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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
College Station, Brazos County, Texas

BULLETIN NO. 407

FEBRUARY, 1930

DIVISION OF RANGE ANIMAL HUSBANDRY

THE INHERITANCE OF CRYPTOR- CHIDISM IN GOATS



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†As of February 1, 1930.

Cryptorchidism is the technical term for the failure of one or both testicles to descend into their normal positions in the scrotum. This defect occurs at least occasionally in nearly all mammals, but is more frequent in Angora goats than in other farm animals. The removal of the undescended testicle is an operation which few stockmen care to undertake. Cryptorchids (commonly called ridglings or "torunos") are a nuisance in flocks and herds because they develop the sexual characteristics and instincts of normal males unless both testicles are removed.

It is generally believed on the basis of case histories that cryptorchidism is hereditary, but the exact manner of its inheritance is not known. Experiments by the Texas Station have resulted so far in building up a special ridgling flock of goats in which nearly half of all males born are ridglings, thus proving the hereditary basis of the defect. If its inheritance is Mendelian in manner there must be at least two pairs of genes governing it even if some cases are not truly hereditary.

To make progress in eradicating this defect from flocks and herds, it is recommended, first, that no ridgling sires be used, and, second, that the normal sons and the daughters of bucks and does which have a high proportion of ridglings in their progeny be discarded from stud flocks.

Since this defect cannot be manifested in females and yet is transmitted at least in part by females, progress in its eradication will probably be less rapid than in the case of defects which both sexes can show.

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THE INHERITANCE OF CRYPTORCHIDISM IN GOATS

BY

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Cryptorchidism is the technical term for failure of one or both testicles to descend into the scrotum before birth or during early youth, as is normal for nearly all species of mammals. One or both testicles may be thus affected. Animals possessing this anatomical defect are commonly known to farmers and stockmen as "ridglings." In southwestern Texas the term "toruno"† is more commonly used than ridgling. Ridglings are usually quite fertile if the descended testicle is normal and is not removed. When it is removed they are always or nearly always quite sterile, but if the undescended testicle is not removed they develop the secondary sexual characteristics and instincts of normal males. Such animals, while not often, if ever, able to get offspring, are a nuisance to have around, as they are frequently fighting and creating disturbance if allowed to run with the main flock, and it is usually inconvenient to keep them separated from the main flock and with the males kept for breeding. In species used for meat they become staggy and hence less valuable than completely castrated males. Ridgling horses develop the disposition of the stallion and are dangerous to handle. After a ridgling has once been born most stockmen handle the problem in one of two ways; either they kill the ridgling before it reaches the age when secondary sexual characteristics begin to develop or they complete the castration by removing the undescended testicle as well as the normal one. If the undescended testicle has stopped in or near the inguinal canal (as frequently happens with horses), its removal may be a rather simple matter. If, however, it remains in its original position high in the abdominal cavity just posterior to the kidneys and slightly ventral to them (as is nearly always the case among goats and sheep), its removal requires entering the abdominal cavity and is thus attended with a higher percentage of loss than normal castration is. Many stockmen through lack

*Superintendents E. M. Peters and E. W. Thomas, of Substation No. 14, where this work was conducted until the fall of 1928, managed and directed the work with the animals used in this experiment. Mr. L. J. McCall, farm superintendent of Substation No. 10, has been in charge since the transfer of the experimental flock to that Substation in 1928. Especial mention should be made of Mr. O. L. Carpenter, to whose painstaking care as shepherd the accuracy of the breeding and kidding records is due.

†This term is rarely if ever written and we have spelled it here as it is most frequently pronounced. It was introduced by the Mexican shepherds and laborers, but we have not been able to find it in dictionaries of the Spanish language.

of experience hesitate to undertake such a delicate operation, but some perform it as a matter of course when a ridgling is found. Often for horses and sometimes for other animals the services of a trained veterinarian are secured.

Prevalence of Ridglings

Ridglings are occasionally found in all species of farm animals. In birds there is no structure to correspond to the mammalian scrotum, and the testicles remain throughout life in the abdominal cavity, where they are formed not far from the kidneys. In using the term "farm animals" in this publication we are leaving poultry out of consideration altogether.

In man cryptorchidism occurs with a frequency of about 25 cases for every 10,000 men, according to the records of the Surgeon General's Office of the United States War Department, covering the cases of a little less than 3,000,000 men examined for military service during the World War. We have not been able to find any very reliable estimate of the frequency of cryptorchidism in the different kinds of farm animals. It is certainly more frequent among Angora goats than among any other class of farm animals. Our own records covering the Angora goats born during the last thirteen years at the Ranch Experiment Station show 1111 normal males and 63 ridglings born in the flocks in which no ridgling sires had ever been used as far back as we could learn. This is a frequency of 54 per thousand males born—a frequency more than twenty times as high as in man. Lest it be thought that this high frequency is a special characteristic of this one flock, it should be added that these records are divided between the grade flock from two sources and mostly born during the years 1918 to 1922, and a registered flock assembled from several other sources and mostly born from 1923 to 1929. The totals from the grade flock are 30 ridglings among 568 males, a frequency of 53 per thousand male births. The totals from the registered flock were 33 ridglings among 606 male births, a frequency of 54 per thousand male births. The two flocks had few blood-lines in common except that some of the bucks used in the registered flock when it was very small were rather extensively used in the grade flock when it was largest, that is, about 1918 to 1922. Most of the registered goats were sired by bucks not used prior to 1923, when the normal grade flock was almost entirely discontinued. The close agreement between the two flocks hints that these figures for frequency may be fairly representative of the breed. We have learned of frequencies much higher than this in scattered cases of grade flocks, but in all or nearly all such cases there has been a history of the use of ridgling sires a year or two before the high frequencies occurred. In our opinion, the frequency quoted for the Station flock is slightly lower than the true frequency for the breed as a whole. This opinion is based on discussions with breeders and ranchmen generally and on the fact that no ridgling sires have been used in the Station flocks from which these figures came.

Veterinary literature gives a prominent place to cryptorchidism in the

horse,* but that may be due to the fact that the horse occupied such a disproportionately large place as compared to other farm animals in veterinary practice, at least until the last few years. Certainly it occurs in horses frequently enough that nearly every stockman of years of experience in a horse-raising community has known or at least heard of such cases. It is probably a little more frequent in swine than in horses, although we cannot be certain of this in the absence of a large amount of carefully collected data. The cryptorchid pig is often castrated in order to protect the flavor of the meat, whereas the cryptorchid calf or lamb is apt to be sent to the market without anything being said to the local veterinarian about it. This may go far to explain the more frequent reference to pigs than to calves or lambs in the veterinary literature on cryptorchidism. Cryptorchidism is generally thought to be much rarer in cattle than in either swine or horses. In the Jersey herd of the Texas Station there was one ridgling in the last ten years among 166 males born. In the Hereford herd of the Texas Station there was one ridgling born in the last ten years among 284 males. Cryptorchidism seems to be more rare in sheep than in other farm animals, although here, too, the data are too fragmentary to serve as much more than an indication. In the Station flock for the twelve years 1918 to 1929, inclusive, there was not found a ridgling among 90 pure-bred Corriedale ram lambs, 407 pure-bred Rambouillet ram lambs, and 1428 grade Rambouillet ram lambs. Several ranchmen operating large flocks of sheep have said that for years they did not know that such a thing as a ridgling occurred among sheep. Nevertheless they do occur at least occasionally. Two cases were found in one of the mutton breeds in the College flock a few years ago. Several writers state (and this agrees very well with the experience of sheepmen with whom we are acquainted) that cryptorchidism is much more frequent in the polled strains of breeds which are prevailingly horned than it is among the horned strains of the same breeds. This is true of the Merino races in this country. Also Völtz and Jantzon† and Dieckmann found that cryptorchidism was more fre-

*For example, one German text-book ("Operationslehre," by Dr. Jos. Bayer, published in 1910 by William Braumüller, Vienna and Leipzig) mentions 1602 cases of cryptorchidism in the horse reported by one writer and 395 by another, with a third writer reporting 153 cases in swine, while a fourth mentions it as somewhat unusual that he had seen 7 cases in cattle during eight years of practice. About 40 per cent of the cases observed in horses were inguinal. In a small percentage of cases one testicle was inguinal, the other abdominal. In nearly one-fifth of the cases in horses both testicles were cryptorchid. Among the swine 10 per cent were cryptorchid on both sides. Two of the seven cases reported in cattle were cryptorchid on both sides. Left cryptorchidism and right cryptorchidism were about equally frequent among the cases of one-sided cryptorchidism in horses and swine.

†Völtz, W., and Jantzon, H. A Test of the Relative Mutton and Wool Production of the Mutton Types of Merino Sheep as Compared to the East Prussian Black-faced Mutton Sheep (Translated Title), *Zeitschrift für Tierzüchtung und Züchtungsbiologie*, 2:83-111. (See especially page 101.)

Dieckmann. 1921. Inheritance in Hornless Merino Rams with Reference to

quent among the polled Merino flocks than among the horned Merino flocks in Germany. Also in Russia it was observed by Zawadowsky* that about half the rams of the Wallachian breed at Ascania Nova were polled and that cryptorchidism is common in this breed, rising to as high as 10 to 20 per cent in some years, according to the testimony of sheep-breeders and shepherds. Völtz and Jantzon believe (and we are inclined to agree with them, although not in possession of critical evidence) that there is no inherently necessary physiological connection between hornlessness and cryptorchidism, but rather that the hornless strains are recent creations and that in the necessary concentration of blood to fix the hornlessness, the cryptorchidism has also become stabilized at a rather high level of frequency, and that it can be gradually eliminated, now that the numbers of animals in the hornless strains have become large enough to permit rigorous culling by the breeders.

Heritability of Cryptorchidism

That this defect is heritable has been the general opinion of stockmen and veterinarians, although there are some who hold that it is not transmissible and who will use a ridgling for a sire if he is unusually good in other respects and can be purchased at a low price. The opinion that it is heritable is based upon a very large amount of fragmentary evidence which seems to deserve much credence, although little if any of it is carefully controlled. It is evidence of about the following sort: A ridgling stallion is rather extensively used in a certain community and many of his sons are ridglings or perhaps his sons are normal, but his daughters for years afterward produce an unusually large proportion of ridgling colts. Or the original stallion himself may not have been a ridgling, but nevertheless among his sons or among his grandsons there appears a larger proportion of ridglings than among the sons or grandsons of other stallions used in the same or adjoining communities. The opinion that it is not heritable is likewise usually based upon a limited amount of evidence of the same sort. For example, a ridgling sire has been used for a year or two in a certain flock and no unusual proportion of ridglings appeared among his sons or grandsons. The general opinion as to its heritability is shown by the fact that all or nearly all states which license stallions standing for public use list cryptorchidism as an hereditary unsoundness.

Even less is known as to the manner of the inheritance of this defect. Some of the case histories seem to indicate that it is dominant, as, for example, when a ridgling sire used in a flock which has not hitherto produced ridglings immediately produces a high proportion of ridglings among his sons. Other case histories indicate that it is recessive, as, for

the Sterility of the Offspring (Translated Title), *Mitteilungen der Deutschen Landwirtschaftsgesellschaft*, Stück 7.

*Zawadowsky, M. M. 1926. Materials for the Study of Morphogenesis. I. Cryptorchid Rams. *Transactions of the Laboratory of Experimental Biology of the Zoopark of Moscow*, 1:76-80.

example, the occasional appearance of it in the progeny of males or females from flocks which have never before produced ridglings. In some flocks the scanty data give the impression that it is a sex-linked recessive because only a small proportion of ridglings are produced and they are scattered almost at random among the progeny of different sires, and yet when a ridgling sire is used there appears no immediate increase in the proportion of ridglings among his progeny.

The high prevalence of ridglings among Angora goats may perhaps be explained by the extensive use of ridglings which were among the few sires introduced in the early importations. That this actually occurred is rumored often enough to demand attention, although naturally positive evidence on a point which might reflect unfavorably upon strains living today is difficult to secure.

The American Angora Goat Breeders Association was first incorporated in 1900. The first flocks were then admitted to registry upon inspection. An importation was made in 1904 from South Africa, but none were imported between that date and 1925. The formal history of the breed is thus very brief as compared to other breeds of farm animals, and if ridgling sires ever were used very extensively in the breed, even before it was organized, it is not surprising that the frequency of ridglings should still be rather high. If cryptorchidism really is hereditary and if all breeders of registered Angoras avoid the use of ridgling sires, it is to be expected that the frequency of ridglings among the kids will tend to decline at least until it reaches the level found in other farm animals.

Such progress might be very much hastened if we knew the exact manner of the inheritance of this defect, because it might then be possible to know how much could be gained by discriminating against the parents and brothers and sisters of ridglings in addition to avoiding the use of ridglings themselves. With this object in mind, the Texas Station undertook to find out exactly how cryptorchidism is inherited in the Angora goat. That task is not yet completed, but the heritability of the characteristic has been established beyond doubt, and a report of what has been learned so far seems advisable.

EXPERIMENTAL WORK

Preliminary Work

A flock of high-grade Angora goats had been purchased when Substation No. 14 was first stocked in 1917, and was gradually replaced by registered Angoras as the numbers of the latter increased. In 1920 a portion of these grades were set aside for use in the project on the inheritance of cryptorchidism. The first plan was to mate half of this group to a ridgling buck born in the grade flock, but sired by a registered buck. The other half were to be mated to a normal registered buck. In succeeding years the bucks would alternate from one group to the other, so that each doe would have equal opportunity to produce kids to both bucks. The ridgling buck (No. 509) produced the following progeny:

Kidding Season	Normal Sons	Ridgling Sons
1921	12	1
1922	6	0
1923	22	1
Total.....	40	2

During the same three seasons the grade does being mated to normal registered bucks produced:

Kidding Season	Normal Sons	Ridgling Sons
1921	87	5
1922	82	5
1923	13	3
Total.....	182	13

Here there was not only a lack of evidence as to how the defect was inherited, but not even evidence that it was inherited at all. It was thought best to test out other ridglings as sires. This was started with the kidding season of 1923. Three other ridglings, two from the grade flock, but sired by normal registered bucks, and one from the registered flock, were used with the following results:

Sire No.	Normal Sons	Ridgling Sons
1052	12	0
1061	4	2
No Number	2	0

This looked encouraging for No. 1061, and consequently he was used again that fall. Two other ridglings which had been born in the registered flock were also tried out. The results for the kidding of 1924 were:

Sire No.	Normal Sons	Ridgling Sons
1061	24	4
250n	6	0
262n	1	0

Line-Breeding to Ridglings

There had been no evidence so far of the inheritance of the defect at all, with the possible exception of the proportion of ridglings in the progeny of No. 1061, which differs from the proportion of ridglings in the grade flock upon which ridglings were never used by almost three times the "probable error"*. It was realized that this defect, if inherited at all, must be inherited in a more complicated manner than had been anticipated at first. Consequently the plan of the experiment was changed to provide for the testing of a large number of ridgling sires

*"Probable error" is a technical term used to measure whether a given result was genuinely caused by the conditions of the experiment or was an accidental variation. A difference which is much more than three times as large as its "probable error" is generally considered to be larger than would be caused by chance alone and is therefore called "significant" in the statistical sense.

and the continued use of ridgling sires on the entire grade flock, with the object of building up a strain of goats which would produce 100 per cent ridglings among their male progeny if possible. If such a purified strain could be produced, it would then be crossed both ways on an ordinary flock of grade Angoras and it was hoped that the results of such crosses would show how the defect was inherited. By this time the registered flock had become so large that the other studies of Angora goats could be carried out on it and the entire grade flock could be spared for the ridgling project.

Four ridglings were bred to separate groups of does in the fall of 1924 and a group of five other ridglings were turned out in one pasture with a group of does. These five included No. 1061 and a son, another grade sired by a normal registered buck, and two pure-bred ridglings. The results from these matings were:

Sire No.	Normal Sons	Ridgling Sons
250n	24	2
277n	1	0
348n	16	10
1280	13	5
Group	26	8
	—	—
Total.....	80	25

Here for the first time was indisputable evidence that something was being accomplished toward fixing the defect. The difference between the proportion of ridglings here and in the grade flock where ridgling sires were never used is five times as large as its "probable error." The progeny of No. 250n did not contribute to this increase and No. 277n was inadequately tested. No. 1280 was a son of the first ridgling used, but his dam had not produced any other ridglings. No. 348n was from the registered flock and had no ridgling sires in his pedigree, but his dam had previously produced another ridgling to the service of a different buck and one normal son to the service of a third buck.

Since No. 1280 and No. 348n were siring the highest percentage of ridgling sons yet observed, they were used on all available grade does in the fall of 1926. The kidding results the following spring were:

Sire No.	Normal Sons	Ridgling Sons
348n	17	10
1280	10	8
	—	—
Total.....	27	18

This was the highest proportion of ridglings yet produced in any season. The proportion sired by No. 348n was slightly lower than that sired by No. 1280, although the difference is very small and of doubtful significance. Both were used again that fall and in addition two sons of No. 348n were tried out on a very small number of does each. The kidding results for the spring of 1927 were:

Sire No.	Normal Sons	Ridgling Sons
348n	17	8
1280	23	6
1449	1	2
1518	4	5
Total.....	45	21

The proportion of ridglings was not as high as in the preceding year, but except for that was the highest yet observed. Both young bucks sired a high proportion, but of course the numbers were too small to be of much significance.

The difference between the progeny of No. 348n and that of No. 1280 seemed to be more distinct than before, but it was thought advisable to try out two sons of each before concentrating entirely on No. 348n and his sons for further breeding. This was done in the fall of 1927. A normal registered buck got into the pasture with one of the sons of No. 1280 and consequently the paternity of the kids born from does in that pasture is in doubt. The kidding results the following spring were as follows:

Sire No.	Normal Sons	Ridgling Sons
1280's Sons:		
1539	11	1
1647	14	4
348'n Sons:		
1518	9	8
1662	11	6
Total.....	45	19

The kids of doubtful paternity are those listed for No. 1539. If they are omitted, the totals become 34 and 18, which is almost the same proportion as was obtained the previous year. Since the son of No. 1280 had the smallest proportion of ridgling sons, it was decided to leave No. 1280 and his sons out of the future breeding program entirely and to try to find among the sons and grandsons of No. 348n some which would sire even larger percentages of ridglings than he did. Accordingly, in the fall of 1928 one son and two double grandsons of No. 348n were tested. The results were as follows:

Sire No.	Normal Sons	Ridgling Sons
1449	8	7
1782	9	9
1791	10	5
Total.....	27	21

This was the largest proportion of ridglings yet produced in one year. To date three bucks have each sired a proportion of 50 per cent ridglings among their sons. Those three (Nos. 1449, 1518, and 1782) are being used for sires in the fall of 1929.

These results by years give a picture of progress in selecting for this

character, but the progress was not steady. No apparent progress at all was made with the first sire nor with any of the sires used in 1923 and 1924 except perhaps with No. 1061. Two sires tried for the first time in 1925 and slightly if at all related to each other produced nearly one-third ridglings among their sons. These two practically maintain the same proportion for the next two years. Beginning with the sons of No. 348n, ridglings are found 50 per cent of whose sons are ridglings. Clearly progress is being made and the somewhat irregular way in which the percentage increases by sudden jumps, then remaining somewhat constant for a year or two before making another increase seems to indicate that the number of Mendelian factor pairs involved is rather small and that some bucks contribute much more to this increase than others do.

But the bucks were not the only changing thing in the situation. The doe flock was changed by culling and by replacements with young grade does sired by the ridglings of the preceding generation. An unusual amount of such culling took place because the numbers of the grade flock were being steadily reduced to make room for the expanding registered flock. Very drastic culling also took place in the fall of 1928, when the grade flock and the ridgling project were moved to Substation No. 10, as it was thought wise to move only those which would be used for breeding purposes for several years. When the project was first begun in the fall of 1920, all does which had previously produced ridgling kids were selected from the grade flock for mating to the first ridgling buck used. There were fifteen of these. The rest of the does selected for the ridgling flock at the start were representative of the grade flock. Those added later were from among the younger does, as it was desired to get as many kids as possible from each doe in order to get a more accurate knowledge of how she would breed in this respect. When the daughters of ridglings reached breeding age they were added to the ridgling flock. In the first few years extreme inbreeding was avoided, but as it became increasingly likely that the genetic situation was quite complicated, the closest possible inbreeding was practiced in order to hasten the fixation of the ridgling characteristic. It is now regretted that more extreme inbreeding was not practiced earlier. If, for instance, No. 509 had been bred to his own daughters in fairly large numbers there would probably now be no doubt as to whether his type of cryptorchidism really was hereditary.

Probable Manner of Inheritance of Cryptorchidism

The daughters of No. 509 when bred to ridgling No. 1280 (a son of 509) produced 16 ridglings and 35 normal males, but when bred to other ridglings the daughters of No. 509 produced 3 ridglings and 29 normal males. The difference in these two proportions of ridglings is nearly four times its "probable error." When bred to other does, No. 1280 sired 3 ridglings and 11 normal sons, a proportion which is only slightly smaller than that he sired out of his half sisters. If any of the factors involved were sex-linked, the daughters of No. 509 should have produced

a larger proportion of ridglings than No. 1280, the son of No. 509, did, whereas the reverse was true. Except when mated to No. 1280, the daughters of No. 509 did not produce a higher proportion of ridglings than was produced by does which were not daughters of any ridgling. Also No. 1280 sired almost as high a proportion of ridglings from does which were not the daughters of ridglings as he did from does sired by No. 509. It looks as if cryptorchidism were not hereditary in the case of No. 509, but it certainly was hereditary in the case of No. 1280. If No. 509's cryptorchidism actually was hereditary, it seems impossible that there can be less than three pairs of Mendelian factors involved.

Proceeding in the same way, we find the evidence indicating that cryptorchidism was not heritable in the cases of Nos. 250n, 1052, and "No Number." The daughters of "No Number" when mated to ridglings produced 2 ridglings and 9 normal sons, even though most of these matings were to ridglings which sired a high percentage of ridgling sons out of other does. The daughters of No. 250n produced 5 ridglings and 15 normal sons to the service of ridgling bucks, most of which sired rather high percentages of ridglings from other does also. The daughters of No. 1052 produced 10 ridglings and 24 normal sons to the service of ridglings, most of which sired high percentages of ridglings out of other does also.

On the other hand, the evidence shows rather clearly that the cryptorchidism of Nos. 348n, 1061, and 1280 was inherited. It also seems fairly certain, although the evidence is less complete, that the cryptorchidism of Nos. 1449, 1518, and 1782 was inherited. The first indication of a large proportion of ridglings in the progeny of a ridgling sire came with the use of No. 1061. The daughters of No. 1061 when mated to other ridglings produced 16 ridglings and 21 normal sons, a higher proportion of ridglings than most of those sires were getting from other does. Both No. 1280 and No. 348n gave very distinct increases in the proportion of ridglings among their sons. The daughters of No. 1280 were not very extensively used, but produced 2 ridglings and 1 normal male to the service of ridgling bucks and 9 normal sons to the service of a normal buck. The daughters of No. 348n were mated mostly to ridgling double grandsons of No. 348n and produced to them 16 ridglings and 21 normal males. The daughters of No. 1449 are just beginning to be of breeding age. Seven of them mated back to No. 1449 produced in the spring of 1929 a total of six daughters and two ridglings with no normal sons. Only seven of the daughters of No. 1518 have yet produced offspring, and they, mated to ridglings which were very closely related, produced in the spring of 1929 five daughters and two ridglings. None of No. 1782's daughters have yet reached maturity, but he himself sired 9 ridglings and 9 normal males the first year he was tried.

Data as to the heritability of cryptorchidism in bucks Nos. 262n, 277n, 1647, 1662, and 1791 are too few to permit an estimate in those cases.

Summing up the present condition of our knowledge of how cryptorchidism is inherited, we can see that there must be at least two different

pairs of Mendelian factors involved even if it is granted that some cases of cryptorchidism do not have a definite hereditary basis. The data indicate that some cases of cryptorchidism do not have a definite hereditary basis, but that is not established beyond all doubt. However, if such cases do not exist, three or more different pairs of Mendelian factors will be required to explain the observed facts. No indication of sex-linked inheritance has been observed unless the progeny performance of the daughters of No. 1061 may possibly be regarded in that light.

Studies of Anatomy

In our experience it is always the right testicle which fails to descend in ridgling Angora goats. We have examined some forty cases in detail for this and have not found an exception. We have questioned ranchmen and shepherds on this point also without learning of an exception. Many of them had already noted this fact from extensive observation. In a small proportion of cases both testicles fail to descend. Seven such cases were noted in the experimental flock. Left cryptorchidism and right cryptorchidism seem to occur with nearly equal frequency in horses. Hobday* reports 77 cases of cryptorchidism in the horse of which 11 were double cryptorchids, 36 had the right testicle retained in the body, and 30 had the left testicle retained.

Warwick† reports 36 cases of cryptorchidism in swine. Three of these were double ridglings; the undescended testicle was the right one in 8 cases and the left one in 25 cases.

In the cases summarized by Bayer (already noted), left cryptorchidism and right cryptorchidism occurred with almost equal frequency in horses and also in swine.

According to information given us by stockmen the proportion of double cryptorchids to single cryptorchids is much higher in those strains of sheep in which ridglings are frequent than it is in Angora goats. We have not been able to learn anything about the relative frequency of right cryptorchidism and left cryptorchidism in cattle and sheep.

We have killed more than twenty ridgling goats and examined their internal anatomy. In every case the undescended testicle was high in the abdomen slightly posterior and ventral to the kidneys. Nothing was found corresponding to the inguinal cryptorchidism so common in the horse. In every case the undescended testicle was much smaller than the normal descended one. Figure 1 shows the normal and the cryptorchid testes of a sixteen-months-old goat. The difference in size is clearly visible against the background, which is the leather case of a

*Hobday, F. T. G. 1903. *The Castration of Cryptorchid Horses and the Ovariectomy of Troublesome Mares*. Published by William R. Jenkins, New York City.

†Warwick, B. L. 1926. *A Study of Hernia in Swine*. Wisconsin Agricultural Experiment Station Research Bulletin No. 69.

hunting knife. In general the cryptorchid testis was from one-fourth to one-tenth the size of the normal one. This difference was relatively greater in the mature goats than it was in the kids and yearlings examined.

The cryptorchid testis does not swing entirely free in the abdomen, but is held from several sides by membranes which attach it to various parts of the inner wall of the abdominal cavity. These are in addition

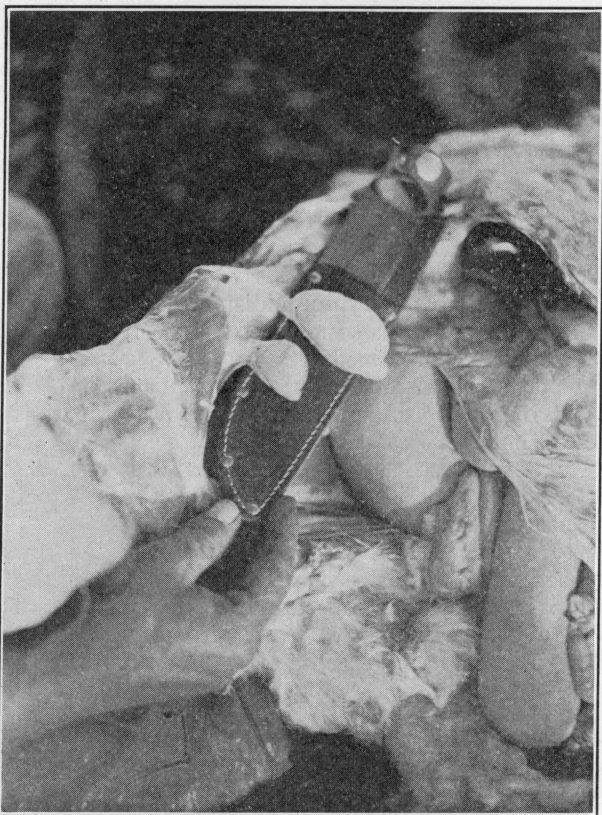


Figure 1. Normal testis and cryptorchid testis from a sixteen-month-old ridgling goat. The cryptorchid testis is still attached.

to the normal attachments to the gubernaculum testis and to blood vessels and nerves. These attachments or adhesions vary in position in different cases. Often they connect the testis to loops of the intestines. Usually also they connect it to the wall of the abdominal cavity at a region just internal to the point of the ilium (hook bones). There are usually one or two other attachments. These attachments consist of very thin membranes and vary in length from about two to about five inches.

They permit considerable movement of the testis within the abdominal cavity, but are usually stronger than the gubernaculum. Figures 2 and 3 show cryptorchid testes still attached to goats just killed for examination. The extent and nature of these attachments may be seen easily.

As soon as the existence of these adhesions was noted the question arose as to whether they might not be the primary cause of cryptorchidism in these goats. No way of testing this hypothesis has yet been devised. However, the hypothesis might explain the apparently irregular inheritance of cryptorchidism. That is, if the thing which is inherited is not cryptorchidism itself, but a certain anatomical structure which makes it very easy for these attachments to develop, then it would be easily possible that in some cases the attachments would be weaker than the gubernaculum in embryonic development and the testis would descend to its normal position and the male would appear normal in spite of having

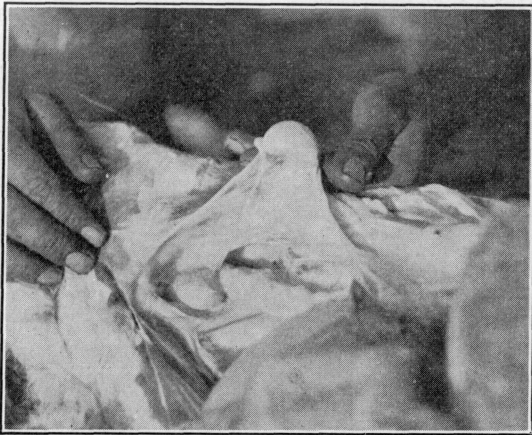


Figure 2. Cryptorchid testis showing membranous attachments. Sixteen-months-old goat.

been equipped by heredity with an anatomical structure which under slightly different conditions of embryonic development would have caused it to develop into an unmistakable ridgling. On the other hand, there may be anatomical causes or accidents of development which are totally different in kind from these, but which may produce the same end result, that is, failure of the testis to descend into its normal position. Something of this kind may have been the explanation for No. 509's cryptorchidism, which seemed not to be heritable and certainly was different in that respect from the cryptorchidism of No. 1280 or of No. 348n. It is interesting to note that an explanation similar to this in principle has been found in the domestic fowl* where there are both

*Landauer, Walter and Dunn, L. C. 1925. Two Types of Rumplessness in Domestic Fowls. *Journal of Heredity*, 16:153-160.

hereditary and non-hereditary types of rumplessness, very similar in general appearance.

Seven Angora goats which were double cryptorchids were examined externally, but only one of these was killed and dissected. In that one it was noted that the adhesions were distinctly more numerous and stronger for the right testicle than for the left, the latter swinging almost free except for its blood vessels, nerves, and the gubernaculum. This agrees well with the idea that the attachments are the primary cause of cryptorchidism. The frequency and strength of the attachment to a loop of the intestines seems also to be significant in view of the fact that all observed single ridglings in goats had the right testicle retained and that in goats, as in other ruminants, the intestines are rather crowded over to the right side of the abdominal cavity to make room for the paunch.

Histology of Cryptorchid Testes

The undescended testicle was examined microscopically in twenty cases to see whether it contained spermatozoa.* In fourteen cases no spermatozoa whatever were seen. In three cases a very few motionless spermatozoa were seen. In one case a few motionless spermatozoa and one weakly motile spermatozoon were seen. In two cases several distinctly motile spermatozoa were seen, although in each case these were an exceedingly small per cent of the number which would have been seen with the same technique applied to a normal testicle. Some of these examinations were made under unfavorable conditions at butchering pens, where considerable haste was necessary and where the supply of water for washing and rinsing the slides was limited. It is barely possible that some of the observed spermatozoa came from water used to rinse the slides and already contaminated from washing slides on which normal testicles had been examined. This possibility is entirely ruled out in at least one case where the spermatozoa were seen in the very first slide examined that day. Hobday says in connection with this point in ridgling horses: "When examined microscopically after removal it is not rare to find spermatozoa in testicles which have remained in the lower part of the inguinal canal, but in those found in the upper part and in those taken from the abdomen itself, this is exceptional. In eleven testes taken from the inguinal canal five contained spermatozoa. Three of these were at the extreme upper portion of the canal, and all five were beyond dispute in such a position that they could be termed 'inguinal' testicles. They were quite out of sight even when the patient was cast and secured on its back." Nielsen† reports examining the

*The epididymis was cut open and contents squeezed onto a clean microscopic slide, then covered with a drop of normal saline or Ringers solution, then a cover glass was placed on top and then the slide was examined under the microscope. In some cases cuts were made into the very center of the testicle and these cut surfaces were touched to the slides.

†Nielsen, Folmer. (About) 1905. *Histological Investigations of Retained Testes in Stallions* (translated title). *Monatshefte für praktische Tierheilkunde*, Vol. 17.

cryptorchid testes from 90 stallions and not finding even one with motile spermatozoa.

Material from the cryptorchid testes of seven ridgling Angora goats (none of which had been used for breeding) was sent to Dr. C. R. Moore, of the University of Chicago, for sectioning and cytological studies. Dr. Moore reports that all seven showed the degeneration typical of cryptorchid testes, whether natural or artificially produced, which he has examined from many other species of mammals. One testis showed signs of germinal activity, but this was far short of reaching a functional stage. He believes it quite out of the question for any one of the seven to have produced functional spermatozoa in the condition in which they were when removed. In the microscopic examinations made at the

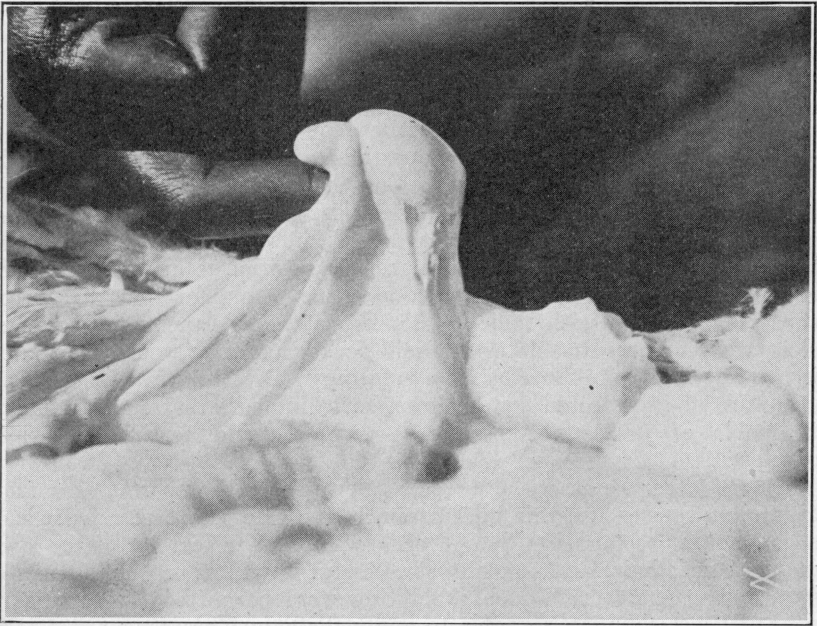


Figure 3. Cryptorchid testis showing membranous and cord-like attachments. From ridgling goat nineteen months old.

slaughter pens immediately after these seven animals were killed, a very few non-motile spermatozoa were seen on the slides prepared from smears from the cryptorchid testes in four cases. In one of those four cases a single feebly motile spermatozoon was seen. In two of the four cases slides prepared from smears from a second cut through the very center of the testicle also showed motionless spermatozoa. Yet the sections prepared under Dr. Moore's direction from three different levels of these testes showed no indication that the spermatozoa could have been formed there. We are unable to account for the discrepancy.

Dr. Moore's extensive studies* on natural and artificial cryptorchidism have led him to the conclusion that the smallness and degeneration so universally characteristic of cryptorchid testes are purely the result of the higher temperature to which they are subjected on account of their position in the abdominal cavity. A ridgling does not become such because he has a defective or degenerate testis to begin with, but rather his testis remains small and infantile because of its position. The immediate cause of ridglings is therefore to be sought in whatever it is which in the first place prevents the testis from descending into its normal position where it could develop properly. Nothing in our experiments or observations conflicts with this idea, although in view of Dr. Moore's findings in regard to the histology of the seven testes which he examined from our flock and the histology of all other cryptorchid testes which he has examined, we are at a loss to explain the spermatozoa which we observed in six of the twenty cases examined.

Fertility of Cryptorchid Testes

Can a ridgling goat ever be fertile after his one normal descended testicle has been removed? This question came to the front early in the investigation. Ranchmen questioned on this point are practically unanimous in believing that such a ridgling is never fertile in the case of goats, although some averred that they had known such castrated ridgling horses to be fertile. Many of them are in a position to know in a general way about the fertility of castrated ridgling goats, for they often turn such ridglings out with their doe flocks and many ranchmen keep such close track of breeding dates in their flocks that they would soon know it if many kids were sired by such ridglings. Dr. Moore's studies of the structure of cryptorchid testes also seem to indicate that such testes are incapable of producing spermatozoa which could fertilize ova and develop.

On the other hand, we observed a very few motile spermatozoa from cryptorchid testes and this would seem to indicate that occasionally such a goat might be fertile, although on account of the scarcity of the spermatozoa and their feeble motility, successful fertilization would probably be a rare event even if such a ridgling were permitted to serve many does. It was thought desirable to apply the actual breeding test to this and in two seasons opportunity was found to breed small groups of does to double ridglings or to ridglings which had had the descended testicle removed. The results were as follows:

Buck No.	Number of does bred	Number of kids dropped
262n (double)	7	none
265n (castrated)	5	none
277n (castrated)	6	two
1175 (double)	7	none
1685 (castrated)	7	none
1539 (double)	20	none
Unnumbered (castrated)	8	none

*Moore, C. R. 1926. The Biology of the Mammalian Testis and Scrotum. Quarterly Review of Biology, Vol. 1, pages 4-50.

The results are uniformly as expected except for buck No. 277n. This goat had been castrated of his normal descended testicle September 8, 1924, and was not put with his six does until two months later. The birth dates of the two kids (April 9 and May 10) correspond to breeding dates of two months and three months after this castration. No. 277n was not hand-bred, but he and his does were in a small pasture surrounded by very good fence on the side adjoining a neighboring ranch and with no gate in that fence. The Station pasture adjacent to this small one was empty of goats during this breeding season. The two kids were born 31 days apart and only two of the six does kidded at all. These facts together almost entirely rule out the possibility of any other buck's having been in the pasture. Mistakes in reading the does' numbers at kidding time cannot be entirely eliminated, but great care was always used in this and it is exceedingly unlikely that two such mistakes would occur among the does mated to one buck and no mistakes of this kind among all the does mated to six other bucks. There seems no reason for rejecting this evidence except that it does not fit in with our other experience nor with what we had expected on the basis of the microscopic studies. No autopsy was made of No. 277n after his death. We feel that further evidence is needed to substantiate the case of 277n, and, meanwhile, can only conclude that ridglings deprived of their descended testicle will be able to get kids very rarely, if at all.

Experience of Ranchmen

We have talked with a number of ranchmen and have heard of experiences which show clearly that as a general policy it is not safe to use ridgling sires. Most ranchmen do not have careful counts of the numbers of kids born, numbers of ridglings, etc. They know that after using certain sires they had an unusual proportion of ridgling kids, and that is enough to convince them of its hereditary nature. We give herewith accounts of two cases where the figures were kept in somewhat more detail. One ranchman in Kimble County selected 200 choice grade Angora does to breed to four bucks which he had just bought at a rather high price from one breeder. Four bucks were delivered to him, but one was found to be a ridgling. He intended to castrate this one, but before he got around to that his helper had turned all four bucks out with the does and they remained there all through the season. Next spring these 200 does dropped about 190 kids, of which 125 or 126 were males. Of these males 45 were ridglings. The same season in his flock of unselected grades he obtained only the usual proportion of about one ridgling among every 35 or 50 kids. Another ranchman in the same county used a ridgling buck unusually desirable in other respects on registered does of his own breeding and in two years got only one ridgling among 24 male kids. The third year he bred 12 of the daughters of this ridgling back to their sire and obtained two ridglings, one of them double, out of the 7 males born. The fourth year he bred 21 of the

daughters of the ridgling to a normal buck not related to them and they produced 3 ridglings among 9 male kids.

Sex Ratio in Goats

In the flock in which ridgling sires were never used the total number of goats born from 1917 to 1929, inclusive, was divided as follows:

Does	Normal Bucks	Ridglings
1184	1111	63

The males constitute 49.8 per cent of all births or almost exactly one-half.

In the flock in which ridgling sires were used the total number of kids born from 1921 to 1929, inclusive, was divided as follows:

Does	Normal Bucks	Ridglings
394	302	111

The males constitute 51.2 per cent of all births, which is slightly but insignificantly more than half of all births. These last figures have an added interest from the fact that the ridgling sires used all had the right testicle retained in their bodies. Presumably all or very nearly all of these 807 kids were produced from spermatozoa which came from the left testicle and yet the sex ratio was very near equality. The notion that spermatozoa from one testicle produce males, while those from the other testicle produce females has long since disappeared from scientific writings, but those who still hold it may find something of interest in the figures just given.

SUMMARY AND PRACTICAL RECOMMENDATIONS

Cryptorchidism occurs at times in all farm animals and is especially frequent in Angora goats.

Breeding experiments have shown that cryptorchidism is inherited or at least that many cases of it are, but the exact manner of its inheritance has not yet been discovered in detail. At least two Mendelian factor pairs must be involved and it is quite possible that there may be more. No very certain indication of sex-linked inheritance was found. There are indications that some cases may not have a definitely hereditary basis after all.

The small size and degenerated structure of the cryptorchid testis is a consequence of its failure to descend to its normal position.

The cryptorchid testis in Angora goats is usually attached to various parts of the wall of the abdominal cavity or to other organs, such as the intestines, by thin folds or cords of membranous connective tissue which are often several inches in length. It seems likely that these attachments are the primary cause of cryptorchidism by preventing the descent of the testis during embryonic life to its normal position in the scrotum.

Ridglings from which the normal descended testicle has been removed are rarely if ever fertile, but they usually develop the normal male instincts and characteristics.

Practical recommendations arising from these findings are as follows:

1. Never use a ridgling for a sire. Even though it may be true that this characteristic is not always hereditary, yet it has so often been found hereditary that the breeder cannot often if ever afford to take the chance of using a ridgling sire.
2. Be extremely reluctant to use a sire which has any ridgling brothers or half-brothers.
3. Cull from the flock all does which produce as many as two ridglings. This may not go far toward solving the problem, but it is a step in the right direction. Does which have produced only one ridgling may perhaps be retained in the flock if they are especially desirable in other respects, but it does not seem wise to retain any of their sons for use in registered flocks.
4. Bucks which sire more than the normal percentage of ridgling sons should be discarded. Whether it would be practical to discard all bucks which sire even one ridgling son is not yet certain.