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A STUDY OF SOME ASPECTS OF REPRODUCTION IN

ROMNEY AND ROMNEY-CHEVIOT HALFBRED

TWO-TOOTH EWES

by

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of the requirements for the
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TABLE OF CONTENTS.

	<u>Page</u>
 <u>CHAPTER I</u> - INTRODUCTION.	
I	DEFINITION OF THE SUBJECT 1
II	AGRICULTURAL SIGNIFICANCE OF THE PROBLEM 2
III	EARLIER INVESTIGATIONS OF FERTILITY DIFFERENCES IN SHEEP 3
IV	OTHER RELEVANT INVESTIGATIONS INTO LEVEL OF FERTILITY 6
V	POSSIBLE AGRICULTURAL SIGNIFICANCE OF THE PRESENT INVESTIGATION 7
 <u>CHAPTER II</u> - NATURE AND SCOPE OF STUDY. 9	
I	THE BEHAVIOUR OF EWES IN THE PRESENCE OF A RAM 12
II	THE STUDY OF FERTILITY 12
 <u>CHAPTER III</u> - EXPERIMENTAL MATERIALS AND MANAGEMENT 14	
I	THE EXPERIMENTAL AREA 14
II	THE EXPERIMENTAL ANIMALS 14
	(a) The ewes.
	(b) The rams.
	(c) The teasers.
III	MANAGEMENT OF EXPERIMENTAL ANIMALS 16

<u>CHAPTER IV</u> - THE BREEDING BEHAVIOUR OF		
	ROMNEY AND HALFBRED TWO-TOOTH	
	EWES BETWEEN MID-FEBRUARY AND	
	THE END OF MAY.	18
I	GENERAL INTRODUCTION	18
II	METHOD OF STUDY	18
A.	ONSET OF THE BREEDING SEASON	20
	Introduction	
	Method of Study	
	Results and Discussion	
	(i) Detection by vaginal smear	
	technique.	
	(ii) Detection by the use of	
	vasectomized rams.	
B.	THE SIGNS AND INTENSITY OF OESTRUS	32
	Introduction	
	Method of Study	
	Results and Discussion	
C.	DURATION OF OESTRUS	43
	Introduction	
	Method of Study	
	Results and Discussion	
D.	THE LENGTH OF THE OESTRUAL CYCLE	51
	Introduction	
	Method of Study	
	Results and Discussion.	
III	GENERAL DISCUSSION	59
IV	SUMMARY	61
<u>CHAPTER V</u> - A STUDY OF THE FERTILITY OF ROMNEY		
	AND HALFBRED EWES	63
I	INTRODUCTION	63
II	THE EXPERIMENTAL ANIMALS - THEIR	
	MATING AND SLAUGHTER	6

CHAPTER V (CONTD.)

A.	THE NUMBER OF OVA SHED	67
	Introduction	
	Method of Study	
	Results and Discussion	
	(i) The weight of the ovaries.	
	(ii) The ovulation rate.	
	(iii) The development of Graafian follicles.	
	(iv) The weights of the pituitary gland.	
B.	THE CONCEPTION RATE	74
	Introduction	
	Results and Discussion	
C.	THE MAXIMUM POTENTIAL LAMBING PERCENTAGE	83
	Introduction	
	Results and Discussion	
III	GENERAL DISCUSSION	86
IV	SUMMARY	91

<u>CHAPTER VI</u> -	STUDIES ON THE GENITAL TRACTS OF SLAUGHTERED EWES	93
I	INTRODUCTION	93
II	METHOD	93
III	RESULTS AND DISCUSSION	96
	Measurement of the genital tracts of pregnant ewes.	
	The genital tracts of non-pregnant ewes.	
	The crown-rump measurements of the foetus.	
IV	GENERAL DISCUSSION	107
V	SUMMARY	108

<u>CHAPTER VII</u> -	SUMMARY AND CONCLUSIONS	110
----------------------	-----------------------------------	-----

<u>REFERENCES</u>	114
-------------------	-----------	-----

<u>APPENDIX</u>	118
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LIST OF TABLES

<u>TABLE</u>	<u>Page</u>
I. Mean Live-weights of Romney and Halfbred Ewes During the Experimental Period	16
II. Analysis of Variance for Changes in Live-weight of Romney and Halfbred Ewes During the Experimental Period	17
III. Number of Oestral Periods Experienced By the Ewes of Group C	26
IV. Distribution of Times of Appearance of Mucus Relative to the Onset of Oestrus in 22 Oestral Periods.	27
V. Time of Appearance of the Metoestral Smear Relative to the Time of Onset of Oestrus .	28
VI. Distribution of Dates of Onset of the Breeding Season	31
VII. Mean Dates of Onset of the Breeding Season of 60 Halfbred Ewes and 54 Romney ewes . .	31
VIII. Distribution of Patterns of Heat Intensity in 123 Romney and 166 Halfbred Oestral Cycles	37
IX. Analysis of Intensity of Oestrus of Ewes at First Observation of Oestrus	38
X. Analysis of Intensity of Oestrus of Ewes at Last Observation of Oestrus	38
XI. Numbers of Oestral Periods which Contain at least One "High Intensity" Rating	39
XII. Relation of Time of Day to the Onset of Oestrus	41
XIII. Duration of Oestrus - Frequencies within Breeds	48
XIV. Mean Durations in Hours of 321 Oestral Periods	50
XV. Duration of Oestral Cycle - Frequencies Within Breeds	54
XVI. Mean Length of Oestral Cycle	55
XVII. Correlation Between Duration of Oestrus and the Length of the Oestral Cycle	57

<u>TABLE</u>	<u>Page</u>
XVIII.	Correlation Between the Duration of Oestrus and the Interval Before a Following Oestral Period 58
XIX.	Mean Weights of 108 Ovaries from Romney and Halfbred Pregnant Ewes 70
XX.	Mean Ovulation Rate in 25 Romney and 29 Halfbred Pregnant Ewes 71
XXI.	Total Number of Graafian Follicles larger than 4 mm. diameter in Ovaries of Pregnant Romney and Halfbred Ewes . 72
XXII.	Mean Weights of the Vacuum Dessicated Pituitaries of 23 Romney and 26 Halfbred Ewes 74
XXIII.	Conception Rates at the First and Second Services of Romney and Halfbred Ewes . . 75
XXIV.	Breeding Histories of 12 Barren Romney Ewes of Group A 76
XXV.	The Maximum Potential Lambing Percentage of the Romney and Halfbred Ewes of Group A 84
XXVI.	Summary of Indices of Fertility 86
XXVII.	Measurements of the Genital Tracts of 22 Halfbred and 25 Romney Pregnant Ewes 98
XXVIII.	Mean Measurements of the Genital Tracts of 12 non-pregnant Romney Ewes101
XXIX.	Test of Significance of Deviations from Error Linear Regression104
XXX.	Tests of Significance of Differences Between Breed Means in Crown-rump Measurements Adjusted for Curvilinear Regression105

LIST OF ILLUSTRATIONS.

<u>Figure</u>		<u>Page</u>
1	Diagrammatic Representation of Experimental Plan	11
2	The Onset of the Breeding Season	30
3	The Duration of Oestrus	49
4	The Length of the Oestrual Cycle	53
5	Growth of Curved Crown-rump Measurement . .	102
6	Growth of Straight Crown-rump Measurement .	103

C H A P T E R I

I N T R O D U C T I O N .

I. DEFINITION OF THE SUBJECT.

"The production of viable young by a mammal is the end result of a complicated chain of events, which begins with the formation of eggs and sperm by the parental gonads, and finishes when lactation has proceeded far enough to permit independent existence on the part of the young. Effective functioning of each link of the chain is necessary for full fertility; breakdown leads to sterility, temporary or permanent."

A.S. Parkes.

In the first sentence of the above quotation, reproduction is defined by its effect, and the general character and extent of the reproductive process is described. The present study is concerned with that main part of the reproductive process which extends from the development of the ovary prior to the maturation of follicles to the early stages of pregnancy, and is limited to the female aspects of fertility.

It is concerned therefore, with three main phases: Ovulation, Fertilization and Implantation, and Development of the Embryo in Early Pregnancy. Imperfections in any one of these three phases may lead to a complete breakdown in the chain of events which leads to full fertility.

"Fertility" as used in the animal husbandry sense, denotes both qualitative and quantitative ability to produce young, and is measured by some form of lambing percentage. It is the end-product - the number of lambs

produced - which is the criterion by which the fertility of a flock of sheep is judged. This study, however, is concerned not with the end-product of the chain per se, but rather with an examination of the functional nature of each one of the links in the chain, and of the manner in which the efficiency of these links may be impaired. In the light of the results of this investigation we may be able more wisely to interpret the end-product differences which have been observed between the two breeds of sheep studied.

II. AGRICULTURAL SIGNIFICANCE OF THE PROBLEM.

Fertility is an important character in ewes whether in flocks kept chiefly for wool production, or in flocks used for the production of fat lambs. When the ewe lambs are retained for breeding, the level of fertility determines firstly, the margin of selection available for the phenotypic and genotypic improvement of the flock by culling, and secondly, the number of surplus ewes and store lambs available for sale. In those cases where the flock is maintained solely for fat lamb production, the economic return is largely governed by the rate of reproduction of the ewes.

In the case of the New Zealand Romney and Cheviot-Halfbred sheep *, the economic significance of fertility is especially noteworthy. In the North Island of New Zealand, Romney ewe flocks are almost universally in use. There is a wide variation however, among the environments in which such flocks are used and on the poorer classes of hill country Romney ewes are not consistently thrifty and lambing percentages are low. In addition, Romney lambs from such country are generally in poor condition at weaning, hogget mortalities tend to be high and the potential for genetic or economic advance is accordingly reduced.

One method of improvement of fertility in hill-country sheep which suggests itself is to cross existing flocks with a breed of higher fertility which is better adapted to the hill environment. Since 1939, Massey Agricultural College has conducted trials with the Cheviot breed for such a purpose. Under the conditions obtaining in these trials, the Cheviot and its crosses with the Romney have

* The term "New Zealand Romney" is used here to indicate that the Romney ewes studied and henceforth referred to in this work as "Romney", were grade sheep, the offspring for many generations of pedigree Romney Marsh rams.

The term "Cheviot-Halfbred" is here used to indicate that the Halfbred ewes studied, and henceforth referred to as "Halfbred" were the first generation offspring of Cheviot rams and N.Z. Romney ewes.

excelled the performance of the Romney itself in lambing percentage on poorer hill-country. Similar results have been obtained in a trial of a less critical nature on the easy country of a fat lamb farm. In the case of the graded-up Cheviot *, the increase in economic potential resulting from higher fertility has been offset by the lower price received for wool. The most profitable stock was found to be the Halfbred resulting from the mating of Cheviot rams with Romney ewes. Breeding work at the College is now proposed which will be directed towards fixing the Halfbred type by interbreeding the progeny of the first cross.

In these trials conducted by the College, fertility of the Romney and Halfbred has been appraised in terms of lambing percentages. The breed differences thus revealed should be a reflection of breed differences in some phase or phases of the reproductive process, and it is to demonstrate the nature of some of these underlying differences that the present work is directed.

III. EARLIER INVESTIGATIONS OF FERTILITY DIFFERENCES IN SHEEP.

The first survey of fertility in British breeds of sheep was made by Heape (1899), who determined the incidence of barrenness, abortion and twinning in flocks of different breeds. Similar surveys were made by Marshall

* Crosses of the Cheviot with the Romney which contain three-quarters or more of Cheviot blood.

(1905, 1908) and Nichols (1924, 1926a, 1926b). These studies clearly indicated that breed differences in fertility exist but that they frequently may be masked by environmental influences. Nichols (1926a) stated:

"Investigations on fertility in sheep have shown that the causes of differences in fertility between pairs of animals within a breed or between pairs of animals of different breeds, are of two types; the fundamental differences are genetic, but the degree of their expression is governed by environmental influences which are largely responsible for variations in fertility."

The truth of this last statement is also borne out by other work. Thus, genetic differences in fertility between range ewes of different breeds have been demonstrated by Cooper & Stoehr (1934), Terrill & Stoehr (1939) and Rasmussen (1941). These workers detected significant differences in lambing percentages and the incidence of barrenness and abortion when ewes of the different breeds studied were run together. That environment has an important effect, on the other hand, was shown by the work of White & Roberts (1927) on the Welsh Mountain breed. They were able to demonstrate differences in fertility within a breed under mountain, lowland and intermediate conditions.

Little information is available on the genetical basis of differences in fertility. Wreidt (1924), working on the Cheviot sheep in Norway, and Lamont (1935), analyzing the records of a New Zealand Romney stud, were able to show that there was a positive daughter-dam relationship in the average number of lambs produced annually. Similar correlations in the Romanov breed have been reported by the Russian workers Heptner (1940) and Belogradskii (1940).

On the other hand, Dry (1936), analyzing the records of a Wensleydale flock of extremely high fertility, found that no such correlation occurred but that the progeny of crosses between this and other breeds also showed high fertility. He therefore concluded that the Wensleydale breed had a high innate level of fertility which was transmitted to its progeny in crosses with other breeds by one or more dominant genes.

The investigations briefly reviewed in this section indicate that while fertility in general may be studied by farm surveys or by actual examination of flock records, the precise evaluation of breed differences demands that the breeds concerned be examined under the same environmental conditions. There is also some indication that differences of a genetic character are not exclusively those which exist between breeds, but may also occur within a breed.

IV. OTHER RELEVANT INVESTIGATIONS INTO LEVEL OF FERTILITY.

Few data are available on the fertility of sheep in New Zealand. The fertility of ewes in a New Zealand Romney stud was investigated by Barton (1947), who found that over a thirteen-year period, the average lambing percentage of the flock was 108.9% and the average incidence of dry ewes 15.8%. In two-tooth ewes he showed that the average lambing percentage was 82.4% and that an alarmingly large proportion (25.2%) of the two-tooth ewes were dry. Gibson (1953), from a survey of farms on the western slopes of the Tararua Range found that on properties composed

entirely of hill-country, the lambing percentage of Romney flocks was almost invariably between 80% and 90%.

In a breed comparison between Romneys and Halfbreds under hill-country conditions, Peren, Hewitt, Ballard & Phillips (1951) found that over a four-year period, the average lambing percentages of the two breeds were 83.2% and 117.4% respectively, and the percentages of ewes without lambs at shearing were 23.1% and 6.3% respectively. Since the age compositions of the flocks compared were not the same, and since the enumeration of ewes dry at shearing included ewes which had lost their lambs as well as ewes which were barren or had aborted, these figures do not reflect true breed differences in fertility. The differences indicated are of sufficient magnitude, however, to show that under certain hill-country conditions Halfbreds are more fertile than Romneys.

V. POSSIBLE AGRICULTURAL SIGNIFICANCE OF THE PRESENT STUDY.

Mention has already been made in Sections I and II of this chapter of the general nature and analytical purpose of this investigation, and also of the agricultural significance of the problem of fertility in ewe flocks. It now remains for us to consider the possible ways in which the phase-analysis of the reproductive process could assist the farmer towards overcoming the general problem of low fertility. In general terms, improvement in livestock management would take the form of manipulation

of the environment, or alteration of the breeding policy. Concerning the first of these, it is evident that if environmental causes are at work in reducing fertility at some stage in the reproductive process, any attempt at increasing fertility by improvement of the environment should coincide in time and character with that same particular vulnerable stage in the reproductive process. Concerning the second course of action, that of alteration of the breeding policy, some mention has already been made. As an example, one could attempt to solve the problem of low fertility in hill-country Romneys by substituting another breed better suited to the particular environment, or one could improve the fertility of the existing Romney flocks by crossing them with rams of more suitable breeds. Alternatively, one might be able to select for high fertility within the Romney breed while the stock is maintained in the unfavourable environment. But most important, in view of the analytical nature of the present investigation, one might be able to practice selection more effectively either on the flock animals themselves, or on their offspring, in the light of a detailed knowledge of the reproductive chain and of its impediments. More especially will this be so if either desirable or undesirable features of the reproductive chain have some consistent, recognizable, phenotypic or behaviouristic manifestation. Whether our endeavours are to be directed towards improving the environment or improving the genetic character of the flock, knowledge of phase-detail will tend to give greater promise of success to such attempts by directing our attention towards the weak links in the chain.

C H A P T E R I I.

NATURE AND SCOPE OF STUDY.

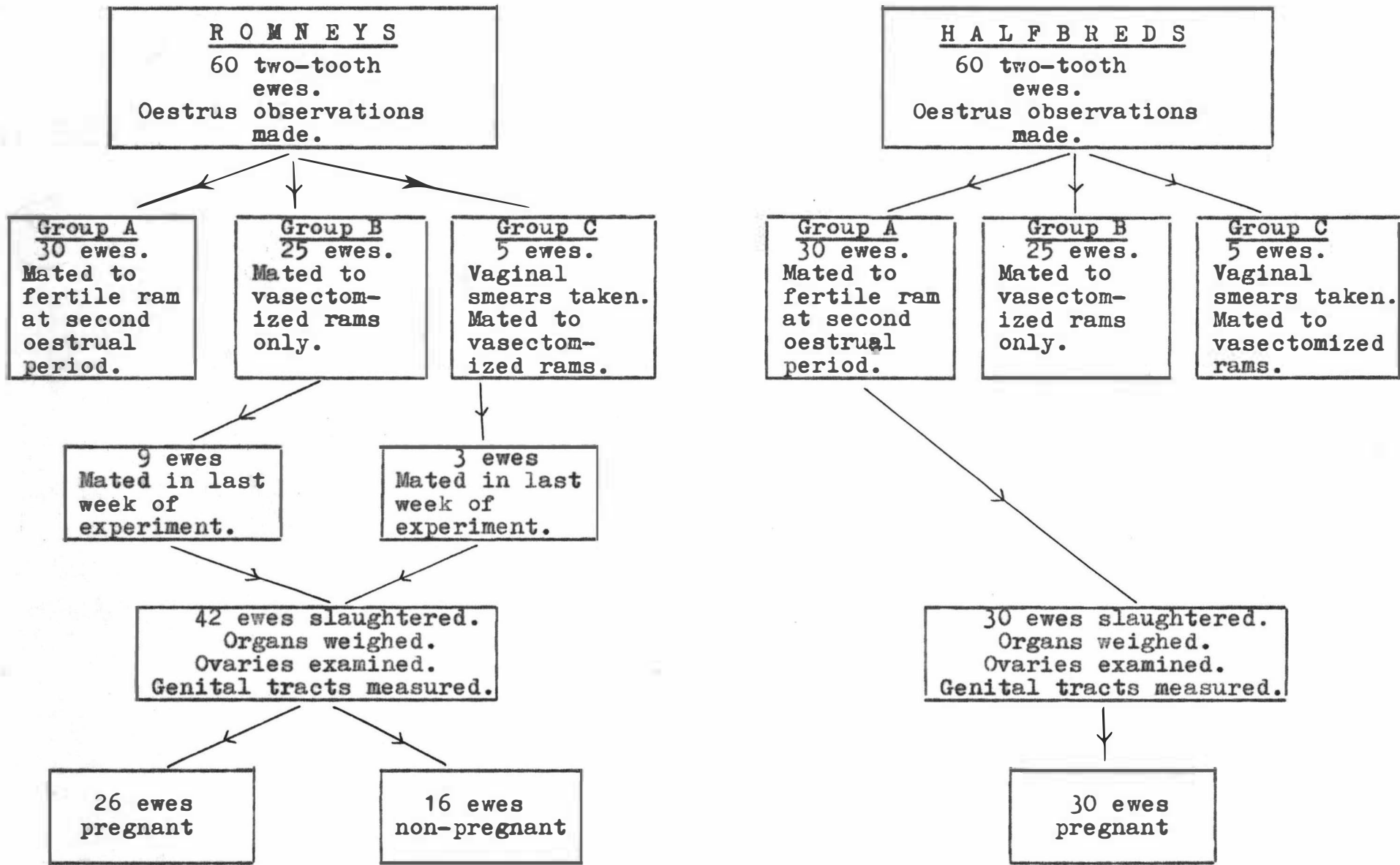
In this study, an attempt has been made to evaluate critically the large differences in lambing percentage which are found between Romney and Halfbred ewes in New Zealand. To this end, a comparative study has been made of the reproductive cycle of ewes from both breeds from the onset of the breeding season through to early pregnancy. Furthermore, differences in the sexual development of the two breeds have been studied by a detailed examination of their genital tracts, and observations have been made on some causes of barrenness in Romney two-tooth ewes.

The study may conveniently be divided into two phases, the behaviour of the ewes in the presence of a ram, and the ewes' fertility as determined from examination of their reproductive organs at slaughter.

Ideally, for such an investigation, the experimental animals should have been bred and reared in the same environment, or at least have been kept in a common environment for several months before observations commenced. Unfortunately, however, animals of such origin were not available, and the ewes which were finally procured did not arrive on the experimental area until twenty days before the onset of the breeding season.

The 60 ewes of each breed which were available for study, were divided at random into two equal groups, one of which was mated to fertile rams and the other to vasectomized rams. The former were killed on, and after, the thirty-third day of pregnancy, and the breeding behaviour of the latter was observed until the end of the experimental period. The experimental plan is illustrated in Figure 1.

Fig. 1. DIAGRAMMATIC REPRESENTATION OF EXPERIMENTAL PLAN.



I. THE BEHAVIOUR OF EWES IN THE PRESENCE OF A RAM.

The onset of oestrus was detected in the field by the use of teasers (vasectomized rams) with raddled briskets. The breeding behaviour of ewes identified in this way was observed by testing them individually with teasers at intervals of eight hours. In a group of ten ewes, the cyclical changes which occur in the vaginal smear were also studied.

In this phase of the experiment it was possible to study the nature of the following phenomena in ewes of the two breeds:-

- (a) The onset of the breeding season.
- (b) The signs and intensity of oestrus.
- (c) The duration of oestrus.
- (d) The duration of the oestruual cycle.

Although observations were initially made on the entire flock, as the ewes became pregnant in the group which was mated, there was a gradual reduction in the numbers studied.

II. THE STUDY OF FERTILITY.

All the ewes which had been selected in the group to be mated were slaughtered; in the case of pregnant ewes this occurred when gestation had proceeded from 33 to 47 days. All the Halfbred ewes, but only a proportion of the Romneys were found to be pregnant. A detailed dissection of the reproductive tracts of slaughtered ewes was undertaken and from the pregnant ewes, for each breed, information on the following was obtained:-

- (a) The development of the ovaries.
- (b) The ovulation rate.
- (c) The number and position of the foetuses.
- (d) The development of the uteri and Fallopian tubes and the relationship between the gravid and non-gravid uteri of ewes bearing single foetuses.
- (e) The crown-rump measurements of foetuses in a 14 day age series.

The examination of the reproductive organs of the non-pregnant ewes made the following contributions to this study:-

- (a) A description of some abnormalities of the ovaries which affect oestral activity.
- (b) A description of some anatomical abnormalities which preclude conception.
- (c) A comparison of the reproductive tracts of ewes which on the one hand, showed normal ovarian activity but failed to conceive, and on the other, did not experience oestrus during the experimental period.

CHAPTER III.

EXPERIMENTAL MATERIALS AND MANAGEMENT.

I. THE EXPERIMENTAL AREA.

The experiment was conducted on the Pahiatua Block of the Massey Agricultural College Sheep Farm, Palmerston North. The experimental area was divided into three paddocks of fourteen, eight and two acres in area respectively. Sheep yards and a large barn subdivided into pens were available for the yarding and handling of the experimental animals. The small paddock of eight acres carried the ten ewes of Group C, and the ewes in oestrus were also held in this area. The main flock of 110 ewes and the group of teasers and rams were alternated between the other two paddocks as the feed supply dictated.

II. THE EXPERIMENTAL ANIMALS.

(a) The ewes.

A flock consisting of 60 Halfbred and 60 Romney two-tooth ewes was procured for the study. An attempt was made to obtain ewes which had been born and reared on similar properties, but this was not possible because of the small number of Halfbred flocks in the country. The ewes were delivered to the experimental area on February 20, 1952.

The Romney ewes which were small and in poor condition, were purchased from a farm in Akitio County, Southern Hawkes Bay, and constituted the culls from a line of 400 two-tooth ewes. The hoggets on this property experienced a severe winter, and the two-tooth ewes in 1952 were in such poor condition that the owner did not put any of them to the ram.

The Halfbred ewes were of mixed origin, but were even in size and in good condition. They were selected as being the best in a line of 99 ewes which were born in the Manawatu and wintered on the College experimental farm in the Akitio County. Of the 99 ewes, 78 were bred by Massey College on the flat country of the Tuapaka farm and 21 were first cross Romney-Cheviot lambs purchased from nearby farmers in the Tuapaka area. Of the 78 Halfbred ewes bred by the College, 26 were late lambs from Romney flock ewes mated to a Cheviot ram and 52 were the ewe lambs from the College Halfbred ram-breeding flock, Romney stud ewes mated to selected Cheviot rams. Although wintered on similar country to that on which the Romneys were carried, the Halfbreds received better management, and were freshened for sale in December, 1951.

(b) The rams.

Three Southdown rams, one a two-tooth and the others four years old, were used for mating the ewes. They were always provided with adequate feed and lost little condition during the experiment. The ewes were hand mated, and no ram performed more than four services during a day. The feet of the rams were constantly attended to and scald, when it occurred, was treated with local applications of bluestone.

(c) The teasers.

Eight teasers were employed during the experiment. Two were run with the ewes continuously, and the others held in reserve for testing ewes for the presence of oestrus. The teasers were changed whenever they showed any diminution in vigour.

The significance of the differences between these means was tested by an analysis of variance using the method of weighted means (Snedecor, 1946, p.289).

TABLE II.

ANALYSIS OF VARIANCE FOR CHANGES
IN LIVE-WEIGHT OF ROMNEY AND HALFBRED EWES DURING
THE EXPERIMENTAL PERIOD.

Source of Variation	d.f.	S.S.	M.S.
Between breeds	1	66372.43	66372.43 * *
Between periods	3	1078.01	359.34 N.S.
Interaction	3	39.18	13.06 N.S.
Between individuals	444	145951.44	328.72

** Significant at 1% level.

There were no significant differences between the mean weights of the ewes at each of the four weighings, suggesting that the condition of the ewes had been maintained throughout the experiment. A highly significant difference of 24 lb. occurred between the mean live-weights of the ewes, when the experiment commenced, and this difference persisted.

C H A P T E R I V

THE BREEDING BEHAVIOUR OF ROMNEY AND HALFBRED TWO-TOOTH EWES BETWEEN MID-FEBRUARY AND THE END OF MAY.

I. GENERAL INTRODUCTION.

For the formulation of sound breeding practices for a particular breed of sheep, a knowledge is required of the duration of the breeding season and the lengths of different phases of the reproductive cycle in the particular environment in which the breed is to be used. In addition to their importance for determining normal farm breeding policies, such accurate statistics will become of increasing importance in the control of fertility by such techniques as the use of hormonal therapy for the induction of pregnancy in the anoestrous ewe (Robinson, 1950) and the augmentation of fertility during the breeding season (Robinson, 1951). Some data on the reproductive cycle of the New Zealand Romney are available (Dry, 1933; Gill, 1933; Goot, 1949; Till, 1950; Walker, 1943) but so far as the author is aware, no such information is available for the New Zealand Cheviot-Romney Halfbred.

Since the oestral cycle is an overt expression of underlying physiological mechanisms and interactions, a complete knowledge of the events of the sexual cycle and the time relations between them may make some contribution to fundamental studies of sex physiology.

II. METHOD OF STUDY.

Observations on breeding behaviour were made on the entire flock of ewes, although Group C consisting of 10 ewes, was run separately from the main flock, and was studied

by a slightly different technique.

The presence of oestrus was detected in the field by running two teasers (vasectomized rams) with the ewes. A coloured paste* was applied to the briskets of the teasers so that any ewes served were marked on the rump. The efficiency of this method as a test for oestrus has been discussed by Kelley (1937). Terrill (1935) found that sterile copulation had no effect on cycle length or ovulation rate but it had a tendency to shorten oestrus. This was confirmed by McKenzie & Terrill (1937). The colours were changed at 12 day intervals and followed the series, yellow, red, blue, black, yellow, blue. Excessive amounts of pigment were trimmed off the wool with shears and the marks on the rumps of all ewes were obliterated with a white, oil-bound distemper sprayed on to the wool before the colour yellow was used for a second time. Extreme care was required in this phase of the work since night observations had to be made under artificial light.

The ewes were examined once a day until the first occurrence of oestrus in the experimental flock, after which examinations were carried out at eight-hourly intervals (7 a.m., 3 p.m. and 11 p.m.). At each inspection a standard routine was followed. About ten minutes before the scheduled observation time, the small paddock containing the ewes of Group C and all ewes found to be in oestrus at the previous examination, was mustered, and the ewes held in a small yard. Next, the

* A limited amount of a commercial tugging paste was available, and supplies of this were supplemented with a paste of powdered raddle with engine oil as a medium.

teasers and rams were mustered into another small yard. The remainder of the flock was then mustered into a large yard and ewes marked during the preceding 8 hours were drafted off. For night inspections, the yards were illuminated with a 200 watt bulb, and all ewes were carefully examined with the aid of a torch. The ewes not on heat were then returned to pasture.

Ewes which had been in oestrus at the previous examination and ewes marked in the field subsequently were then tested individually for oestrus with a teaser ram, as described in a later section, and those ewes found to be out of oestrus were marked on the head with the current colour and returned to the main flock.

Group C was then tested as a group. The ten ewes were confined in a small yard with a vigorous teaser, and ewes which were found to be in oestrus were then tested individually at each examination until they went out of oestrus.

All records were entered in a day-book at the time of examination, and then transferred to an individual record book, where the complete breeding history of each ewe could be readily followed.

A. THE ONSET OF THE BREEDING SEASON.

Introduction.

The ewe has a definite breeding season, consisting of a series of sexual cycles, followed by anoestrus, a period of rest or sexual quiescence (Heape, 1900; Marshall, 1903; Kelley and Shaw, 1943; Hammond Jr., 1944; Hafez, 1952). The ovary is not necessarily quiescent

during anoestrus, as the presence of spontaneous ovulations during the non-breeding season has been demonstrated in the Merino (Roux, 1936), the Karakul (Loginova, 1939) and mixed British breeds (Hammond Jr., 1944). Also, the date of onset of the breeding season has been shown to be different for different breeds (Cole & Miller, 1935; McKenzie & Terrill, 1937; Hammond Jr., 1944; Hafez, 1952) and between different strains of the same breed (Kelley & Shaw, 1943), although in one environment, the date of onset for any one breed is relatively constant (Hafez, 1952).

Hammond Jr., (1944) made the important observation that the mid-point of the breeding season of British breeds of ewes coincided with the shortest day, and this in general was confirmed by Hafez (1952) although he found that the Dorset Horn did not conform to this pattern.

Yeates (1949) demonstrated that the major factor determining the time of onset of the breeding season is the change to decreasing hours of daylight, and Robinson (1951) has postulated that there is an inverse relationship between day-light hours and pituitary activity, there being different thresholds of activity required to initiate ovulation in different breeds, or alternatively, the general pituitary activity in some breeds is always higher than in others.

Hafez (1952) considers that breed differences in the length of the breeding season are possibly related to their geographic origin, that is, the light environment under which they evolved. That these variations in the length of the breeding season have a genetic basis is further supported by the fact that progeny of crosses of

different breeds have breeding seasons intermediate in length between those of the parents (Cole & Miller, 1935; Schott, Phillips & Spencer, 1939; Kelley & Shaw, 1943). It would appear therefore from these results of breed crosses, and from the strain differences within a breed reported by Kelley & Shaw (1943), that the extent of the breeding season in ewes is an expression of the genotype in response to light stimulus, and that this pattern may be modified by selection.

This fundamental breeding pattern may be modified by other environmental factors. Goot (1949) found that there was a tendency for two-tooths to enter the breeding season later than mature ewes, and Hafez (1952) has shown that ewe lambs have a restricted breeding season, although in a small sample, he was unable to detect differences between yearlings and older ewes in the time of onset.

Malnutrition has been shown to delay the onset of the breeding season (Quinlan & Mare', 1931; Roux, 1936) but, while Grant (1934) and Wallace (1951) believe that onset can be hastened by nutritional flushing, this has not been found to be the case by McKenzie & Phillips (1932), Underwood & Shier (1941), Briggs, Darlow, Hawkins, Wilham & Hauser (1942) and Till (1950).

Quinlan, Steyn & De Vos (1941) report that the commencement of the breeding season is a gradual process since the level of gonadotrophic and follicular hormone required for normal ovulation and heat may be attained quite slowly. That the first ovulation of the breeding season may be unaccompanied by heat is revealed by examination of slaughter-house material (Grant, 1934;

Robinson, 1950) and by the vaginal smear technique (Cole & Miller, 1935). As an explanation of this phenomenon of silent heat, Hammond Jr., Hammond & Parkes (1942) suggest that normal physiological heat can only occur in the presence of a waning corpus luteum, and this has been confirmed by Robinson (1950).

The nature of the cyclical changes in the vaginal mucosa during the breeding season has been described by Casida & McKenzie (1932), Hawkins & Darlow (1933), Grant (1934), Cole & Miller (1935) and McKenzie & Terrill (1937). The vaginal smear, because it consists of exfoliated cells, reflects these changes in the mucosa and its nature has been regarded as a reliable test for oestrus by Polovceva & Fomenko (1933) and Cole & Miller (1935), while other workers (Darlow & Hawkins, 1931; Grant, 1934) although finding well-marked changes in the smear, found that these were not an accurate index of the stage of the cycle. Richter & Rittau (1933), taking samples from the vaginal canal only three times weekly, failed to find distinctive changes in the character of the smear at different stages of the cycle.

Cole & Miller (1935) report that the vaginal smear indicates that the reproductive organs are not in complete rest during the anoestrus, and that during early and late anoestrus, there are cyclical changes nearly as pronounced as those taking place during the sexual season, and similar in character.

Method of Study.

The date of onset of the breeding season of a ewe was considered to be the first day a ewe would stand for

service by a ram during the experimental period, and was determined by the system of "spotting" in the field by a teaser with a raddled brisket. The efficiency of this method as a test for oestrus has already been discussed.

An attempt was also made to study the nature of the onset of the breeding season by the vaginal smear technique.

Five ewes were randomly selected from Group B of each breed, and starting on March 3rd, vaginal smears were taken from these ewes daily, observations ceasing on May 20th. In the afternoons, prior to sampling, the ewes of Group C, which were depastured separately from the main experimental mob, were mustered into a small yard. The ewes were run two at a time on to a raised platform in a narrow race, so that their movements were restricted and sampling facilitated. A glass speculum, lubricated with water, was inserted into the vagina as far as the cervix and then withdrawn slightly. Samples were obtained from the vaginal wall with moist cotton swabs on wooden applicators, and the smears were made by rolling the swab across a clean, labelled, microscope slide. The macroscopic appearance of the smear was recorded. Each night, the smears taken during the day were fixed for five minutes in methyl alcohol and batches of slides were stained every five days. No microscopic examinations have been made of these smears.

Results and Discussion.

(i) Detection by the vaginal smear technique.

Darlow & Hawkins (1931) and Cole & Miller (1935) have described the vaginal smear, and state that the most striking changes are macroscopic viz:-

- (a) a profuse flow of transparent mucus during early oestrus.
- (b) a voluminous, dry, cheesy smear consisting almost solely of squamous, epithelial cells, in early metoestrus.
- (c) a scant smear consisting of epithelial cells and leucocytes, during dioestrus.

In evaluating the smears taken in this investigation, at first complete descriptions were made of each smear until a sufficient body of data had been built up to enable the evolving of a subjective grading which would permit an adequate, but concise description of each sample. Each sample was described for the three characteristics, quantity, viscosity and density according to the following grades:-

<u>Quantity</u>	<u>Viscosity</u>	<u>Density</u> *
Scanty	Fluid	Clear
Medium	Moderately viscous	Few cells
Copious	Viscous	Cloudy
Extremely copious	Extremely viscous	White
	Dry	Cheesy

Also, occasionally the vagina was found to be extremely dry, and the speculum coated when withdrawn. This condition was recorded when present.

Descriptions are presented in the appendix, of the vaginal smears of 5 Romney and 5 Halfbred ewes on 79 consecutive days.

* Cell content was estimated subjectively by the opacity of the smear.

Table III shows the breeding performances of the ewes in Group C during the sampling period.

TABLE III.

NUMBER OF OESTRUAL PERIODS EXPERIENCED BY
THE EWES OF GROUP C.

Breed	Ewe No.	Date of first heat.	No. of heats experienced during sampling period.
Romney	451	12th April	3
	456	8th "	3
	468	12th "	3
	478	19th "	2
	545	5th "	3
Halfbred	41	29th March	4
	71	9th April	3
	79	3rd "	3
	82	6th "	3
	90	12th "	3

During the sampling period, it was possible to study the vaginal smears of 10 ewes during 20 complete oestral cycles and 30 oestral periods. All three of the characteristic types of smear described by Cole & Miller (1935) were found to occur, but they did not bear any constant time relation to heat, and they are not regarded as an accurate index of the stage of the oestral cycle. These data are discussed only in relation to the first day of heat and smears of a type atypical of the particular stage of the dioestral cycle at which they were taken, have been disregarded.

According to Cole & Miller (1935), early oestrus is accompanied by a profuse inflow of watery mucus to the vagina from the cervix. Smears indicative of this

phenomenon were detected in this investigation, such smears being described as "copious, fluid, clear" in the records. The data presented in Table IV show the distribution of the times of onset of mucus flow in relation to the first day of heat.

TABLE IV.

DISTRIBUTION OF TIMES OF APPEARANCE OF MUCUS
RELATIVE TO THE ONSET OF OESTRUS IN 22 OESTRUAL PERIODS

Relation to onset of oestrus (days)	-2	-1	Onset of oestrus	+1	+2
No. of observations in each class	1	9	9	9	2

In eight of the 30 oestral periods observed (involving six ewes), the vaginal smear gave no indication of the presence of mucus, although in two of these cases, the wool below the vulva was damp with mucus, suggesting that there had been a profuse flow of short duration. There were six cases observed in which mucus was found on two consecutive days, and three cases of it occurring on three consecutive days. Occasionally the mucus was cloudy on the first day and subsequently became clear.

These data show that in a group of 10 ewes there was a range of four days in 22 oestral cycles in the time of onset of mucus flow relative to the onset of oestrus, and in addition, with smears taken at 24 hour intervals, no mucus was detected in 26.6% of all observed cases of oestrus. Thus, in this experiment, it was considered

that little reliance could be placed on the presence of mucus as a definite sign of oestrus, so that it was not used in the attempt to detect silent heats before the onset of the breeding season.

A much more constant feature in the observations made in this investigation was the typical metoestral smear, described by Cole & Miller as a "voluminous, dry, cheesy smear with large squamous epithelial cells predominating; occasionally a few leucocytes present. This stage extends from near the end of the second day to the fourth to eight day of oestrus." Even more striking than the nature of the smear, was the character of the vagina, which was frequently dry so that the speculum was difficult to insert, and when withdrawn was coated with an adhesive layer of dry, cheesy material.

Only six instances were found in this investigation when oestrus was not followed by this characteristic type of smear, and five of these instances occurred in the records of two ewes, suggesting that individuality may deform the normal smear picture.

TABLE V.

TIME OF APPEARANCE OF THE
METOESTRAL SMEAR RELATIVE TO THE TIME OF
ONSET OF OESTRUS.

Time after onset of oestrus (days)	1	2	3	4
No. of observations in each class.	6	13	1	1

In nearly 75% of all observations, the metoestral smear was first observed two days after the onset of

oestrus and such smears lasted for a range of 1 - 3 days. In two cases, the metoestrual smear appeared twice in a single cycle with an interval of 2 days, but this may possibly have been due to faulty sampling.

When the individual ewe records prior to the onset of the breeding season were examined, not one instance of the clear-cut metoestrual smear was found, so that it is concluded that if silent heats did occur before the breeding season commenced they were not followed by a typical metoestrual smear, thus differing from the results of Cole & Miller.

Smears taken during dioestrus showed no regular macroscopic appearances, varying both in volume and cell density, so that they proved to be of no use for determining the stage of the cycle.

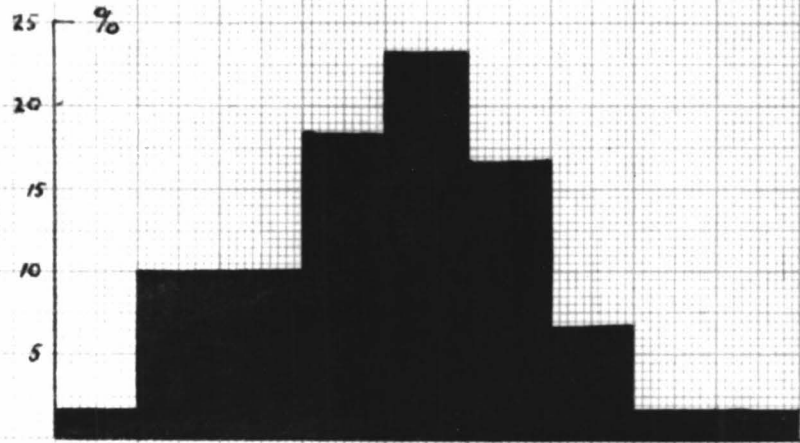
(ii) Detection by the use of vasectomized rams.

Observations on the ewes commenced on February 24th when the teasers were first joined with the ewes and the first occurrence of oestrus was recorded on March 12th. With the exception of six Romneys, all ewes had entered the breeding season by May 30th, the end of the observation period. It is unlikely that any ewes experienced their first oestrus of the breeding season prior to February 24th since Goot (1949) found the earliest onset in a flock of stud Romney ewes in the Manawatu occurred on March 11th.

Table VI shows the distribution of the times of onset of the breeding season. This distribution is also shown graphically in Figure 2.

Fig. 2. The onset of the breeding season.

ROMNEYS



HALFBREDS

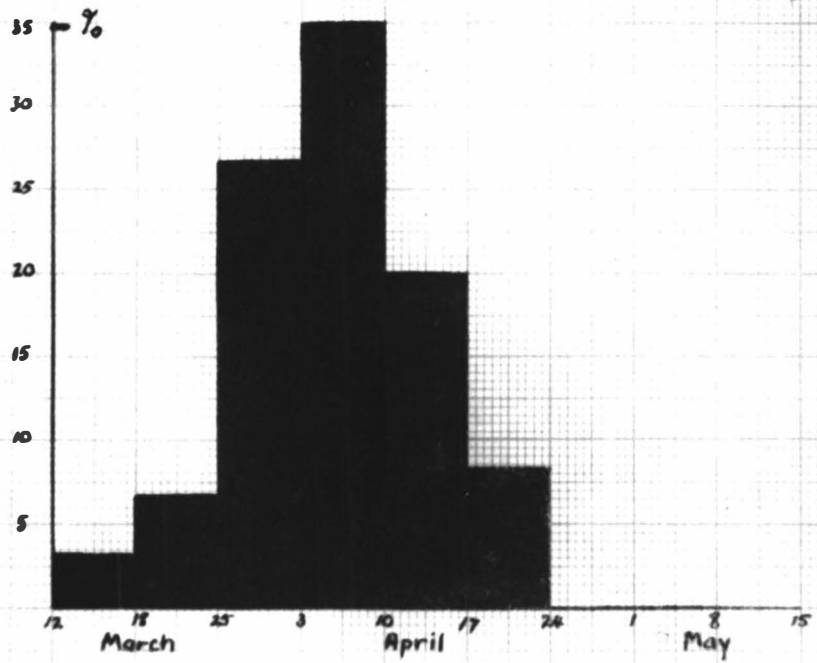


TABLE VI.

DISTRIBUTION OF DATES OF ONSET OF THE
BREEDING SEASON.

Weeks	Romneys			Halfbreds		
	No. of observations	% of all ewes observed.	Accumulated %	No. of observations	% of all ewes observed.	Accumulated %
12-18.iii.	1	1.7	1.7	2	3.3	3.3
19-25.iii.	6	10.0	11.7	4	6.7	10.0
26.iii.- 3.iv.	6	10.0	21.7	16	26.7	36.7
4-10.iv.	11	18.3	40.0	21	35.0	71.7
11-17.iv.	14	23.3	63.3	12	20.0	91.7
18-24.iv.	10	16.7	80.0	5	8.3	100.0
25.iv. - 1.v.	4	6.7	86.7			
2-8.v.	1	1.7	88.4			
9-16.v.	1	1.7	90.1			

For the purposes of statistical analysis, the dates of onset of the breeding season were coded, with March 12th at the beginning of the scale.

TABLE VII.

MEAN DATES OF ONSET OF THE BREEDING SEASON
OF 60 HALFBRED EWES AND 54 ROMNEY EWES.

Breed	Range	Mode	Mean
Romney	12.iii. - 5.v.	11.iv. - 17.iv.	12.iv.
Halfbred	15.iii. - 21.iv.	4.iv. - 17.iv.	5.iv.

The onset of the breeding season of the Halfbreds is much more concentrated, with all ewes on heat by April 21st, and a peak period of three weeks from March 25th to April 17th during which 81.7% of the Halfbred ewes first came on heat. The mean time of onset is a week earlier than that of the Romneys which bred, and this difference was found to be statistically significant ($p < 0.01$) when tested by an analysis of variance. In contrast, the Romneys show a much more dispersed distribution, with six ewes not entering the breeding season during the period of observation. The modal period contains only 23% of all observations and it occurs a week later than that of the Halfbreds.

B. THE SIGNS AND INTENSITY OF OESTRUS.

Introduction.

The external signs of oestrus in the absence of a ram are slight. Occasionally there is congestion of the vulva and a flow of mucus but the mutual behaviour of the ewe and ram are the only reliable indications of oestrus, (Marshall, 1903; McKenzie & Phillips, 1930; Grant, 1934). McKenzie & Terrill (1937) have described the behaviour of the ewe in oestrus in the presence of a ram. McKenzie & Phillips (1930) found that the beginning of oestrus was abrupt in some cases and gradual in others and Quinlan & Mare (1931) report that both the beginning and end of oestrus are gradual. Grant (1934), stated that oestrus began abruptly and ended gradually, while Roux (1936) reported that oestrus began abruptly and ended either gradually or abruptly. McKenzie & Phillips (1937) found

that the manner of beginning and ending of heat was quite variable and there were no indications that one end of the oestral period was more abrupt or gradual than the other.

Intensity of heat has been studied by McKenzie & Terrill (1937) and Hafez (1952), the former finding that ewes were extremely variable in this respect and that while intensity of heat often changed within an oestral period, there was no relationship between length of oestrus and intensity, nor was there any seasonal trend. Hafez (1952) found that there were marked breed differences in intensity and that mountain breeds also showed a seasonal trend. Kelley (1937) reports that oestrus in the Dorset Horn is more intense than in the Merino.

There are few data available on the time of day of the initiation of oestrus. Kelley (1937) found that 65% of the observed oestral periods of Merino ewes commenced between 5 p.m. and 7 a.m. and McKenzie & Terrill (1937) found that 55.9% of observed oestral periods were initiated between midnight and noon, although there were no significant differences between the four six-hourly intervals at which they made their observations. This behaviour in sheep is in contrast to the situation in the rat, where 75% of all heat periods commence between 4 p.m. and 10 p.m. (Asdell, 1946).

Method of Study.

A ewe was considered to be in oestrus only when she permitted the teaser to mount. Ewes raddled in the field by teasers were removed from the main flock and tested individually for oestrus at eight-hour intervals.

Testing for oestrus was carried out in an outside pen of size 10 x 4 yards during the greater part of the experimental period, but for the last month, because of continued bad weather, the ewes were tested in a pen of size 6 x 3 yards inside the barn.

The teasers used for testing for oestrus were always segregated and were replaced when they showed any diminution of vigour. A total of six teasers was used for testing purposes.

In the initial stages of the experiment, extensive notes were made of the behaviour of individual ewes when tested with a teaser, and on the basis of these observations, a subjective grading of intensity of heat was evolved, ewes being rated as "high", "medium" or "low" for intensity. When there was any doubt about the reactions of a ewe, testing was repeated using a different teaser, as suggested by Roux (1936).

Results and Discussion.

It was not possible to determine from external appearances whether a ewe was in oestrus. Ewes marked prior to an inspection were frequently found near one of the teasers in the field, but when separated from the teasers did not show abnormal behaviour.

When a ewe was confined in a pen with a teaser, a more constant pattern became evident. As the teaser approached, nearly all ewes, whether in oestrus or not, would urinate, and ewes not on heat would move away. The teaser normally sniffed the urine, raised the head high, wrinkled the nose and moved the head slowly from side to side. Teasing actions then commenced. These consisted of striking at the hind legs of the ewes with the forefeet, rubbing the

head against the ewe's flank and quite frequently butting the ewe. Extremely vigorous teasers, or teasers which had been rested from teasing for a period, would attempt to mount almost immediately, but teasers with lower libido, or teasers which had been unsuccessful in their last attempt at service, would prolong the teasing process.

The behaviour of the ewe in oestrus showed considerable variation and the following is a description of the grades into which intensity of oestrus was classified:

- (i) High grade intensity. The ewes stand readily for the ram and urinate but rarely move when he approaches. Occasionally, the ewe moves towards the ram when he enters the pen. The stance is normally rigid, with vibrant tail, and the ewe occasionally looks backwards towards the ram and bleats during the teasing process. Such ewes accept service readily.
- (ii) Medium grade intensity. The ewe urinates as the ram approaches and then moves away a few yards. Such ewes are restless during the teasing process and occasionally move a step or two when he attempts to mount. They show considerable interest in the ram.
- (iii) Low grade intensity. The ewes often show fright at the approach of the ram, usually urinate, and frequently move rapidly around the pen. Prolonged teasing and often several attempts at mounting are experienced before such ewes finally stand for service. In testing ewes in this grade of intensity

of heat, it was often found that by substituting a more vigorous teaser, ewes could be served which previously would not stand.

Because the intensity of heat varies within an oestral period, the analysis of the patterns of intensity throughout oestrus presented considerable difficulty, since so many different combinations could occur, and also the duration of oestrus varied considerably. A full analysis would require classification of patterns within oestral periods of different lengths. In this investigation patterns of intensity have been analysed in nine classes, according to the intensity rating at the first testing, and at the last, viz:-

Class 1	Start high	End high
" 2	" high	" medium
" 3	" high	" low
" 4	" medium	" high
" 5	" medium	" medium
" 6	" medium	" low
" 7	" low	" high
" 8	" low	" medium
" 9	" low	" low

The frequencies of these different patterns are shown in Table VIII. This analysis applies only to cycles of length greater than 0 - 8 hours, for which intensity gradings are available.

TABLE VIII.

DISTRIBUTION OF PATTERNS OF HEAT
INTENSITY IN 123 ROMNEY AND 166 HALFBRED
OESTRUAL CYCLES.

Class		1	2	3	4	5	6	7	8	9
Romneys	No.	17	21	31	11	11	18	-	1	13
	%	13.7	17.1	25.2	8.9	8.9	14.6	-	0.8	10.6
Halfbreds	No.	48	29	40	2	19	16	1	1	10
	%	28.9	17.5	24.1	1.2	11.5	9.6	0.6	0.6	6.0

The most striking breed difference occurs in Class 1, showing that Halfbred oestral periods exhibit a much greater tendency to start and end with a high rating than those of the Romneys. There is also a greater proportion of Romney than Halfbred oestral periods which start and end with low intensity. Statistical analysis shows that there is a highly significant breed difference between the distributions of intensity patterns ($\chi^2 = 21.10$ for 8 d.f. ($p < .01$)).

These data are presented in a condensed form in Tables IX and X, where observations are grouped according to the intensity of heat at the first and last observations respectively. The data for Table IX are obtained by pooling the number of observations falling in Classes 1,2,3, Classes 4,5,6 and Classes 7,8,9, while for Table X, Classes 1,4,7, Classes 2,5,8 and Classes 3,6,9 are grouped.

TABLE IX.

ANALYSIS OF INTENSITY OF OESTRUS
OF EWES AT FIRST OBSERVATION OF OESTRUS.

Breed		Start high	Start medium	Start low
Romney	n	69	40	14
	%	56.1	32.5	11.4
Halfbred	n	117	37	12
	%	70.5	22.3	7.2

TABLE X.

ANALYSIS OF INTENSITY OF OESTRUS
OF EWES AT LAST OBSERVATION OF OESTRUS.

Breed		End high	End medium	End low
Romney	n	28	33	62
	%	22.8	26.8	50.4
Halfbred	n	51	49	66
	%	30.7	29.5	39.8

The data in Table IX show that a higher proportion of Halfbred than Romney oestral cycles begin with a high intensity rating, and this breed difference was found to be significant. ($X^2 = 6.39$ for 2 d.f. ($p < .05$)).

A similar trend is shown in Table X where 30.7% of Halfbred compared with only 22.8% of Romney oestral cycles finish with a high rating. This difference was not found to be significant ($p < 0.2$).

An attempt has been made to study from these data the manner of the onset and close of oestrus. The literature

on this aspect of oestrus has already been reviewed.

The gradings for intensity of heat used in this study differ from those used by McKenzie & Terrill (1937) and Hafez (1952) in that the high grade of intensity was reached by only a few sheep in their studies, whereas in this study most oestral periods contain at least one high intensity rating, as shown in Table XI.

TABLE XI.
NUMBERS OF OESTRUAL PERIODS WHICH
CONTAIN AT LEAST ONE "HIGH INTENSITY" RATING.

Breed	No. of Cycles	No. containing "high" rating	% of Total
Romney	123	84	68.3%
Halfbred	166	132	79.5%

This table shows that 68.3% of the oestrus periods of the Romneys and 79.5% of the Halfbreds include at least one high intensity rating. The difference between the breeds was significant ($X^2 = 5.71$ ($p < .05$)), which suggests that Halfbreds have more intense heat periods than Romneys. However, observations were made at intervals of eight hours, and it may well be that the period of peak intensity is shorter than eight hours in a sufficient number of the observations to account for the difference between breeds.

If a high intensity rating is regarded as indicative of the peak intensity, a phase which occupies different proportions of the oestral cycle in different ewes, a study of the incidence of lower intensity ratings at each

end of the oestral period should provide a method of determining the manner of onset and termination of oestrus. Cycles which begin with a high intensity rating may, within the limits imposed by the eight-hourly examinations, be regarded as having a quicker onset than cycles which go through a low rating at the first test, or a low and then a medium rating at the first two tests, before achieving the high rating of peak intensity.

If this assumption is valid, the data in Table IX suggest that Halfbreds have a more abrupt onset of oestrus than Romneys since a significantly greater proportion of the Halfbred oestral periods fall in the "start high" category. Similarly, Table X shows that 50% of the Romney oestral periods fall into the "end low" category, suggesting that this breed tends to go out of oestrus slowly. Halfbreds seem to be more variable, about one-third of the observations falling into each category. However, great caution must be observed in interpreting the data in this way since any of several factors may invalidate the original assumption. It is quite possible that intervals of eight hours are too long for studying a phenomenon of this kind, there may be ewes whose peak intensity never attains the "high" grading used in this experiment, and the subjective gradings may be in error. The willingness of a ewe to stand for one teaser but not for another has already been noted. In addition, it is possible that the presence of an observer, or some other disturbing factor, might affect the behaviour of the ewe or teaser during testing.

The pattern of intensity throughout an oestral period may have an effect upon fertility, especially during the peak period of the tupping season. Kelley (1937) has shown that faulty synchronization between coitus and ovulation is a major cause of infertility, and it is suggested that when paddocks are large, and the number of ewes on heat at any one time is high, ewes with heats of low intensity, or with only short periods of high intensity, may have reduced chances of successful service. Since it is generally agreed that ovulation in the ewe takes place towards the end of oestrus (Quinlan & Maré, 1931; Cole & Miller, 1935; Green & Winters, 1935; Anderson, 1938) it would appear that a high intensity at the close of oestrus is especially important for ewes with a long oestral period.

The observed times of onset of oestrus showed strikingly regular distributions in this study. The differences are small, as shown in Table XII, but even when the distributions are examined cycle by cycle, without exception, a larger proportion of oestral cycles were found to commence between 7 a.m. and 3 p.m.

TABLE XII. RELATION OF TIME OF DAY TO THE ONSET OF OESTRUS.

Time at which first observed.		7 a.m.	3 p.m.	11 p.m.
Romney	n	41	63	42
	%	28.0	43.2	28.8
Halfbred	n	53	67	55
	%	30.3	38.3	31.4

In both breeds, equal proportions were found to be on heat at the 7 a.m. and 11 p.m. observations, and a greater proportion at the 3 p.m. observation. On statistical analysis, there was found to be no difference between the breeds, but a significantly greater proportion of the Romney observations commenced during the 7 a.m. to 3 p.m. period. ($\chi^2 = 6.34$ for 2 d.f. ($p < .05$)). The difference between periods were also significant for the total observations of both breeds ($\chi^2 = 7.45$ ($p < .05$) for 2 d.f.).

This result is at variance with that of Kelley (1937) who found that over 65% of the observed onsets of oestrus of Merino ewes occurred between 5 p.m. and 7 a.m., although with Dorset Horn ewes he found that more oestral periods commenced in daylight than in the dark. Hafez (1952) found that in 64% of the cases, the onset of oestrus began during the daylight hours, with no evidence of a breed difference. While finding that onsets of oestrus were fairly evenly distributed throughout the six hour intervals at which they made their observations, McKenzie & Terrill (1937) found that a larger number of heat periods began between midnight and noon than between noon and midnight. From all the evidence therefore, it would appear that the peak incidence of oestrus each day occurs during the early part of the daylight hours, which is in agreement with the results of this experiment.

C . DURATION OF OESTRUS.

Introduction.

Only the length of true oestrus, the period when the ewe will stand for service from the ram, has been estimated in this experiment. Breed differences in the duration of oestrus have been reviewed by McKenzie & Terrill (1937) and recently by Hafez (1952), showing mean durations ranging from 3 to 77 hours. However, these estimates have been obtained from studies in a wide range of environments and from different populations of ewes of the same breed so that they will not apply universally, since as shown by McKenzie & Terrill, the duration of oestrus can be affected by the ages of the ewes studied, the stage of the breeding season and the localities in which the studies are made.

The duration of oestrus in the New Zealand Romney has been studied by Walker (1943) who gives the mean durations of heat of North and South Island Romneys as 1.47 and 1.41 days respectively, Goot (1949) who found 67% and 27% of oestral periods lasting respectively one and two days, and Till (1950) who found 50% and 24% lasting 24 to 48 hours and 10 to 38 hours respectively. The data of both Goot and Till were obtained from North Island Romneys.

Method of Study.

The commencement of oestrus was taken as the first time a ewe would stand for service from the ram. This occasionally occurred in the yards, but most frequently was inferred from the colour on the rump of the ewe as a result of coitus with a teaser in the field. The marked ewes were then withdrawn from the flock and individually tested for oestrus at eight-hourly intervals.

The minimum duration of oestrus was assessed as the time between the first observation and the last observation at which the ewe was on heat, and the maximum was regarded as this minimum plus sixteen hours. Thus a ewe found on heat at 7 a.m. and again at 3 p.m. on April 1st, but out of heat at 11 p.m. would be recorded as having a heat of 8 - 24 hours' duration. This maximum figure allows for the case where a ewe may have first come on heat just after the 11 p.m. observation on March 31st and gone out of heat just before the 11 p.m. observation on April 1st. Measurements of the length of oestrus therefore fall into overlapping classes, each with a range of sixteen hours. However, equal intervals between the three daily observations has provided much more precision in measurement than in the experiments of Kelley (1937) and Till (1950) where ewes in oestrus were detected in the paddock by teasers, but testing was carried out only during daylight.

In calculating the mean length of oestrus, it was assumed that all observations within a class were distributed between the maximum and minimum durations in such a manner that the mid-point was a satisfactory estimate of the mean of observations falling within that class.

Not all records fitted into the normal pattern of successive positive tests with a teaser during an oestrus period. Fourteen observations involving three different patterns of behaviour which were not normal were recorded. It was necessary to classify these cases and adopt a convention for entering such records for analysis. The following classes were found:-

- (1) A ewe is found which has been marked in the field by the teaser, but will not stand for service when first tested, but is on heat at subsequent tests. Seven observations involving this class of behaviour were found.

Three explanations are suggested (a) the ram detected the ewe in pro-oestrus and rape-served her in the paddock, (b) the ewe was on heat when marked in the field, but was frightened or disturbed when tested in the yard with a strange teaser - after separation from a teaser for eight hours, she would stand more readily, and (c) the ewe, and the teasers used to test her were incompatible, as suggested by Roux (1936), who found that occasionally, a ewe would stand for service by a vigorous ram, but not for one which was less vigorous. Such an effect would be largely eliminated in this experiment however, since only vigorous teasers were employed, and where a ewe attracted a teaser but did not stand for service, testing was repeated using a different teaser.

In recording such observations for analysis, the onset of heat was taken as the time the ewe was marked in the field and the failure of the ewe to stand for service at the first test was attributed to extreme nervousness.

- (2) A ewe is found to have the current colour on the rump, but does not attract the teaser on testing, nor show any signs of heat. On being returned to the field, the ewe will again be marked after an

interval of 1 - 2 days, and when tested with a teaser, is found to be on heat. Five observations occurred involving this class of behaviour. The first marking was disregarded. Three possible explanations are suggested:-

(a) The ewes were rape-served by pure chance, just prior to oestrus.

(b) Possibly ewes in pro-oestrus are attractive to rams and may be cornered and raped or may actually stand for service in the field, after teasing. Just why they are not marked again for a period of 1 - 2 days is a matter for conjecture.

(c) McKenzie & Terrill (1937) suggest that extremely short cycles of 3 - 6 days might result from the failure of ovulation and hence luteinization.

In such cases, ewes will come on heat again after a few days' interval, when ovulation may occur. There would appear to be an insufficient interval between the times at which the ewes were marked in the observations under discussion, for this phenomenon to be the explanation.

- (3) One case occurred where a ewe in oestrus gave a positive test at two successive observations, followed by a negative test at the third observation, and a positive (of low intensity) at the fourth observation. This failure to stand at the third testing has been explained as being due to the influence of some environmental factor on the ewe which affected her behaviour, and for the purpose of analysis this observation was regarded as positive.

Results and Discussion.

Data are presented for the duration of 321 oestral periods. Of the 60 Romney ewes studied, six did not exhibit oestrus during the experimental period, and since all ewes in Group A were bred at their second oestrus, there is a reduction in the number of observations for succeeding cycles. The frequency distribution of the lengths of oestrus for successive cycles is shown in Fig. 3, and the numerical distribution of the lengths of all cycles observed, in Table XIII.

The durations of oestrus range from 0 to 72 hours in the Halfbreeds with a mean of 28.0 hours, while the Romneys showed a range of 0 to 48 hours with a mean of 20.4 hours. In both breeds the modal class is 16-32 hours, but in the Romneys, only 28% of the observations are of greater length than the modal group, while in the Halfbreeds, 50% of all observations are greater than the mode. Statistical analysis of the data in Table XIII shows that the duration of heat differs significantly between the two breeds ($X^2 = 31.76$ for 8 d.f. ($p < .01$)).

The histograms in Fig. 3 suggest that with succeeding cycles, the duration of oestrus tends to lengthen. The mean durations of oestrus for succeeding cycles in the breeding season are shown in Table XIV. The data have been grouped according to the number of cycles experienced by a ewe during the experimental period.

TABLE XIII.

Length of oestrus (hrs.)		0-8	0-16	8-24	16-32	24-40	32-48	40-56	48-66	56-72
Romneys	n	19	21	31	34	28	13	-	-	-
n = 146	%	13.0	14.4	21.2	23.3	19.2	8.9	-	-	-
Halfbreds	n	7	10	28	43	42	33	7	3	2
n = 175	%	4.0	5.7	16.0	24.6	24.0	18.9	4.0	1.7	1.1

Mean duration of oestrus* Romney
20.4 hrs.

Halfbred
28.0 hrs.

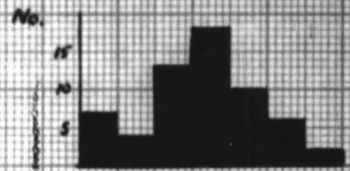
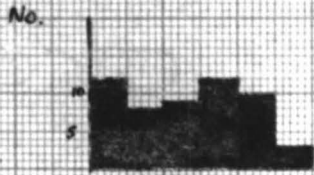
* calculated from original data.

DURATION OF OESTRUS - FREQUENCIES WITHIN BREEDS.

Fig. 3. The duration of oestrus.

ROMNEYS

HALFBREDS



First Cycle



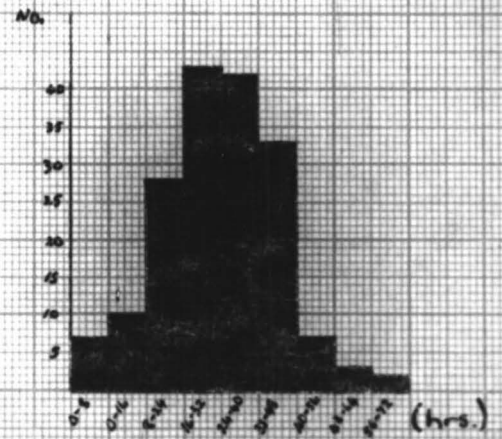
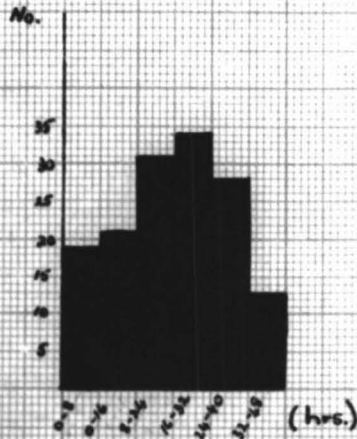
Second Cycle



Third Cycle



Fourth Cycle



All Cycles

TABLE XIV.

MEAN DURATIONS IN HOURS OF 321 OESTRUAL PERIODS.

No. of Cycles Experienced.	Breed	No. of ewes in class.	First Cycle	Second Cycle	Third Cycle	Fourth Cycle	Fifth Cycle
One	Romney	5	16.8				
	Halfbred	1	4.0				
Two	Romney	21	18.7	18.5			
	Halfbred	27	20.9	25.1			
Three	Romney	18	20.4	21.1	21.3		
	Halfbred	10	23.6	28.8	32.0		
Four	Romney	5	15.2	24.0	27.2	17.6	
	Halfbred	20	26.6	31.2	35.6	33.2	
Five	Romney	5	12.8	22.4	21.6	24.0	30.4
	Halfbred	2	10.0	24.0	28.0	32.0	28.0
MEAN	Romney		18.2	20.4	22.4	20.8	30.4
	Halfbred		22.6	28.2	34.0	33.1	28.0

In both breeds there was a tendency for oestrus to lengthen during the experimental period. Statistical analysis of the data from which Fig. 3 is derived shows that in the Halfbred this increase in the mean duration of oestrus is significant ($X^2 = 21.72$ for 9 d.f. ($p < .01$)), but in the Romneys did not even approach significance. If it is assumed that the experiment terminated before the middle of the breeding season, this result is in agreement with Grant (1934) and McKenzie & Terrill (1937) who found that the first oestrus of the breeding season tended to be shorter than succeeding periods, and noticed a tendency for the duration of oestrus to increase to a peak value in the middle of the breeding season and then to decline. Hammond Jr. (1944) from casual observation, also concluded that the duration of oestrus increased to a peak and then declined.

D. THE LENGTH OF THE OESTRUAL CYCLE.

Introduction.

The oestral cycle consists of a follicular phase during which there is follicle growth and maturation and which can be very variable in length, followed by a luteal phase which is generally more constant in length (Hammond Jr., 1944).

Data on cycle length in different breeds and localities have been tabulated by McKenzie & Terrill (1937) and Hafez (1952). Although some wide ranges are evident, the means show a remarkable constancy, varying between 15.5 and 17.5 days. Breed differences in the length of the cycle are reported by Cole & Miller (1935), Roux (1936), Briggs et al (1942), and Hafez (1952), but these have not been detected by other workers (McKenzie & Phillips, 1930; Grant, 1934; Clark, 1934; McKenzie & Terrill, 1937). The normal range of cycle lengths may be considered to be 14 to 19 days (McKenzie & Terrill, 1937). Cycles of greater length than 19 days may be considered to be due to ovarian dysfunction or may be multiples of the normal cycle due to the occurrence of silent heats (Roux, 1936). The duration of the oestral cycle in the New Zealand Romney has been observed by Dry (1933), Gill (1933), Walker (1943), Goot (1949) and Till (1950).

Method of Study.

The duration of the oestral cycle was regarded as being the interval between the earliest observations of two successive occurrences of oestrus of a ewe. No maximum and minimum durations were allowed for in determining the length of the cycle. Normal cycles were considered to be

those falling in the range 14 to 19 days (McKenzie & Terrill, 1937), and for the calculation of means cycles with lengths outside that range were excluded from the data.

Results and Discussion.

The distribution of the lengths of 207 oestral cycles are shown graphically in Fig. 4, and numerically in Table XV.

All of the Halfbred cycles fell within the "normal" limits of 14 to 19 days (McKenzie & Terrill) but only 89.0% of the Romney observations were within this range. This finding is not greatly at variance with that of Goot (1949) who found that 93% of Romney cycles fell within the normal range. Apart from these abnormal cycles, the Halfbreds showed less variability than the Romneys, with 80% of cycles in the range 16 to 18 compared with 53% in the case of the Romneys.

The mean lengths of all normal cycles are presented in Table XVI.

An analysis of variance showed that the difference between the breed means for all cycles was non-significant. These data do not demonstrate the gradual lengthening of the oestral cycle with succeeding cycles of the breeding \times season as shown by Hammond Jr. (1944), but the numbers of observations on the lengths of the third and fourth cycles are small.

McKenzie & Terrill (1937) believed that cycles shorter than normal might be due to early regression of the corpus luteum, and cycles of 3 to 6 days' and 19 to 23 days' duration might be due to the failure of ovulation and subsequent luteinization; this would be followed by a

Fig. 4. The length of the oestral cycle

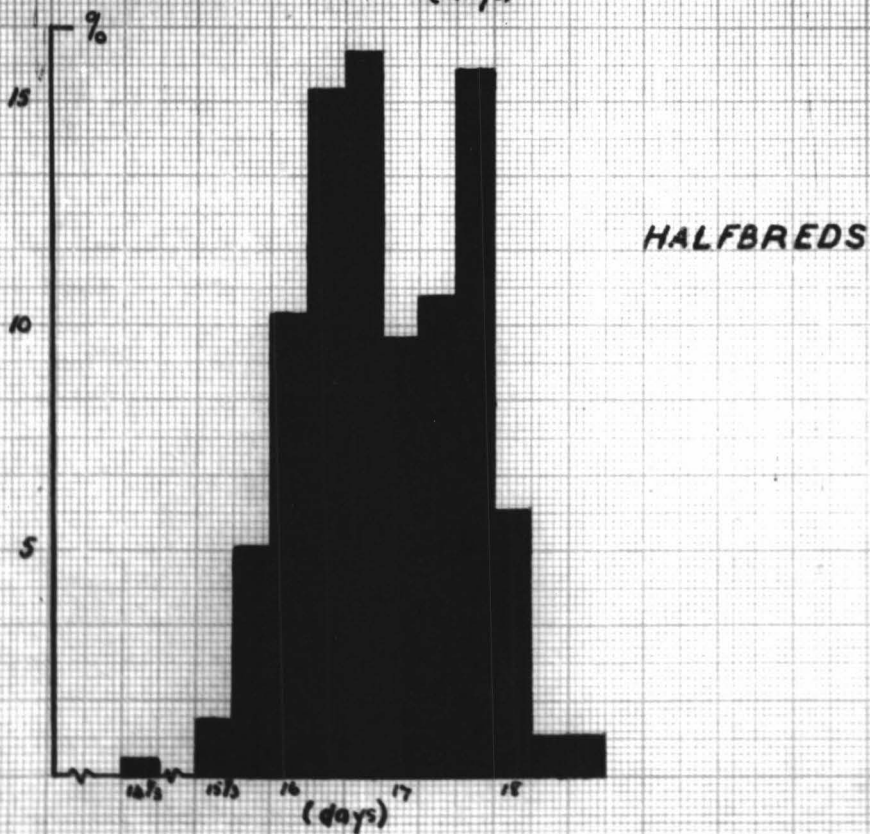
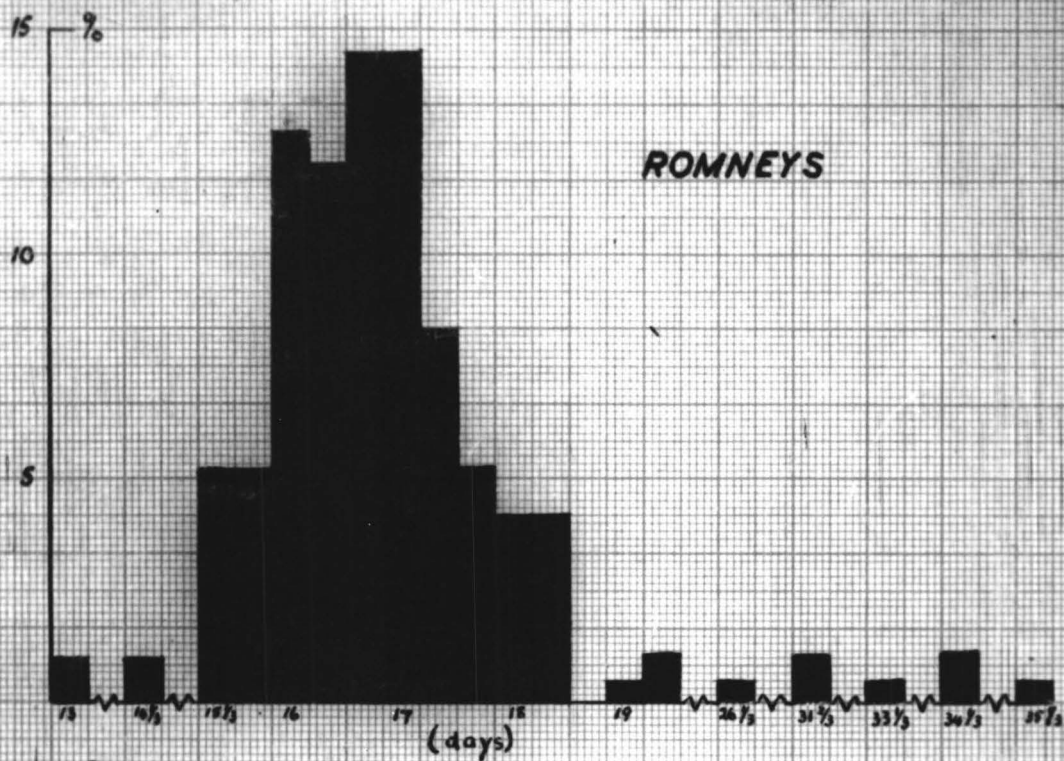


TABLE XV.

DURATION OF OESTRUAL CYCLE - FREQUENCIES WITH BREEDS.

ROMNEYS

Duration in days	13	14½	15½	15⅔	16	16½	16⅔	17	17½	17⅔	18	18½	19	19½	26½	31⅔	33½	34½	35½
n	1	1	5	5	12	11	13	13	8	5	4	4	1	2	1	2	1	2	1
%	1.1	1.1	5.4	5.4	13.0	13.0	14.1	14.1	8.7	5.4	4.4	4.4	1.1	2.2	1.1	2.2	1.1	2.2	1.1

HALFBREDS

Duration in days	14½	15½	15⅔	16	16½	16⅔	17	17½	17⅔	18	18½	18⅔	
n	1	3	6	12	18	20	11	13	19	8	2	2	
%	0.9	2.6	5.2	10.4	15.7	17.4	9.6	11.3	16.5	7.0	1.7	1.7	

TABLE XVI.

MEAN LENGTH OF OESTRUAL CYCLE.

Breed	First Cycle		Second Cycle		Third Cycle		Fourth Cycle		All Cycles	
	n	Mean length (days)	n	Mean length (days)	n	Mean length (days)	n	Mean length (days)	n	Mean length (days)
Romney	42	16.6	25	17.0	10	16.7	5	16.5	82	16.7
Halfbred	59	16.6	32	17.0	22	17.0	2	17.4	115	16.9

second ovulation which, if accompanied by heat, would result in a cycle of 3 to 6 days' duration and if not, by a cycle of 19 to 23 days' duration. Very long cycles might be caused by early death of the embryo (in the case of ewes which have been bred), undetected oestrus, or by the occurrence of a silent heat. In the case of silent heat, the lengths of long cycles would be multiples of normal cycles.

In these data, 6.5% of the Romney cycles ranged between 31.7 and 35.3 days in length, suggesting that they consisted of two abnormal cycles, probably separated by a silent heat. One cycle of 26.3 days occurred, which probably consisted of either two abnormal cycles, or an abnormal and a normal cycle, with a silent heat between them. Silent or weak heats have been shown to occur most frequently at the beginning and end of the breeding season by Grant (1933, 1934), Cole & Miller (1935) and McKenzie & Phillips (1930), and their occurrence during the breeding season has been inferred by several workers (notably Hafez, 1952). Goot (1949) concluded that in a New Zealand Romney Marsh stud the incidence of silent heats did not exceed 2% of all cycles. Hafez showed that the occurrence of silent heats is highest in the second half of the breeding season and is affected by breed, age and nutrition.

The relationship between the duration of oestrus and the length of the oestral cycle was investigated. The length of oestrus was correlated both with the length of the cycle of which it forms a part, and also with the length of the preceding oestral cycle. These correlation coefficients are shown in Table XVII.

TABLE XVII.

CORRELATION BETWEEN DURATION OF
OESTRUS AND THE LENGTH OF THE OESTRUAL CYCLE.

Correlation	Romney			Halfbred		
	No. of pairs	r	P	No. of pairs	r	P
Between length of oestrus and length of succeeding cycle.	82	0.046	> 0.05	115	0.244	< 0.05
Between length of oestrus and length of preceding cycle.	82	0.013	> 0.05	115	-0.017	> 0.05

No relationship was found between the lengths of oestrus and the oestral cycle in the Romneys, but in the Halfbreds, a small, but significant correlation was found between the length of oestrus and the length of the cycle of which it forms a part. This would appear to suggest that the luteal phase tends to be the more constant phase of the cycle, so that changes in the length of oestrus are reflected in changes in the length of the cycle. This hypothesis was tested by correlating the length of oestrus and the time interval between the end of that oestral period and the onset of the next one. These relationships are shown in Table XVIII.

TABLE XVIII.

CORRELATION BETWEEN THE
DURATION OF OESTRUS AND THE INTERVAL BEFORE A
FOLLOWING OESTRUAL PERIOD.

Breed	No. of pairs	r	P
Romneys	82	-0.392	< 0.01
Halfbreds	115	-0.367	< 0.01

In both breeds a significant, small order, negative correlation occurs, which suggests that the follicular and the luteal phase are not independent, long oestral periods tending to be followed by a shorter luteal phase. Grant (1934) and McKenzie & Terrill (1937) found no relationship between oestrus and the length of the oestral cycle, but obtained a negative correlation between the length of oestrus and the succeeding interval, which is similar to the result in this experiment.

III. GENERAL DISCUSSION.

During the breeding season of the ewe, the events of the oestral cycle are an overt expression of an ovarian rhythm which is controlled by gonadotrophin secretions from the anterior pituitary. Yeates (1949) showed that reduction in the length of daylight was the stimulus which initiated the breeding season, and Robinson (1951) postulated that there was an inverse relationship between the length of daylight and the level of pituitary secretion. He suggested that for each breed there was a threshold level of gonadotrophin secretion which, when attained, resulted in ovulation and the initiation of the breeding season.

In this investigation, Halfbred ewes were found not only to enter the breeding season significantly earlier than the Romneys, but also to have a more concentrated period of onset with all ewes experiencing oestrus within a period of six weeks. In contrast, the Romneys were much more protracted, with only 90% of the ewes entering the breeding season over a period of eleven weeks. This range of variation in the Romneys is unlikely to be due to genetic causes alone as it is not comparable with previous observations on the onset of the breeding season of two-tooth Romney ewes in the Manawatu district. Goot (1949) found from the records of a Romney stud, that over a period of seven years, on the average 92.6% of all two-tooths had entered the breeding season by April 21st, and the latest observed onset was May 12th. Similarly, Till (1950) found in a sample of 80 two-tooth Romneys that all ewes had experienced their first oestrus by April 15th.

The Romney ewes studied in this investigation were small in size, and had suffered from poor management during the hogget period, which is in contrast to the ewes studied by Goot and Till, which were in particularly good condition. The observations of Quinlan & Mare' (1931) and Roux (1936), that malnutrition can delay the onset of the breeding season, have already been noted and it is possible that the severe winter which the Romney ewes experienced resulted in a depression of pituitary activity with a subsequent retardation of the onset of the breeding season. Alternatively, the delay in onset may have been due to refractoriness of the ovaries as a result of a general stunting of growth, while the function of the pituitary was unimpaired.

The observations on the nature of the oestral cycle appear to indicate that there was a much more definite ovarian rhythm in the Halfbreds than in the Romneys. Although no significant difference was detected between the lengths of "normal" cycles in the two breeds, 11.0% of the Romney cycles, and none of the Halfbred cycles fell outside the range of 14 - 19 days. The possible explanations of these abnormal cycles have been discussed, and it appears that the Romney ewes were more prone to ovary dysfunctions such as failure of luteinization after ovulation and silent heats, than were the Halfbreds. Further evidence for a more marked ovarian rhythm in the Halfbreds was the fact that their oestral periods were longer and more intense, and it was suggested that oestrus was more abrupt in onset and cessation than in the Romneys.

When the observations on the breeding behaviour of the ewes studied in this experiment are considered in relation to the tupping period under normal farming conditions, certain factors become evident which would have implications on the fertility of the ewes at the subsequent lambing. Breeding behaviour in relation to fertility will be further discussed in Chapter V.

One obvious requirement for fertility is that the ewe must be mated. On hill-country farms in the Manawatu, the rams are usually joined with the ewes on about March 20th and withdrawn after a mating period of seven to eight weeks (Hewitt, 1953). In this experiment, even if the mating period had been extended to ten weeks, 10% of the Romney ewes, because they did not experience oestrus, would not have been mated, and an additional 10% which had only one oestral period would have had only one opportunity of conceiving. In addition, when considering the nature of oestrus, it was suggested that because oestrus is of shorter duration in the Romney than in the Halfbred, is of lower intensity, and has a more gradual onset and cessation, the ewes of this breed would be less likely to be served under practical conditions than the Halfbreds, especially where paddocks were large and the number of rams per hundred ewes was small.

IV. SUMMARY.

The breeding behaviour of a group of Romney and Halfbred ewes was observed during the first eleven weeks of the breeding season. The following results were obtained:

1. The mean dates of onset of the breeding season in the two breeds differed significantly, being earlier in the Halfbreds than in the Romneys. Six Romney ewes did not experience oestrus.
 2. The intensity of oestrus was observed and the patterns of intensity within an oestral period were found to differ significantly between the two breeds. Halfbreds were shown to have oestral periods of higher intensity, and it was concluded that the onset and close of oestrus was more abrupt in this breed.
 3. The mean duration of oestrus in Halfbred ewes was demonstrated to be significantly longer than in Romneys. In the Halfbreds, but not in the Romneys, there was a significant tendency for the duration of oestrus to increase with succeeding cycles.
 4. No significant difference was found between the lengths of the oestral cycles in the two breeds, but the lengths of 11% of the Romney cycles fell outside the normal range of 14 to 19 days.
 5. Correlations were calculated showing the relationship between the duration of oestrus and the length of the oestral cycle.
 6. It was concluded that during the breeding season, the ovarian rhythm of the Halfbreds was more accentuated than in the Romneys. The possible effects of these differences in breeding behaviour upon the fertility of the two breeds are discussed.
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C H A P T E R V.

A STUDY OF THE FERTILITY OF ROMNEY AND HALFBRED EWES.

I. INTRODUCTION.

Asdell (1946) has defined fertility as a qualitative term denoting ability to produce young, the quantitative equivalent being fecundity, which denotes the number of young produced per individual. As Goot (1951) remarks, little distinction is made between the two concepts in the literature, in the main, probably because of the difficulty in procuring suitable information which would make their separation possible. Goot discusses the most common methods used for estimating fertility in sheep and suggests seven indices for its calculation. All of these methods assess fertility at lambing or at a subsequent stage. In this study, however, fertility must be assessed before lambing and the final index is expressed as a "maximum potential lambing percentage".

In this chapter the fertility of a sample of Romney and Halfbred two-tooth ewes will be discussed in relation to three phases of the reproductive process:

- A. The number of ova shed.
- B. The conception rate.
- C. The maximum potential lambing percentage.

II. THE EXPERIMENTAL ANIMALS - THEIR MATING AND SLAUGHTER.

The study on fertility was conducted on the 30 Romney and 30 Halfbred ewes comprising Group A, the selection of

which has already been discussed. These ewes were identified by a distinguishing brand and at their second oestral period were mated to fertile rams. However, by May 22nd only 19 Romney ewes had been bred, and to ensure that a sufficient sample of Romney ewes would be available for study, all Romneys coming on heat after that date were mated, so that by May 30th a group of 12 Romney ewes additional to those in Group A had been bred. These ewes may be regarded as a random sample of the Romneys which came on heat during the experimental period, since no selection was practised. They do not constitute a random sample of all the Romney ewes however, since some of these did not experience oestrus while under study.

Ewes were mated at their second oestrus, and the mating procedure was designed to ensure that ewes were given maximum opportunity for conception. They were hand-served* by a different ram at each observation period at which they were on heat and at the first observation period after heat had terminated. Since ewes with heat periods recorded as less than eight hours in duration were not on heat at any observation period, the last mating was made standard procedure so that the time of the last mating was the same for all ewes. Ewes which did not conceive were served again at the following oestrus.

* The ewe was restrained in a small service crate, a narrow strap was held across the anus, and the penis of the ram was directed into the vagina by the attendant.

The beginning of pregnancy was regarded as the last day on which a ewe was on heat (Winters and Feuffel, 1935) and it was the intention to slaughter ewes in groups when between 35 and 45 days pregnant. Thirty-five days was selected as the earliest stage of pregnancy at which to slaughter because it allowed a period corresponding to two oestral cycles for ewes to return to service, and also because after this stage, the main changes in the foetus are those of growth (Green and Winters, 1945). It was not always possible to arrange killing dates so that this ideal was realised, and in practice the lengths of pregnancy of the ewes at slaughter ranged between 33 and 37 days. Ewe 462 was accidentally mated and was killed when 81 days pregnant.

Ewes to be slaughtered were starved for a minimum of 15 hours and were then killed and dressed in the College slaughter-house. The following organs were removed:

Pituitary - this was removed as soon as possible after slaughter. A transverse cut was made in the head just behind the poll and the gland was dissected out. It was freed from its vascular membranes, weighed, quickly transferred to a small labelled bottle filled with cold acetone, and held in a chiller. When the morning's killing had been completed, all pituitaries were placed in a refrigerator at below 0°C.

Thyroid - this was dissected out from the neck as soon as the skin had been cleared from the throat - it was carefully trimmed and weighed.

Genital tract - the abdomen was opened as for normal evisceration and a label was attached to the left

Fallopian tube. The tract was then removed and wrapped in a wet towel until dissection could be undertaken.

Liver - removed from all attachments and weighed.

Spleen - separated from connective tissue and weighed.

Heart - trimmed free of blood vessels, emptied of clotted blood and weighed.

Lungs - the trachea was removed at the junction of the bronchi - trimmed free of connective tissue and weighed.

A fuller description of the dissection of the genital tract will be given in Chapter IV. The ovaries were removed, weighed and placed in labelled bottles containing 5% formalin. They were not examined in the fresh state because the structure is then soft and the Graafian follicles collapse on sectioning, but after preservation in formalin, the ovary becomes much more rigid. The ovaries of slaughtered ewes which did not breed during the experimental period were sent to the Diagnostic Section of Wallaceville Animal Research Station for examination, and a full report on them is appended. All other ovaries were serially sectioned into slices about 1 mm. in thickness and the number of corpora lutea, and follicles with a maximum diameter greater than 4 mm., was recorded.

The uteri of the ewes were opened, the number and the position of foetuses present noted, and the condition of the membranes and endometrium described where abnormal.

A. THE NUMBER OF OVA SHED.Introduction.

Hammond (1921) stated that the limiting factor determining the fertility of the ewe is the number of ova shed at any one heat period. That this is not determined by the number of oocysts present in the ovary has been shown by Asdell (1924) who found that the removal of one ovary did not affect the ovulation rate. The number of large follicles present in the ovary may be an indication of fertility however. Kappeli (1908), for example, found that ovaries of the highly fertile domestic sow had more follicles larger than 3 mm. in diameter than the ovaries of the lowly fertile, wild sow. The size of the follicle has also been used as an index of sexual development by Phillips, McKenzie, Christensen, Richards & Petterson (1945), and as an index of the effect of injected gonadotrophins by Robinson (1950).

That the number of follicles which ripen at any one oestrus is controlled by the gonadotrophic principle of the anterior pituitary was first shown by Smith and Engle (1927). Much research work has been directed towards the augmentation of fertility of ewes by the injection of gonadotrophins, notably follicle stimulating hormone (F.S.H.), and this has recently been reviewed by Robinson (1951b). From these investigations have come two conclusions which are probably of fundamental significance in the determination of the number of ova shed. Firstly, there is a dose-response relationship to injected F.S.H. (Robinson, 1951a), which suggests that the effect of F.S.H.

is a quantitative one. Secondly, there is evidence that there are breed differences in the response to injected F.S.H. (Robinson, 1950; Wallace, 1952). Breed differences in ovulation rate may therefore be caused by the secretion of gonadotrophins at different levels as a result of differences in pituitary activity, by differences in the sensitivity of the ovaries to similar blood-levels of gonadotrophin, or by a combination of these two factors.

Breed differences in ovulation rate have been mainly inferred from lambing percentages. A wide range of data of this nature has been presented by Asdell (1946). Precise estimated of ovulation rates based on the examination of ovaries of ewes have been obtained by Marshall (1904), Hammond (1921), Clark (1934), McKenzie & Terrill (1937), Hammond Jr. (1944) and Robinson (1950, 1951a).

Nutrition has been shown to exert a marked effect on the ovulation rate, and hence careful standardization of the nutritional environments in which the breeds under consideration are studied is essential when investigating breed differences in this phase of reproduction. That flushing, in the form of an increased plane of nutrition prior to mating, could increase the lambing percentage has been observed by Heape (1899), Marshall (1905) and Nichols (1924, 1926a) and that this increase in the lamb crop was due to an increased proportion of twins was demonstrated by Marshall & Potts (1924), Underwood & Shier (1941) and Wallace (1951). Direct evidence that flushing produced an increase in the ovulation rate was presented by Clark (1924). The effect of winter feeding on the subsequent fertility of ewe lambs has

been demonstrated by Esplin, Madsen & Phillips (1940), and that the higher fertility of the lambs which were better fed was associated with a greater number of well developed Graafian follicles was shown by Phillips et al (1945).

Method of Study.

In this study the ovulation rate has been calculated from the number of corpora lutea vera in the ovaries of pregnant ewes. The formation of the corpus luteum in the ruptured Graafian follicle has been described by Quinlan & Mare (1931), Casida & McKenzie (1932), McKenzie & Terrill (1937). The number of corpora was determined by serially sectioning the ovary. Macroscopic examination only was carried out, although Winters & Feuffell (1936) report four cases of fusion of corpora which could be recognized only microscopically.

Results and Discussion.

Twenty-six Romney and 30 Halfbred ewes were found to be pregnant at slaughter. Unfortunately, in removing the genital tracts at slaughter, one ovary from a Halfbred ewe (96) was lost, and one ovary from a Romney ewe (415) was accidentally destroyed prior to sectioning.

(i) The weight of the ovaries.

Data are presented on the fresh weights of the ovaries of 29 Halfbred and 25 Romney ewes.* Since, as shown by Robinson (1950) there is a correlation between ovarian weight and the number of corpora lutea, the weights of ovaries should be classified according to the number of corpora lutea present.

TABLE XIX.

MEAN WEIGHTS OF 108 OVARIES FROM ROMNEY
AND HALFBRED PREGNANT EWES.

Breed	Corpus absent		One corpus present		Two corpora present	
	n	Mean Wt. (g.)	n	Mean Wt. (g.)	n	Mean Wt. (g.)
Romney	25	0.62	25	1.54	0	-
Halfbred	26	0.70	22	1.50	10	2.02

None of these differences between mean weights of ovaries was significant, suggesting that there is no difference in the size of the ovaries in pregnant ewes of the two breeds.

* The ovary weights of ewe 462 have been excluded, since the right ovary was definitely abnormal. A report on this ovary from the Wallaceville Animal Research Station states:

462 Right ovary 3.1 g. A few very small follicles, but the tissue is mainly grey-brown mottled material showing fibrosis, calcification and pigment, all probably the effect of long standing haemorrhage.

(ii) The ovulation rate.

On the assumption that each corpus luteum corresponds to an ovum shed at the oestrus at which the ewe conceived, the mean ovulation rate can be calculated for the two breeds.

TABLE XX.

MEAN OVULATION RATE IN 25 ROMNEY AND
29 HALFBRED PREGNANT EWES.

Breed	No. of ewes	Total no. of corpora lutea	Mean ovulation rate
Romney	25	25	1.00
Halfbred	29	42	1.45

Statistical analysis of the frequency distributions in Table XX, shows that this mean difference of 0.45 ovulations per ewe between the breeds is highly significant ($X^2 = 13.32$ for 1 d.f.) showing that in this sample, the maximum potential fertility of the Halfbreds is higher than that of the Romneys, since the number of ova shed at a heat period constitutes an upper limit to fertility.

(iii) The development of Graafian follicles.

The use of follicle size as an index of ovaria development and fertility has already been discussed. The following table shows the total number of follicles greater than 4 mm. in diameter found in the ovaries of the pregnant ewes slaughtered.

TABLE XXI.

TOTAL NUMBER OF GRAAFIAN FOLLICLES LARGER THAN
4 MM. DIAMETER IN OVARIES OF PREGNANT
ROMNEY AND HALFBRED EWES.

Breed	No. of ewes.	No. of follicles > 4 mm. diameter.	Mean no. of follicles
Romney	24	33	1.38
Halfbred	29	73	2.52

breed

This difference between/means was found to be statistically significant ($X^2 = 8.38$ for 3 d.f. ($p < .05$)) but an interpretation of its biological significance is difficult, since the minimum size of follicle was arbitrarily chosen as being the minimum size which could accurately be measured and counted. Grant (1934) states that during successive inter-oestral periods the follicles grow slowly up to a diameter of 5 - 7 mm., and at oestrus, the largest follicle will grow rapidly and rupture. This picture may be complicated by follicular atresia which is undetectable macroscopically. The diameter of the mature follicle at ovulation has been given as approximately one centimetre by Grant (1934), Cole and Miller (1935), and Roux (1936). During pregnancy the ovary, with the exception of the corpus luteum, undergoes atrophy, but large follicles will persist until about six weeks after service (Grant, 1934). The follicles measured in this study will therefore be those which were well advanced at service and will correspond to the follicles measured in the ovaries of non-pregnant ewes by McKenzie et al (1945).

It is suggested that breed differences in the numbers of large follicles found in this investigation are an index of ovarian development and will be reflected in breed differences in ovulation rate.

(iv) The weights of the pituitary gland.

It was suggested in the introduction to this section that breed differences in the number of ova shed may be determined by differences in either the level of F.S.H. secreted by the anterior pituitary, or by the sensitivity of the ovaries of different breeds to similar levels of F.S.H. secretion. Turner (1952) suggested that breed differences in the level of anterior pituitary secretion might be reflected in breed differences in the weight of the pituitary, and at his suggestion the pituitaries of the ewes slaughtered in this experiment were removed and weighed.

The pituitaries were weighed on a triple-beam balance after dissection, the weights being recorded to the nearest 0.1 gm. However, these weights were not considered to be sufficiently accurate, and for analysis, the weights of the pituitaries after vacuum dessication were employed. Three changes were made of the acetone in which the pituitaries were stored, and the glands were then vacuum dessicated and quickly weighed on an accurate aperiodic balance. Unfortunately, five sample deteriorated due to the leakage of acetone from containers during storage.

TABLE XXII.

MEAN WEIGHTS OF THE VACUUM DESSICATED
PITUITARIES OF 23 ROMNEY AND
26 HALFBRED EWES.

Breed	No. of ewes.	Mean Weight of Dry Pituitary.
Romney	23	0.120
Halfbred	26	0.129

The difference between the means of the two breeds was not statistically significant ($F = 2.45$ for 47 d.f.). There remains the possibility that differences exist between breeds in the gonadotrophin potency of the pituitary. The glands are in deep-freeze storage, and their gonadotrophin potency will be assayed.

B. THE CONCEPTION RATE.

Introduction.

The conception rate is an important practical index which measures the facility with which ewes become pregnant.

In normal farming practice the tuppings season is restricted, with the aim of having a concentrated lambing in the spring. Ewes therefore have a limited number of opportunities of conception, and especially where ewes are late in entering the breeding season, a low conception rate will mean a large number of barren ewes.

Results and Discussion.

The conception rate may be expressed either as the percentage of ewes conceiving at successive services (Quinlan & Maré, 1931) or as the mean number of tuppings

during the season, per ewe which becomes pregnant (Goot, 1949).

In this study the conception rate has a limited significance since it was possible to mate the ewes a maximum of only two times during the experimental period, and also because 12 Romney ewes were mated for the first time in the last week of the experiment.

TABLE XXIII.

CONCEPTION RATES AT THE FIRST AND SECOND SERVICES
OF ROMNEY AND HALFBRED EWES.

Breed	First Service			Second Service		
	No. of ewes mated	No. con-ceiving.	% con-ceiving	No. of ewes mated	No. con-ceiving	% con-ceiving
Romney	36	23	63.9	5	3	60.0
Halfbred	30	28	93.3	2	2	100

The difference between breeds in conception rate was not statistically significant ($X^2 = 1.26$ for 1 d.f. ($p < 0.3$)). All the Halfbred ewes conceived during the experimental period. Of the 30 Romney ewes in Group A, six were not mated and six did not conceive. Their breeding histories are presented in Table XXIV. The histories of the ewes have been grouped into five classes, in which they may be conveniently discussed.

TABLE XXIV.

BREEDING HISTORIES OF 12 BARREN ROMNEY EWES
OF GROUP A.

Class	Ewe No.	Date of last oestrus	Date(s) mated	Date of slaughter
a	463	No observed oestrus		13.vi.
	491	" "	" "	" "
	499	" "	" "	" "
	529	" "	" "	" "
b	554	17.iv.	-	"
	577	5.v.	-	"
c	417	15.v.	27.iv; 15.v.	24.vi.
d	470	25.v.	25.v.	3.vii.
	476	25.v.	25.v.	3.vii.
	481	17.v.	17.v.	24.vi.
e	513	4.v.	4.v.	13.vi.
	425	7.v.	7.v.	13.vi.

None of the ewes in classes (a) and (b) was mated, those in class (a) not having any observed oestral activity and those in class (b) experiencing only one period of oestrus. The ovaries of all these ewes except ewe 577 were sent to Wallaceville Animal Research Station for examination. The following is an account of the morbid anatomy and histology of these ovaries.

463. Left ovary 0.5 gms. Six developing Graafian follicles, a few small atretic follicles. Right ovary 1.5 gms. One large corpus luteum and one small follicle.
491. Left ovary 0.9 gms. Two large corpora lutea, two developing Graafian follicles and two atretic Graafian follicles.

Right ovary 0.5 gms. Eight small developing Graafian follicles.

499. Left ovary 0.5 gms. Four small Graafian follicles, ? one with luteal tissue invasion. Numerous scars (? c. albica).

Right ovary 0.7 gms. Six small Graafian follicles.

529. Left ovary 0.5 gms. One small Graafian follicle and one large corpus albicans. A highly vascular area also evident.

Right ovary - missing.

554. Left ovary - five small Graafian follicles seen.

Right ovary. One large Graafian follicle (thin-walled) and one large, thick-walled, cystic corpus luteum.

- *577. Left ovary. One corpus luteum.

Right ovary. One large Graafian follicle.

* Macroscopic examination at Massey College by the writer.

The report shows that all ewes in class (a), with the possible exception of 499, had ovulations before slaughter. Since they were slaughtered 13 days after observations on the periodicity of oestrus were concluded, these must have occurred either as true heats during the 13-day period, or as silent heats during the observation period.

Of the ewes in class (b), 554 was prevented from showing further oestrus by the presence of a persistent cystic corpus luteum and 577 at slaughter, showed evidence of a recent ovulation.

Ewe 417 failed to conceive because of an anatomical defect of the genital tract, and among the animals mated and slaughtered from Group B, ewe 555, which did not conceive, was found to have a somewhat similar condition.

These conditions have been described in the report from Wallaceville. Photographs of the genitalia are shown in Plates (i) and (ii).

417. Left ovary showed no marked activity.

Right ovary contains one large cystic corpus luteum and one large Graafian follicle.

The left Fallopian tube terminates about half-way along the edge of the broad ligament without terminal dilation and the lumen appears normal.

The right Fallopian tube is normal.

The left horn of the uterus is absent but the right horn, body and cervix appear normal.

The vagina is distended with glairy mucus and ends blindly as there is no continuity with the vestibule and a septum of thick tissue at the level of the hymen separates the two cavities.

555. Left ovary - one large corpus luteum.

Right ovary - six small Graafian follicles and a few small atretic follicles.

Left Fallopian tube and horn of the uterus are normal, but the right Fallopian tube ends in a small cystic dilation lined with columnar epithelium and there is no evidence of fusion with the right horn of the uterus. The horns and body of the uterus, and the cervix, appear normal.

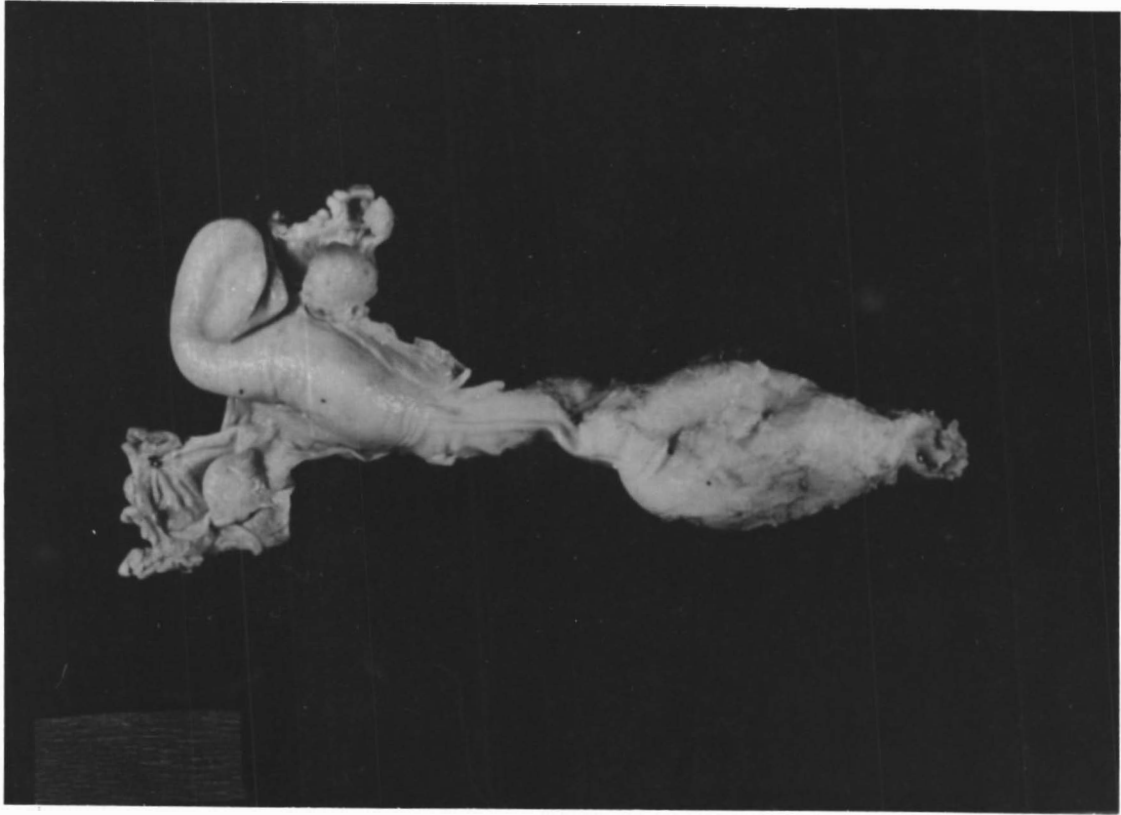


PLATE (i)
Genital Tract of
Ewe 417

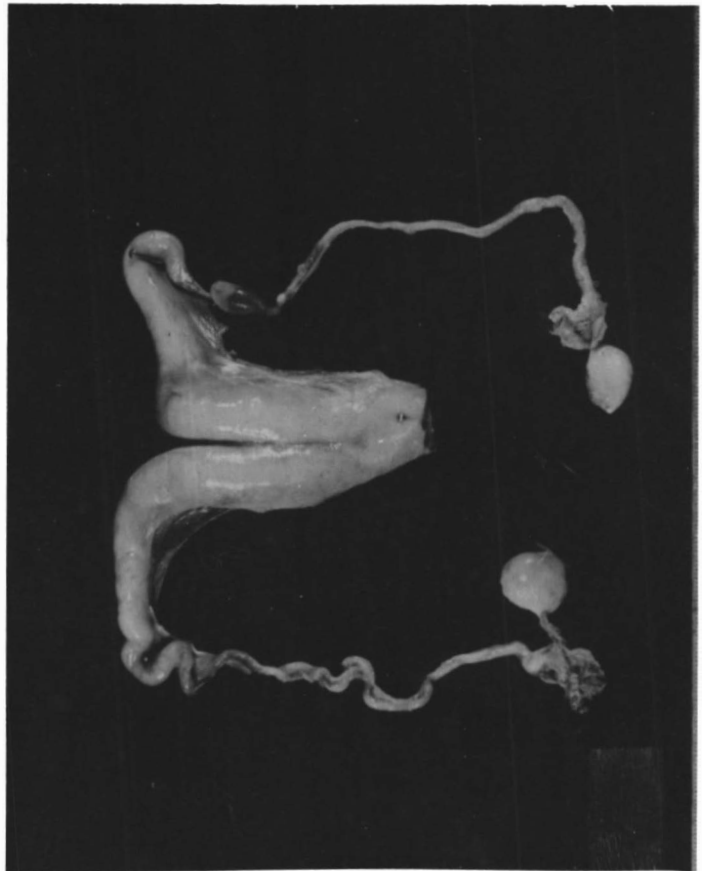


PLATE (ii)
Genital Tract of Ewe 555

The ewes 470, 476 and 481 grouped into class (a) all had ovaries and reproductive tracts which appeared normal. Because observations on the periodicity of oestrus ceased a week after they were mated, it is not known whether there was any disturbed cyclic activity. The following is a description of the ovaries from a macroscopic examination by the writer.

470. Left ovary - weight 1.2 gm. - one corpus albicans and one large follicle - normal.
Right ovary - weight 0.6 gm. - one large follicle - normal.
476. Left ovary - weight 0.7 gm. - one small corpus luteum.
Right ovary - weight 0.8 gm. - one very small corpus (albicans?).
481. Left ovary - weight 0.8 gm. - one small corpus luteum (albicans?).
Right ovary - weight 1.1 gm. - one corpus luteum and one large follicle.

Ewes 513 and 425 have been grouped separately in class (e) because they showed no recurrence of oestrus during the 23 days they were observed following service. This interval is greater than the maximum length of the normal oestral cycle (19 days). The following is a description of the macroscopic appearance of the ovaries, made by the writer.

513. Left ovary - weight 0.9 gm. - normal.
Right ovary - weight 1.3 gm. - one small cystic corpus luteum (ca. 3 mm. diameter) - ovarian tissue extremely fibrous.

425. Left ovary - weight 1.6 gm. - one large corpus luteum with an antrum ca. 4mm. in diameter - ovary normal.

Right ovary - weight 0.8 gm. - one large follicle - ovary normal.

The right ovary of ewe 513 was definitely abnormal because of the presence of a cystic corpus luteum which would prevent the recurrence of heat. However, the left ovary of ewe 425 may have been normal, since the presence of an antrum in a corpus is not necessarily pathological (Quinlan & Maré, 1931). The failure of ewe 425 to exhibit oestrus again after service may therefore be due either to conception followed by early degeneration of the fertilized ovum, or to the occurrence of a silent heat.

If it can be agreed that the mating system employed in this experiment largely eliminated the effects of the fertility of the ram upon conception and faulty timing between ovulation and copulation, the results of post-mortem examination of the 12 Romney ewes of Group A indicate four main causes of barrenness.

- (a) The failure of ewes to enter the breeding season during the mating period. (Four cases.)
- (b) Pathological conditions of the ovary which interfere with normal activity. (Four cases)
- (c) Anatomical defects of the genitalia which preclude conception. (One case)
- (d) Failure of fertilization or implantation. This may be due to pure chance, or to some hormonal imbalance. (Three cases)

Kelly (1937) found that failure to conceive was frequently associated with three different sets of circumstances: (a) those associated with absent, weak or irregular oestrus, (b) those probably associated with an irregularity subsequent to normal oestrus and prior to the proper time for conception, and (c) those resulting in early abortion, or resorption of the embryo. He inferred the last cause from abnormal dioestral cycles following mating. These causes of barrenness in Merino ewes appear to be similar to those found for Romneys in this experiment.

C. THE MAXIMUM POTENTIAL LAMBING PERCENTAGE.

Introduction.

As discussed by Goot (1951), there are several different methods of calculating a lambing percentage, but the one most commonly used indicates the number of lambs docked (that is reaching 1 - 4 weeks of age) per hundred ewes put to the ram. Such an index is of considerable practical importance because it is a net figure of productivity, excluding losses from conception to birth and neo-natal mortality.

In this study, the ewes were killed before pregnancy had proceeded beyond 45 days. The index derived will therefore approximate to that cited by Goot (1951) which measures the number of lambs born per hundred ewes put to the ram. Hammond (1921) has stated that losses due to foetal degeneration are normally small in sheep, and it has been shown by Robinson (1951a) that the peak mortality of fertilized ova occurs between the fifteenth and seventeenth day of pregnancy. Thus by the thirty-third day of

pregnancy, the earliest stage at which the ewes were slaughtered, it may be assumed that the foetuses found had survived the critical period for loss, and would survive to full term. In such a study as this, it must be assumed that the major causes of late foetal mortality, such as environmental conditions and disease, will affect each breed similarly.

Results and Discussion.

Lambing percentage is calculated on the basis of the number of ewes put to the ram, so that the only unbiased estimate of the lambing percentage in this study will be that calculated from Group A which consisted of a random selection of 30 ewes from each breed. Inclusion of data from the 12 Romney ewes belonging to Group B mated in the last week of the experiment would introduce a bias, since all these ewes showed ovarian activity before they were mated, whereas in the total sample of Romney ewes studied, six ewes did not show ovarian activity during the experimental period.

TABLE XXV.

THE MAXIMUM POTENTIAL LAMBING PERCENTAGE OF THE
ROMNEY AND HALFBRED EWES IN GROUP A.

Breed	No. of ewes exposed to breeding.	No. of ewes not pregnant.	Total no. of foetuses.	Mean no. of foetuses per pregnant ewe.	Maximum potential lambing percentage.
Romney	30	12	18	1.00	60.0
Halfbred	30	0	37	1.23	123.3

The difference between the breeds in lambing percentage is highly significant ($\chi^2 = 6.56$ for 1 d.f. ($p < .01$)). Halfbreeds are shown to have a higher fertility than the Romneys as demonstrated by the difference in the number of ewes not pregnant, and also a high fecundity as evinced by the difference in the mean number of fetuses per pregnant ewe.

III. GENERAL DISCUSSION.

For convenience, some indices are presented in Table XXVI which permit ready comparison of the magnitude of the differences between the phases of reproduction in which the two breeds were found to differ significantly.

TABLE XXVI.

SUMMARY OF INDICES OF FERTILITY.

Breed	Indices based on pregnant ewes only.			Indices based on ewes of Group A.	
	Mean no. of follicles > 4 mm. diameter	Mean ovulation rate.	Mean no. of foetuses.	% of ewes non-pregnant	Maximum potential lambing %
Romney	1.38	1.00	1.00	40%	60.0%
Halfbred	2.52	1.45	1.23	0%	123.3%

In this investigation the Halfbred has significantly surpassed the Romney in maximum potential lambing percentage, the closest approach to a practical index of fertility which could be obtained in this experiment. The figures presented show that nearly two-thirds of the difference between the two breeds can be accounted for by barrenness in the Romney ewes. The remaining third of the difference is due to the incidence of multiple foetuses in the Halfbreds. Obviously, one of the first steps which should be taken in analyzing the fundamental reasons for the low lambing percentage of the Romneys is a consideration of the factors which caused the high incidence of barrenness.

In the first place, eight of the 12 barren Romney ewes in Group A failed to be mated because of absent or irregular oestrus. Their infertility is due to a breakdown in one of the early links in the chain of events which leads to full fertility. The possible causes of their failure to breed have been discussed in Chapter V.

In the second place, in the other four ewes of Group A there was failure at a later phase of the reproductive process, that of fertilization and implantation. In one of these ewes infertility was permanent as a result of an anatomical defect of the genitalia. It is impossible to assess the importance of such causes of permanent infertility in the Romney breed from the small sample studied in this investigation, but it would be desirable to make a survey of the incidence of such abnormalities from slaughter-house material. Three of the Romney ewes of Group A were barren although their breeding behaviour was normal and their ovaries and genitalia on examination were found to show no evidence of any pathological condition. The possibility that their failure to breed was due to mating with an infertile ram, or to faulty synchronization between mating and ovulation cannot be completely excluded, but the risk of such factors having an effect was reduced to a minimum by the mating system employed. If these possible causes of infertility are disregarded, the failure of the ewes to conceive must have been due either to failure of the ova to be fertilized, or the failure of implantation of the fertilized ovum. Reference to Table XXVI shows that a

similar situation occurred in the Halfbreds since there is a discrepancy of 0.22 ova per ewe in the number of ova shed and the number of foetuses present. The fact that no traces of degenerated or resorbed foetuses were found suggests that this discrepancy is due to the failure of fertilization or implantation of ova.

The data in Table XXVI would appear to suggest, because of the agreement of the number of ova shed with the number of foetuses present, that the ova of the Romneys are more fertilizable than those of the Halfbreds, or alternatively, that the uterine environment of the Romney is more favourable for attachment. This apparent superiority is almost certainly a delusion however, since because of the low ovulation rate in the Romneys, the failure of one egg to become fertilized or implanted will mean the failure of the ewe to conceive, whereas in the Halfbreds with their higher ovulation rate, this may result in only partial loss before attachment. Indeed, when the conception rate of all the Romney ewes actually mated is contrasted with that of the Halfbreds, although the two indices did not differ significantly, it appears that Halfbreds are more effective in this phase of reproduction than the Romneys.

In the section of this chapter dealing with the conception rate, it was stated that the failure of fertilization and implantation might be due to hormonal imbalance. Although this possibility could not be investigated in this study, it is worthwhile considering the effects of an upset in the normal endocrine relationships on the normal phases of the reproductive process. The possible causes of failure are (after Robinson, 1951):

- (a) Some ova might be unfertilizable due to the stage of maturity at which they were ovulated.
- (b) The environment of the genital tract might be unfavourable for sperm motility.
- (c) Accelerated transport of ova through the Fallopian tubes might reduce the chances of the ova remaining in contact with sperms in an environment suitable for fertilization.
- (d) The tubal environment might not be optimal for fertilization.
- (e) The endometrium might not be in the optimum condition for nidation of the fertilized ova.

Any one of these abnormal conditions may cause barrenness, but their enumeration is of no significance in this experiment where the presence of a hormonal imbalance is inferred from its effect, and not from any study of its mechanism.

The difference between the breeds in ovulation rate was highly significant, demonstrating that the potential fecundity of the Halfbreeds exceeds that of the Romneys, since the number of ova shed at a heat period constitutes the upper limit to the number of foetuses which can be carried. As already discussed, the ovulation rate is very sensitive to the effects of nutrition and it is necessary to consider whether this difference between the ovulation rates was a breed difference alone, or whether it was due wholly or in part, to differences in the nutritional history of the animals. Such nutritional differences might have occurred either in the short-term, resulting

in a flushing effect, or in the long-term, resulting in differences in the growth and development of the animals.

Since the ewes of both breeds experienced the change from their home pastures to the experimental area at the same time, the duration of flushing, if it occurred would be similar for both breeds, although the stimulus of flushing need not be similar if there was an interaction between the breeds and the plane of nutrition. As a criterion of flushing, Friedman & Turner (1939) state that the flushed ewes must show a significant gain in weight. In this experiment however, as shown in Tables I and II, there was no significant change in the mean liveweights of the ewes of either breed during the experimental period, which suggests that the change of pastures which occurred at the commencement of the experiment did not have a flushing effect on the ewes.

The effect of the nutritional history of the ewes is likely to be of importance however, since, as shown by Esplin, Madsen & Phillips (1940) and Phillips et al (1945), the feeding of lambs during their first winter can have a marked effect on their subsequent fertility. The results obtained by the latter group of workers showed that these differences are also manifested in the development of the ovaries as measured by follicle size and number, and in the length development of the genital tract.

In the description of the experimental animals (Chapter III) and in the discussion of Chapter IV, emphasis was placed on the fact that the Romney ewes suffered a particularly severe winter in their first year. Unfortunately there is no way of evaluating the differences between the nutritional regimes

to which the ewes of the two breeds were subjected during the hogget stage, but support for the opinion that the Romneys were under-developed is afforded by the fact that there was a significant difference between the live-weights of the Romneys and Halfbreds at the commencement of the experiment, and also by the fact that in the flock from which the Romneys were drawn, no two-tooth ewes were considered to be sufficiently well grown to put to the ram in 1952. On the other hand, the Halfbreds were wintered on very similar country, and even allowing for the better management which they received, the differences in the size of ewes of the two breeds may be more a consequence of the greater thrift of the Halfbreds than of the inferior management of the Romneys.

That the follicular development of the ovaries may be used as an index of the potential ovulation rate as suggested by Phillips et al (1945), was confirmed in this experiment since, as shown in Table XXVI, the significantly greater mean number of follicles over 4 mm. in diameter in the Halfbreds was accompanied by a significantly greater ovulation rate.

IV. SUMMARY.

Certain aspects of reproduction were investigated in a group of Romney and Halfbred ewes. The ewes which experienced oestrus were mated to fertile rams and all the ewes in this group were subsequently slaughtered. The following results were obtained:

1. No significant difference was found between the mean weights of the ovaries of the two breeds.
 2. The ovulation rate was significantly higher in the Halfbreds than in the Romneys.
 3. The mean number of follicles of diameter greater than 4 mm. was significantly higher in the Halfbreds than in the Romneys.
 4. No significant difference was found between the weights of the dried pituitaries of Romneys and Halfbreds.
 5. The conception rate of Halfbreds was found to be higher than that of Romneys, but this difference was not statistically significant.
 6. All the Halfbreds, but only a proportion of the Romneys were found to be pregnant when slaughtered. The causes of barrenness in Romney ewes are discussed.
 7. The maximum potential lambing percentage was calculated and this was found to be significantly higher in the Halfbreds than in the Romneys.
 8. The possible causes of the differences in fertility between the two breeds are discussed.
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CHAPTER VI.

STUDIES ON THE GENITAL TRACTS OF SLAUGHTERED EWES.

I. INTRODUCTION.

Ewes were slaughtered primarily for the purpose of examining their ovaries, and determining the number of fetuses present. However, by making measurements on the dissected genital tract, it was possible to gain additional information on some aspects of genital development. Observations were also made on the crown-rump measurements of the fetuses.

II. METHOD.

The slaughtering procedure and the removal of the genital tract have been described in Chapter V. Specimens were wrapped in damp towels after removal, and a complete dissection was undertaken in the laboratory.

The ovaries were removed, weighed and preserved, and the reproductive tract was then straightened by dissecting off the mesenteries and suspensory ligaments along the lateral margins.

Because it was found that the vagina was stretched during removal at slaughter, this structure was removed. Measurements were made on the completed dissection, which was Y-shaped. Since there are few anatomical landmarks which can be accurately located on different specimens, and used as reference points, only three measurements of the genital tract were taken.

Location of reference points.

Cervix - the posterior tip of the ventral cervical fold. (Point A.)

End of uterine horn - this point is difficult to define. According to Sisson "There is no demarcation between the uterine tube and the horns of the uterus The horns are four or five inches (ca.10-12 cm.) long and taper in such a manner in their junction with the uterine tubes, that no clear distinction between the two exists." Nevertheless, both Phillips et al (1945) and Cloete (1939) measured the Fallopian tube, but in neither case is the exact reference point given. Before commencing this study, a preliminary survey was made of a number of reproductive tracts obtained from a local freezing works, and a landmark identified which proved to be easily located in all the specimens subsequently examined. The Fallopian tube was considered to commence at a point where there was a sudden reduction in the diameter of the uterine horn. This normally occurred after the first acute flexion of the uterine horn. (Point B.)

Fimbriated funnel - the junction between the membranous tissue of the fimbria and the cylindrical structure of the Fallopian tube. (Point C.)

The following measurements were taken with calipers for each side of the dissected genital tract.

Measurement A - the total length of the genital tract excluding the vagina, being the distance between Point A and Point C.

Measurement B - the length of the uterine horn, being the distance between Point A and Point B.

Measurement C - the length of the Fallopian tube, being the distance between Point B and Point C.

After measurement, the entire reproductive tract was placed in a shallow tray and the uterine horns were opened with scissors so that the number and position of the foetuses and the relations of the foetal membranes could be seen. The membranes were carefully removed, the amnion pierced, and the umbilical cord of the foetus severed close to the navel.

While in its natural position, the distance between the forehead and the root of the tail of the foetus was then measured. This measurement has been called the "curved crown-rump measurement" of the foetus. It must not, however, be confused with the "curved" measurement of Malan and Curson (1936) which uses the same landmarks but follows the curvature of the back and neck, but it is identical with the "maximum straight measurement" used by Cloete (1939) on young foetuses.

The foetus was then placed on its right side with its neck and back in the same straight line and with the long axis of the head at right angles to this line. This was most easily achieved by placing the foetus against the edge of a shallow, flat-bottomed dish and applying pressure below the chin. The distance between the forehead and the root of the tail was then measured with dividers. This measurement, called the "straight crown-rump measurement" corresponds to that taken by Cloete (1939).

The foetuses were then placed in 5% formalin in labelled bottles.

III. RESULTS AND DISCUSSION.

Forty-two Romney ewes of which 26 were pregnant, and 30 Halfbred ewes all of which were pregnant, were slaughtered.

Before discussing the measurements of the organs of pregnant and non-pregnant ewes, two phenomena, that of pigmentation of the uterine mucosa, and the transuterine migration of ova will be discussed.

Pigmentation was found to occur both as patches on the cotyledons, and also widespread over the entire uterine mucosa. Six Romneys and two Halfbreds were found having pigmented patches, and widespread pigmentation occurred in two Romneys. Pigmentation has been reported by Grant (1933), who found that neither its occurrence nor its intensity bore any relation to the stage of reproductive activity, and the condition is also reported to be common in New Zealand and of no known significance (Jebson, 1952).

Three cases were found, involving two single-bearing Romney ewes and one single-bearing Halfbred ewe, of the transference of a fertilized ovum from the horn corresponding to the ovary of origin to the opposite horn of the uterus. In the Halfbreds, there were seven sets of twins, six of which resulted from double ovulations of one ovary. In all cases, however, one foetus was found in each uterine horn. This is apparently quite normal in sheep and has been observed by Curson (1934), Robinson (1951a) and by Boyd, Hamilton & Hammond Jr. (1944) who discuss the possible mechanisms of the process. Its cause is not understood however. That it is not solely

a mechanism for distributing fetuses equitably in polyovular species is shown by the fact that, whereas in the horse, migration is frequent, in the cow it is not, although both species are normally monovular. Hence there must be some other factor or factors operating to cause transuterine migration (Boyd, et al, 1944).

Measurement of the Genital Tracts of Pregnant Ewes.

Data are presented in Table XXVII on the measurements of the reproductive tracts of 22 Halfbred and 25 Romney ewes.* Only the data from ewes bearing single lambs are included and the measurements have been grouped for the "gravid" and "non-gravid" sides without reference to left and right. Correlation coefficients showing the relationship between the lengths of the different organs measured and the duration of gestation are also presented.

The significance of the differences between sides was tested by an analysis of variance, which showed that in Measurements A and B, the gravid is significantly longer than the non-gravid side in both breeds. The correlation coefficients between the measurements and the duration of pregnancy were calculated to determine whether covariance

* The genital tract of Ewe 462 was not measured because the ewe was killed at an advanced stage of pregnancy. This reduces to 25, the number of observations in the Romney sample.

The genital tract of Ewe 96 was damaged at slaughter so that complete measurements could not be taken. In addition, seven Halfbred ewes bore twins thus reducing to 22, the number of Halfbreds in the sample.

TABLE XXVII.

MEASUREMENTS ON THE GENITAL TRACTS OF 22 HALFBRED AND
25 ROMNEY PREGNANT EWES.

Measure- ment	Breed	Gravid Side		Non-gravid Side		Significance of difference between means of sides.
		Mean length (cm.)	r	Mean length (cm.)	r	
A	Romney	46.25	0.32	44.53	0.25	* *
	Halfbred	46.30	0.38	42.82	0.36	* *
B	Romney	28.89	0.28	27.27	0.22	*
	Halfbred	29.93	0.47*	27.48	0.41	* *
C	Romney	17.52	0.29	17.32	0.15	N.S.
	Halfbred	15.80	-0.14	15.57	-0.04	N.S.

* Significant at 5% point.

** Significant at 1% point.

N.S. Not statistically significant.

analysis should be used in testing differences between breeds. In the case of the length of the Fallopian tubes, the only measurement in which the breed means differ greatly, these correlations were non-significant. In Measurements A and B there are positive correlations which, although small, suggest that both the gravid and non-gravid sides of the genital tract tend to increase in length as pregnancy progresses. Since Measurement A is the sum of Measurements B and C, the correlation which it shows with the duration of pregnancy is merely a reflection of the changes in Measurements B and C.

Measurement B includes the lengths of the cervix and the pars indivisa as well as the uterine horn, since the ventral fold of the cervix was the only posterior landmark which could be located accurately. Cloete (1939) showed that the cervix increases in length with advancing pregnancy, and the pars indivisa also shows an increase, but only in the last stages of pregnancy. Changes in the lengths of these two sections of the tract will not, however, affect the differences between the sides, since their lengths will be included the Measurement B on both sides of a single reproductive tract. By measuring the reproductive organs without dissection, Cloete (1939) found that during the first three months of pregnancy there was a gradual increase in the greater curvature of the uterine horns. This was similar in both the pregnant and the non-pregnant sides, although the growth of the latter was always at a slower rate than that of the former. His data showed that there was also an increase in the lesser curvature which was similar for both sides. It is concluded that the changes

in the length of the uterine horns are of a similar nature in this study, where the tract was straightened by dissection, to those in the study of Cloete (1939), where the tract was measured in its natural position.

The Fallopian tube is the only anatomical structure included in Measurement C, and these data do not indicate that its length is affected by pregnancy, nor does the gravid side differ significantly in length from the non-gravid side. Cloete (1939) found that the Fallopian tubes increased in length throughout pregnancy, but this he concluded was due to mechanical stretching rather than to actual growth since the increase in length was not accompanied by an increase in weight.

The difference between the mean lengths of the Fallopian tubes in the Halfbreds and in the Romneys was tested by an analysis of variance and found to be highly significant. The implications of this anatomical difference upon fertility would be difficult to assess.

The Genital Tracts of Non-pregnant ewes.

Sixteen non-pregnant Romney ewes were slaughtered. Of these, four did not show any ovarian activity during the experimental period, and eight had normal oestral cycles but did not conceive, although their genitalia appeared normal. The mean measurements of the reproductive tracts of these two classes of ewes are presented in Table XXVIII. A description has been included in Chapter V of the ovaries of the other six non-pregnant ewes. This group consisted of two ewes with anatomical defects which precluded conception, and four ewes with abnormal oestral activity.

TABLE XXVIII.

MEAN MEASUREMENTS OF THE
GENITAL TRACTS OF 12 NON-PREGNANT ROMNEY EWES.

Description	No. of ewes	Mean lengths (cms.)		
		Measurement A	Measurement B	Measurement C
No ovarian activity	4	36.48	18.95	17.2
Normal ovarian activity	8	41.72	22.85	19.04
Difference between means		5.34	3.90	1.84
Significance of difference between means.		* *	* *	N.S.
* * Significant at 1% point.				
N.S. Not statistically significant.				

The two groups of ewes show significant differences in the total lengths of their tracts and in the measurement from the cervix to the end of the uterine horn. This suggests that the failure of the four ewes to show ovarian activity was due to infantility of their genitalia, a factor which is known to cause infertility in two-tooths (Jebson, 1952). Alternatively, the failure of the four ewes to show ovarian activity may have been due to some cause other than underdeveloped genitalia, and the greater lengths of the genital tracts of the ewes which experienced oestrus, a result of the stimulus of ovarian activity.

Fig. 5. Growth of curved crown-rump measurement.

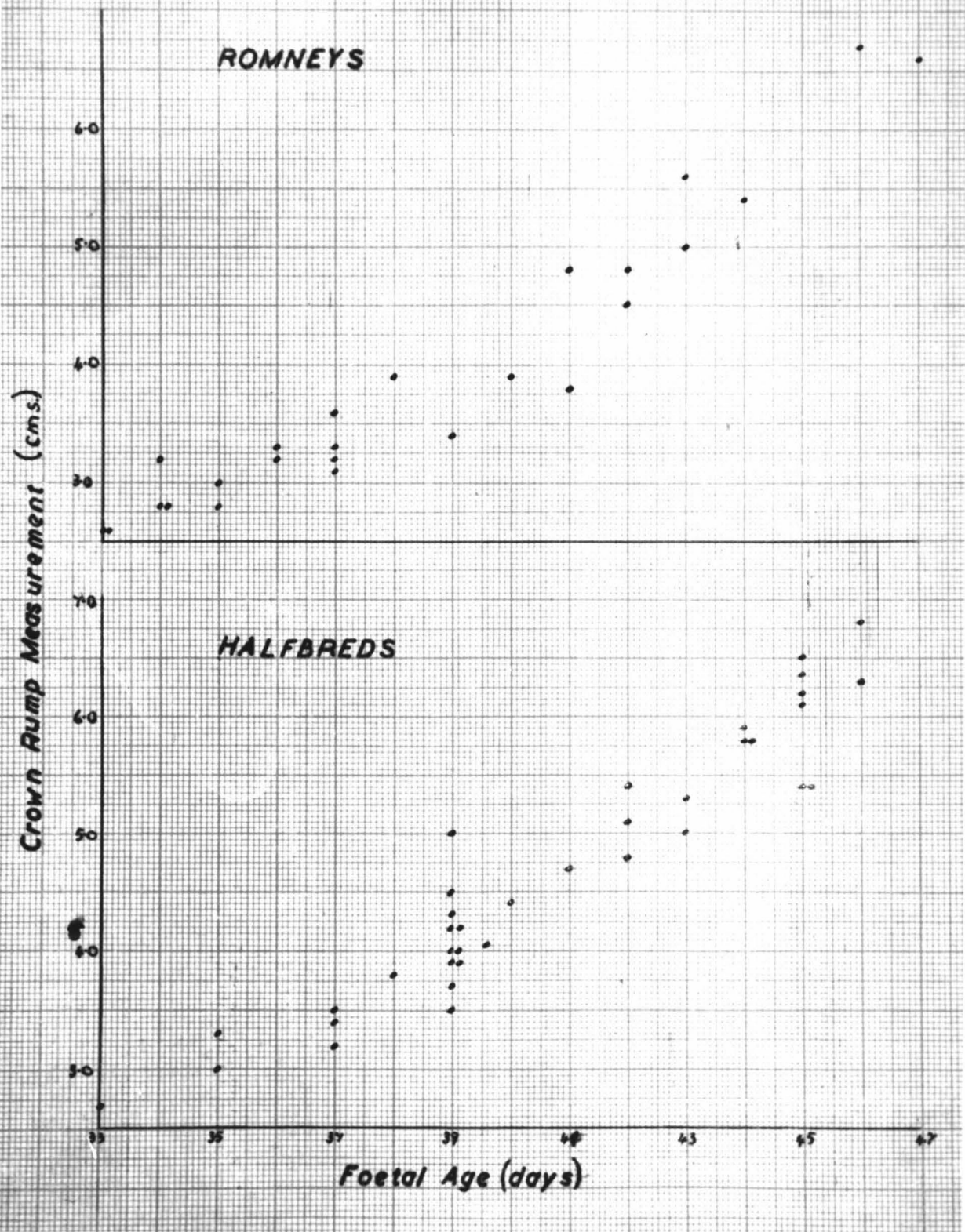
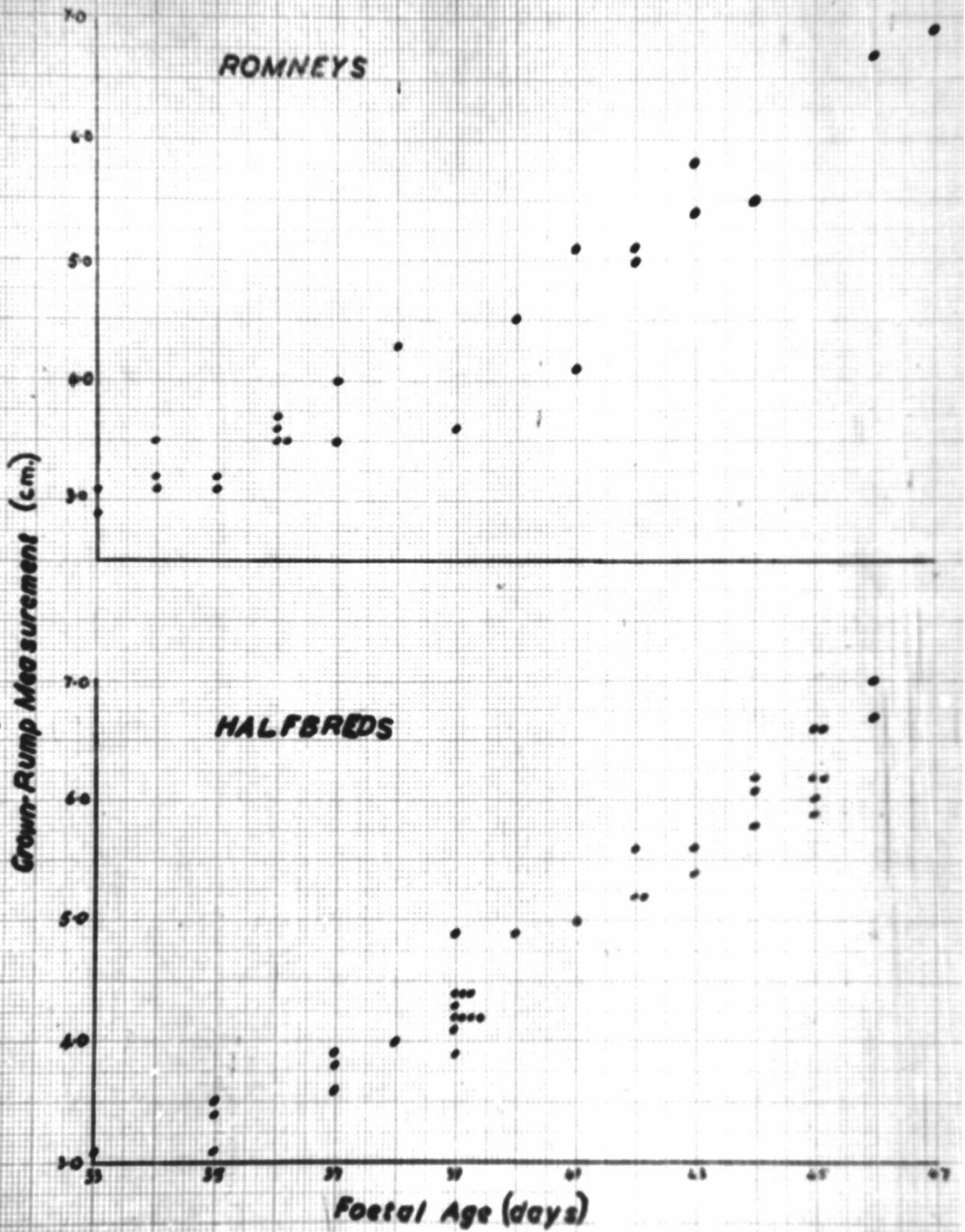


Fig. 6. Growth of straight crown-rump measurement



The crown-rump measurements of the foetus.

Data are presented on the straight, and curved crown-rump measurements, of 25 Romney and 37 Halfbred foetuses in an age series ranging from 33 to 47 days. The data for the Halfbreds include the measurements of seven sets of twins, but these have not been analysed separately.

The data are presented graphically in Figs. 5 and 6.

In analysing breed differences in the two measurements concerned, it was necessary to determine whether the relationship between crown-rump measurement and age was non-linear, as was suggested by the graphical representation of the data. Hence it was necessary to use the analysis of covariance as described by Snedecor (1946), including as dependent variates, the age of the foetus, and its square. The tests of significance of the departures from linear regression are presented in Table XXIX.

TABLE XXIX.

TEST OF SIGNIFICANCE OF DEVIATIONS
FROM ERROR LINEAR REGRESSION.

(a) Curved crown-rump measurement.

Source of Variation	d.f.	S.S.	M.S.
Deviations from linear regression	59	7.212403	
Deviations from quadratic regression	58	5.745112	0.099054
	1	1.467291	

$$F = \frac{1.467291}{0.099054} = 14.81 \quad * * \quad (P < .01)$$

TABLE XXIX (CONTD.)

(b) Straight crown-rump measurement.

Source of Variation	d.f.	S.S.	M.S.
Deviations from linear regression.	59	4.097031	
Deviations from quadratic regression.	58	3.523553	0.060751
	1	0.574378	
$F = \frac{0.574378}{0.060751} = 9.45 ** (P < .01)$			

Since both measurements showed a significant departure from linearity, it was necessary to test the significance of the difference between breed means adjusted for the curvilinearity of the regression on age. These tests are given in Table XXX.

TABLE XXX.

TESTS OF SIGNIFICANCE OF DIFFERENCES
BETWEEN BREED MEANS IN CROWN-RUMP MEASUREMENTS
ADJUSTED FOR CURVILINEAR REGRESSION.

(a) Curved crown-rump measurement.

Source of Variation	S.S. for Y	1 - R ²	Errors of Estimate		
			S.S.	d.f.	M.S.
Total	89.87	.068209	6.288833	59	
Error	82.10	.069977	5.745112	58	0.09905
Breeds			0.543721	1	0.543721

$$F = \frac{0.54372}{0.09905} = 5.49 * (P < .05)$$

TABLE XXX. (CONTD.)

(b) Straight crown-rump measurement

Source of Variation	S.S.for Y	1 - R ²	Errors of Estimate		
			S.S.	d.f.	M.S.
Total	83.19	0.050152	4.172145	59	
Error	76.34	0.046151	3.523553	58	0.060751
Breeds			0.648592	1	0.648592

$$F = \frac{0.648592}{0.060751} = 10.68 * * (P < .01)$$

All foetuses were sired by Southdown rams, but as shown by this analysis, for both methods of measurement, the crown-rump lengths of foetuses from Halfbred and from Romney ewes, differ significantly.

IV. GENERAL DISCUSSION.

Throughout the earlier sections of this investigation emphasis has been placed on the physiological phases of reproduction and anatomical detail has been noted only insofar as structural defects have impaired physiological function. The data presented in this chapter were for the most part collected as information subsidiary to the other sections of the study. However, from the analysis of these data, certain phenomena have been detected which provoke speculation.

Although the Romneys and Halfbreds differed in size and live-weight, when pregnant ewes only were considered, no significant difference was found between the two breeds in the development of the genital tract as measured by its total length. The only character in which the breeds were found to differ was in the mean length of the Fallopian tubes, which was shown to be significantly greater in the Romneys.

When non-pregnant Romney ewes were considered however, it was found that the genital tracts of ewes which experienced regular oestrus throughout the experimental period were significantly longer than those of ewes which did not experience oestrus. The implications of this observed difference could not be discussed with any finality, but it was suggested that some "cause and effect" relationship existed between the absence of oestrus and the under-development of genitalia - either the genital tract was retarded in growth as a result of a lack of the stimulus resulting from ovarian activity, or alternatively,

the failure of the ewes to experience oestrus was due to some other factor which had caused a general retardment of the development of the reproductive organs. Such a factor could have been the poor nutritional status of the Romney ewes in their first winter since, as shown by Phillips et al (1945), underfeeding of lambs in their first winter can result in reduced growth of the reproductive tract.

V. SUMMARY.

The genital tracts of the slaughtered ewes were examined. Certain measurements were made on the dissected genital tract, and the crown-rump measurements of the foetuses were taken by two different systems of measurement. The following results were obtained:

1. Pigmentation of the uterine mucosa occurs occasionally, but appears to have no effect on fertility.
2. Transuterine migration of foetuses occurred both in ewes bearing single lambs, and in ewes bearing twins.
3. The Fallopian tubes of pregnant Romney ewes were found to be significantly longer than those of Halfbreds.
4. The genital tracts of non-pregnant Romney ewes which experienced normal oestrus were significantly longer than those of ewes which did not experience oestrus during the experimental period.
5. By both methods of measurement, the crown-rump

lengths of fetuses from Halfbred ewes were found to be significantly greater than those from Romney ewes.

6. The significance of the measurements of the genital tract in pregnant and non-pregnant ewes is discussed.
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CHAPTER VII.

SUMMARY AND CONCLUSIONS.

It was the purpose of this investigation to elucidate some of the reasons for the differences which have been shown to occur between the lambing percentages of Romney and Halfbred ewes under farm conditions. To this end, an examination has been made of the functional nature of each of several links in the chain of events which constitutes reproduction. The study commenced with the observation of the breeding behaviour of ewes during the breeding season and concluded at the stage of early pregnancy. As a result, breed differences in fertility have been assessed before the reproductive process was completed, and the final index, termed "the maximum potential lambing percentage", expresses the total number of foetuses found as a percentage of the number of ewes which were put to the ram.

The maximum potential lambing percentage was found to be significantly higher in the Halfbred ewes than in the Romneys, and it was found that approximately two-thirds of this difference was due to a high incidence of barrenness in the Romney ewes, and one-third to the incidence of twinning in the Halfbreds.

Concerning the causes of barrenness in Romney ewes, it was found that in two instances conception was precluded by the mechanical blockage of the genital tract by anatomical defects, while the remaining instances of

barrenness were attributed to physiological causes. The anatomical defects would almost certainly cause permanent sterility, and the occurrence of two such cases in the 42 Romney ewes which were slaughtered would appear to make it worthwhile to investigate the incidence of such abnormalities by a survey of the genital tracts of ewes slaughtered at freezing-works.

Cases of barrenness attributable to physiological causes fell into two categories - those associated with absent, or aberrant oestrus (in which case the ewe was not mated), and those associated with the failure of fertilization or implantation. Barrenness of both categories is believed to be due to ovarian dysfunction, in the first because of an interference with the follicular phase of the oestral cycle, and in the second by some hormonal imbalance during the luteal phase.

In addition to this high incidence of barrenness in the breed, the study of the breeding behaviour of the ewes subscribed further evidence that the Romneys are more prone than Halfbreds to irregularities of ovarian activity. In this section of the investigation, it was found that whereas all the oestral cycles of the Halfbreds were normal, those of the Romneys included a proportion which were abnormal. Further, the oestral periods of the Halfbreds were longer, more intense, and appeared to be more abrupt in onset and cessation than in the Romneys, and from these observations it was concluded that the ovarian rhythm during the breeding season of the Halfbred is more accentuated than that of the Romney.

The observations on the reproductive organs of slaughtered animals showed that in addition to having a higher ovulation rate, the ovaries of the Halfbreds contained more large-sized Graafian follicles than those of the Romneys, suggesting that there was a difference between the breeds in the follicular development of the ovaries. By measuring the dissected genital tracts of the non-pregnant Romney ewes, it was possible to demonstrate that ewes which did not experience oestrus during the breeding season had genital tracts which were significantly shorter than those of ewes which experienced regular oestral activity. It was suggested that while the under-development of the genital tract might have resulted from the lack of ovarian hormonal stimulus during the breeding season, it was also possible that the absence of oestrus and the retarded growth of the genital tract were due to the effects of poor nutrition. Under-nutrition was also considered as a factor which would accentuate the breed differences in the time of onset of the breeding season, the ovulation rate and the development of the ovaries.

The adverse environmental conditions to which the animals of the two breeds were subjected prior to the commencement of the experiment have been described, and it was concluded that although the animals were wintered on properties of a similar nature, the Halfbreds enjoyed better management than the Romneys, and there is little doubt that the Romneys had suffered from some degree of undernutrition. The marked difference in live-weight

of the animals of the two breeds is probably not entirely the result of differences in nutrition but reflects to some extent the superior thrift of the Halfbred hogget under hill-country conditions. It seems probable therefore, that part of the difference in fertility which was detected between the Romney and Halfbred ewes was due to the effect of the poorer conditions to which the Romneys were subjected, although the magnitude of this effect could not be assessed.

In conclusion it should be emphasized that under normal farming conditions the difference in fertility in favour of the Halfbreds would have been even greater. It was shown that the low fertility of the Romney ewes was mainly a result of a high incidence of barrenness. In a normal tugging season, which is shorter than the mating period of this experiment, the incidence of barrenness in the Romneys would have been increased because of the wide variation which was shown by the ewes in the times of onset of the breeding season. In contrast to this situation in the Romneys, the times of onset of the breeding season in the Halfbreds were concentrated, and all ewes would have experienced oestrus in the early part of the tugging season.

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A P P E N D I X

APPENDIX I

LIVE-WEIGHTS OF EWES IN POUNDS.

ROMNEYS

<u>Ewe</u>	<u>26.11.52</u>	<u>25.11.52</u>	<u>24.1v.52</u>	<u>1.vi.52</u>
401	66	71	76	73
402	76	79	81	78
403	83	87	85	85
406	75	82	77	-
407	70	72	74	74
408	81	86	86	74
410	64	68	72	72
411	81	82	84	73
414	67	67	68	65
415	76	74	74	75
417	91	88	88	84
419	73	70	74	81
422	76	75	80	74
424	68	71	78	-
425	78	82	75	79
429	74	71	67	69
431	70	75	74	-
433	74	80	83	78
434	69	73	71	66
436	70	71	73	69
440	75	82	80	74
441	71	78	81	75
449	68	74	68	73
450	74	75	79	-
451	69	72	72	64
456	68	77	81	72

ROMNEYS (CONTD.)

Ewe	26.ii.52	25.iii.52	24.iv.52	1.vi.52
462	77	82	81	80
463	63	64	66	65
466	77	78	78	-
467	77	80	84	75
468	76	79	82	75
469	77	75	78	76
470	75	80	81	80
471	76	81	81	-
474	69	71	69	-
475	69	71	71	67
476	75	79	77	75
478	81	90	87	81
481	72	74	72	72
482	79	81	83	84
485	71	74	76	71
491	73	67	68	70
499	64	66	65	65
503	85	87	89	-
506	79	83	84	84
513	68	68	72	73
526	72	76	77	76
529	71	69	71	71
539	86	91	93	87
542	74	73	72	71
543	76	81	81	-
544	81	77	78	73
545	79	81	82	78
552	77	77	80	79
553	54	56	60	55

ROMNEYS (CONTD.)

Ewe	26.ii.52	25.iii.52	24.iv.52	1.vi.52
554	75	74	76	72
555	79	80	81	76
571	70	61	70	64
577	64	69	70	71
588	69	74	75	69

HALFBREDS.

Ewe	26.ii.52	25.iii.52	24.iv.52	1.vi.52
3	108	110	116	112
5	96	101	101	99
6	98	93	101	98
7	95	101	103	--
9	93	103	100	102
10	105	104	107	101
13	91	99	100	100
14	105	94	98	91
16	116	114	117	110
17	96	98	101	101
18	92	96	98	-
19	96	104	105	---
21	114	115	115	-
24	90	94	97	94
26	81	85	88	85
28	85	88	92	88
29	92	94	95	94

HALFBREDS (CONTD.)

Ewe	26.11.52	25.11.52	24.1v.52	1.vi.52
31	97	93	96	-
32	96	97	97	95
33	99	103	104	-
34	104	97	100	98
36	96	102	105	-
39	110	107	113	107
41	85	91	94	87
50	85	75	87	87
51	94	98	102	102
52	85	88	90	89
54	94	87	98	91
55	107	104	108	-
56	91	91	96	94
57	96	100	103	101
58	99	98	99	95
59	103	111	111	-
60	85	93	88	89
61	83	85	86	85
62	87	87	90	93
63	89	90	93	-
64	86	92	94	-
66	93	96	94	-
67	92	97	99	-
71	94	105	106	98
72	111	115	113	-
73	95	98	102	89
74	123	123	123	-
75	110	112	114	110
78	99	101	105	-

HALFBREDS (CONTD.)

Ewe	26.11.52	25.111.52	24.1v.52	1.v1.52
79	99	100	103	94
80	123	121	127	114
81	96	98	103	-
82	93	97	100	95
84	87	86	87	-
85	82	74	82	-
87	108	111	112	111
90	104	108	110	95
91	79	83	86	83
92	104	108	111	102
93	118	117	110	102
96	130	125	130	126
97	100	104	109	101
98	104	107	108	101

APPENDIX II.

OBSERVATIONS ON BREEDING
BEHAVIOUR.

The symbols used are as follows:-

- H - High intensity of oestrus.
 - M - Medium intensity of oestrus.
 - L = Low intensity of oestrus.
 - ? - Intensity of oestrus not recorded.
 - O - Ewe recorded as out of oestrus.
 - * = Ewe was mated to a fertile ram throughout oestrus and at first observation period at which she was out of oestrus.
-

APPENDIX III

WEIGHTS OF CARCASSES AND ORGANS AT SLAUGHTER

ROMNEYS

Ewe	Starved Live-weight (lb.)	Carcass Weight (lb.)	Dressing Percentage	Weights of Organs (g.)					
				Thyroid	Pituitary ¹	Spleen	Heart	Lungs	Liver
474	61.7	28.2	45.7	2.4	0.096	33.5	197.4	285.2	429.3
503	82.8	40.0	48.2	4.1	0.088	59.5	166.2	320.5	581.0
543	74.3	35.8	48.2	3.1	0.119	41.1	163.0	340.3	561.3
450	70.5	32.7	46.4	3.5	0.106	46.0	204.0	317.5	552.1
431	64.6	30.2	46.8	1.8	0.138	45.3	135.9	322.0	455.3
424	69.7	32.6	46.8	3.9	0.104	45.9	170.9	346.0	502.5
406	74.9	35.2	47.0	3.5	0.116	61.5	192.1	387.0	640.5
471	76.8	36.9	48.1	2.9	0.127	37.8	180.6	310.4	511.7
466	70.1	33.8	48.2	3.2	0.111	51.0	141.1	328.5	517.1
441	75.2	34.4	45.7	4.0	0.100	42.0	156.5	304.0	649.3
407	73.8	33.0	44.7	7.0	0.103	57.1	198.8	309.1	565.6
414	66.8	27.7	41.5	2.7	0.103	42.5	163.2	325.0	548.5
513	68.7	30.8	44.8	4.0	0.104	51.0	152.0	283.3	529.7
411	71.2	32.0	44.9	5.9	0.111	37.4	182.7	351.6	506.7
481	75.8	32.6	43.0	3.5	- ²	63.7	189.5	396.9	546.3
462	83.0	38.0	45.8	2.3	- ²	50.0	159.9	336.8	544.0
482	76.2	40.7	53.4	2.7	- ²	71.5	168.5	431.0	606.8
425	79.3	36.3	45.8	4.0	0.134	61.0	199.2	304.6	581.8
415	75.7	36.0	47.6	3.1	0.129	52.4	182.4	347.2	456.1
403	84.9	39.7	46.8	3.2	0.158	55.8	201.4	351.3	567.5
476	80.2	37.8	47.1	3.0	0.124	47.0	168.7	318.6	550.0
506	82.8	39.3	47.5	3.0	0.116	113.5	188.5	371.0	542.4
478	90.6	41.6	45.9	3.6	0.104	61.3	204.5	426.7	644.0
410	71.3	32.7	45.9	2.8	0.119	40.1	157.7	349.1	512.0
433	83.0	39.8	48.0	3.2	0.123	54.0	178.9	361.4	570.7

APPENDIX III (CONTD.)

ROMNEYS (CONTD.)

Ewe	Starved Live-Weight (lb.)	Carcass Weight (lb.)	Dressing Percentage	Weights of Organs (g.)					
				Thyroid	Pituitary ¹	Spleen	Heart	Lungs	Liver
434	68.2	31.7	46.2	3.8	0.103	52.1	143.9	326.0	527.5
449	78.2	35.7	45.7	4.5	0.155	50.4	184.3	386.2	635.9
542	75.4	33.3	44.2	4.7	0.133	56.6	164.5	361.0	524.5
545	78.9	34.0	43.1	6.0	0.174	54.9	188.0	367.2	541.9
469	80.9	36.5	45.1	3.3	0.114	96.3	187.4	367.5	686.0
467	82.8	37.0	44.7	4.4	0.147	54.2	180.0	336.7	530.7
539	93.9	46.4	49.4	4.9	0.162	68.1	204.2	396.0	668.9
470	83.0	38.1	45.9	4.4	0.123	42.7	181.9	399.9	637.0
456	75.7	31.9	42.1	2.6	0.117	83.1	193.0	366.7	583.1
555	79.7	37.6	47.2	2.5	- ²	61.8	190.2	365.9	497.3
417	87.1	40.7	46.7	3.4	- ²	110.3	214.2	439.7	652.0
577	72.6	32.4	44.6	3.2	- ²	40.5	150.2	356.9	578.5
529	68.1	30.0	44.1	3.6	0.101	41.5	172.1	362.2	495.0
491	66.1	30.3	45.8	4.2	0.091	37.9	148.1	288.0	517.0
554	72.0	33.5	46.5	3.2	0.092	41.6	144.9	270.5	443.9
499	60.4	26.7	44.2	2.6	0.091	46.1	171.5	284.0	512.0
463	62.0	27.0	43.6	- 3	0.095	33.0	149.5	320.0	528.5
<u>HALFBREDS.</u>									
33	86.8	43.8	50.5	7.2	0.126	70.0	233.2	377.0	556.9
74	107.6	56.7	52.7	4.8	- ²	71.2	301.9	470.3	642.5
18	91.2	45.3	49.7	3.9	- ²	54.3	200.2	347.0	613.0
72	105.5	51.8	49.1	5.9	0.158	60.2	257.6	416.7	816.1
31	86.9	44.0	50.6	4.6	0.130	56.7	186.7	428.8	617.5

APPENDIX III (CONTD.)

HALFBREDS (CONTD.)

Ewe	Starved Live-weight (lb.)	Carcass Weight (lb.)	Dressing Percentage	Weights of Organs (g.)					
				Thyroid	Pituitary ¹	Spleen	Heart	Lungs	Liver
85	79.9	39.7	49.7	4.0	0.111	40.5	197.0	375.0	553.8
19	101.7	46.8	46.0	5.3	0.166	67.3	264.4	422.2	763.4
36	96.8	47.0	48.6	3.5	0.134	58.2	201.7	364.0	622.8
84	81.2	39.2	48.3	5.7	0.129	53.4	222.8	364.0	617.7
66	101.1	46.2	45.7	4.9	0.157	60.7	240.1	425.0	676.8
59	99.7	49.8	50.0	5.8	0.126	54.9	218.1	419.6	731.5
63	86.0	42.9	49.9	3.8	0.151	54.4	223.3	410.4	581.1
7	95.2	47.7	50.0	6.5	0.104	58.5	246.0	444.9	678.8
21	104.7	52.3	50.0	3	- - ²	77.6	259.5	516.0	778.9
78	93.0	47.1	50.7	4.4	0.115	45.4	216.6	324.4	597.0
67	89.7	42.1	46.9	4.3	0.158	58.2	438.0	229.2	712.8
55	97.3	49.4	50.8	4.2	0.125	70.4	196.5	427.7	719.1
81	94.8	49.3	52.0	4.8	0.103	65.3	237.8	408.0	673.5
64	87.0	44.1	50.7	5.0	0.096	46.0	203.8	341.5	593.9
6	94.4	46.6	49.4	6.8	0.151	66.0	268.0	379.8	640.0
16	106.3	54.9	51.7	6.5	0.118	70.0	272.2	401.7	658.4
34	94.5	45.2	47.8	4.7	0.128	62.0	208.7	366.7	646.5
92	96.3	51.0	53.0	8.7	0.143	49.0	255.8	410.9	631.0
91	81.2	43.0	53.0	4.0	0.076	44.5	170.0	325.5	544.4
17	96.8	47.3	48.9	4.2	0.136	64.0	268.0	357.0	743.0
96	120.4	65.5	54.4	5.1	0.141	72.1	266.9	549.1	769.2
3	97.6	54.5	55.8	4.1	0.134	56.2	222.9	437.7	765.0
52	87.2	42.2	48.4	4.8	0.101	56.5	223.8	380.7	623.5
87	107.3	55.7	51.9	5.3	0.140	68.6	236.5	416.3	789.8
73	95.1	45.9	48.3	3.4	- - ²	51.0	209.8	406.0	652.7

¹ Weight of vacuum dessicated pituitary.
³ Gland lost at slaughter.

² Specimen deteriorated in storage.

APPENDIX IV.

MEASUREMENTS OF THE GENITAL TRACTS.

ROMNEYS

Ewe	Left Side				Right Side			
	Measurement A (cm.)	Measurement B (cm.)	Measurement C (cm.)	Presence of Foetus ¹	Measurement A (cm.)	Measurement B (cm.)	Measurement C (cm.)	Presence of Foetus ¹
474	38.5	24.0	13.9	0	38.2	25.1	13.0	+
503	43.7	27.5	16.2	+	41.2	27.3	12.6	0
543	39.5	25.0	14.7	0	40.5	22.0	18.0	+
450	34.3	23.6	10.8	0	42.5	27.5	14.5	+
431	34.4	19.6	14.0	0	34.7	22.1	14.3	+
424	41.6	26.5	16.0	0	41.0	26.4	15.0	+
406	49.0	28.0	20.0	0	55.5	32.1	23.2	+
471	45.5	29.0	15.9	0	43.5	29.0	14.9	+
466	39.0	25.5	13.7	0	40.2	26.2	14.6	+
441	46.2	27.0	20.5	0	51.0	29.5	21.8	+
407	53.1	37.0	16.5	0	52.5	35.5	17.2	+
414	42.7	26.5	15.5	0	46.2	30.5	16.2	+
513	38.0	22.0	16.2	0	41.0	23.5	18.0	0
411	45.5	30.0	16.0	0	48.0	29.5	19.0	+
481	44.3	24.7	20.0	0	43.5	24.0	18.2	0
462 ²	-	-	-	+	-	-	-	0
482	58.5	40.0	19.1	+	54.1	32.5	22.1	0
425	40.3	24.6	15.7	0	40.3	24.0	16.2	0
415	48.5	26.5	22.0	0	48.5	29.8	18.5	+
403	40.0	25.0	15.0	0	41.5	25.5	15.9	+
476	42.7	21.0	21.5	0	41.0	21.5	19.5	0
506	40.5	24.7	16.7	0	42.0	23.5	19.0	+
478	54.0	32.5	21.5	+	46.5	23.6	23.0	0
410	44.5	27.7	17.2	0	40.4	24.7	15.5	+
433	51.5	31.5	20.2	0	51.5	33.7	18.0	+

APPENDIX IV (CONTD.)

ROMNEYS (CONTD.)

Ewe	Left Side				Right Side			
	Measurement A (cm.)	Measurement B (cm.)	Measurement C (cm.)	Presence of Foetus ¹	Measurement A (cm.)	Measurement B (cm.)	Measurement C (cm.)	Presence of Foetus ¹
434	44.0	21.5	22.7	0	42.0	22.2	19.3	0
449	45.5	28.0	17.0	+	42.5	24.0	18.5	0
542	44.0	23.6	20.3	0	41.7	22.0	19.3	0
545	41.0	23.2	18.2	0	39.0	23.0	16.0	0
469	53.5	32.5	21.2	0	51.2	31.6	20.0	+
467	45.5	25.3	20.0	+	42.2	21.2	21.2	0
539	51.7	33.3	18.5	+	50.0	33.0	17.3	0
470	44.5	22.0	23.0	0	43.5	22.8	20.6	0
456	48.5	31.5	17.0	+	49.0	30.5	18.5	0
555 ³	-	-	-	0	-	-	-	0
417	-	-	-	0	-	-	-	0
577	37.8	19.6	18.0	0	39.1	19.2	19.6	0
529 ⁴	43.7	23.5	21.0	0	-	-	-	0
491	39.2	20.6	17.0	0	36.7	21.0	17.0	0
554	36.5	23.2	13.2	0	35.5	21.8	14.1	0
499	34.2	16.4	17.2	0	33.2	16.3	16.7	0
463	37.3	20.2	16.1	0	38.3	19.2	19.2	0
<u>HALFBREDS.</u>								
33	44.0	28.2	14.0	0	45.1	29.5	15.6	+
74	43.5	29.0	14.6	+	41.0	24.5	16.0	0
18	43.2	31.5	12.3	0	44.7	29.2	14.7	+
72	39.2	25.0	13.9	0	46.0	30.2	14.3	+
31	41.7	29.0	14.2	+	47.0	35.2	14.3	+
85	35.4	19.6	17.3	+	36.0	22.7	17.0	0

APPENDIX IV. (CONTD.)

HALFBREDS (CONTD.)

Ewe	Left Side				Right Side			
	Measurement A (cm.)	Measurement B (cm.)	Measurement C (cm.)	Presence Of Foetus ¹	Measurement A (cm.)	Measurement B (cm.)	Measurement C (cm.)	Presence of Foetus ¹
19	57.2	36.4	21.5	+	53.8	36.1	19.8	+
36	43.6	30.0	13.7	+	39.3	24.0	15.8	0
84	49.2	29.0	20.0	0	50.0	34.1	15.3	+
66	49.7	33.5	15.5	+	45.6	32.0	14.5	+
59	46.5	30.5	15.9	+	43.5	29.5	15.0	0
63	46.2	28.8	15.8	+	38.2	24.1	14.5	0
7	48.5	30.7	19.5	0	51.0	31.5	19.5	+
21	59.2	42.5	16.9	+	52.1	37.0	14.8	+
78	46.0	29.5	17.0	+	48.8	31.0	18.2	+
67	40.0	23.5	15.8	0	45.0	30.2	14.8	+
55	46.6	28.0	18.7	+	44.0	26.2	17.5	0
81	44.2	30.0	14.6	+	40.0	26.1	15.6	0
64	51.0	32.1	19.2	+	40.8	26.4	14.3	0
6	49.5	32.8	16.6	0	49.0	32.6	16.5	+
16	54.0	25.8	17.7	+	51.5	33.8	17.8	+
34	52.4	36.2	16.0	+	49.6	34.5	15.0	0
92	45.0	27.7	16.3	0	49.4	23.0	16.5	+
91	46.5	32.5	13.3	+	41.6	28.7	13.0	0
17	44.9	28.2	17.0	0	50.0	33.3	16.6	+
96 ⁴	-	-	-	0	52.3	36.1	16.5	+
3	45.6	30.0	16.0	+	43.0	26.2	16.7	0
52	56.5	40.5	16.6	+	55.2	39.2	16.5	+
87	47.2	33.7	14.1	+	42.5	30.1	12.5	0
73	39.7	24.4	14.6	+	39.0	25.0	14.2	0

¹ Presence of a foetus is recorded as "+".

³ Genital tract was abnormal.

² Ewe was at an advanced stage of pregnancy.

⁴ One side of genital tract damaged at slaughter.

APPENDIX V.

WEIGHTS AND DESCRIPTIONS OF OVARIES.

ROMNEYS.

Ewe No.	Left Ovary			Right Ovary		
	Weight (gm.)	No. of corpora lutea	No. of follicles > 4 mm.	Weight (gm.)	No. of corpora lutea	No. of follicles > 4 mm.
474	1.0	0	1	1.9	1	0
503	0.4	1	1	1.2	0	1
543	0.5	0	0	2.0	1	0
450	0.6	0	0	1.8	1	1
431	0.6	0	1	1.1	1	0
424	0.8	0	1	1.6	1	0
406	0.5	0	1	1.6	1	1
471	0.4	0	1	1.2	1	0
466	0.4	0	1	1.3	1	0
441	0.6	0	1	1.5	1	0
407	0.3	0	0	1.4	1	0
414	0.4	0	0	1.4	1	1
513	0.9	0	1	1.3	1	0
411	0.6	1	0	1.1	0	2
481	0.8	1	0	1.1	1	1
462	0.9	1	0	3.1	0	0
482	0.8	1	0	1.4	0	1
425	1.6	1	0	0.8	0	1
415	0.6	0	1	1.3	-	-
403	0.9	0	2	1.4	1	0
476	0.7	1	0	0.8	1	0
506	0.6	0	1	1.7	1	0
478	0.4	1	0	1.5	0	1

APPENDIX V (CONTD.)

ROMNEYS (CONTD.)

Ewe No.	Left Ovary			Right Ovary		
	Weight (gm.)	No. of corpora lutea	No. of follicles > 4 mm.	Weight (gm.)	No. of corpora lutea	No. of follicles > 4 mm.
410	0.4	0	2	1.5	1	1
433	0.7	0	1	1.3	1	0
434	0.6	0	0	1.1	1	1
449	0.6	0	1	1.3	1	0
542	1.4	1	0	0.8	0	2
545	0.5	0	1	0.9	1	0
469	0.4	0	1	1.4	1	0
467	1.2	1	1	0.5	0	2
539	1.5	1	1	0.5	0	2
470	1.3	1	1	0.7	0	1
456	1.3	1	1	0.7	0	1
577	1.0	1	0	0.8	0	1
529	0.8	0	0	-	-	-
491	0.9	2	2	0.5	0	0
554	0.8	0	0	1.1	0	1
499	0.5	0	0	0.7	0	0
463	0.5	0	0	1.5	0	1

HALFBREDS.

33	0.9	0	0	1.9	1	1
74	1.5	1	2	0.9	0	5
18	0.4	0	0	1.1	1	0
72	0.4	0	0	2.0	1	2
31	0.5	0	0	1.5	2	0
85	1.1	1	0	0.5	0	2

APPENDIX V (CONTD.)

HALFBREDS (CONTD.)

Ewe No.	Left Ovary			Right Ovary		
	Weight (gm.)	No. of corpora Lutea	No. of follicles > 4 mm.	Weight (gm.)	No. of corpora lutea	No. of follicles > 4 mm.
19	2.2	2	1	0.6	0	0
36	1.7	1	2	0.4	0	0
84	1.0	0	2	1.3	1	0
66	2.1	2	3	0.6	0	2
59	1.5	1	1	0.9	0	4
63	1.3	1	1	1.2	1	1
7	0.5	0	0	1.6	1	0
21	2.4	2	2	1.1	0	5
78	0.7	0	1	1.3	2	1
67	1.2	1	1	1.1	1	1
55	2.0	1	3	0.7	0	2
81	1.6	1	0	0.8	0	1
64	1.7	1	1	0.8	0	4
6	0.8	0	3	1.6	1	0
16	2.1	2	2	0.7	0	1
34	1.6	1	0	0.7	0	1
92	0.8	0	1	2.0	1	1
91	1.1	1	1	0.5	0	1
17	0.9	0	1	2.2	2	2
96	-	-	-	2.5	2	1
3	2.1	2	1	1.0	1	0
52	1.1	1	1	1.2	1	0
87	1.6	1	2	0.7	0	2
73	0.5	0	2	1.8	2	0

APPENDIX VI.

CROWN-RUMP MEASUREMENTS OF FOETUSES.

ROMNEYS

Ewe	Age of Foetus (days)	Curved Crown-rump Measurement (cm.)	Straight Crown-rump Measurement (cm.)
474	40	3.9	4.5
503	42	4.8	5.0
543	34	3.2	3.5
450	33	2.6	3.1
431	36	3.2	3.6
424	43	5.0	5.4
406	46	6.7	6.7
471	43	5.6	5.8
466	37	3.2	3.5
441	44	5.4	5.5
407	47	6.6	6.9
414	38	3.9	4.3
411	42	4.5	5.1
462 ¹	81	-	28.2
482	39	3.4	3.6
415	36	3.3	3.7
403	37	3.6	4.0
506	34	2.8	3.1
478	41	4.8	5.1
410	34	2.8	3.2
433	33	2.6	2.9
449	37	3.1	3.5
469	37	3.3	3.5

APPENDIX VI. (CONTD.)

ROMNEYS (Contd.)

Ewe	Age of Foetus (days)	Curved Crown-rump Measurement (cm.)	Straight Crown-rump Measurement (cm.)
467	41	3.8	4.1
539	35	3.0	3.2
456	35	2.8	3.1
<u>HALFBREDS.</u>			
33	40	4.4	4.9
74	39	4.5	4.9
18	39	4.2	4.4
72	42	4.8	5.2
31	45	6.2	6.6
	45	6.1	6.2
85	39	3.9	3.9
19	43	5.0	5.4
	43	5.3	5.6
36	45	6.1	6.2
84	39	3.5	4.2
66	35	3.0	3.4
	35	2.5	3.1
59	37	3.2	3.8
63	39	3.7	4.2
7	41	4.7	5.0
21	39	4.0	4.3
	39	4.0	4.2
78	39	4.2	4.4
	39	4.3	4.4

APPENDIX VI. (CONTD.)

HALFBREDS (Contd.)

Ewe	Age of Foetus (days)	Curved Crown-rump Measurement (cm.)	Straight Crown-rump Measurement (cm.)
67	39	4.0	4.1
55	38	3.8	4.0
81	33	2.7	3.1
64	37	3.5	3.9
6	44	5.8	6.2
16	44	5.5	5.8
	44	5.9	6.1
34	46	6.8	7.0
92	39	3.9	4.2
91	45	6.5	6.6
17	46	6.3	6.7
96	42	5.4	5.9
3	37	3.4	3.6
52	45	5.4	5.9
	45	5.4	6.0
87	42	5.1	5.2
73	35	3.3	3.5

¹ Ewe mated by accident.

APPENDIX VII.

DESCRIPTIONS OF VAGINAL SMEARS.

The following is a list of the symbols used:

Column (1) - Quantity.

- A - Scanty
- B - Medium
- C = Copious
- D - Extremely copious.

Column (2) - Viscosity.

- A - Fluid
- B - Moderately viscous
- C - Viscous
- D - Extremely viscous
- E - Dry.

Column (3) - Density.

- A = Clear
- B - Few cells
- C - Cloudy
- D = White
- E = Cheesy.

Column (4) -

- + Ewe was on heat.
 - * The vagina was dry and the speculum coated with adhesive cheesy material.
 - s The wool below the vulva was damp with mucus.
-

APPENDIX VII.

ROMNEYS.

Ewe No.	451				456				468				478				545			
Date	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
March 3	A	C	E		B	C	A		A	C	E		D	C	D		A	A	A	
4	A	C	E		B	C	A		B	C	E		C	C	D		A	A	A	
5	A	A	A		B	A	A		A	B	A		A	A	A		A	B	B	
6	A	A	A		A	A	A		B	D	B		A	A	A		A	B	B	
7	A	A	A		C	A	A		A	C	E		A	C	C		A	B	B	
8	A	A	A		A	A	A		A	B	B		A	C	C		A	B	B	
9	A	A	A		B	A	A		B	C	C		A	C	C		A	B	B	
10	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
11	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
12	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
13	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
14	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
15	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
16	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
17	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
18	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
19	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
20	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
21	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
22	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
23	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
24	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
25	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
26	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
27	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
28	B	B	B		A	A	A		B	C	C		A	C	C		A	B	B	
29	A	A	A		A	A	A		C	C	C		A	C	C		A	B	B	
30	A	A	A		A	A	A		C	C	C		A	C	C		A	B	B	
31	A	A	A		A	A	A		C	C	C		A	C	C		A	B	B	

APPENDIX VII. (CONTD.)

ROMNEYS (CONTD.)

Ewe No.	451				456				468				478				545			
Date	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
April 1	B	C	C		A	D	C		B	C	D		A	C	B		A	C	B	
2	A	D	C		A	C	B		B	D	D		A	C	B		A	C	C	B
3	C	C	D		A	B	B		A	E	D		A	A	A		A	C	D	D
4	B	D	D		A	C	C		A	C	C		A	C	B		A	C	C	D
5	A	C	D		A	B	B		A	A	C		A	A	B		A	C	C	C
6	A	C	B		A	A	B		A	D	C		A	C	B		A	C	C	C
7	A	C	C		A	B	B	+	A	C	C		A	A	B		A	C	C	C
8	A	C	B		A	A	B	*	A	A	C		A	A	B		A	C	C	C
9	A	C	C		A	B	D		B	C	C		A	A	A		A	C	C	C
10	A	C	C		A	A	A		B	A	C		A	A	A		A	C	C	C
11	A	A	A		A	A	A		C	A	C		A	A	A		A	C	C	C
12	A	A	B	+	A	A	B		C	A	A	+	A	A	A		A	C	C	C
13	B	A	B	+	B	D	E		C	C	B	+	A	C	C		A	C	C	C
14	A	D	E		B	D	C		B	D	E	*	B	C	A		A	C	C	C
15	A	D	E	*	A	C	E		B	C	C		A	D	C		A	C	C	C
16	B	C	B		A	B	C	*	B	C	C		A	C	C		A	C	C	C
17	A	A	D		A	B	C		B	D	C		A	C	C		A	C	C	C
18	A	D	A		A	D	C		B	C	C		A	C	C		A	C	C	C
19	A	C	A		A	C	A		A	C	C		A	C	C		A	C	C	C
20	B	D	E	*	A	A	A		B	C	D		B	C	C		A	C	C	C
21	B	A	C	*	A	A	A		A	C	D		C	C	C		A	C	C	C
22	B	D	C		A	A	A		A	C	C		A	C	C		A	C	C	C
23	C	A	C		A	A	A		A	C	B		A	A	A		A	C	C	C
24	B	C	C		A	A	B	+	A	A	C		A	A	B		A	C	C	C
25	A	C	C		A	A	A	+	A	A	C		A	A	B		A	C	C	C
26	A	C	C		B	D	E	*	A	A	C		A	A	B		A	C	C	C
27	B	C	C		A	A	B		A	A	C		A	A	B		A	C	C	C
28	A	A	B		B	B	B		D	A	A	+	A	A	B		A	C	C	C
29	A	A	B		C	B	D		C	B	A		A	A	B		A	C	C	C
30	C	A	A	+	C	B	D		B	C	C		A	A	A		A	C	C	C

APPENDIX VII (CONTD.)

ROMNEYS (CONTD.)

Ewe No.		451				456				468				478				545			
Date		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
May	1	B	D	C	+*	A	C	E		B	E	E		A	A	A		B	B	C	
	2	A	A	A	*	A	B	B		A	C	B		A	A	A		A	A	C	C
	3	B	C	E	*	A	A	B		B	A	C		A	A	B		B	A	B	B
	4	A	A	C	*	A	A	C		A	C	C		A	A	B		A	A	C	B
	5	A	C	C	*	A	B	C		B	C	C		A	A	B		A	A	B	E
	6	B	C	C	*	A	C	C		C	C	C		B	A	B		A	A	C	B
	7	A	A	C		A	A	B		A	C	C		C	B	B		A	A	A	A
	8	A	C	C		A	A	C		A	A	C		B	A	B		A	A	A	A
	9	A	A	B		A	A	C		A	A	C		B	A	B		A	A	A	A
	10	A	A	B		A	A	C		A	A	C		B	A	B		A	A	A	B
	11	B	C	C		D	A	A		A	A	C		B	A	C		B	B	C	C
	12	B	C	C		C	A	A		A	A	C		B	A	C		B	B	D	C
	13	A	C	B		B	C	B		B	A	D		A	B	C		B	B	C	E
	14	B	A	A		B	B	E		C	C	B		A	C	A		B	B	A	D
	15	A	A	A		C	D	B		C	A	D		A	A	C		B	B	C	E
	16	A	A	A		B	B	E		C	B	B		A	A	C		B	B	A	D
	17	A	A	A		B	B	D		B	A	D		A	A	C		B	B	A	E
	18	A	A	B		A	A	C		B	D	E		A	A	C		B	A	A	A
	19	A	A	B		A	A	C		B	D	E		A	A	C		B	A	A	A
	20	B	E	E	*	B	A	C		A	B	C		B	A	A		B	A	B	A

APPENDIX VII (CONTD.)

HALFBREDS

Ewe No.		41				71				79				82				90			
Date		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)				
March	3	A	A	A		A	A	B		A	A	A		A	D	E					
	4	B	C	B		A	A	A		B	A	A		A	A	A					
	5	A	A	B		A	A	A		A	A	A		A	A	B					
	6	A	D	C		C	B	A		B	B	E		A	B	A					
	7	B	D	C		B	D	E		A	D	E		A	A	B					
	8	A	C	E		B	C	D		A	B	E		A	A	B					
	9	A	B	B		A	A	A		A	B	B		A	A	C					
	10	B	C	C		A	A	B		A	B	B		A	A	C					
	11	C	D	C		A	A	B		C	C	C		A	A	C					
	12	B	C	D		A	A	B		C	C	D		A	A	D					
	13	A	A	B		A	C	B		B	C	B		A	A	B					
	14	B	D	D		A	A	A		B	D	C		A	A	A					
	15	C	C	D		A	C	A		B	C	C		A	A	A					
	16	D	C	D		A	A	A		D	B	C		A	A	A					
	17	C	C	C		A	B	C		A	A	C		B	A	A					
	18	A	A	A		A	A	A		A	A	A		B	A	A					
	19	A	A	A		A	A	B		A	A	C		A	A	D					
	20	B	D	C		A	A	A		B	D	C		A	A	D					
	21	B	D	D		B	D	D		A	E	E		B	A	A					
	22	C	B	C		A	A	A		A	A	A		A	A	A					
	23	C	B	C		A	B	C		A	A	A		A	A	D					
	24	B	D	D		C	B	C		A	A	A		A	A	D					
	25	A	A	A		C	D	D		A	A	A		A	A	D					
	26	A	C	A		B	B	B		A	A	A		A	C	C					
	27	B	C	C		A	B	B		A	B	B		A	A	C					
	28	C	C	C		A	C	A		A	A	B		A	B	A					
	29	C	B	A	+	A	A	B		A	B	A		A	C	B					
	30	B	B		+	A	A	A		A	B	A		A	B	C					
	31	B	A	C		A	C	B		A	A	A		A	B	C					

APPENDIX VII (CONTD.)

HALFBREDS (CONTD.)

Ewe No.	41				71				79				82				90			
Date	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
April 1	A	C	C		A	A	A		A	A	A		B	C	C		C	C	D	
2	B	D	E		A	A	B		D	A	B		D	A	A		B	D	D	
3	C	C	E		A	A	A		C	A	C		B	A	A		B	D	D	
4	B	D	E		A	A	A		A	A	E		A	A	A		A	D	B	
5	A	A	A		A	A	A		B	B	D		A	A	A		A	B	B	
6	A	A	B		A	A	A		B	B	C		A	A	B		A	B	A	
7	A	A	B		A	C	B		B	C	C		A	B	B		A	B	B	
8	A	A	B		B	A	A		B	C	D		A	B	B		A	B	B	
9	B	A	C		A	D	E	+	B	C	B		A	C	B		A	C	D	+
10	A	C	A		B	E	E	+	B	C	B		A	C	A		A	C	C	+
11	A	A	A		B	E	E	*	A	C	B		A	A	B		A	C	C	+
12	B	A	B		A	C	B		A	A	B		A	C	D		A	C	D	+
13	A	B	A		A	A	B		A	A	B		A	C	A		A	C	C	+
14	C	A	A	+	A	A	B		A	A	C		A	D	C		A	C	C	
15	C	A	C		A	A	B		A	A	A		A	C	B		A	C	C	
16	B	A	C		A	A	A		A	A	A		A	C	B		A	C	C	
17	B	B	B		A	A	A		A	A	A		A	C	C		A	C	C	
18	B	B	B	*	B	A	B		A	A	A		A	C	C		A	C	C	
19	C	C	E	*	A	C	A		A	A	B		A	B	C		A	A	B	
20	A	D	C		B	C	A		B	C	D		B	A	B		A	A	A	
21	A	C	B		A	A	A		B	D	C		B	A	B		A	A	A	
22	B	C	C		A	A	A		B	C	C		B	A	B		A	A	C	
23	B	A	C		A	A	A		A	D	C		D	A	C		A	A	C	
24	A	A	B		A	A	A		A	C	C		C	A	B		A	A	C	
25	A	A	A		C	C	A	+	A	C	E		C	A	A		A	A	B	
26	A	A	A		D	A	A	+	A	A	B		A	A	B		A	A	A	
27	A	A	C		B	C	C	+	A	A	B		A	A	A		A	A	A	
28	B	C	C		B	D	E	*	A	A	A		A	C	D		A	A	A	
29	B	A	A		A	A	B		A	A	A		A	A	B		A	A	A	
30	A	A	A		A	A	A		A	A	A		C	A	A		B	A	C	

APPENDIX VII (CONTD.)

HALFBREDS (CONTD.)

Ewe No.	41				71				79				82				90			
Date	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
May 1	B	A	A		A	A	A		A	A	A		B	A	B		A	A	B	
2	C	A	A	+	A	A	B		A	A	A		C	A	A		A	A	B	
3	C	A	A	+	A	A	A		A	A	A		A	A	A		A	A	A	
4	A	A	C		A	A	A		A	A	A		A	A	B		A	A	A	
5	B	A	C		A	A	A		C	A	A		A	A	B		A	A	A	
6	B	A	C	*	A	A	A		D	A	A	+	A	A	B		A	A	A	
7	B	A	C		A	A	A		A	A	A	+	A	A	B		A	A	A	
8	A	D	C		A	A	A		A	E	C	+	A	A	B		A	A	A	
9	A	C	C		A	A	B		B	B	C	+	A	A	A		A	A	A	
10	A	A	B		B	A	A		B	C	C		B	A	A		A	A	A	
11	A	A	A		A	A	A	+	A	A	B		D	A	A		A	A	A	
12	A	A	A		D	A	A		A	A	A		B	A	C		A	A	A	
13	A	A	A		B	A	A	*	A	A	A		B	B	A		C	A	A	
14	A	A	B		B	C	B		A	A	A		B	A	B		C	A	A	
15	A	A	A		A	A	B		A	A	B		C	A	D		C	A	A	
16	A	A	A		C	A	A		A	A	A		B	C	D		C	A	A	
17	A	A	B		A	A	A		A	A	A		A	X	A		C	A	A	
18	A	A	A		A	A	A		A	A	A		A	A	A		A	A	A	
19	C	A	A	+	A	A	A		A	A	A		B	A	B		A	A	A	
20	B	A	B	+	A	A	A		A	A	B		A	A	A		A	A	A	