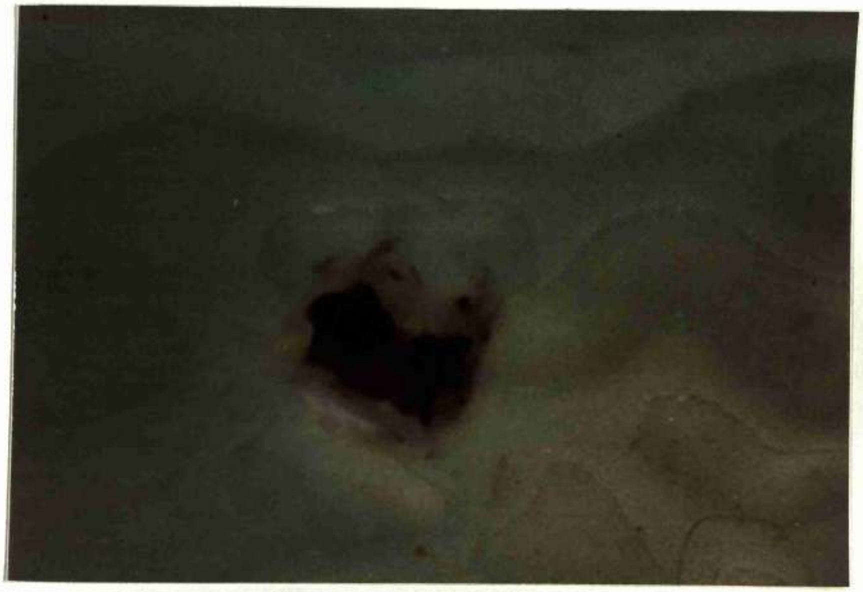
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PELVIC REGION
86	No.66	113mm.	54 days		VENTRO DORSAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PELVIC REGION
87	No.66	113mm.	54 days		LATERAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PECTORAL & PELVIC
88	No.68	115mm.	54 days		LIMBS. LATERAL

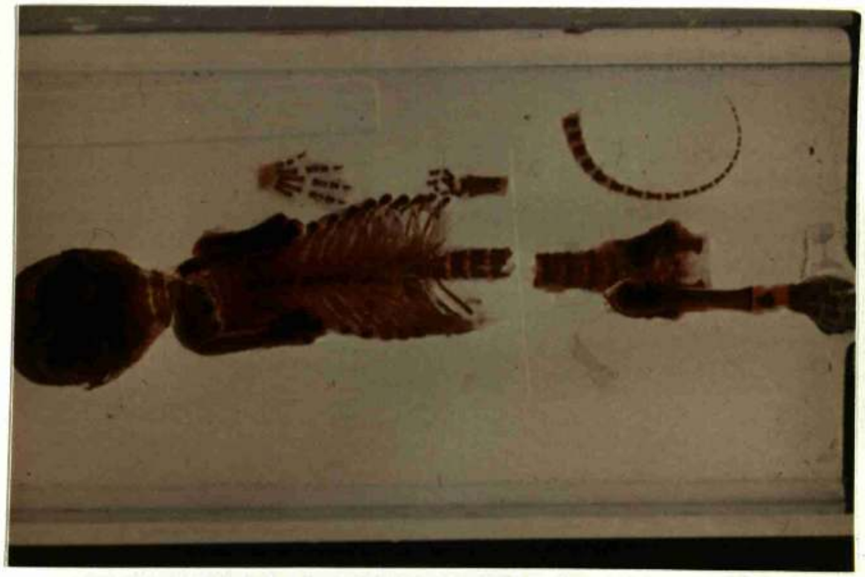
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PECTORAL & PELVIC
89	No.68	115mm.	54 days		LIMBS DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	CRANIAL ASPECT
90	No.68	115mm.	54 days		LUMBAR VERTEBRA



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSAL ASPECT
91	No.69	120mm.	56 days		LUMBAR VERTEBRA

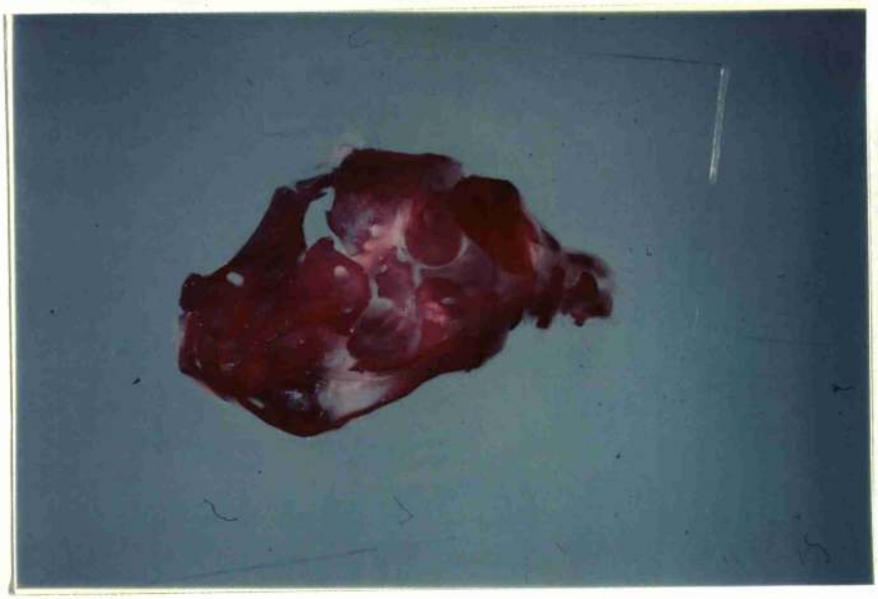
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
92	No.70	121mm.	56 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
93	No.70	121mm.	56 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
94	No.72	125mm.	57 days		DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
95	No.73	125mm.	57 days		VENTRO DORSAL

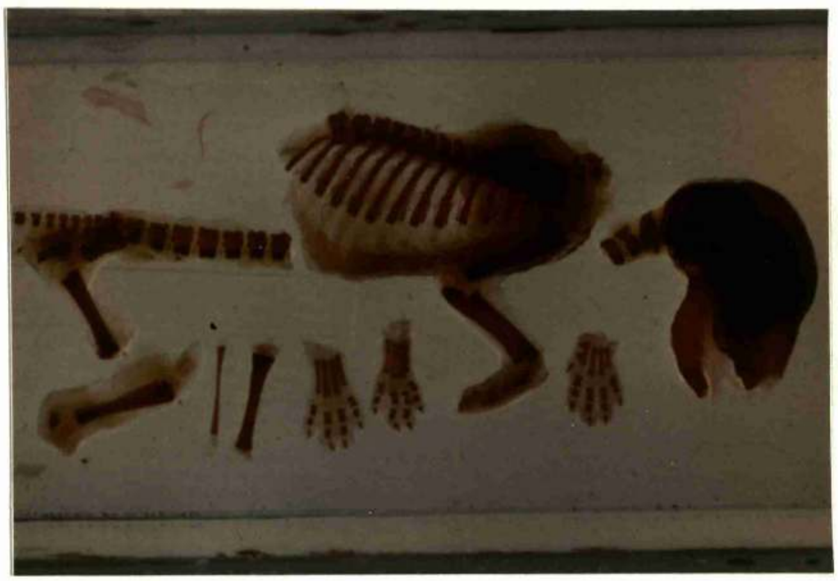


AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
96	No.73	125mm.	57 days		DORSO VENTRAL/ OBLIQUE

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
97	No.74	127mm.	57 days		LATERAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
98	No.74	127mm.	57 days		DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	CRANIAL ASPECT
99	No.75	130mm.	58 days		HUMERUS



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
100	No.75	130mm.	58 days		

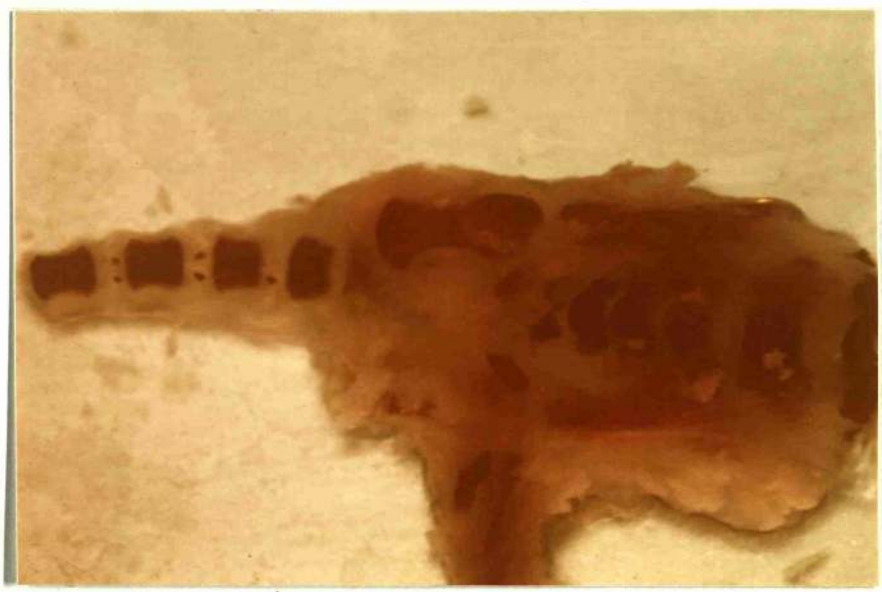
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
101	No.75	130mm.	58 days		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	CERVICAL VERTEBRAE
102	No.75	130mm.	58 days		CRANIAL VIEW

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	CERVICAL VERTEBRAE
103	No.75	130mm.	58 days		VENTRO DORSAL

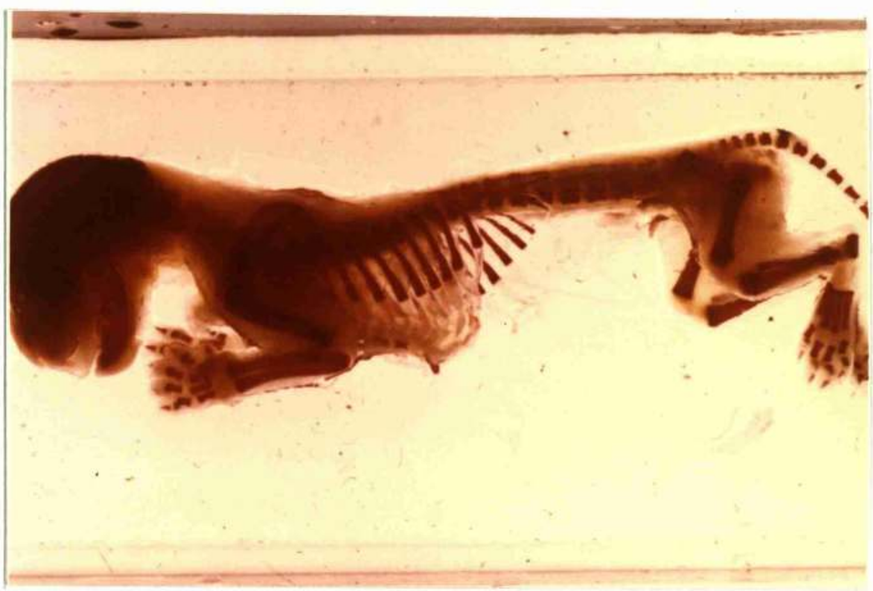
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PELVIC LIMB
104	No.78	133mm.	59 days		CRANIAL ASPECT.TOP LATERAL ASP. BELOW

AZ 105 | LITTER No.78 | C.R. 133mm. | ESTIMATED AGE 59 days | ALIZARIN | FEMOROTIBIAL JOINT LATERAL VIEW

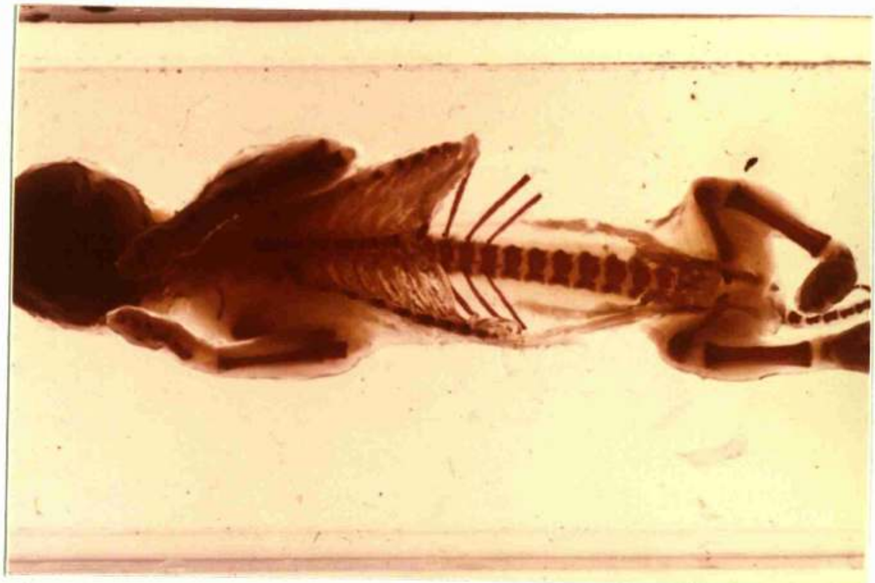


AZ 106 | LITTER No.78 | C.R. 133mm. | ESTIMATED AGE 59 days | ALIZARIN | PELVIC REGION VENTRO DORSAL

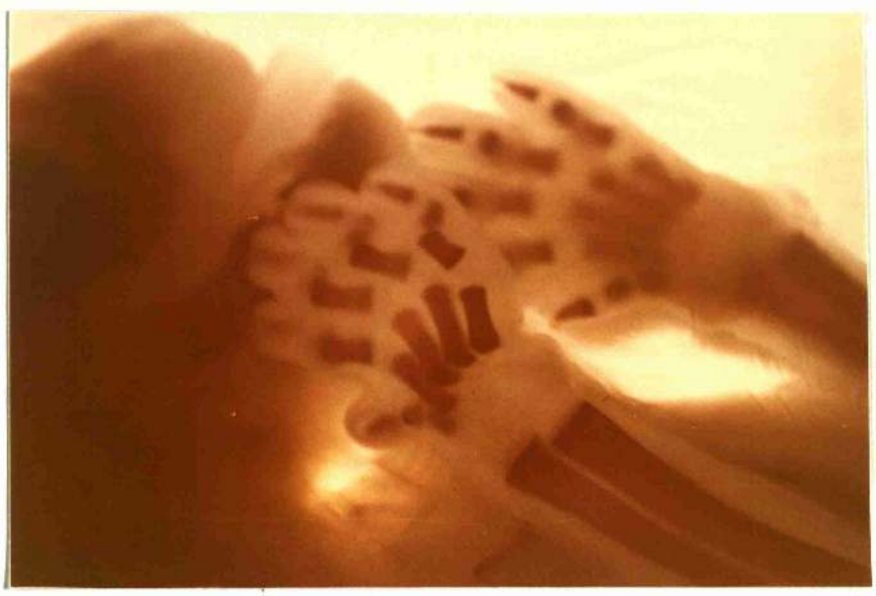
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PELVIC REGION
107	No.78	133mm.	59 days		LATERAL/OBLIQUE



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
108	No.79	136mm.	60 days		

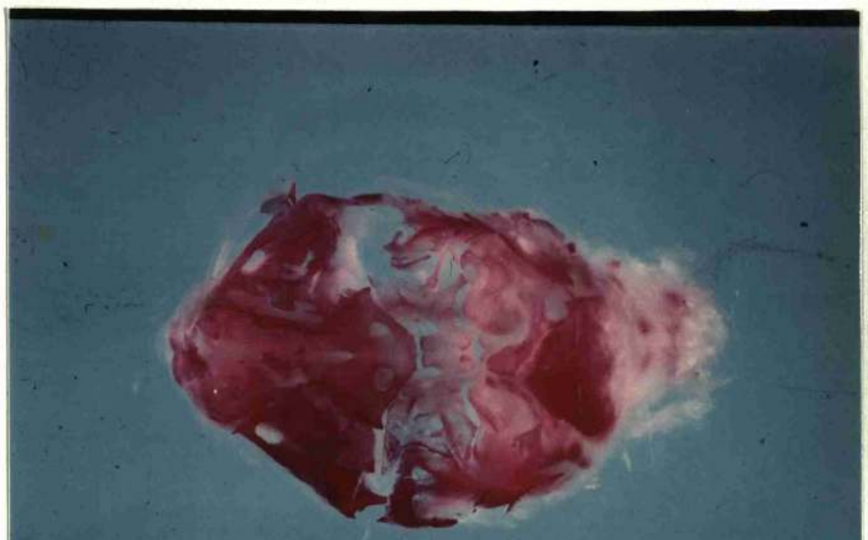


AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
109	No.79	136mm.	60 days		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	DORSUM RIGHT
110	No.79	136mm.	60 days		MANUS

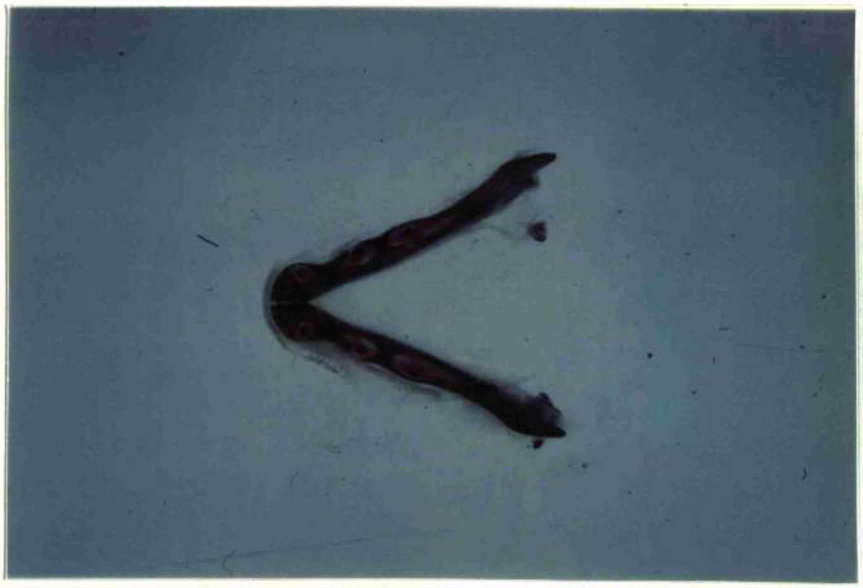
HEAD
PARASAGITTAL



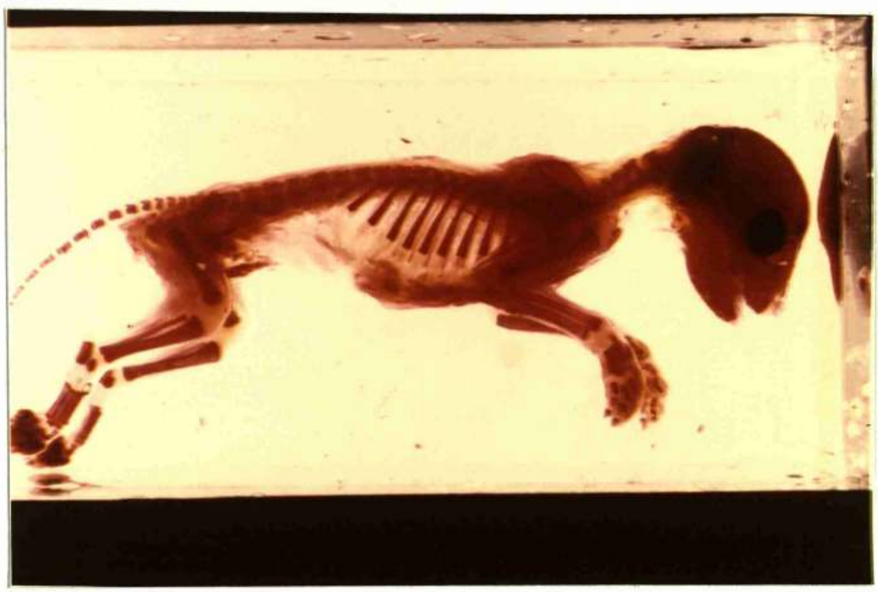
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
111	No.83	——	at birth		DORSO VENTRAL

HEAD
LATERAL

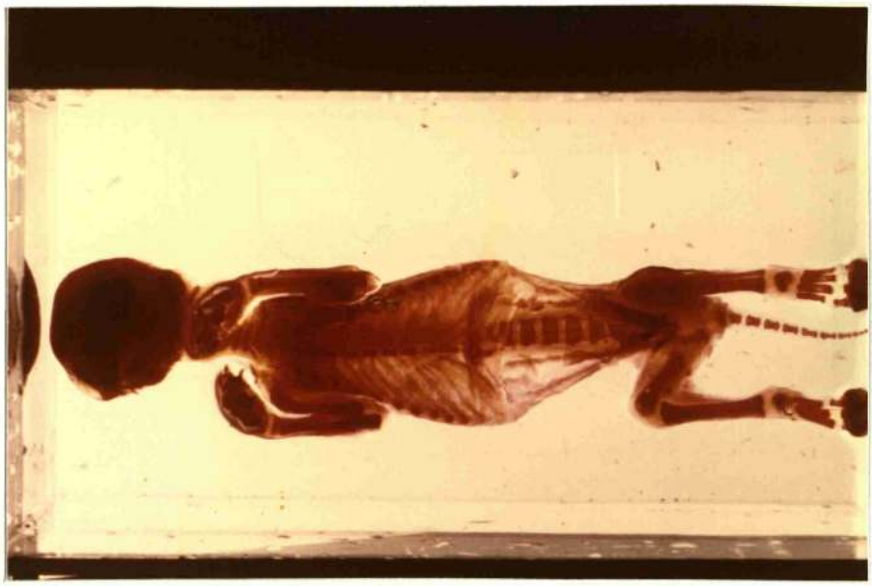
AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	HEAD
112	No.83	------	at birth		VENTRO DORSAL



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	MANDIBULA
113	No.83	----	at birth		

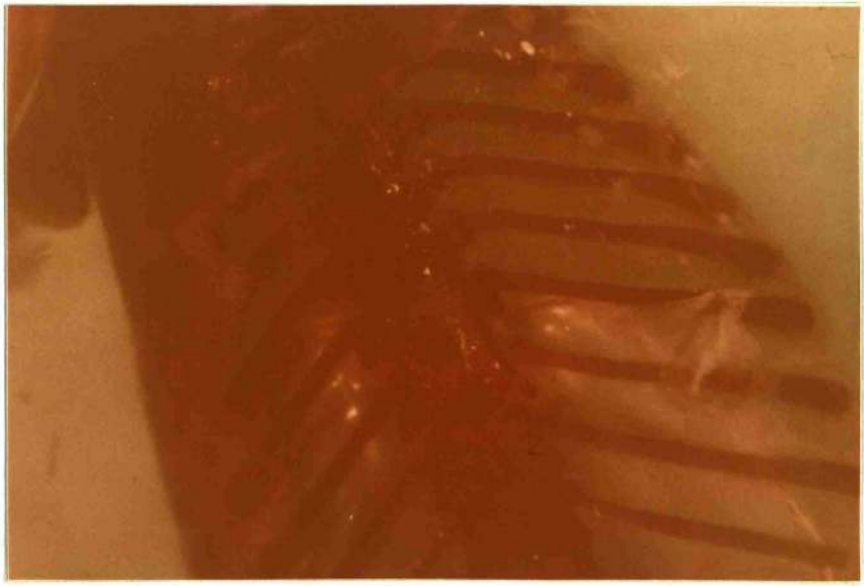


AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL
114	No.84	----	at birth		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	VENTRO DORSAL
115	No.84	----	at birth		

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LATERAL SHOULDER
116	No.84	----	at birth		



AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	THORAX
117	No.84	----	at birth		DORSO VENTRAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PELVIC LIMB
118	No.84	----	at birth		LATERAL VIEW

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	PELVIC REGION
119	No.85	——	1 day P.P.		VENTRO DORSAL

AZ	LITTER	C.R.	ESTIMATED AGE	ALIZARIN	LUMBAR VERTEBRA
120	No.85	——	1 day P.P.		CAUDAL VIEW

SERIES OF PLATES FOR RADIOGRAPHY
OF PREGNANT CATS

FIG. 1. Radiograph of 37, 41 days, ventral-dorsal exposure. Uterus can be seen displacing abdominal contents anteriorly. Foetuses are seen in both left and right lateral abdominal positions.

FIG. 2. Radiograph of litter 53, 47 days, lateral exposure. Uterus can be seen largely filling abdominal cavity.

FIG. 3. Radiograph of litter 70, 56 days, lateral exposure. The sternum and phalanges are now visible. The foetus placed most ventrally illustrates those structures.

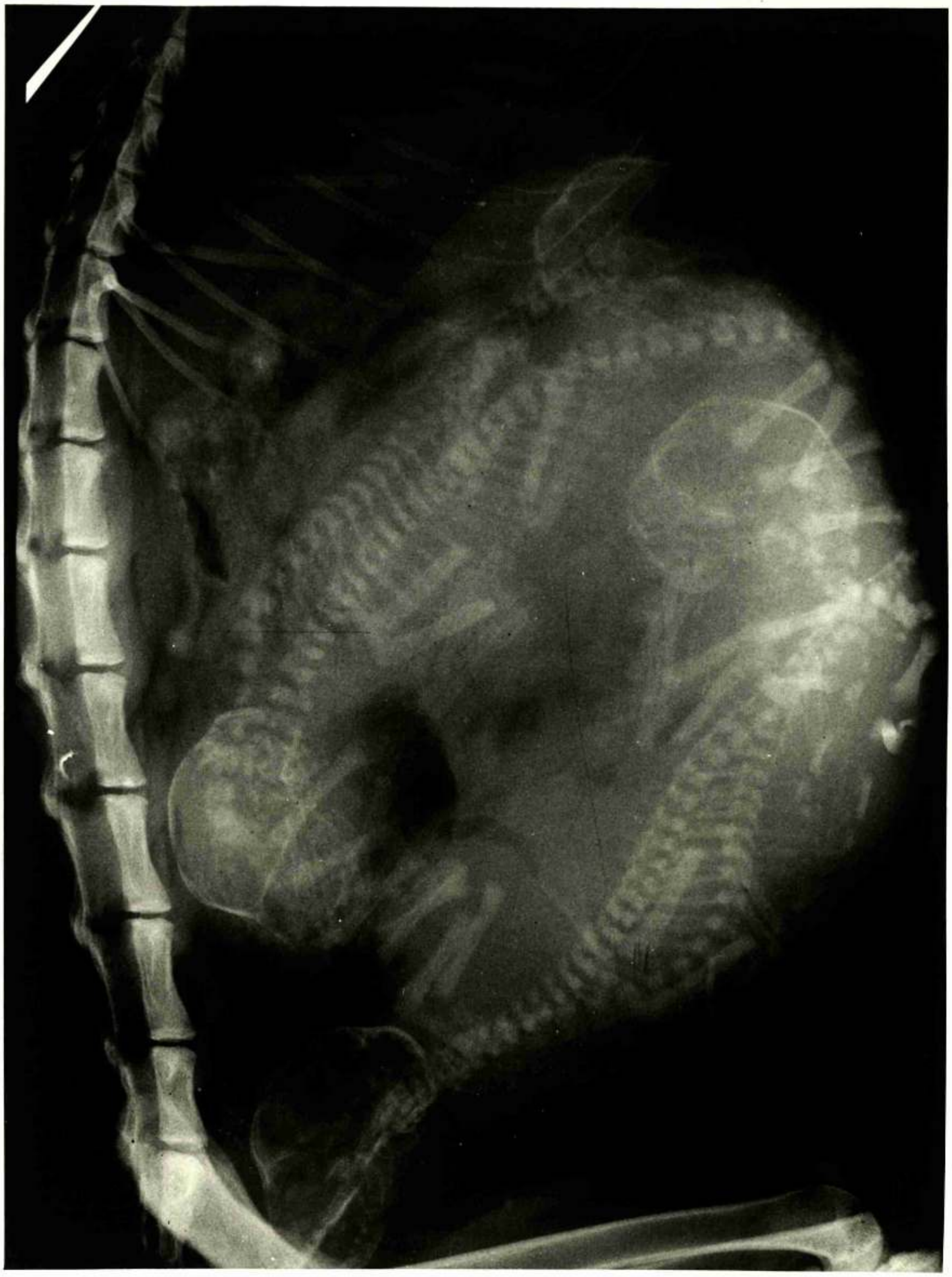


FIG. 4. Radiograph of litter 82, at parturition, lateral exposure.
The foetal skull can be seen lodging in the pelvic inlet.
The teeth can be observed forming in the mandible.

PATTERNS OF OSSIFICATION

IN THE FELINE FOETUS

BY

JOHN S. BOYD, B. V. M. S., M. R. C. V. S.

APPENDIX I

CROWN RUMP LENGTH MEASUREMENT

Arey (1948) states embryos are measured in two principal ways, the commonest being the crown rump length (designated C.R.) or sitting height and this is defined as the distance from vertex to breech. The form of the measurement is illustrated by Arey (1948).

It is agreed that there is no absolutely accurate method of estimating the age of an embryo from its length, Hamilton, Boyd and Mossman (1952) and these authors cite earlier work by Streeter (1942, 1945 and 1948), but they recognise that crown rump length may be useful in estimating the approximate ages and define the crown rump length (C.R.) as the skull to the breech (i.e. the mid-point between the apices of the buttocks). This definition is also given by Langman (1969) who again warns that this can only be an approximate indication of the real age of the embryo.

In the early veterinary literature Lesbre (1897) uses the term crown rump length and it is defined in his text book (1923) as the dimension taken from the vertex of the head to the origin of the tail. Evans (1973) in his dissertation of prenatal development of domestic and laboratory mammals states that measurement of embryos and foetuses are cited as crown rump (C.R.) lengths. He repeats the definition that crown rump measurement is the distance between the highest point of the head and the most caudal extent of the buttocks at the base of the tail. He offers a caution on the use of this measurement in domestic mammal foetuses pronouncing that care must be taken with foetal posture during measurement.

The measurement of foetuses in this work corresponds to that given and illustrated by Arey (1948) for crown rump length. In Group A each foetus was carefully placed before measurement to produce a standard position and then the crown rump length was taken. With foetuses of less than C.R. 35 mm. there/

there was some difficulty in positioning due to a tendency to curving but here a thread held between two pairs of forceps was used to establish the distance between crown and rump and then the length of thread was read against the scale on the calipers. Foetuses of over 35 mm. and up to 120 mm. were measured using calipers as illustrated in Fig. C.1. The scale on the calipers was capable of recording 0.01 mm. Foetuses of over 120 mm. were measured using a metric stick as shown in Fig. C.2. When a litter was received each individual was measured as described. Any grossly abnormal individual was discarded and not used further in the study. The separate foetuses in a litter having been measured for C.R. length, the average C.R. length for that litter was then calculated. This average litter C.R. length is the figure that appears in Table I and is the figure used in assessing the approximate age of the litter.

As the number of foetuses in each litter varied, it was not always possible to carry out all four techniques for examination in each litter. Similarly the numbers of each sex varied with each litter and so with the numbers of litters available for study it was not possible to obtain sufficient males and females to allow all the techniques to be carried out in duplicate at each litter size, which would have allowed comment of sexual variation, if any, to have been made.

References

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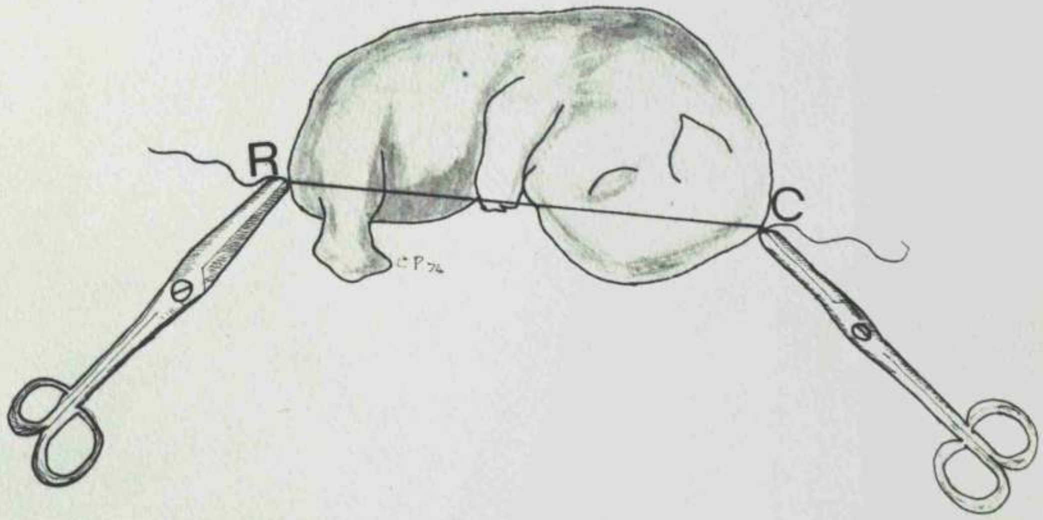
(1942). Developmental horizons in human embryos: age group XI 13-20 somites, and age group XII 21-29 somites.
Contrib. Embryol. Carnegie Inst. Wash. 30. 211-245.

(1945). Developmental horizons in human embryos: age group XIII embryos 4 or 5 mm. long and age group XIV indentation of lens vesicle.
Contrib. Embryol. Carnegie Inst. Wash. 31. 26-63.

(1948). Developmental horizons in human embros: age groups XV, XVI, XVII and XVIII being the third issue of a survey of the Carnegie Collection.
Contrib. Embryol. Carnegie Inst. Wash. 32. 133-203.

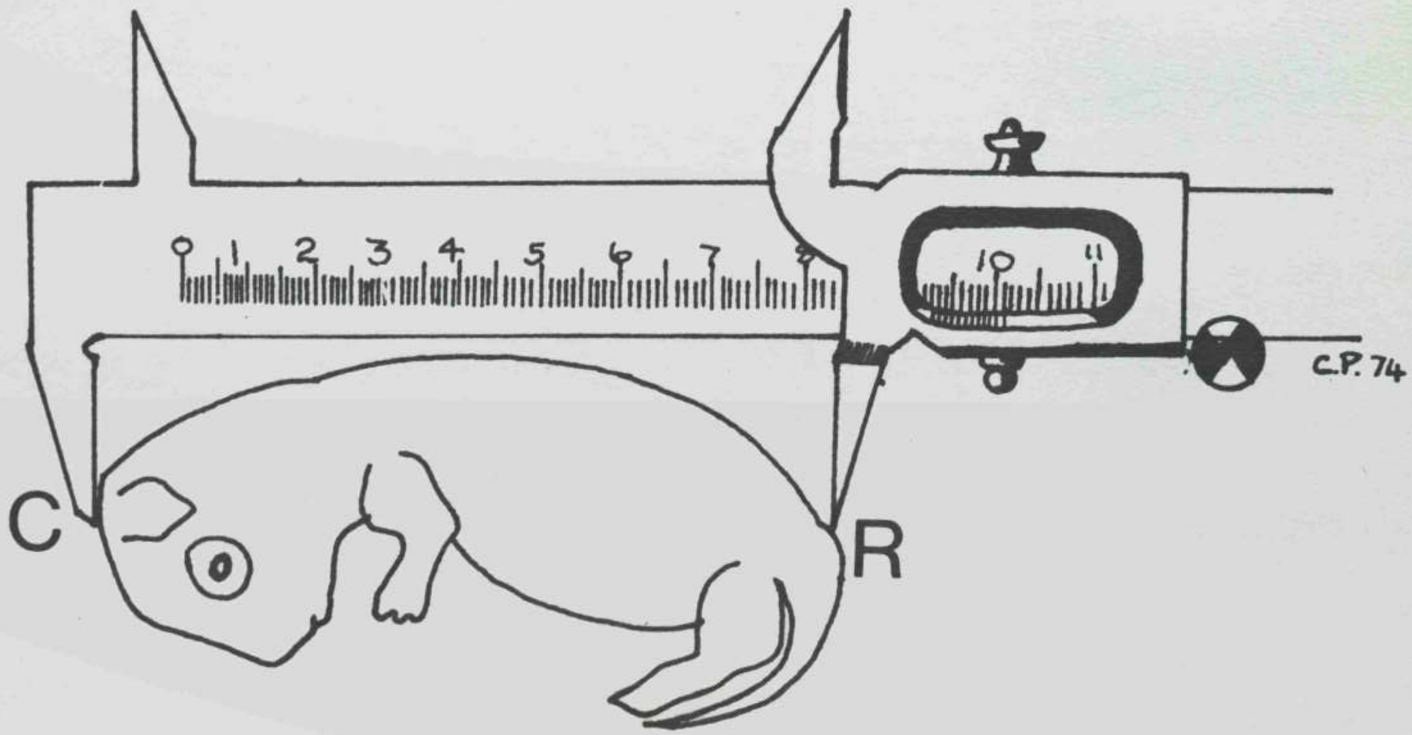
CR MEASUREMENT → THREAD TECHNIQUE

FOETUS BELOW 35mm



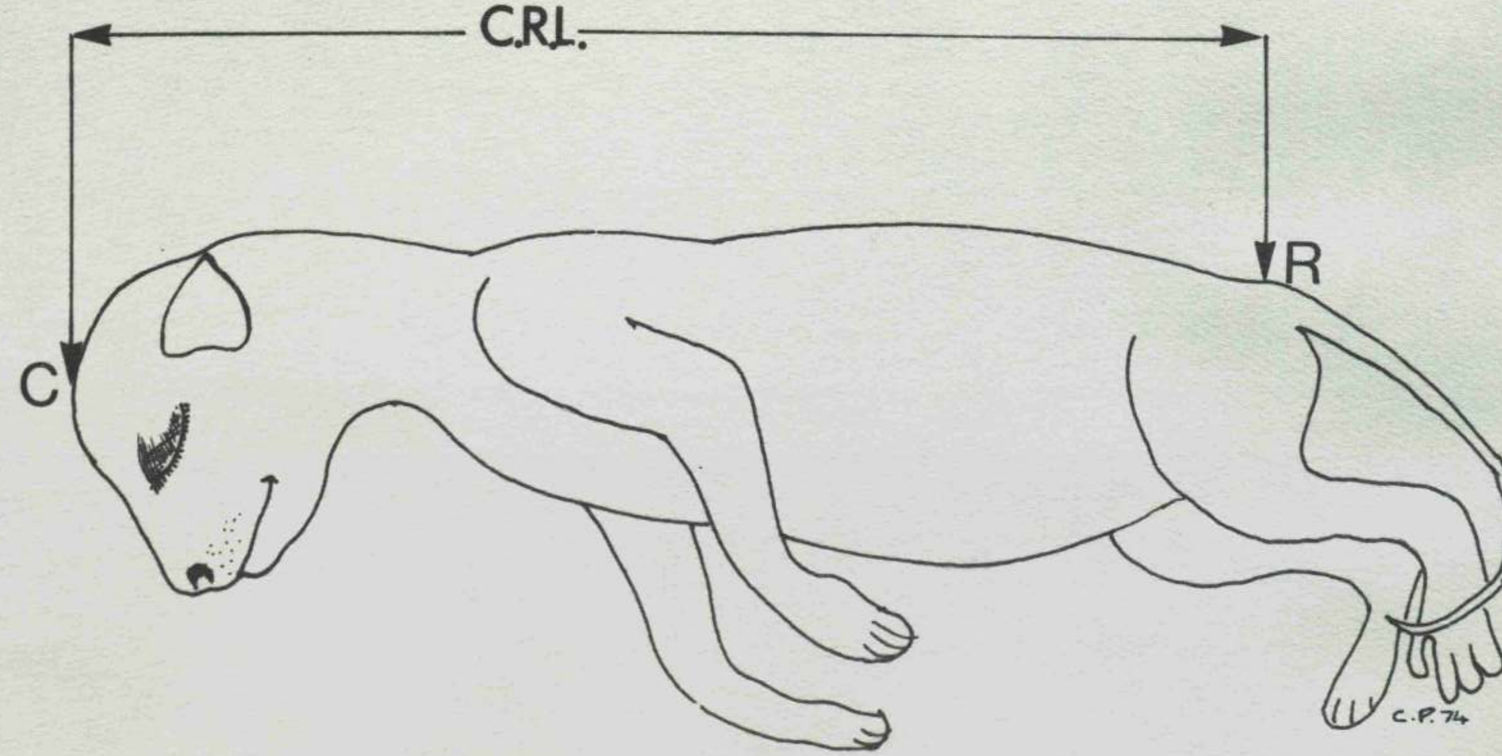
CR MEASUREMENT — CALIPERS TECHNIQUE

FOETUS 35mm–120mm



CR MEASUREMENT — METER STICK TECHNIQUE

FOETUS 120mm & over



PATTERNS OF OSSIFICATION

IN THE FELINE FOETUS

BY

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APPENDIX II

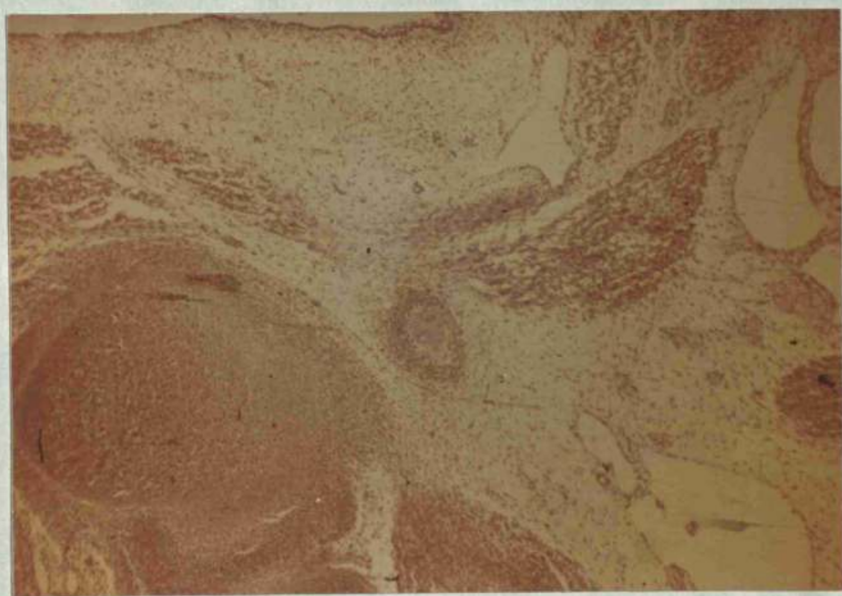

FIG. H.1 CLAVICLE. H. & E. X 4.
Litter No.8 C.R.23.2mm. 27 Days Text P.20 Vol. I.

The centre for the clavicle is evident in the middle of the field. There is calcified tissue to be found in the mesenchymal condensations forming the clavicle and osteoblasts are now present.

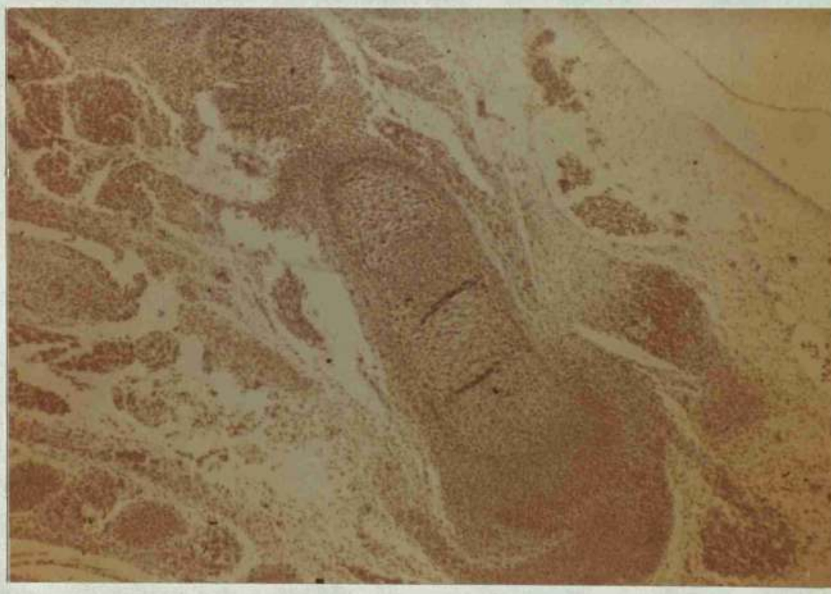

FIG. H.2	HUMERUS.		H. & E.	X 4.
Litter No. 4	C.R. 18mm.	24 Days	Text P.33	Vol. I.

The developing shaft of the humerus is found in the centre of the field. There is evidence of degeneration of cartilage cells at the middle of the shaft.

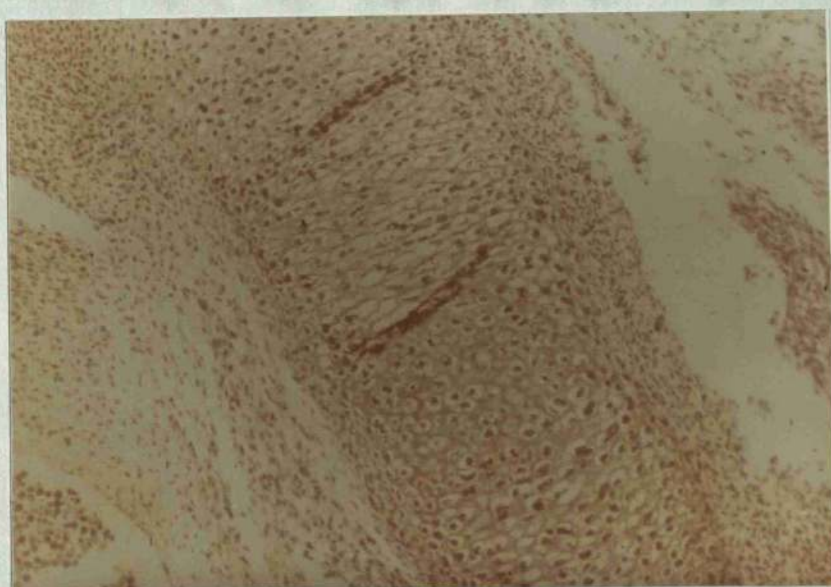

FIG. H.3 HUMERUS. H. & E., X10.
Litter No. 4 C.R. 18mm. 24 Days Text P.33 Vol. I.

This field demonstrates the middle of the shaft of the humerus and shows the degenerating cartilage cells which are rounded and swollen.

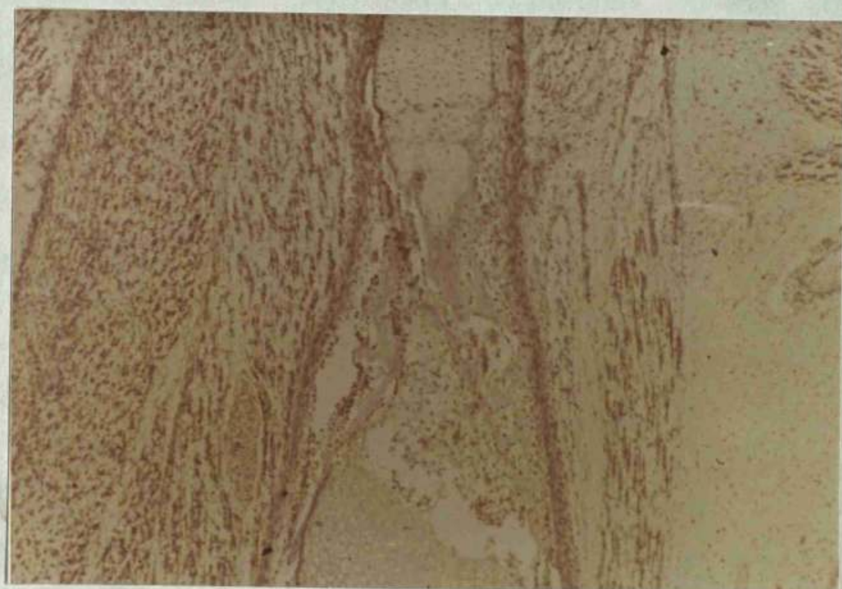

FIG. H.4 HUMERUS. H. & E., X 4.
Litter No.16 C.R. 32mm. 30 Days Text P.33 Vol. I.

In this field, in the shaft of the humerus, there is invasion of the collapsed centre of the cartilaginous shaft by the periosteal bud. The central area is surrounded by a periosteal collar.

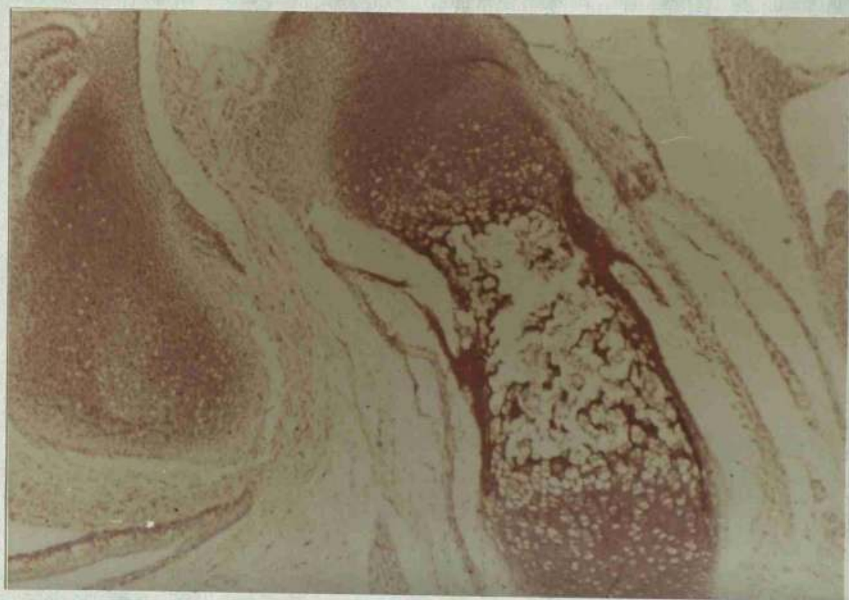

FIG. H.5 OSSA DIGITORUM MANUS - PHALANX MEDIA. H. & E., X 4.

Litter No.46 C.R. 85mm. 44 Days Text P.74 Vol. I.

The shaft demonstrates the typical changes seen to occur in early endochondral ossification of a long bone with a periosteal collar surrounding the collapsed central portion of the shaft which has been invaded by the periosteal bud.

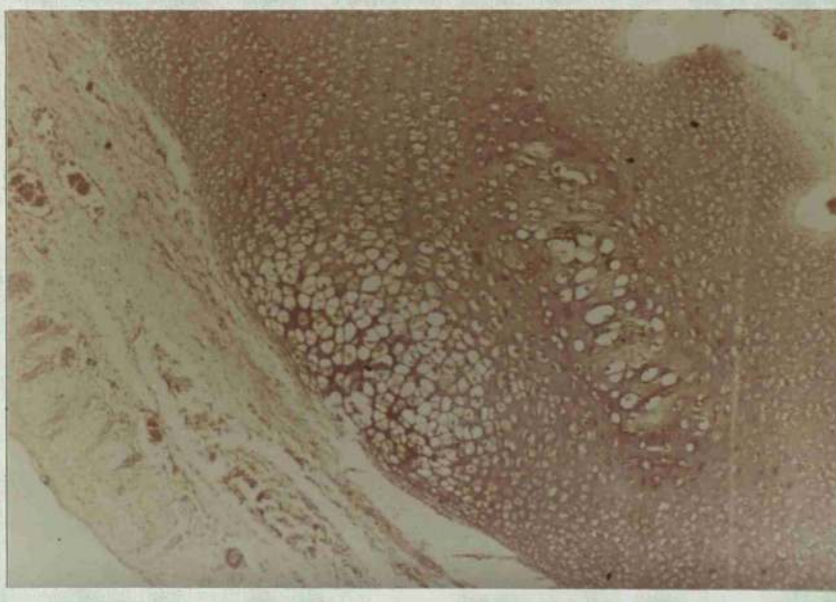

FIG. H.6 TARSUS. CALCANEUS. H. & E., X 4.
Litter No.46 C.R. 85mm. 44 Days Text P.114 Vol.I.

There are degenerating areas of cartilage cells to be seen in the model of the calcaneus, and deposition of calcified ground substance.

FIG. H.7 Litter No.32 — VERTEBRAE THORACICAE. C.R. 63mm. 39 Days — H. & E., Text P.152 — X 4. Vol. I.

The area of degenerating cartilage cells to be seen in the right of the field shows signs of invasion of the cartilaginous body by osteogenic components and blood vessels. The area top left indicates these changes occurring in the developing lamina.

FIG. H.8	MANDIBULA.		H. & E.,	X 4.
Litter No.16	C.R. 32mm.	30 Days	Text P.229	Vol.I.

The cartilaginous precursor of the mandible lies at the top centre of the field and below this is seen an area of ossifying tissue.

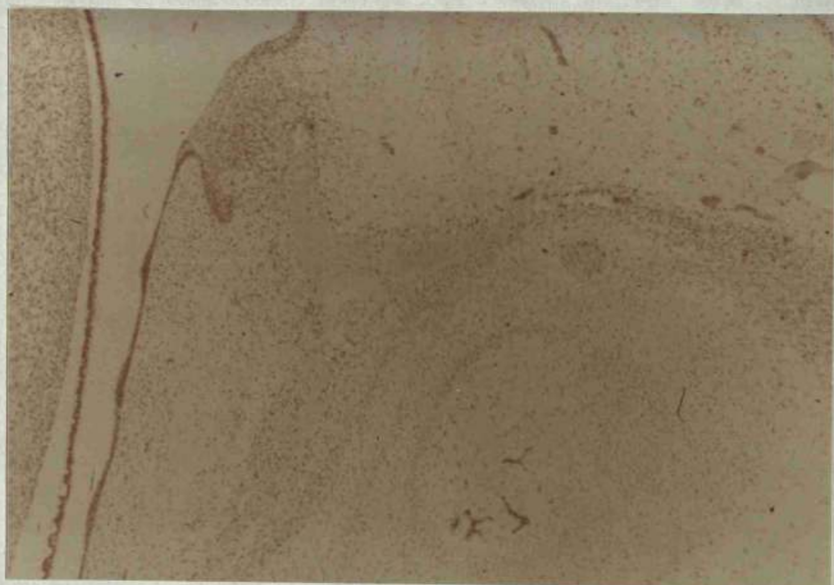

FIG. H.9	OS FRONTALE		H. & E.,	X 4.
Litter No.16	C.R. 32mm.	30 Days	Text P.290	Vol.I.

This field shows intramembranous ossification occurring in the mesenchymal layer of the developing frontal bone.