

THE SIGNIFICANCE of an ACHONDROPLASIA-LIKE CONDITION

met with in CATTLE.

- * -

by

W. F. A. E. CREW.

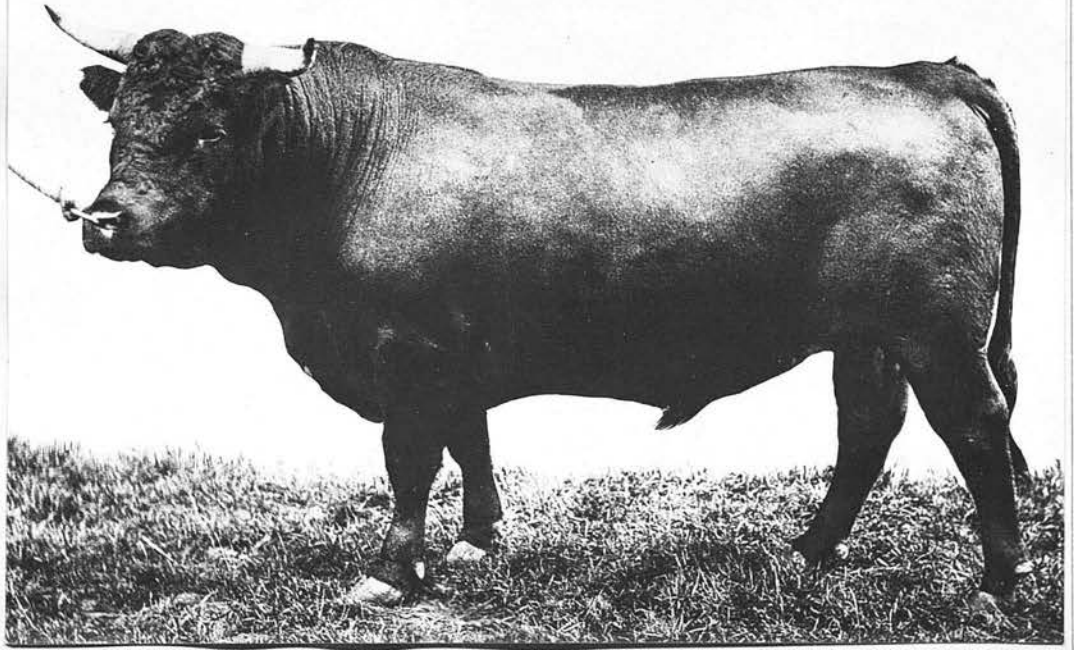
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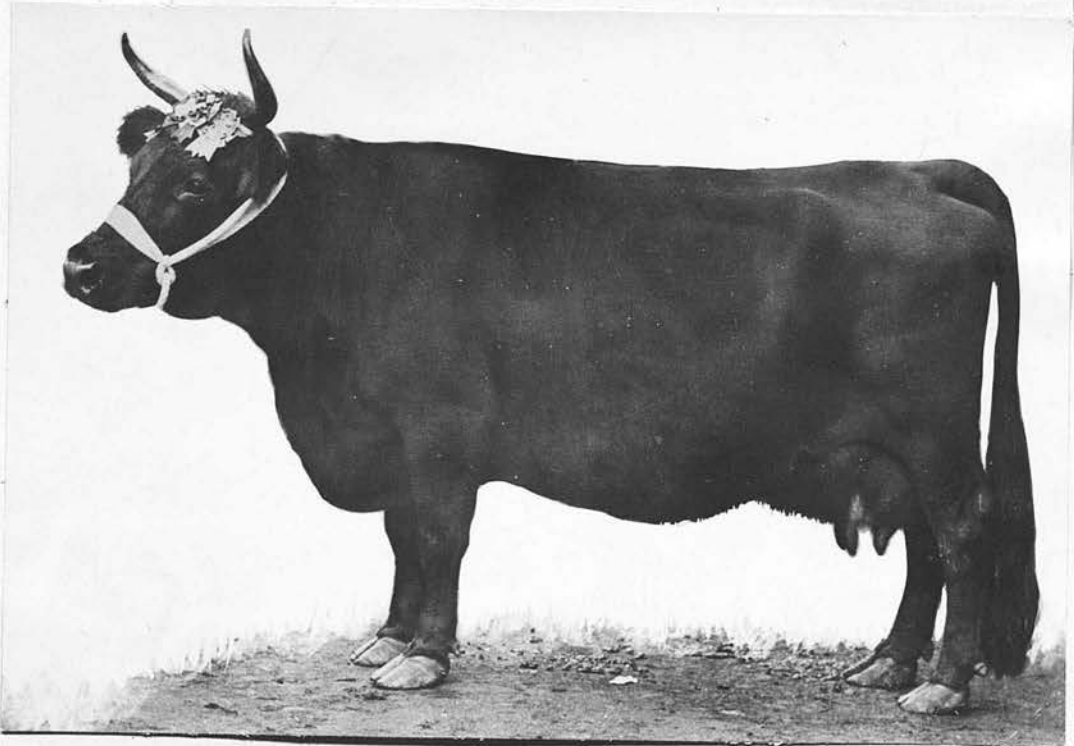
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A typical exhibition Dexter bull.



A typical Dexter cow.

§ I. The Dexter.

The Dexter is the breed of the smallest cattle in Great Britain. Formerly it was indigenous to the South and South-Western districts of Ireland but of late years it has become increasingly popular in England. It is highly valued for its general hardiness and utility, being an economic feeder, an excellent milker and a ready fatterer, of pleasing appearance, and thriving well on the poorest of land. It is used profitably as a cross in the production of 'small beef.'

Its general appearance, as defined in the terms of the standard of excellence laid down in the Kerry and Dexter Herdbook, is as follows : -

Head short and broad, with great width between the eyes and tapering gracefully towards the muzzle which should be large with wide distended nostrils. Eyes bright, prominent, and of a kind and placid expression. Neck short, thick, and deep, and well set into the shoulders, which, when viewed in front, should be wide, showing thickness through the heart, the breast coming well forward.

Horns. These should be short and moderately thick, springing from the head with an inward and slightly upward curve.

Body. Shoulders of medium thickness, full and well filled in behind; hips wide, quarters thick and deep and well-sprung, flat and wide across the loins, well ribbed-up, straight underline, udder well forward and broad behind, with well placed teats of moderate size; legs short (especially from knee to fet-lock), strong, and well placed under the body which should be as close to the ground as possible. Tail well set on and level with the back.

Skin. The skin should be soft and mellow, and handle well, not too thin. Hair fine, plentiful and silky.

Coat colour. Bulls : whole black or whole red (the two colours being of equal merit). A little white on the organs of generation not to disqualify an animal which answers all other essentials of this standard description. Cows : black or red (the two colours being of equal merit). White on udder and the extension of white on udder slightly along inside of flank or underside of the belly, or white on tassel of tail, may be allowed on an animal which answers all other essentials of this standard description.

Weight. Bulls should not exceed 900 lbs. live weight when in breeding condition. Cows should not exceed 800 lbs.

In view of that which is to follow it is desired to call attention to these two characters of the ideal Dexter : brachycephaly, and micromelia.

An acquaintance with different herds of Dexter cattle in England has demonstrated that within the breed there is very considerable variation in external characterisation and that through selection by the breeder different herds have come to possess distinctive herd characters. Two undesirable characters are encountered occasionally : 'bad tail-head' - the tail not being terminal but seeming to take origin further forward along the back and arching upwards and backwards; and a combination of bent forelegs with inwardly turned hoofs : "its toes turn in after a peculiar fashion, and it tends to walk over the outer digits, especially in the case of the hind feet."

§ II. The History of the Dexter Breed.

The history of the Dexter is wrapped up in that of the Kerry and like that of almost every breed is befogged by anecdote and speculation. It is generally accepted that the Dexter is an offshoot of the Kerry. Legend has it that the first Dexter had its origin in the chance mating of a recumbent Kerry cow and a seal from the sea. Be this as it may, it is certain that the breed has arisen out of the old-fashioned Kerry stock as a result of an outcross. The Dexter differs from the Kerry in that "the leg bones are shorter and more substantial, the neck thicker and shorter, the horns heavier, not so elevated and airy, and the head heavier and not so deer-like as in the case of the original Kerry." The native ancestral stock from which the modern Kerry has been developed was a black-coated race, being of the same stock as the native Celtic cattle of Great Britain. The modern Kerry is all that remains of the race which in former days was to be found throughout the whole length and breadth of Ireland. There are historical records of the importation of Longhorns, Shorthorns, Herefords, and Devons into Ireland and by the middle of the XIXth century the old native race as such had become almost entirely replaced by imported stock and was extinct in all parts save in Kerry and Donegal.

Individual beasts of what may be spoken of as Dexter proportion existed among the old-type Kerries as far back as 1780 for such were briefly remarked upon by Young, while in 1802 Tighe definitely states that among the Kerry cattle some were remarkable in that "their size does not exceed a moderate suckling calf." Wakefield not only describes two sorts of cattle on/

on the borders of Kerry but also records his opinion as to the method by which these cattle of diminutive proportions were produced. But it was not until 1845 that these cattle were referred to as Dexters; before this they were spoken of as a peculiar variety of the Kerry. In 1845 Low recorded how the Dexter was produced and how it got its name. According to this authority, the breed "was formed by the late Mr. Dexter, agent to the late Maude, Lord Hawarden. This gentleman is said to have produced this curious breed by selection from the best of the mountain cattle of the district. He communicated to it a remarkable roundness of form and shortness of legs. The steps, however, by which the improvement was effect have not been recorded; and some doubt may exist whether the original was the pure Kerry or some other breed proper to the central parts of Ireland now unknown, or whether some foreign blood, such as the Dutch, was not mixed with the native race."

Wilson has dealt fully with the arguments for and against the validity of Low's conclusions and decides that they are not supported by the known facts. There certainly was a Mr. Dexter, a coastguard officer who resided in Kerry during 1832 - 1858, and according to this gentleman it was his grandfather who introduced the Dexter into Ireland after having made the breed in England. Young writes of this older Dexter: "Mr. Dexter, of Cullen, had a ram . . . and a great number of ewes sent to him, the breed much improving," and further: "there have been many English bulls introduced for improving the cattle of the country at a considerable expense and great exertions in the breed of sheep; some persons, Mr. Dexter chiefly, have bought English rams, which they let out at seventeen guineas

a season, and also at 10/6 a ewe, which indicates a spirited attention." But Young, a most careful observer, makes no reference to Dexter as a breeder of cattle, and Wilson suggests that "the original Mr. Dexter was a breeder of Leicester sheep which in comparison with the native sheep were shortlegged and stout." It is probable that the sheep imported by Mr. Dexter and new to the district were commonly referred to as 'Mr. Dexter's sheep' by his neighbours, then as time went on as 'Dexters' simply, and that later the name would be applied to other animals which presented the same kind of characters. Wallace cites an author who "while travelling in Kerry some years ago found that the word 'Dexter' was used in the generic sense with reference to all diminutive animals, even men if low set and bandy-legged; and also that the term was in the first instance applied to short-legged sheep kept by a resident coast-guard officer."

The early records of the Dexter breed are unreliable and a better idea of its ancestry can be derived from the genetical analysis of the modern Dexter.

§ III. The Genetic Constitution of the Modern Dexter.

A statistical study of the results of the mating of Dexter with Dexter shows that four classes of calves are produced : Black Dexter type, Red Dexter type, Black Kerry type, and Red Kerry type. By Dexter type is meant a relatively massive head, stout body and short limbs; by Kerry type is meant a relatively slender head, slim body and long limbs. Of the four classes the Black Dexter type is by far the most common, the Red Kerry type the least common, whilst the other two occur in more or less equal numbers.

The appearance of four phenotypes in such proportions suggests at once that the Dexter is itself to be regarded as a Mendelian di-hybrid and its parental stocks differed one from the other in respect of at least two pairs of contrasted characters : coat colour and bodily conformation. The old type Kerry, black, slender, and long-limbed, could have been one of the parental stocks. If this were the case, then the other must have been a red, stout, short-limbed stock.

Wilson brings forward considerable evidence to show that such an animal was imported into Kerry during the formative period of the Dexter and that it was crossed with the native Kerry stock. He quotes Wakefield as saying that "In the South I met with some persons who had imported Devon cattle; Lords Bantury Shannon, and Doneraile, Mr. Hyde, and others possess considerable numbers of them." Wilson also points out that in the XVIIth and XVIIIth centuries many English emigrants, sailing from Bristol channel ports, settled in Kerry and West Cork bringing with them their own red cattle. He quotes the Duke of St. Albans as saying : "In a letter written in 1580 and preserved in the/

the Record Office among the Irish MSS., Sir Nicholas White, Master of the Rolls in Ireland, says that Dingle Harbour, in Kerry, was known as 'Coon edaf dearg' which in the Irish means 'red ox haven.' White says that this name was owing to the first settlers who came from Cornwall and brought cattle with them. The native cattle were black." Wilson sums up the evidence thus "The probability, therefore, that Dexter cattle are descended from Black Kerries and Red cattle of Devon type is very high; and if further proof were wanted it can be found by setting a red Dexter cow side by side with a red Devon." The modern red Dexter is a mottled red showing delicate blackish tracteries on the red ground : this same mottling is seen in the modern red Devon.

It is indeed probable that the Dexter had its origin in the mating of Black Kerry and Red Devon. It would seem to be a simple matter to put this suggestion to the test of direct experiment by mating a Kerry and a Devon. But the modern Kerry is not the Kerry of the time when the Dexter was produced, nor is the modern Devon genetically the same as the Devon taken to Ireland by the English emigrants.

The original mating can be illustrated by the use of the conventional formulae and chess-board. Let B represent the factor for the dominant character Black coat colour, and b that for the corresponding recessive Red coat colour; let S represent the factor for the dominant character Dexter-type bodily conformation, and s that for the corresponding recessive Kerry type. Then :

BBss	-	Black Kerry
bbSS	-	Red Devon
BbSs	-	The original Dexter.

With/

With the appearance of the Dexter the following matings became possible :

(1)	Dexter	x	Kerry	
	BbSs		BBss	
	BS		Bs	BBSs Black Dexter type
	Bs		Bs	BBss Black Kerry type
	bS	x	Bs	BbSs Black Dexter type
	bs		Bs	Bbss Black Kerry type

or, 50 % Dexter type, 50 % Kerry type.

(2)	Dexter	x	Devon.	
	BbSs		bbSS	
	BS		bS	BbSS Black Dexter type
	Bs		bS	" " "
	bS	x	bS	bbSS Red Dexter type
	bs		bS	" " "

or, 100 % Dexter type (50 % Black, 50% Red.)

The following genotypes, BBSs, BbSs, and BbSS, within the phenotype 'Black Dexter' were thus available for further breeding. (It may be assumed that Red was not, as it still is not, an esteemed colour.) The intermating of these would yield the following results :

BbSs	x	BBSs		
			BbSS	Black Dexter type
BS			2 BBSs	" " "
Bs		BS	BbSS	" " "
bS		Bs	2 BbSs	" " "
bs			BBss	Black Kerry type
			Bbss	" " "
				33.3 %

BbSs	x	BbSS		
			BbSS	Black Dexter type
BS			BBSs	" " "
Bs		BS	2 BbSS	" " "
bS		bS	2 BbSs	" " "
bs			bbSS	Red Dexter type
			bBss	" " "
				33.3 %

BBSs/

BBSs	×	BbSS			
			BBSS		
BS		BS	BbSS		
Bs		bS	BBSs	Black Dexter type	100 %
			BbSs		
BbSs	×	BbSs			
			1 BBSS	Black Dexter type	
			2 BBSs	" " "	
			2 BbSS	" " "	56.25 %
BS		BS	4 BbSs	" " "	
Bs		Bs	1 bbSS	Red Dexter type	
bS		bS	2 bbSs	" " "	18.75 %
bs		bs	1 BBss	Black Kerry type	
			2 Bbss	" " "	18.75 %
			1 bbss	Red Kerry type	6.25 %

Quite early in the history of the breed a number of geno -
 :types appeared and of these some were much more common than
 others. Individuals homozygous for the bodily conformation
 characters were rare. It is probable that the picture of the
 ideal Dexter was taking shape, the breeders were already aiming
 at a short-legged beast with the coat colour of the native Kerry.

§ IV. The Monstrous Calf of the Dexter.

As time went on, it may be assumed, the matings became more and more confined to those between Black Dexter-type and Black Dexter type, and the phenotypic selection which was thus practised was really meant to isolate the genotype BBSS.

Slowly it came to be recognised that this phenotypic selection resulted in the production of a deformed and still-born calf; that as the mating of Dexter type and Dexter type became more common the proportion of these monstrous calves increased. Ultimately it was accepted that with such matings a proportion of still-born monstrous calves was to be expected. In 1919 the Society founded in 1917 to promote the interests of Kerry and Dexter cattle breeding in Ireland decided to change its name to 'The Kerry Cattle Society of Ireland.' "This alteration was deemed advisable as herds of pedigree Dexter cattle have practically ceased to exist in Ireland owing to the difficulty of breeding these cattle pure. It is the experience of Irish breeders that when Dexter cows are mated with a Dexter bull a large proportion of the progeny are either still-born or deformed. As a result of constant disappointment owners have gradually given up the attempt at breeding pedigree Dexters and, as far as Irish breeders are concerned, their whole attention is now directed to the development of the Kerry breed."

"Concurrently with the ban upon Dexters in Ireland, a boom was started in England." To supply the demand for Dexter cattle the Irish breeders earnestly sought for methods by which Dexter-type calves could be produced and the monstrous calf avoided. The result of their experimentation has been that the Irish Dexter/

Dexter, the so-called 'foundation stock' Dexter, is got not by a Dexter × Dexter mating but by using a Dexter bull and Kerry cows. This mating has never yielded a monstrous calf; it has produced on the average equal numbers of good type Dexters and of 'sneem' Kerries (see Dexter × Kerry mating, p. 7). The Kerry type animal so produced is a diminutive Kerry; Sneem is the district of Kerry in which the foundation stock Dexter is raised for export to England, and 'sneem' is used locally as a term of reproach being applied to any undersized creature. The relative numbers of red and of black individuals varies considerably for it is certain that many Kerries are heterozygous for their black coat colour character.

In England, the English Kerry and Dexter Cattle Society was founded in 1892 and published its first Herdbook in 1900. By the regulations laid down therein "a cross between the Kerry and the Dexter is considered a half-breed and cannot be entered." Quickly, as Wilson says, "what was formerly known to Kerry men now became known to other breeders who bred Dexters according to the rules of the Herdbook - that such a procedure invariably resulted in the production of a proportion of dead mis-shapen calves."

General Description of the Monstrous Calf.

The abnormalities which these still-born calves exhibit are constant and are so characteristic that the foetus is known as a 'bull-dog' calf. The cranium is bulging, the nose markedly depressed, the lower jaw protruding, the upper lip is split, barring the teeth, while the swollen tongue, thrust far out, curls up over the nose. Owing to the disproportionate development of the buttocks, the tail seems to have its origin far up on the back/

back; usually there is a gaping deficiency of the abdominal wall through which the intestines pass to form a large umbilical hernia. The skin hangs loosely in folds; there is abundant subcutaneous fat. The limbs are ridiculously short and the digits unusually separated.

The period of gestation in the Dexter is approximately 284 days. In the great majority of cases it can be foretold that a pregnancy is to terminate in the production of a 'bull-dog' fœtus, for in such cases the pregnant cow begins to increase in size very rapidly about the 3d or 4th month, and ultimately becomes very distended. The early obliteration of the hollow in the flank just in front of the hip is recognised as a sure sign of impending trouble. When it is noticed that the cow is losing 'water' which dribbles from the vulva and that she is becoming less and less distended. After a time the loss of fluid ceases, but after a short interval the cow is as 'big' as ever. Again there is the flow of fluid from the vulva and the decrease in size, and again the cycle is repeated. Following one of these discharges of fluid from the vulva the fœtus is aborted. The fluid is described as being clear in the majority of cases; in a few it has been turbid. But, as Seligmann has previously recorded, it is not invariable for a Dexter with a considerable degree of excess of amniotic or allantoic fluid to give birth to a deformed calf. Moreover, the pregnancy which results in the abortion of a dead monstrous calf is not invariably associated with such excess. Extremely rarely, so the breeders say, the first indication of anything abnormal is a premature labour. In such cases the calf is not delivered naturally, it always must be removed by operative procedure and is dead when delivered.

The puerperium following the delivery of the 'bull-dog' differs from that following the birth of a normal calf. The placenta comes away in small fragments or has to be extracted manually, instead of being thrown off complete in a half to four hours. In fact, herdsmen will state that there is no afterbirth in the case of the 'bull-dog.' The lochia last longer than is usual, the blood-stained discharge persisting in certain cases even as long as a fortnight instead of the usual one to four days. The abortion of a foetus other than a 'bull-dog' is followed by an immediate cessation of mammary activity, the abortion of a monstrous calf on the contrary does not interfere with this and the cow produces milk.

The normal Dexter calf is a small individual compared with calves of the same age but of the larger breeds. No specimen of the normal Dexter foetus has been available for comparison but an 'off-type' (a Kerry type) foetus was obtained at the 8th month of pregnancy. The 'bull-dog' foetus of the same age is very much smaller.

Age of 'bulldog'	Weight.	Length. in cms.	Diameter shoulders.	Length off Foreleg.	Length off Hindleg.
7 months	12lb. 15oz.	28.0.	44.1 cms.	5.1 cms.	5.7 cms.
7	10 3	30.5	42.6	7.3	7.0
7	11 11	30.2	39.9.	6.1	5.7
4-5	6 11	17.8	30.2	6.1	6.4
3-4	3 8	20.5	17.0	3.0	6.0

An examination of many specimens has shown that there is never any suggestion of putrefaction or of mummification of the foetus. The abortion quickly follows the death of the calf. The death of the foetus is associated with severe foetal anasarca - foetal dropsy - in the case of the earlier abortions and of the majority of the later ones, and with profound dystocia in the/

the cases which proceed until near term. In practically all cases in which there is hydramnios (or hydrallantois) foetal anasarca is present, the foetus is a fluid-logged shapeless mass and the almost complete subcutaneous covering of the abdominal wall is devoid of skin over a circular area based upon the umbilical cord. In the case of the older foetus death results from dystocia. The prolonged and difficult labour is made inevitable by the shape and consistency of the foetal head which cannot be accommodated by the maternal birth passages.

The 'bull-dog' foetus is a creature which has a head of unusual shape and consistence. The size of the foetus and the shape of the head are to be regarded as significant features.

Incidence of the Monstrous Calf.

In the Herdbooks there are to be found many entries of 'premature' or of 'dead' in the column which shows the births during the year. It is not to be expected that such a record is critical. English Dexter breeders, anxious to have this problem solved, supplied the following absolutely trustworthy figures :

Total Births	Normal Calves	'Bull-dog' Calves
646	530	116

e.g. 1 in 5.5 births.

At first sight there would seem to be neither rhyme nor reason in the occurrence of the monstrous calf. Some herds are singularly free from them, others yield so many that the breeder gets rid of his stock. A certain cow will produce a series of most excellent Dexter calves and then to the same sire will yield a typical monster. A cow to the service of several different/

ent bulls will produce a series of 'bull-dogs' and then the next season produce a prize-winner. There is no Dexter out of a Dexter x Dexter mating that is not related more or less closely to a monstrous calf. The 'bull-dog' appears in all herds in numbers that range from 5% - 30% of the total births. During the last two years the present writer has examined twenty-seven cases.

The Coat Colour of the Monstrous Calf.

Just as Black is the more common colour of the Dexter and for the same reason, so is the coat colour of the 'bull-dog' foetus more often black than red. Of the 27 cases examined, 20 were black and the remaining 7 red - as close an approximation to a 3 : 1 ratio as can be.

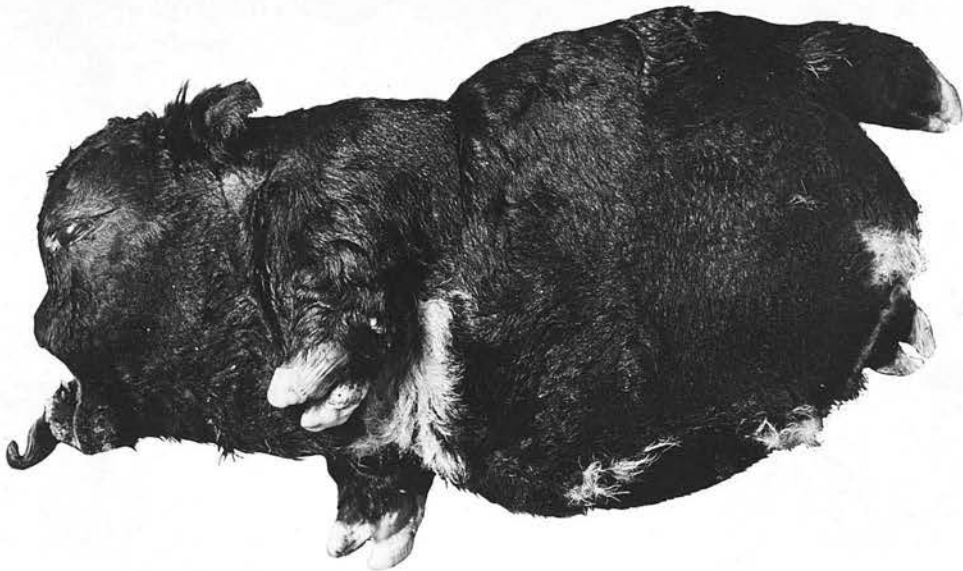
The Sex of the Monstrous Calf.

Of the twenty-seven cases examined, twenty-one have been males and six females. For a long time none but a male was received and sex-linkage was suspected. But more recently six females have been examined ; at first these were regarded as possible cases of abnormal differentiation of the sex-organisation in a male, but the demonstration of definite ovarian tissue in the gonads made it certain that the condition is not sex-linked. In the older fetuses the scrotum is well defined as is also the vulval cleft but in the earlier specimens the sodden skin and the great rent in the abdominal wall make the identification of the sexual apparatus peculiarly difficult. Moreover, since the specimens cannot be examined until at least 18 - 24 hours after delivery the histological evidence is rather weakened. But the evidence is such as to show quite definitely/

ly that the 'bull-dog' foetus may be either male or female, though, if the series of cases examined can be regarded as a representative sample, the majority of monstrous calves are male.



4 - 5 months 'bull-dog' fetus. Hydrocephalus.
Black ♂



7 months 'bull-dog' fetus
Black with white on
underline.



A characteristic head.



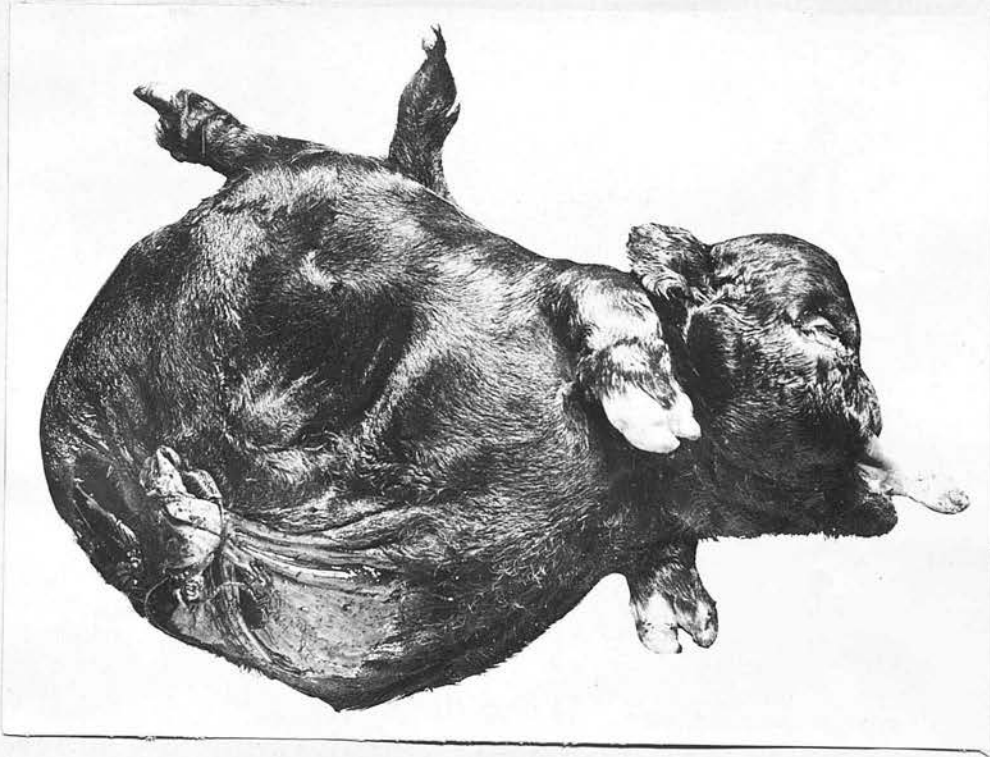
A 5 - 6 months 'bull-dog' fetus.
Umbilical hernia. Black ♀



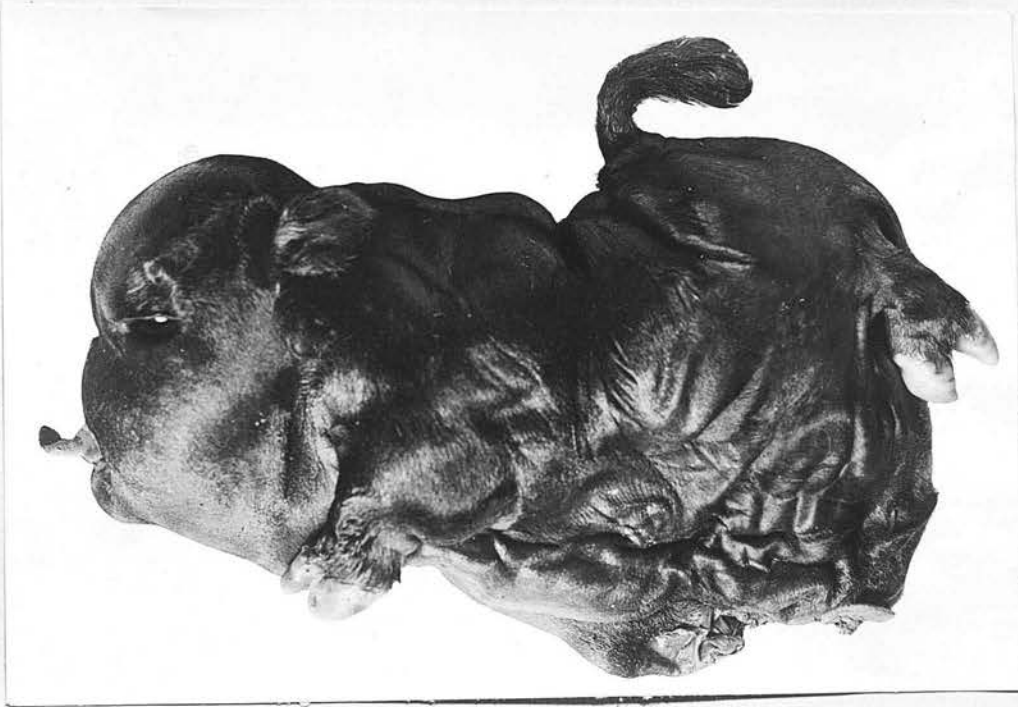
5 - 6 months black ♀



5 - 6 months black ♂
showing wrinkling of the skin.



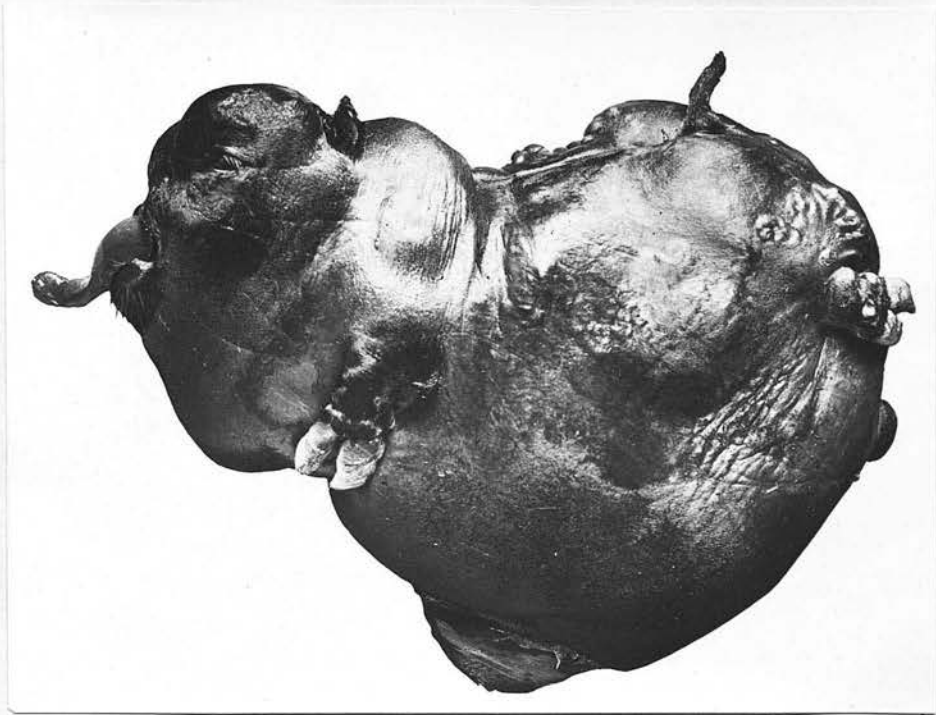
6 - 7 months black ♂



6 - 7 months black ♂



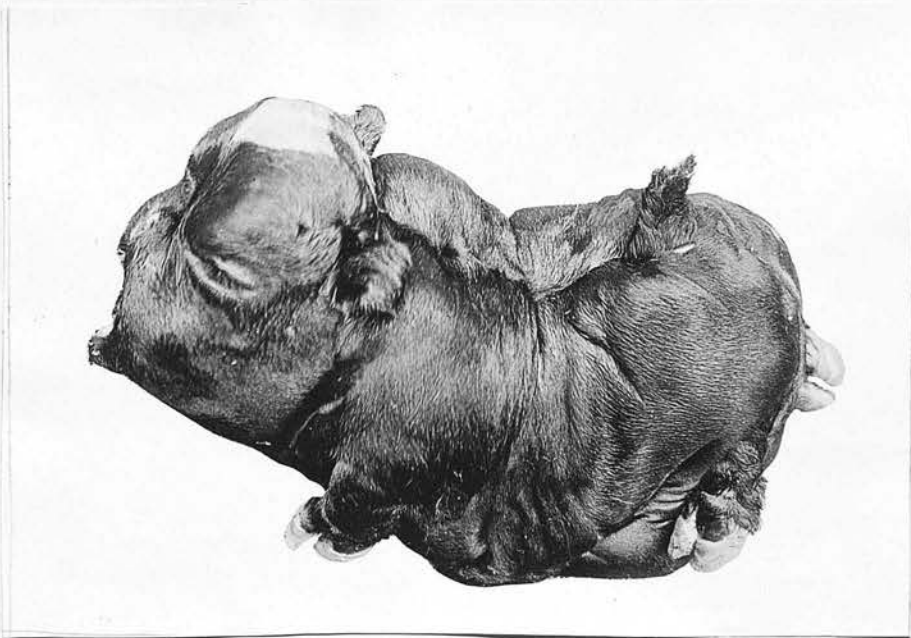
6 - 7 months black ♂



5 - 6 months black ♀
showing fetal anasarca and umbilical hernia.



A nearly full-time 'bull-dog' foetus.
Black ♀



A 6 - 7 months 'bull-dog' foetus
Red with white blaze.
♂



A characteristic 'bull-dog' head.



Sagittal section of head to show the dilatation of the ventricles and of the iter.

§ V. The Pathology of the Monstrous Calf.

Fetal Anasarca.

Fetal Anasarca in the great majority of cases is present. This condition is not uncommon in cattle and is almost invariably associated with the death and abortion of the foetus at 6 - 7 months. According to Williams, foetal anasarca has been recorded only in ruminants among the domesticated mammals. The cause is not known; it has been ascribed by some writers to a congenital absence of the thoracic duct. In the case of the 'bull-dog' it is invariably associated with hydrops amnii and it is reasonable, therefore, in this case to suspect that both conditions are due to one and the same cause, although in ruminants generally there is no doubt that the two conditions can occur quite independently.

Hydramnios.

The normal amount of fluid present in the amnion of the cow is about 5 - 6 litres, the amount in the allantois about 6 - 15 litres. Any material excess is considered abnormal. The amniotic fluid is clear and the allantoic turbid in later pregnancy. The fluid evacuated in the case of the 'bull-dog' is clear : the condition present in this case is probably hydramnios and not hydrallantois. When examined, no definite cell elements can be recognised in either stained or unstained preparations. The amount of fluid evacuated in one case was approximately 160 litres.

Hydramnios is not uncommon in cattle and is the rule in such species crosses as Bos americanus × Bos taurus or Bos americanus × Bos indicus. Williams records that in one case/

case (not in the Dexter) after trocarisation of the fetal membranes and the withdrawal of 12 - 15 gallons of the fluid, the original volume was restored within 48 hours. The cow showed signs of great thirst and the author remarks that :
 "apparently, the water consumed went almost immediately to the fœtus and was deposited in the fetal membranes, while the cow, drinking greedily, was suffering from water starvation."

The exact cause of hydramnios is not known, nor can it be until the origin of the liquor amnii itself has been demonstrated. The prognosis in cases of severe hydramnios in cattle generally is very unfavourable both for cow and calf, for, as a result of the pronounced uterine dilatation and uterine paresis, the cervix is not dilated naturally and the abdominal muscles, losing tone for the same reason, do not aid in the expulsion of the fœtus. Delivery is always by operative procedure as is also the removal of the placenta. In the Dexter, however, the prognosis is entirely satisfactory as far as the cow is concerned; normal labour pains come on, the cervix is dilated, and the fœtus is expelled without any artificial interference unless it is an older fœtus, for in this case the head cannot pass the pelvic brim and operative interference is imperative. The placenta must be removed manually in most cases. The difference in the prognosis in the case of the Dexter and other breeds rests on a difference in the general musculature. The Dexter is a peculiarly muscular individual and can withstand the stretching which hydramnios involves much better.

Hydrocephalus.

In one case hydramnios and fetal anasarca were associated with/

with pronounced hydrocephalus. Literally, there was no brain.

The Skeleton.

The shape of the skull of the monstrous calf is characteristic. Brachycephaly is marked, the cephalic index being about 100 % and the skull being diminished in length and enlarged in width. The head is large with bulging forehead and parietal eminences; the nasal region is much depressed; the bones of the vault are thicker than is usual and the most striking feature of all is the extreme shortness of the base.

The supra-, ex-, and basi-occipitals, the basi-, ali-, and pre-sphenoids are fused into one mass of bone and no suture of any sort can be identified. The orbito-sphenoid is distinctly delimited. In a normal Dexter fetus of 7 months the basi-occipital measured 3.1 cms. and the basi-sphenoid 2.5 cms. giving a total antero-posterior length of 5.6 cms. when measured on the exterior of the skull and one of 5 cms. when measured on the interior aspect. These combined bones in a 'bull-dog' fetus of the same age measured 1.2 cms. and 1.3 cms. respectively. In the normal the foramen measured 2.6 x 2.8 cms.; in the 'bull-dog' it was 1.8 cm. long and was waisted, measuring 0.9, 0.8, 0.9 cm. in width. No distinct condylar faces were discernable. Internally the ethmoid in the normal covered the orbito-sphenoid, in the 'bull-dog' it did not.

The vomer is extremely robust in the monstrous calf and has a very broad articulation laterally with the palatines. There is no hard palate and the nasal portion of the skull is completely exposed ventrally in consequence of the entire absence of any inward growth of the maxillae and palatines. The posterior palatine/

palatine processes of the premaxillae are present being fused with the anterior end of the vomer. The maxillae are greatly foreshortened as are also the nasals. The foreshortening of the maxillae is illustrated by the unusual prominence of the lachrymals and by the fact that while the general contour and proportions of the post-palatine processes of the maxillae are normal the pre-maxillae, normal in design, practically come back to the level of the maxillo-palatine suture. Viewed ventrally, the premaxillae lie much deeper than the inner margin of the maxillae and palatines, the contour of these latter being such that there is no suggestion of any effort to make a palate. In this respect the skull is distinctly reptilian. The abnormalities of the skull are such as affect its posterior fossa and save for various degrees of asymmetry and for the greater thickness of the vault the remaining peculiarities are such as could follow from the abnormality in the ossification of the base.

The skull of the 'bull-dog' calf resembles that of the Bulldog in one respect only : both show foreshortening of the facial region due to an arrest of development of the nasals and maxillae.

In the case of the limbs of the 'bull-dog' fetus the epiphyses of the long bones do not differ materially from those of the normal but there is a profound difference in the length of the shaft. The shortening affects the proximal bones of the limbs more than the distal. The digits are separated more widely than in the normal calf of the same age. Sections of the epiphysial line of the long bones of the limbs show certain characteristic features. Normally, bone formation proceeds by (1) endochronial ossification at the junction of epiphysis and diaphysis/

diaphysis, determining growth in length; and (2) periosteal ossification determining growth in thickness. In endochondral ossification three zones can be distinguished in the area between the undifferentiated cartilage of the epiphysis to the diaphysis : (1) the zone of proliferating cartilage cells in which the multiplying cartilage cells lie in a clear matrix; (2) the zone of parallel columns of cartilage cells in which the hyaline matrix is the seat of calcification; and (3) the line of ossification in which each column of zone 2 extends as far as the bone marrow from which vascular loops extend to erode the cartilage columns in a regular manner. The septa separating the columns become eroded and denuded of their cells and become encrusted with calcareous salts and on their surfaces osteoblasts are deposited by the vascular loops. These osteoblasts lay down successive layers of true bone whilst the calcareous material of zone 2 is removed by osteoclasts.

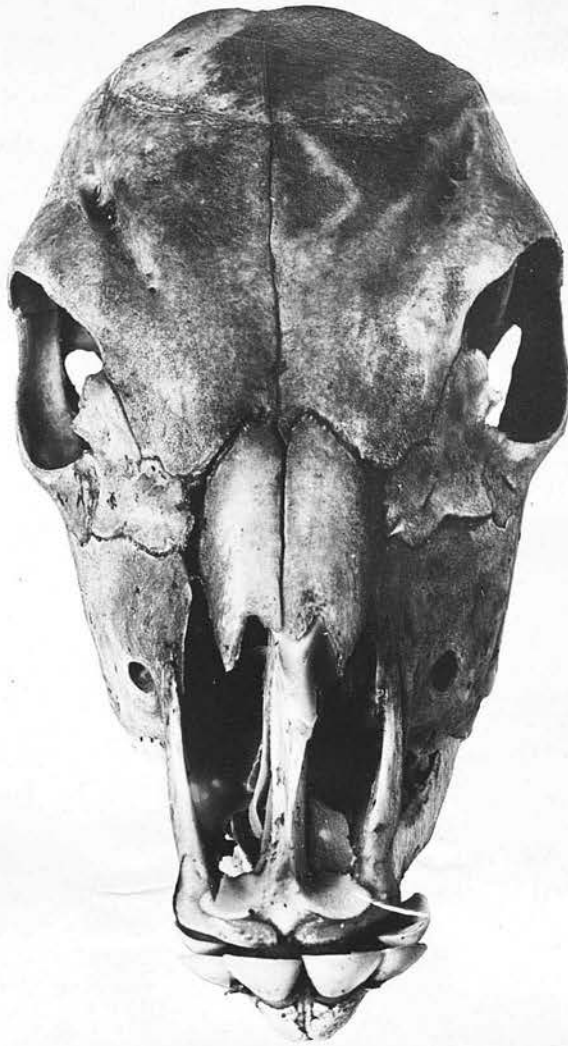
In the case of the monstrous calf zone 1 is unaltered but on the surface of this there is a vascular fibrous are enclosing small islets of cartilage. There is no zone 2, the columnar arrangement of the cartilage cells being entirely absent and the cells, few in number, are scattered irregularly. The matrix is not hyaline but shows fibrillation and the deposition of calcareous salts is irregular. Zone 3 is thin and irregular. Endochondral ossification occurs but the absorption of bone trabeculae is defective so that reconstruction of the cancellous tissue fails. The trabeculae are excessively thick with comparatively small rounded areolae between them. The condition is one of abnormal endochondral ossification in that there has been defective absorption at the stage of secondary areolar formation/

formation. Periosteal ossification in these cases is normal and the abnormality is restricted to the epiphysial line where the cartilage cells are entirely passive, where there is no division, no column formation, and no vacuolation and hypertrophy. The vertebral column is also involved, in some cases being less than half the length of that of a normal foetus of the same age, and along with this abnormality there are other affecting the size and shape of the thorax and of the pelvis.

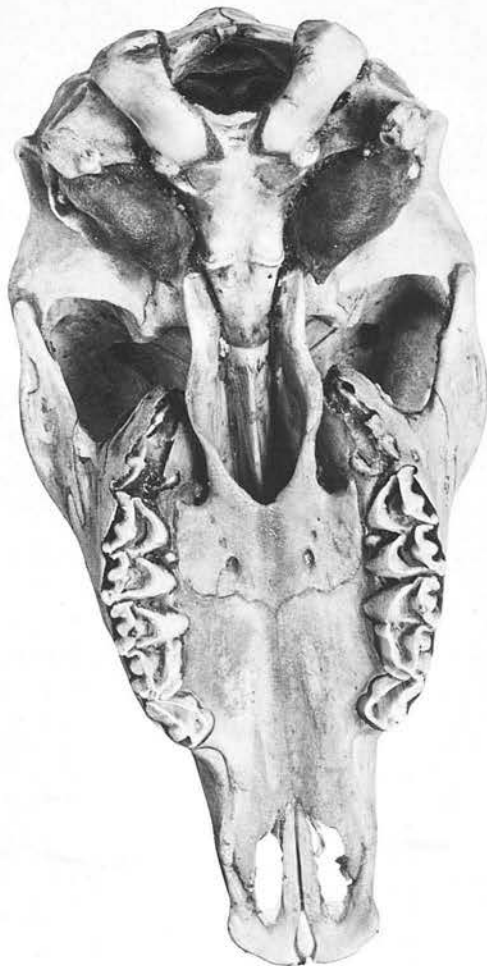


The skull of an adult Dexter cow.





The skull
of a normal
calf foetus
of the 6th.
month.

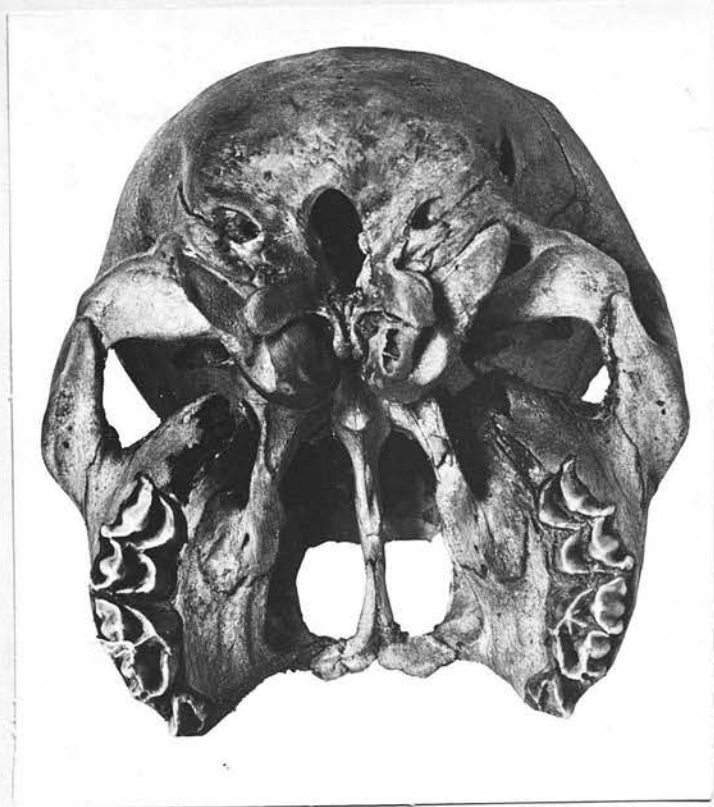




The skull of an adult typical bulldog. Save for the fore-shortening of the facial region this skull exhibits none of the peculiarities of that of the monstrous Dexter calf.



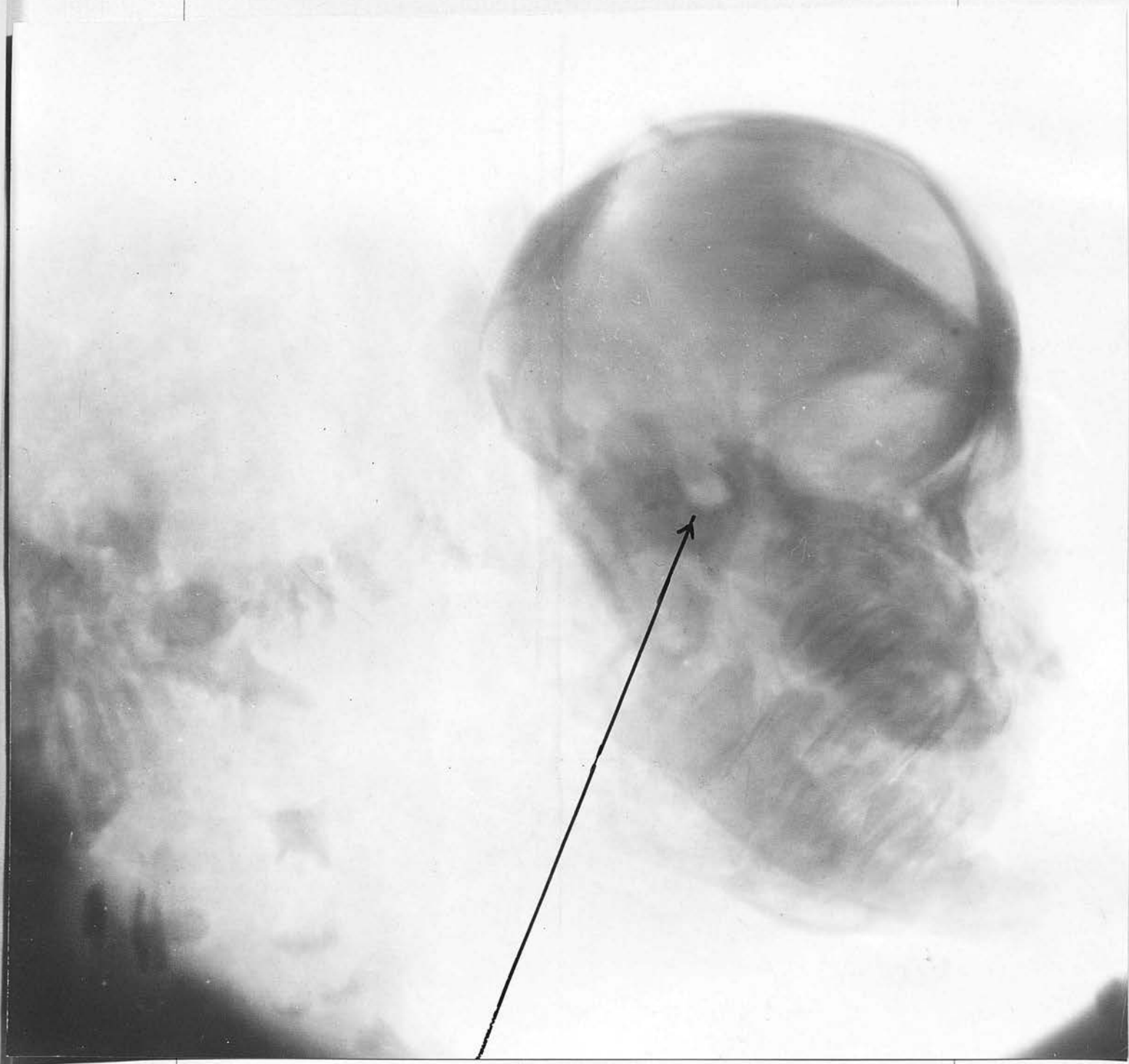
The skull of a typical 'bull-dog' foetus of the 6th month.





sella turcica

skull of normal 6 months calf: fetus.



sella turcica

skull of 6 months 'bull-dog' fetus.

Forelimb.

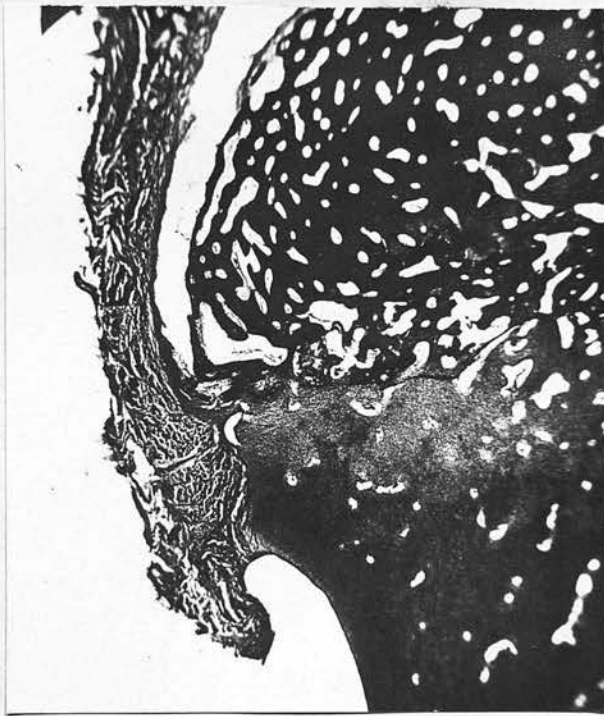


Scapula
Acromion
Humerus
Radio-Ulna
Carpus
Metacarpus
1st. Phalanx
2nd.
3rd.

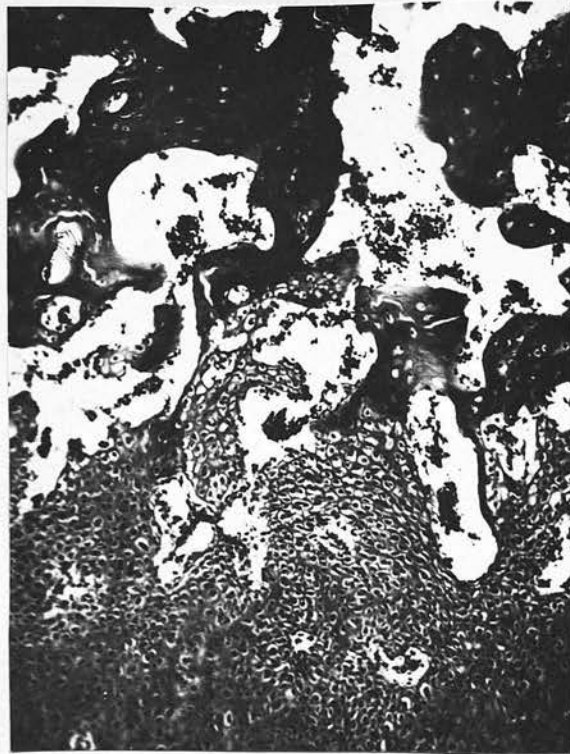
Hindlimb.



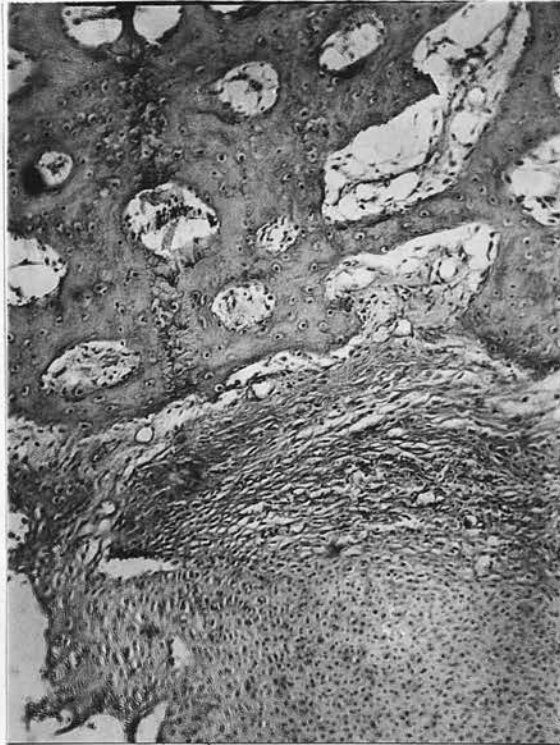
Femur
Tibio-Fibula
Tarsus
Metatarsus
1st. Phalanx
2nd.
3rd.



Section through the end of a long bone x 22. Shows complete failure of reconstruction of cancellous bone.



The epiphysial line x 110. Shows the very imperfect attempt at column formation.



Section of epiphyseal line x 110. Shows calcified cartilage ; failure of absorption of this and complete absence of reconstruction of cancellous tissue. Osteoblasts are present but fail to deposit osteoblastic bone. The epiphysis is normal. There is no sign of any cell-proliferation and none of any attempt to form the serrated zone. The ossifying junction is occupied by a thick mass of osteoid tissue which separates the cartilage from the diaphysis and this area is non-vascular. The condition is one of abnormal endochondral ossification.

§ VI. Diagnosis.

In the search for a diagnosis it was necessary to review certain pathological conditions which affect the human subject. It was found that the lesions which characterise the 'bull-dog' calf simulate very closely indeed some of the most typical features of achondroplasia as met with in the human.

This condition has long been known to human obstetricians and pathologists. As early as 1817 Romberg had described a human foetus with remarkably short limbs and others were recorded by Chaussier (1819), Weber (1829), Busch (1836), and Dumenil (1856). These writers though satisfied that the condition which they were describing was not rickets hesitated to give it a name. Virchow in 1856, however, described another case and definitely diagnosed rickets and by doing so attracted the attention of the medical profession to the condition. Winkler (1871) suggested the name 'Rachitis micromelia' in order to call attention to the outstanding peculiarity of this supposed variety of rickets - the remarkable shortness of the limbs. In 1876 Parrot described the condition as a discrete form of disease of human foetuses, distinguishable from rickets and from congenital syphilis, and gave to it the name 'Achondroplasia'. The characteristic features of achondroplasia, according to Parrot, were (a) micromelia, (b) abnormal shape of the cranium, (c) absence of thoracic deformity, and (d) marked thickening of the skin. In spite of Parrot's writings the condition was generally regarded as either rachitic or syphilitic in nature until Porak confirmed and extended Parrot's conclusions. He showed that the condition was hereditary, that it occurred among other animals than/

than man and that it had existed from very early times. Kaufmann (1893) described fourteen cases and suggested the name 'Chondrodystrophia foetalis'. The name achondroplasia has the advantage of priority and custom has decided that it will be employed, but that suggested by Kaufmann is the more descriptively accurate. Up till 1900 only the achondroplastic fetus had been studied but in that year Marie described the condition as exhibited by the living adult. Apert (1901-2) and Mery & Labbé (1902) described further cases and distinguished between achondroplasia, cretinism, and myxoedema. Durante (1902) described two distinct forms : true achondroplasia and periosteal achondroplasia. But even yet the group name 'achondroplasia' accommodates a considerable number of pathological conditions which may or may not be different modes of expression of a polymorphic disease. Such very different conditions have been described as micromelia, chondritis foetalis, osteogenesis imperfecta, pseudo-chondritis, cretinoid dysplasia, micromelia chondromalacia, osteoporosis, periosteal aplasia, and chondrodystrophia foetalis with its three varieties, hyperplastica, hypoplastica, and malacica. In this paper achondroplasia is referred to as a group name.

The human achondroplast presents the characteristic features of the condition. The trunk is shortened in some cases; the limbs are short and thick and markedly curved with the convexity outwards; the head is larger than usual with bulging forehead and parietal eminences; the bridge of the nose depressed; the skin thick and wrinkled. The foot is rotated inwards, the vertebral column straight and the back flat though the buttocks and abdomen are prominent. The condition is reminiscent of the earlier/

earlier fetal proportions, the limbs being short in relation to the trunk. Another persistent fetal character is the 'main en trident' or 'bident', the second and third metacarpals forming an angle of about 40° with one another instead of the usual 32° . In the newly formed fetal hand the metacarpals form an angle of $\pm 90^{\circ}$ so that the digits are widely separated; this divergence diminishes during the course of further development but less in the case of the achondroplast than in the normal. Still another fetal condition is mirrored in the achondroplastic pelvis which is smaller than the normal.

The great majority of achondroplasts are still-born but a few survive to become robust muscular adults. The adult is of low stature and of great muscular development, has a normal sized trunk, a large head, and short limbs of the rhizomelic type - thick short hands and feet, and spread digits when extended. The shortness of the limbs is not due to any crookedness or bending of the bones as in rickets or osteomalacia, nor the result of multiple fractures as in osteogenesis imperfecta, nor to the congenital absence of any bone. All the customary bones are present but they are much shorter than usual.

Achondroplasia in the human is a hereditary disease. An achondroplastic race cannot exist for the reason that an achondroplastic woman cannot come to a normal confinement and in the absence of surgical interference both mother and child must perish. Caesarian section is necessary in order to save both and craniotomy must be carried out if the mother alone is to be saved. Micromelia and foreshortening of the facial region, however, are familial characteristics and they may be regarded as low grades of the condition of achondroplasia. In various cases/

cases the human achondroplast has had an achondroplastic father, mother, brother(s), sister(s), grandfather, father and brother and sons, an achondroplastic co-twin, a normal co-twin. An achondroplastic parent of either sex married to a normal mate may have normal children. Rischbeith gives a long series of such cases. It is of interest to note that Catherine de Medici, Natalie, sister of Peter the Great, and the Empress Anna of Russia tried without success to raise a race of these dwarfs by arranging their inter-marriages.

In the case of the human there would seem to be different grades of this condition : the lowest grade being seen in the case of the adult of low stature whose arms and legs are short in relation to the trunk; the highest grade being that seen in the still-born fetus which exhibits several if not all of the following characters : shortened limbs and base of skull, depressed nose, harelip, abnormality of hard palate, narrowed foramen magnum, umbilical hernia, anasarca, hydramnios, prominent abdomen, thickened skin, abundant subcutaneous fat, apparent lordosis, brachycephaly, inturned feet, 'main en trident', shortened vertebral column. These are the very characters of the 'bull-dog' calf.

The pathology of the condition has been described in detail by Emerson, Murk Jansen, Keith, Shattock, and Sartorius, among others. It corresponds with the lesions found in the case of the 'bull-dog' calf. The condition is not one of arrest of cartilage formation: it is one of an arrest of bone formation in cartilage. The parts in the posterior fossa of the skull are arrested in their growth, there is considerable contraction of the foramen, great shortening of the basi-occipital and basi-sphenoid/

:sphenoid followed by a contraction of the naso-pharyngeal space. The ossification of the pre-sphenoid is also arrested and the distance of the pituitary fossa from the fronti-ethmoid junction is greatly reduced with the result that the nasion is drawn inwards. The limbs show the condition of micromelia, the humerous and femur are affected more than the ulna and tibia, and the site of the lesion is limited to those lines where bone is replacing cartilage.

The conditions found in the case of the 'bull-dog' calf are such as are found in the clinical and pathological entity known as achondroplasia.

It would seem that the exhibition type Dexter itself is a low-grade achondroplast and that the 'bull-dog' calf produced by the mating of two such individuals is a high-grade achondroplast, exhibiting the classical features of the condition in a most pronounced form..

§ VII. The Endocrine System of the Monstrous Calf.

In the case of the human many and varied causes have been suggested : Bohn and Schwob as early as 1868 suspected a disturbance or an insufficiency of the placenta. Parrot (1876) considered that a congenital nutritive disturbance of the cartilage cells was responsible. Klebs (1889) suggested that a compression of the fœtus by the umbilical vesicle was the cause. Von Franqué (1893) and Rindfleisch (1889) also suspected mechanical pressure. Dor (1893) suggested that an auto-intoxication was the cause. Poncet and Leriche considered that the achondroplasts constituted a distinct race, while Buck and Mayer (1900) held that the condition was a hereditary process and that the most severe cases were the last of a degenerate race. Porak and Durante (1905) inclined to the opinion that the condition was sclerosis of cartilage resulting from an auto-intoxication. Cestan and Regnault described the condition as a form of intrauterine rickets. Marie (1900) suspected abnormality of some gland of internal secretion, while Lugano and Devay agreed with Leblanc in regarding a malfunctioning of the thyroid as the cause. Collman described a case in which the thyroid was much enlarged, as did also Virchow and Neumann. Bowlby, on the other hand, records a case in which the thyroid was absent. Regnault, however, concludes that in the majority of cases this gland is normal. Vargas held that the thymus was responsible, while Parhon, Shunda, and Zalplachta (1905) went further by suggesting that the condition was due to a combination of hypofunctioning of the pituitary, thyroid and thymus, together with a hyperfunctioning of the sexual glands.

Murk/

Murk Jansen advanced an ingenious hypothesis to explain the conditions found in these cases. He argues that the responsible cause is a compression of the fetus by a too small amnion or by a hydramnios. Keith disagrees emphatically with Jansen's conclusions, pointing out that a comparison of such contrasting conditions as the frontocephaly of achondroplasia and epistocephaly and simopropsia leads directly to the conclusion that such differences in end-results can be explained in terms of different action on the part of the agencies regulating growth. This growth-regulating mechanism is in all probability the endocrine system and Keith argues that in the light of recent advances in endocrinology it is probable indeed that the stimulus which brings about the preparatory pre-ossification changes in bone formation is an internal secretion "such as we may expect to arise either in the pituitary, thyroid, suprarenal, or genital glands, or by an interaction of secretions from all of these", and that the cause of achondroplasia is a malfunctioning of one or more of these glands of internal secretion.

The present study has not furnished a complete answer as to which, if any, of the glands of internal secretion is to be regarded as the responsible causal agent in the production of achondroplasia, granting, that is, that this condition in the 'bull-dog' is achondroplasia. But this much is certain: there is profound abnormality in some of the ductless glands. If it is desired to investigate the cause of achondroplasia in the human the most satisfactory way will be to maintain a herd of Dexters and to produce abortion of fetuses during the first three months of pregnancy.

The Pituitary.

In the case of the human achondroplast smallness of the pituitary has been commonly reported and this fact has been deemed to be of some significance as it has been conclusively established that this gland is concerned in the normal growth processes. But no definite and constant histological abnormality of the pituitary has been found. The pituitary of the 'bull-dog' fetus is definitely smaller and is more compressed than in the normal. Histologically it presents the usual structure save that in many cases there are areas of oxyphil cells in the pars intermedia. The cells of the anterior lobe appear to be more closely packed than is usual and the vascularity of the gland to be less than in the normal. It is not profitable to discuss the possible significance of such vague impressions as these. But advantage was taken of the melanophore test devised by Hogben and Winton in order to examine the functioning of the posterior lobe of the pituitary of the monstrous calf. These workers have shown that following an injection of a minute quantity of posterior lobe extract into a frog previously kept under these condition which conduce to skin pallor there is a very characteristic and rapid darkening due to a marked expansion of the melanophores. In the case of the normal cattle fetus the pituitary is active, as estimated by the test, at the beginning of the third month. The pituitary is ground up in a mortar with sand with distilled water and the extract injected intra-abdominally. In the case of the 'bull-dog' fetus the pituitary of a six months specimen gives a very doubtful reaction. A four months pituitary gives a still more doubtful reaction. It is granted that this test is one for posterior lobe activity and that a mal-functioning of/
of/

32

of the pituitary which would constitute a possible cause of achondroplasia would be one involving the anterior lobe. Nevertheless it would appear to be not without significance that in the 'bull-dog' foetus the posterior lobe is physiologically relatively inactive at the 4th and 6th month; it is not unreasonable to think that the measure of the activity of the posterior lobe can be regarded as an indicator of the functioning of the gland as a whole.

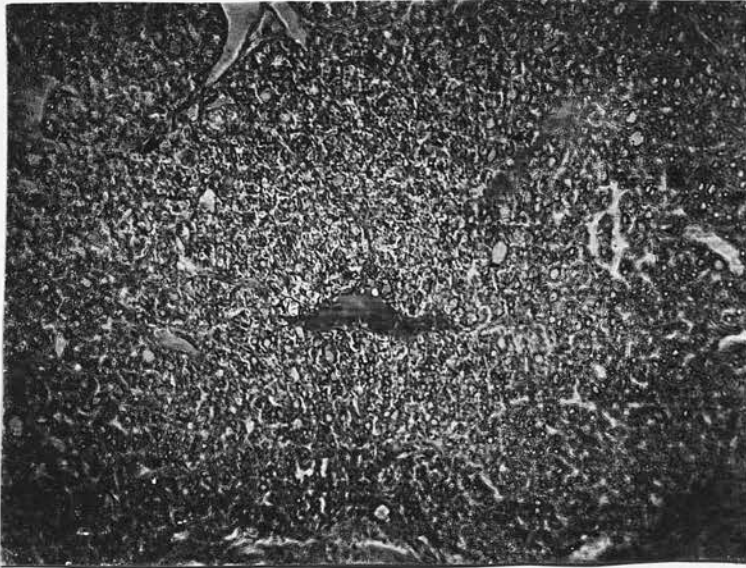
If this be so then indeed there is reason to suspect that a malfunctioning of the pituitary during the earlier months of foetal life is responsible for the abnormalities in ossification and growth. If, for example, the pituitary does not function properly at the time when the normal processes of ossification begin and if for the normal development of bone the guiding stimulus of the pituitary is necessary, then a retardation of pituitary activity or an insufficiency of its secretion could lead to abnormality in bone formation and the degree of imperfection in the end results will vary with the degree of retardation of the pituitary functioning and with the difference in the time at which the various parts of the skeleton become ossified.

The suspicion that a malfunctioning of the pituitary may be involved in the causation of the conditions found in the monstrous calf is strengthened by the work of Krogh who showed that posterior lobe activity takes part in the production and maintenance of capillary contractile tonus; insufficiency (or excess) results in capillary dilatation and œdema and this may be regarded as the cause of anasarca, hydrocephalus and hydramnios. It was found by Smith, and confirmed by Hogben, that general œdema commonly follows injection of pituitary extracts into larval Amphibians.

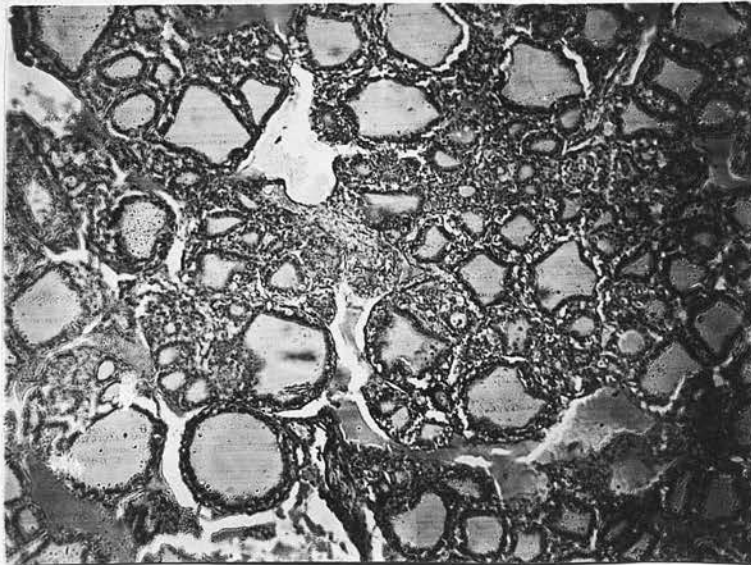
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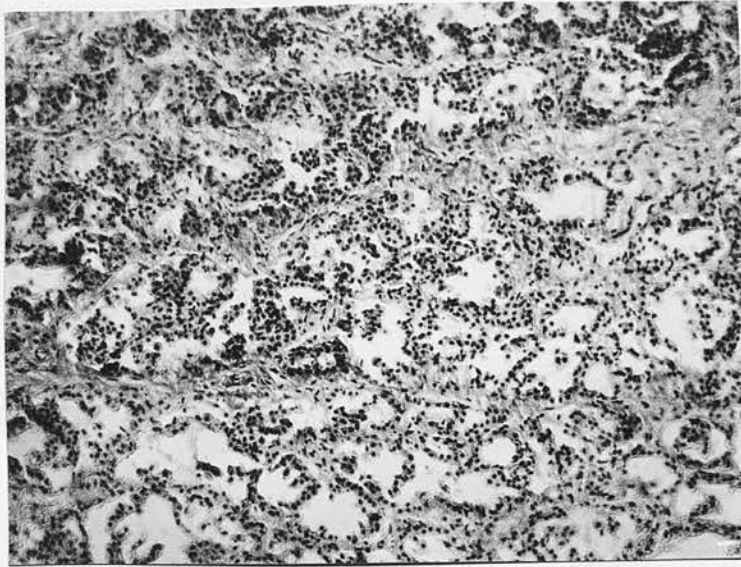
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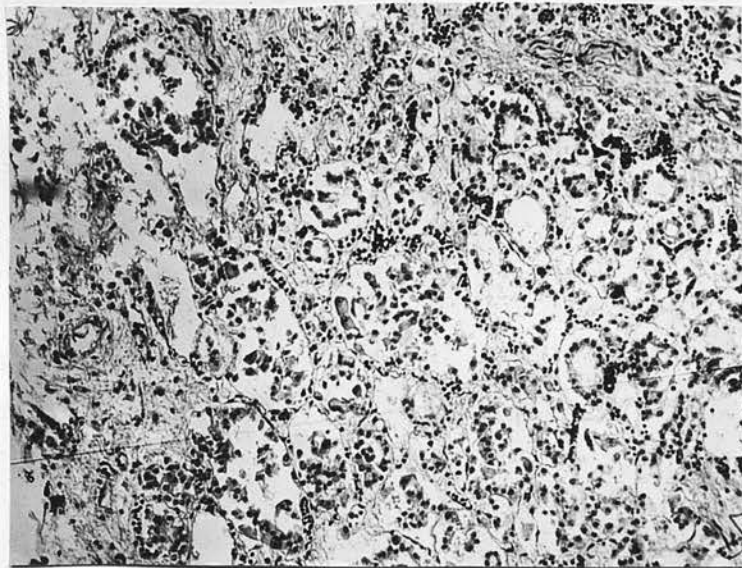
The thyroid of a three-months normal calf fetus.
x 75.



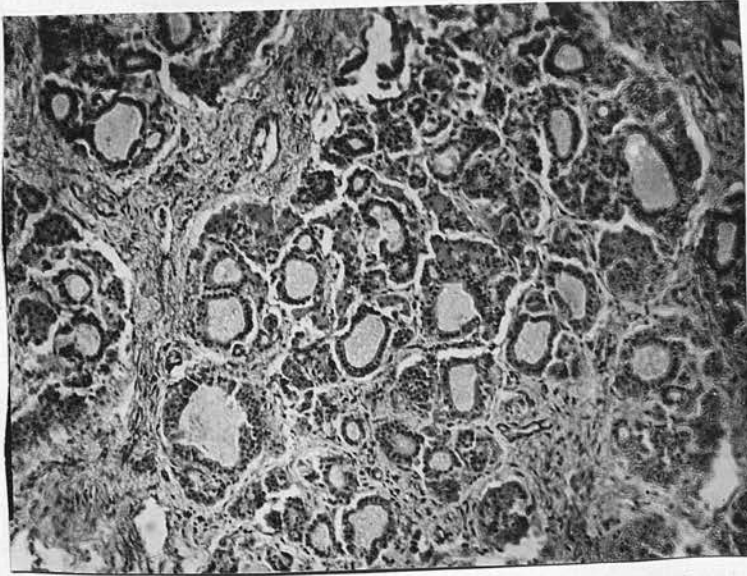
The thyroid of a six-months normal calf fetus.
x 75.



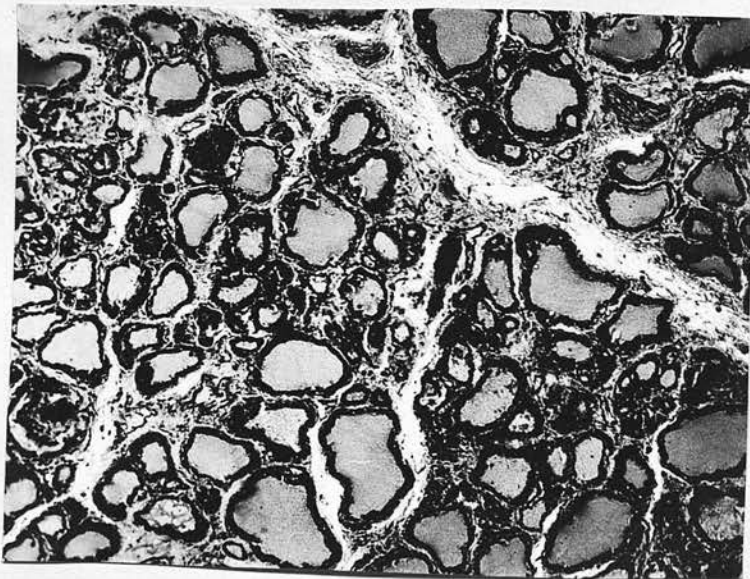
Thyroid of a "bull-dog" fetus. Showing Hyperplasia.
x 110.



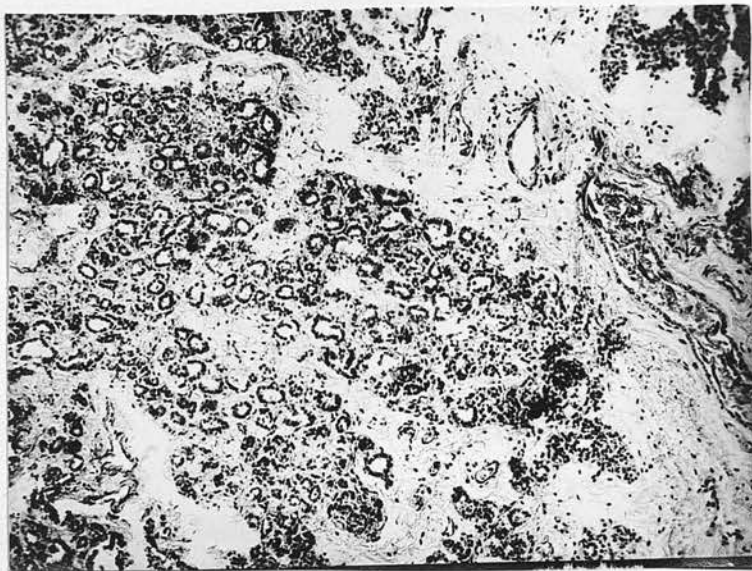
Thyroid of a "bull-dog" fetus. Showing Hyperplasia.
x 110.



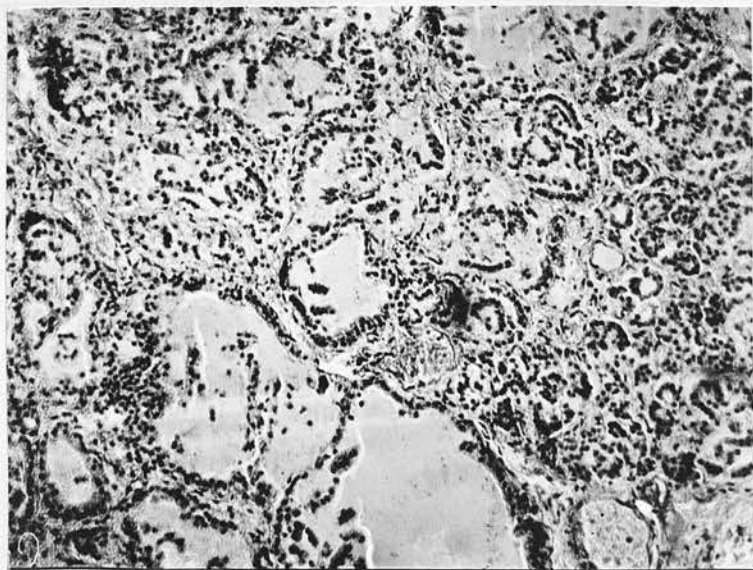
Thyroid of a "bull-dog" foetus. Showing commencing
Involution. Fibrosis.
x 110.



Thyroid of a "bull-dog" foetus. Showing commencing
Involution. Fibrosis.
x 110.



Thyroid of a "bull-dog" fetus. Showing Involution.
x 110.



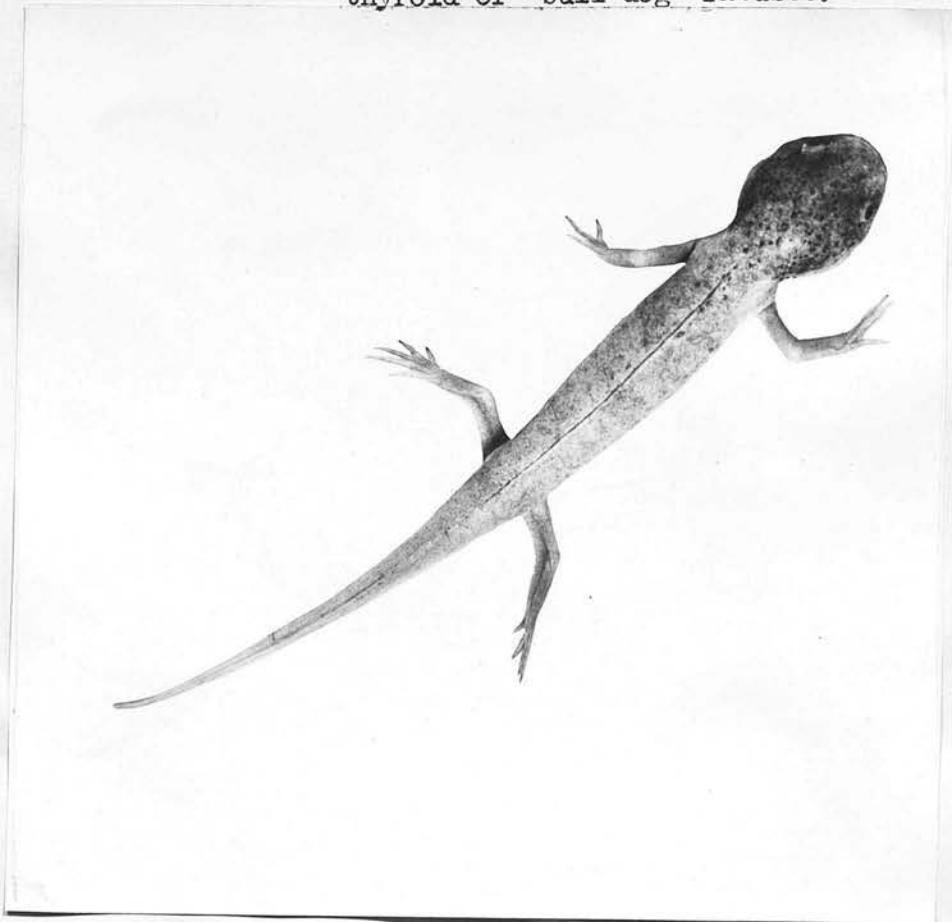
Thyroid of a "bull-dog" fetus. Showing Involution.
x 110.

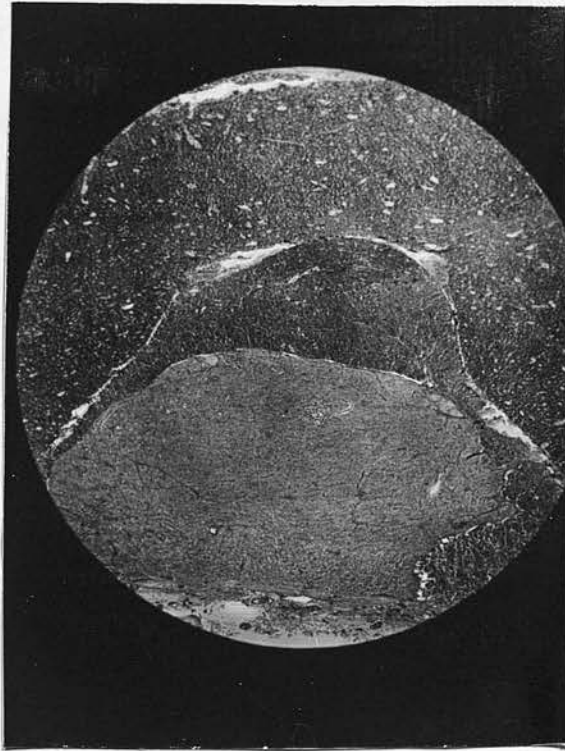


Rana temporaria. To show the effect of injection of the extract of a functional posterior lobe of the pituitary. Both frogs were kept under conditions conducive to light colouration. Into the one below and to the right a minute quantity of extract of posterior lobe was injected intra-abdominally and the typical response followed quickly. In the case of the pituitary of the "bull-dog" calf this result is not obtained.



Amblystoma. Metamorphosis induced by feeding with the
thyroid of "bull-dog" fetuses.





The pituitary of a 'bull-dog' fetus x 15 .
A normal pituitary structure.



The adrenal of a 'bull-dog' fetus x 85 . Showing the areas
of cartilage bone formation.

The Thyroid.

In the case of the 'bull-dog' calf Seligmann (1904) found that the thyroid was abnormal and concluded that the condition was one of foetal cretinism. In seven cases the thyroid was oedematous and purple, the isthmus absent or irregular in shape. Histologically the gland consisted of masses of more or less cubical or spheroidal cells and the capillary network was extremely dense. Very few vesicles and sometimes only the faintest trace of a vesicular arrangement could be detected. There was complete or almost complete absence of colloid and the lumina of the vesicles were packed with cells. In 1911 Sheather described the thyroid as being normal in size, shape, and histological structure save that there was a slight excess of interstitial tissue in some parts of the gland. The vesicles were perfectly formed and filled with colloid. Crew and Glass (1922) described the thyroid glands of five foetuses and demonstrated that in these cases the thyroid did not show the histological features of a hypo-functioning but rather those of a hyper-functioning gland. In the large series of cases which have now been examined the thyroid has varied considerably. In some, mostly in young specimens, it has been unremarkable; in others it has been enlarged and the histological picture has been that of a thyroid from a case of hyper-thyroidism: no colloid was present, the small irregular vesicles contained papillary ingrowths of epithelium and desquamated material, and the sections consisted of masses of solid cellular hyperplasia. In the older specimens the thyroid showed the typical signs of involution, the vesicles were enlarged, irregular and full of colloid, the epithelium low and the previously hyperplastic intervening/

:tervening tissue undergoing retrogression and transformation into fibrous tissue.

The sequence of events as suggested by the different histological appearances seen in various cases would seem to be : first, a developing thyroid; then, a hyperplastic hyperfunctioning thyroid; and finally, an involuting gland with fibrous atrophy and progressive hypofunctioning. Such a scheme would accommodate the different descriptions which have been given by previous writers and would explain the diagnosis of foetal cretinism. The seriation of events is typical of cretinism but it is also the typical course of events which follows removal of the anterior lobe of the pituitary in mammals, as has been shown by Cushing and more recently by Dott. The lesions found in the thyroid do not necessarily indicate that the condition is that of foetal cretinism. The mother of a monstrous calf is not goitrous herself. Shattock, in Seligmann's paper, suggests that the maternal thyroid is probably sufficient for the mother's needs only; but the experiments of Halstead and of Edmunds on the dog show that were this so the thyroid of the foetus would be greatly enlarged. The conditions found in the thyroid of the 'bull-dog' foetus can be regarded as secondary to a malfunctioning of the pituitary.

Since Gudernatsch demonstrated the efficiency of thyroid feeding to accelerate Anuran metamorphosis, the value and specificity of this test at least as an indicator of the iodine content of the gland, as demonstrated by Lenhart and Swingle, has been universally recognised. Using the Axolotl, the larval form of the Mexican salamander, there is the opportunity of demonstrating thyroid activity in a most spectacular way, for a single/

single meal of fresh gland suffices to induce metamorphosis. This is a critical test for thyroid iodine: the transformation does not occur in aquaria without this stimulus and it cannot be induced by the oral administration of inorganic iodine. The axolotl test has been shown to be a specific test for thyroid activity by Laufberger, Jensen, L. Kaufmann, and Huxley & Hogben. An axolotl weighing 64 gms. was fed with 2 gms. of fresh thyroid taken from a seven months 'bull-dog' fetus. Complete metamorphosis resulted with shedding of the larval skin in the usual 12-14 days after the thyroid meal. A second axolotl of 23 gms. was fed with 1 gm. of thyroid from a 4-5 months 'bull-dog' fetus. Metamorphosis occurred with shedding of the larval skin at about the same time as in the previous instance. In the case of the normal calf fetus this cannot be applied successfully before the fourth month of intrauterine life. From the fourth month onward the thyroid is active, as estimated by this test, before this it is not. It will be noted that according to the tests used the pituitary is functional before the thyroid.

These observations give a clear demonstration that physiologically active iodine is present in the thyroid of the monstrous calf of the Dexter at an early stage of fetal life. They do not support the contention that the condition is that of cretinism.

The Adrenals.

The adrenals have in no case been perfectly normal. In some there has been an undue amount of fibrous tissue in the cortex and in the medulla. In the majority there have been found/

found areas of cartilage and in many there are present areas of cartilage bone with Haversian canals and areas of calcified cartilage with osteoblastic bone on its surface. The different stages in this bone formation would appear to be : hyperplasia of the fibrous tissue; formation of hyaline cartilage in these areas; fibrillation of the cartilage; calcification in the matrix; absorption of the calcified cartilage by osteoclasts; and deposition of osteoblastic bone on the surface. The exact significance of this cartilage bone formation in abnormal situations has not been established but since similar areas have been found in other organs in which there is plentiful connective tissue it is suggested that the condition is a general one and possibly is secondary to a malfunctioning of the pituitary.

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No other abnormality of the endocrine system was encountered. It may be remarked, however, that in contradistinction to the general finding of sexual precocity in the living human achondroplast the differentiation of the sex-organisation in the case of the monstrous calf of the Dexter is not so advanced as in a normal cattle foetus of the same age.

The tentative conclusions arrived at from this study are as follows : Very possibly the condition results from a malfunctioning of the pituitary between the second and third months of intrauterine life. Under these conditions the proper control of cartilage bone formation is lacking. The thyroid undergoes hyperplasia and this is followed by involution. The severity of the condition may be determined by the degree of retardation in the functioning of the pituitary or by the delay in the production of an efficient internal secretion by this gland. But
it/

it is not claimed that a definite answer has been given to the question as to the primary cause of the condition. It is felt, however, that the study of the monstrous calf of the Dexter has provided a strong argument in favour of using this material for a complete and thorough study of the conditions akin to achondroplasia. A small herd of Dexters would provide the finest experimental material for a demonstration of the bearing of Genetics upon Pathology and upon the science of Animal Breeding.

§ VIII. The Significance of the Monstrous Calf.

The following points have to be considered : the Dexter had its origin in the mating of two distinct races of cattle and is peculiar for its bodily conformation characters, being in all probability a low-grade achondroplast. The mating of Dexter and Dexter results in the production of four classes of calves in such proportions as to suggest that the Dexter is a Mendelian di-hybrid in respect of its coat colour and bodily conformation characters. A certain proportion of the calves produced by Dexter \times Dexter matings are still-born and exhibit characters which constitute the condition of high grade achondroplasia - the characters of their parents greatly exaggerated. Associated with these foetal characters there are usually anasarca and hydramnios and in some cases hydrocephalus. The cause of death is either the cause of the hydramnios or that of the peculiarities in the skeleton which render normal delivery impossible. In all probability the cause is endocrinal in nature and possibly is a mal-functioning of the pituitary. The incidence of the condition is such as to suggest that it is genetic in its origin. There is but one way of producing a monstrous calf of this sort and that is to mate Dexter with Dexter. (Report has it that the same condition is found in the small Breton breed of cattle.)

These facts can be accommodated by the following scheme. The old-fashioned Kerry and the old-fashioned Devon furnished those factors which in combination yielded the original Dexter, a big-headed, stout-bodied, short-limbed individual. Or, the original/

original Dexter was the result of a mutation. It suffices to suppose that the original Dexter had the factorial constitution symbolised by the formula $Bb (S l_1 l_2)(s l_1 l_2)$. Under these circumstances the Dexter would behave in breeding as was suggested on pp. 8 and 9.

	Dexter	x	Dexter	
Black Dexter type 56.25 %	Red Dexter type 18.75 %		Black Off-type 18.75 %	Red Off-type 6.25 %

e.g. in every four offspring, on the average, two 'achondroplasts of the same grade as their parent, one non-achondroplast, and one a somewhat more pronounced case of 'achondroplasia' than either of the parents. So far the story is not one of pathology, for considering what is known of the human subject it is seen that a low-grade 'achondroplast' is physiologically efficient. In order to interpret the 'bull-dog' calf in terms of Genetics the following hypothesis is suggested. During the formative period of the breed two independent mutations occurred. Each of these resulted in the appearance of a factor, L_1 and L_2 respectively; these factors intensified the action of the factors which caused the production of the low grade of the achondroplasia-like condition. L_1 and L_2 are modifying amplifying factors and their action is additive. Either alone produces a greater degree of the 'achondroplasia' characterisation and together they yield the highest grade which is seen in the non-viable 'bull-dog' calf. The 'lethal' constitution is $(SS + L_1 + L_2)$. These mutations in the early Dexter and not in the parental breeds and would seem to be linked with the factor S.

Before the appearance of these mutant factors the gametes provided by the Dexter were as follows :

$B(S l_1 l_2)$ $B(s l_1 l_2)$ $b(S l_1 l_2)$ $b(s l_1 l_2)$

after the factors L_1 and L_2 had appeared independently and in all probability in different individuals the series of gametes would be as follows :

A	-	$B(S l_1 l_2)$	E	-	$b(S l_1 l_2)$
B	-	$B(s l_1 l_2)$	F	-	$b(s l_1 l_2)$
C	-	$B(S L_1 l_2)$	G	-	$b(S L_1 l_2)$
D	-	$B(S l_1 L_2)$	H	-	$b(S l_1 L_2)$

and the following zygotes would appear in due course :

AA	SS		}	Homozygous Black
AB	Ss			
AC	SS + L_1		}	Heterozygous Black
AD	SS + L_2			
AE	SS		}	Heterozygous Black
AF	Ss			
AG	SS + L_1		}	Heterozygous Black
AH	SS + L_2			
BB	ss	(off type)	}	Homozygous Black
BC	Ss + L_1			
BD	Ss + L_2		}	Heterozygous Black
BE	Ss			
BF	ss		}	Heterozygous Black
BG	Ss + L_1			
BH	Ss + L_2			
CC	SS + L_1 + L_1		}	Homozygous Black
CD	SS + L_1 + L_2	('bull-dog')		
CE	SS + L_1		}	Heterozygous Black
CF	Ss + L_1			
CG	SS + L_1 + L_1		}	Heterozygous Black
CH	SS + L_1 + L_2	('bull-dog')		
DD	SS + L_2 + L_2		}	Homozygous Black
DE	SS + L_2			
DF	Ss + L_2		}	Heterozygous Black
DG	SS + L_1 + L_2	('bull-dog')		
DH	SS + L_2 + L_2			

EE/

EE	SS		Red
EF	Ss		"
EG	SS + L ₁		"
EH	SS + L ₂		"
FF	ss		"
FG	Ss + L ₁		"
FH	Ss + L ₂		"
GG	SS + L ₁ + L ₁		"
GH	SS + L ₁ + L ₂	('bull-dog')	"
HH	SS + L ₂ + L ₂		"

Random matings in a population containing individuals of the following factorial constitution :

AA	AB	AC	AD	AE	AF	AG	AH
BB	BC	BD	BE	BF	BG	BH	
CC	CD	CE	CF	CG	CH		
DD	DE	DF	DG	DH			
EE	EF	EG	EH				
FF	FG	FH					
GG	GH						
HH							

would yield a percentage of monstrous calves and the percentage would differ according to the relative numbers of the genotypes present in that population. The variety of the genotypes present is decided in great part by phenotypic selection. If it is assumed that Red coat colour is not desired then the numbers of the genotypes EE EF EG EH FG FH GG GH HH will be reduced very quickly. Further if it is assumed that the makers of the Dexter breed were aiming at a beast as short-legged as possible, if it is assumed, that is, that they were actually seeking the biologically unattainable - a high-grade 'achondroplast' with the constitution represented by the formula:

:la ($SS + L_1 + L_2$), then the genotype BB would be discarded for the breeder would choose his 'best' individuals for further mating. The genotypes CD CH DG GH are the 'bull-dog' calves and being still-born would not be available for breeding. In this way the following genotypes would be left :

AA	(S l_1 l_2)(S l_1 l_2)	Lowest grade of 'achondro-
AB	(S l_1 l_2)(s l_1 l_2)	plasia' in the Dexter.
AC	(S l_1 l_2)(S L_1 l_2)	Intermediate grade
AD	(S l_1 l_2)(S l_1 L_2)	" "
BC	(S L_1 l_2)(s l_1 l_2)	" "
BD	(S l_1 L_2)(S l_1 l_2)	" "
CC	(S L_1 l_2)(S L_1 l_2)	Exhibition Dexter - a
DD	(S l_1 L_2)(S l_1 L_2)	higher grade but viable.

The result of the random mating of these genotypes will be as follows :

Gametic series : A - 5/16, B - 3/16, C - 4/16, D - 4/16

	A 5/16	B 3/16	C 4/16	D 4/16
A 5/16	AA 25/256	AB 15/256	AC 20/256	AD 20/256
B 3/16	AB 15/256	BB 9/256	BC 12/256	BD 12/256
C 4/16	AC 20/256	BC 12/256	CC 16/256	CD <u>16/256</u>
D 4/16	AD 20/256	BD 12/256	CD <u>16/256</u>	DD 16/256

AA	25/256	BB	9/256	CC	16/256	DD	16/256
AB	30/256	BC	24/256	CD	<u>32/256</u>		
AC	40/256	BD	24/256				
AD	40/256						

In such random matings, therefore, the incidence of the monstrous/

monstrous calf would be $12/5\%$ of the total births. But if, as suggested above, the breeder persisted in selecting his animals for breeding from the $(SS + L_1)$ and $(SS + L_2)$ individuals it is probable that only the genotypes BC BD CC CD would be used and in these circumstances the 'bull-dog' fetus would appear much more commonly. :-

Gametic series B - $\frac{1}{4}$, C - $\frac{1}{2}$, D - $\frac{1}{4}$

	B $\frac{1}{4}$	C $\frac{1}{2}$	D $\frac{1}{4}$
B $\frac{1}{4}$	BB $1/16$	BC $2/16$	BD $1/16$
C $\frac{1}{2}$	BC $2/16$	CC $4/16$	<u>CD</u> <u>$2/16$</u>
D $\frac{1}{4}$	BD $1/16$	<u>CD</u> <u>$2/16$</u>	DD $1/16$

BB	$1/16$	CC	$4/16$	DD	$1/16$
BC	$4/16$	<u>CD</u>	<u>$4/16$</u>		
BD	$2/16$				

Under these circumstances the percentage of monstrous calves is 25%. The proportion of 'bull-dog' calves varies with the relative proportions of the different genotypes in the herd and with the amount of deliberate selection of individuals with certain characters which are held in esteem.

§ IX. A Suggestion as to the Method by which the 'bull-dog' Calf might be Eradicated.

According to the scheme which has been elaborated in this paper there are Dexters which though of excellent characterisation from the point of view of the breeder will not throw monstrous calves when mated with others of a similar genetic constitution. If the breeder altered his standards of excellence, there would soon be no problem. There are true-breeding races of domesticated mammals which present certain characters very closely akin to many of those which in combination constitute the condition of achondroplasia - the dachshund, Natas cattle, and Yorkshire pigs are examples, perhaps, - and in such races it would seem that the amplifying lethal mutations have not occurred, as they seem to have done in the case of the Dexter and of the Breton cattle. It is biologically possible, to 'fix' a degree of achondroplasia as a racial character. But the Dexter breeders are seeking to attain the biologically impossible: a highest degree 'achondroplast' which is viable. Hydramnios and dystocia render their efforts of no avail. They must be content to modify their standards somewhat: an $(SS + L_1 + L_2)$ individual cannot be produced; but an $(S + L_1 + l_2)(S + L_1 + l_2)$, or an $(S + l_1 + L_2)(S + l_1 + L_2)$ - can, and these individuals are very excellent Dexters.

The methods suggested are as follows:

1st step. To obtain a herd in which all the individuals carry the factor S in the duplex condition.

Theoretically, the quickest way to do this is to mate several Dexter bulls and as many Dexter cows as possible to Kerries and to retain only those individuals which yield none but Dexter type/

type offspring. It must be remembered that the 'foundation stock' Dexter is always Dexter \times Kerry bred and thus must always be heterozygous for its bodily conformation characters. If this is impracticable, then the next best thing to do is to obtain Dexters which have never thrown 'offtype' calves : there are such. In this way SS males and females will be secured.

2nd. step. To remove either the L_1 or the L_2 factor from the herd.

The males retained after the 1st step may have one of the following constitutions :

A	(S L_1 l_2)	(S L_1 l_2)
B	(S l_1 L_2)	(S l_1 L_2)
C	(S l_1 l_2)	(S L_1 l_2)
D	(S l_1 l_2)	(S l_1 L_2)
E	(S l_1 l_2)	(S l_1 l_2)

The females retained may be A, B, C, D, or E.

Choose the best male, as young a one as possible, and mate him to the largest possible number of females. Discard all the females which after repeated matings produce a 'bull-dog' calf. It is probable that either A or B will be the type chosen in the case of the sire. In the case of the dam types A and B are equally good Dexters, and C and D though not so good are by no means 'offtype'.

A mated with	A	will give	No	'bull-dog'	calves.
A	" "	B	" "	All	" "
A	" "	C	" "	No	" "
A	" "	D	" "	50 %	" "
B	" "	B	" "	No	" "
B	" "	C	" "	50 %	" "
B	" "	D	" "	No	" "
C	" "	C	" "	No	" "
C	" "	D	" "	50 %	" "
D	" "	D	" "	No	" "

If the type E is used at all then it will not throw a monstrous calf in any mating, but it is assumed that the breeder wishes to get as low-set and bulky animal as possible.

Keep to one sire and discard every female that produces a 'bull-dog'. Obtain a son of the sire out of a female that after repeated matings with the sire has not produced a monster and mate him with the females which have not been discarded. Mate the sire to his daughters and discard all, and their mothers also, that produce a monstrous calf. In this way if the sire is an A individual the B and D females will ultimately be removed from the herd; if he is a B type animal then the A and the C type females will become removed. When this is accomplished the monstrous calf will no longer appear.

§ X. Evidence from Other Sources that the Conditions found in the Monstrous Calf of the Dexter are Genetical in Origin.

The Species cross Bos americanus × Bos taurus is complicated by the occurrence of hydramnios during the pregnancy which results in the production of the F₁ generation, and by dystocia in the case of the F₁ male which renders the birth of a male almost impossible. Moreover, if an F₁ male is born alive it is invariably sterile. The case resembles that of the Dexter in that hydramnios and dystocia are involved.

Certain breeders, believing that the production of 'cattalo' would prove advantageous, mated bison bulls with Hereford and Aberdeen Angus heifers. (The reciprocal cross could not be made though the reason is not stated.) The pregnancy in every case was complicated by severe hydramnios with the result that the majority of the females aborted. In fact only about one in thirty produced a living calf and of these a male was a rarity for the size and shape of the male hybrid were such that the mother died in labour in the great majority of cases. It was found that the size and shape of the head of the male and the length of his neural spines were such as could not be accommodated by the birth passages of the cow and the offspring or the mother or both died.

In this case analogous lethal factors are involved : complementary lethals resulting in the production of a degree or of a kind of development of the skeleton of the offspring which renders its natural birth impossible, and in the production of hydramnios which in a great number of instances end in abortion. In this case, however, the factors concerned in the/

the production of the conditions leading to dystocia are sex-linked and are not linked with those concerned in the production of hydramnios. In the case of the Dexter monster the dissociation of hydramnios and dystocia has been recorded but extremely rarely and has not been critically observed. In the great bulk of the cases the presence of a monster and of hydramnios in association is the rule, so that the factors concerned are the same or else they are so closely linked that their dissociation is extremely rare. The cattalo case differs also in that the surviving F_1 male is sterile.

The condition met with in the bison \times cattle crosses can be interpreted in terms of the factorial hypothesis as follows :

A and A' are complementary autosomal factors and together result in the production of hydramnios.

B is a dominant autosomal factor complementary to d, a sex-linked recessive, and the combination Bd results in the production of certain skeletal characters which lead to dystocia.

C is a dominant autosomal factor complementary to e, a sex-linked recessive, and the combination Ce results in sterility.

The series de is balanced by DE.

According to this scheme the constitution of the individuals will be as follows :

Bison δ	AABBCC(DEX)Y	Cattle δ	A'A'bbcc(deX)Y
♀	AABBCC(DEX)(DEX)	♀	A'A'bbcc(deX)(deX)
F_1 δ	AA'BbCc(deX)Y		
♀	AA'BbCc(DEX)(deX)		

There will be hydramnios in all cases. Of the fetuses which continue to term there will be dystocia in the case of the/

the male but in the female parturition will be possible, since de is balanced by DE. Similarly, the female will be fertile, the male sterile. The fact that a few F₁ males are produced is to be explained by the variation in the maternal musculature, by differences in the size of the birth passages in cows of various ages and sizes, by differences in the foetal presentation, and by differences in the management of labour.

The females of the F₁ were then back-crossed to the bison or to the bull and this procedure was continued for several generations. It was found that as time went on the incidence of hydramnios became less and less and that the proportion of dead-born calves was steadily becoming reduced. Fertile males were obtained. These facts are easily accommodated by the scheme outlined above. It will be found that a backcross of an F₁ female to the bison sire will yield a generation in which the incidence of hydramnios is reduced by 50 %, as are also those of dystocia and of sterility in the case of the males. After a few years of breeding in this way several genotypes would exist and chance selection guided to some extent by the breeder's art would surely in time completely remove hydramnios, dystocia and sterility. The peculiar results of this species cross can be interpreted genetically and, looking at the problem broadly, the case of the Dexter is very similar. Hydramnios characterises another species cross - Bos americanus × Bos indicus - and one case of this was treated by Lewis who performed hysterectomy in order to obtain a living hybrid.

The case of the monstrous calf of the Dexter, considered in conjunction with those of the species crosses mentioned above, suggests that in certain instances the factor of the geneticist may/

may be endocrinal in nature, affecting the development of the tissues in such a way that conditions unfavourable to the fetus are produced. Dystocia may be the result of an abnormal size or proportion which cannot be accommodated by the maternal birth passages and there is much circumstantial evidence which shows that proper growth is regulated through the mechanism of the endocrine system and that abnormality of a component member of this system is followed by abnormality in the proportions of the individual. A 'lethal' factor may be one which affects the proper and timeous functioning of a ductless gland.

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§ XI. The Possible Bearing of the Case of the Monstrous Calf of the Dexter upon the Species Question.

A species as recognised by the extreme systematist is an association of individuals all of which exhibit a common morphological character complex; such species are commonly defined without any first-hand knowledge as to their behaviour as breeding units. It is perhaps due to this fact that most workers of the Mendelian school, with the notable exception of Bateson, have turned their attention from the historic problem of the origin of species to the more immediate question as to the origin of characters. Nevertheless, as Bateson has rightly pointed out, the fundamental discontinuity of species in the Linnean sense as breeding units has still to be interpreted in terms of the factorial hypothesis which hitherto has shed much light on the discontinuity of animal structure but not upon the discontinuity of the breeding unit. Until further light has been shed on this issue the validity of the assumption upon which the evolution theory rests will not have found a satisfactory basis in experimental enquiry.

The species may be a gene-complex, as suggested by Morgan and the morphological characters may be linked with physiological characters which really separate unit from unit. The case of the Dexter provides an opportunity for offering a suggestion as to the manner in which a discrete breeding unit may have its origin. Mutation affecting a purely morphological character may result in the origin of a distinct breeding unit. For example, a tailless cock - a dominant mutant form of the ordinary domestic fowl - cannot fertilise a hackleless hen - another dominant mutant form - for the simple reason that he cannot/



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cannot balance himself during the sexual act. Each bird is perfectly fertile when mated with normal fowls. This is an established fact in the case of two such birds in possession of the present writer. The case would seem to be an excellent example of the manner in which the two discrete breeding units may arise.

A mutant lethal factor may be such that in the simplex state its action is balanced by its normal allelomorph, but in the duplex state the combined action of the two results in the production of anatomical anomaly and physiological derangement of a kind that render the further development of the zygote impossible or profoundly abnormal. Such is the case of the homozygous yellow mouse. Or else, a mutant factor may be of such a nature that alone, either in the simplex or in the duplex condition, it produces no evident effects; but combined with a complementary factor of the same nature it results in a non-viable condition and the mating of two individuals which carry such complementary factors is rendered abortive.

A mutant appears in a stock; a lethal factor is present in the simplex state and in the course of time there will make their appearance also individuals with this factor in the duplex state. The nature of the factor is such that alone it results in no appreciable effect. Synchronously, or at a different time and in a different race of the same stock, another mutation occurs and a factor appears whose action is complementary to that of the one referred to above; and in time individuals with this factor in the duplex state will be produced. Two distinct breeding units may thus arise within a common stock : each can successfully mate within its own group and with the parent stock but the mating/

mating between the groups is rendered abortive. The expression of the action of such complementary lethal factors may take the form of incompatibility in the the shape of the copulatory apparatus, or in the physiological relationship between the male and female, or between the ovum and sperm, of anatomical anomaly or of physiological derangement leading to an abnormal development of the zygote and its death, of hydramnios or of dystocia, or of sterility of the F_1 heterogametic sex. The two groups, however, have had their origin in a common germplasm and so, in the light of 'return' (Morgan) and 'regional' (Duerden) mutations, it is to be expected that parallel mutations will occur. Members of the two groups will exhibit characters which were borne by the common stock from which the groups arose, and characters which have resulted through mutations since the groups became distinct, some of these characters being the result of parallel mutation and some of mutation which has occurred in one group only. Such mutant morphological characters as are linked with the respective complementary lethals cannot be brought into genetic association and will become the distinguishing characters of the group.

SUMMARY.

1. Dexter cattle are remarkable for their bodily conformation. They produce four classes of calves in such proportions as to suggest that the Dexter itself is a di-hybrid in respect of its characters : coat-colour and bodily conformation. A proportion of the calves are still-born and characteristically deformed, presenting certain constant features closely simulating those which constitute the condition of Achondroplasia in the human.
2. The proportions in which these monstrous calves occur suggest that the 'bull-dog' calf results from the action of complementary lethal factors which are 'amplifying' factors producing an exaggerated form of the Dexter characterization.
3. The pituitary, thyroid and adrenals are abnormal. It is suggested that the lethal factor in this case is such as affects the proper and timeous functioning of the pituitary.
4. The case of the 'bull-dog' calf is interpreted in terms of the factorial hypothesis and a suggestion is made as to the methods by which it can be eradicated through breeding.
5. The possible bearing of the case of the monstrous calf of the Dexter upon the Species Question is briefly discussed.

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