

# STUDIES ON THE SODIUM-POTASSIUM BALANCE IN ERYTHROCYTES OF AUSTRALIAN MERINO SHEEP

## II. OBSERVATIONS ON THREE MERINO STRAINS

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### *Summary*

Estimations were made of the sodium-potassium balance in the erythrocytes of samples of ewes and rams and their progeny in three Australian Merino strains—two medium Peppin and one fine wool. In all three strains  $[K^+]$  values occurred in a continuous distribution within a range of 6 to approximately 20 m-equiv/l packed red blood cells. In the fine wool strain there were no values beyond this, but in both medium strains animals were found with values in excess of 50. Means and variances of  $[K^+]$  values, even excluding these extremes, were greater in the two medium strains. The variance was also significantly higher for females than males, though sex means did not differ significantly.

It is suggested that the presence of animals with extreme  $[K^+]$  values traces back to the incorporation of some genes from a British breed into the medium strains. Further, the between-strain differences in variances when these extremes are excluded, combined with some between-sire differences, indicate that polygenes may be operating on the  $[K^+]$  level as well as a pair of major genes which place it as high or low.

There is an indication that ewes with  $[K^+]$  values near the mode have a better reproductive performance than ewes with values outside the modal class.

## I. INTRODUCTION

As discussed by Koch and Turner (1961), these studies on the sodium-potassium balance in the erythrocytes of Australian Merino sheep were originally designed to investigate any possible association between potassium level in the erythrocytes and the ability of the lamb to survive, by comparing the  $[K^+]$  values at birth for lambs which survived with those which did not. Previous work (Koch and Turner, loc. cit.) having shown that the  $[K^+]$  levels at birth are all so high that classification into Evans' (1954) high and low categories is not feasible, this plan was abandoned. As an alternative, parents were sampled at mating to investigate the relationship between their  $[K^+]$  values and the outcome of the mating.

As no information was then available on possible strain or sex differences in the distribution of  $[K^+]$  values for individual sheep, sires and dams were sampled from three Merino strains at mating, male and female progeny resulting from these matings being sampled approximately 15 months later.

Estimates of both  $[Na^+]$  and  $[K^+]$  were made, but the present analyses are confined to  $[K^+]$  values.

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## II. MATERIAL AND METHODS

### (a) *Experimental Sheep*

The sheep sampled came from two breeding experiments at the C.S.I.R.O. National Field Station, "Gilruth Plains", Cunnamulla, Qld. In one experiment, small closed families are under selection for high and low values of single characters, and in three pairs of these, under selection for body weight, staple length, and fibre population density, respectively, increased neonatal mortalities have been observed in the progeny of half-sib matings, indicating the possibility that some deleterious recessive gene might be present. The families are part of a large flock of medium Peppin Merinos, designated the G strain for this paper, whose general management has been described by Turner, Dolling, and Sheaffe (1959). Pen matings are used, and in these particular groups two sires are mated annually in each family, each sire to approximately 25 ewes of varying ages. During one mating period (May 1956), the ram and his ewes were sampled in one of the two groups in each family. No ram lambs in these families are castrated, and all offspring are retained, without selection, until at least 12 months of age. In August, 1957, when the progeny were 10-11 months old, samples were taken from all surviving offspring of the sampled parents.

In the second experiment, two of the Merino strains described by Roberts and Dunlop (1957) are used—the fine wool (F) and one of the medium Peppin strains (A), which is of different origin from the G strain. Parents in the second experiment are selected at random, and the majority of the ram lambs are castrated at marking. Otherwise management is similar to that of the first experiment. Six sires were mated in 1956 in the F and seven in the A strain, each to 15-20 ewes of varying ages. All sires and approximately 12 ewes from each sire group were sampled in the mating pens in May 1956. All surviving progeny of all sexes were sampled in August 1957, whether their dams had been sampled or not. As mating began a month earlier in the second experiment than in the first, the progeny were approximately a month older.

### (b) *Environment*

The environment has been described by Turner, Dolling, and Sheaffe (loc. cit.). Cunnamulla lies on the plains of south-west Queensland, the district being one of high summer temperatures, with an average annual rainfall of approximately 15 in.

### (c) *Determination of Sodium and Potassium Concentrations in Packed Red Blood Cells*

The techniques used for sampling and for the estimation of the sodium-potassium balance in the red blood cells were similar to those described by Koch and Turner (loc. cit.). The apparatus used in the present series was a Beckman model DU with a flame photometer attachment. All values of  $[K^+]$  quoted are in m-equiv/l packed red blood cells.

### (d) *Statistical Methods*

In some strains there were outlying values of  $[K^+]$  which were so far beyond the nearest value that it seemed reasonable to regard them as belonging to a sub-population. Overall means including them were calculated, as well as means and

TABLE 1  
FREQUENCY DISTRIBUTION OF SHEEP IN THREE AUSTRALIAN MERINO STRAINS, ACCORDING TO POTASSIUM CONCENTRATION IN THE PACKED  
RED BLOOD CELLS  
Original data

[K <sup>+</sup> ] (m-equiv/l)	Number of Adults				Number of Progeny						Grand Total for Each Strain			
	Fine Wool		Medium Peppin		Fine Wool		Medium Peppin				Fine Wool	Medium Peppin		
	F		A		F		A		G		F	A	G	
	♀	♂	♀	♂	♀	♂*	♀	♂*	♀	♂				
Under 6	—	—	—	—	—	1	—	2	4	5	1	2	10	
6<10	34	6	23	1	63	17	27	23	22	22	77	74	108	
10<14	28	—	25	3	52	7	9	8	6	10	38	45	71	
14<18	2	—	10	1	9	—	3	—	4	1	2	14	14	
18<22	1	—	5	1	7	—	2	—	—	—	1	8	9	
22<26	—	—	—	—	3	—	—	—	—	—	—	—	3	
Over 50	—	—	1†	1†	3†	—	—	—	2§	1§	—	2	6	
Total No.	65	6	64	7	138	27	41	33	38	39	119	145	221	
Mean	8.0		20.8		8.7		10.2		12.0		9.2		11.4	
Including all	10.0		12.7		8.7		10.2		9.0		9.2		10.7	
Excluding 50 +	8.0		11.9		8.7		10.2		8.6		10.7		11.9	
Standard deviation, excluding 50 +	2.40		3.39		1.92		3.51		2.01		2.40		10.3	

\* Includes five rams in the F and eight in the A strain.

† Ewe value 60.0, ram 70.0.

‡ Values 56.4, 64.8, and 78.0.

§ Ewes' values 60.0 and 70.0, ram 70.0.

variances which excluded them. Even these variances differed between strains and sexes, and tests of the significance of differences between strain and sex means were carried out using logarithmic transformations, still excluding the outlying obser-

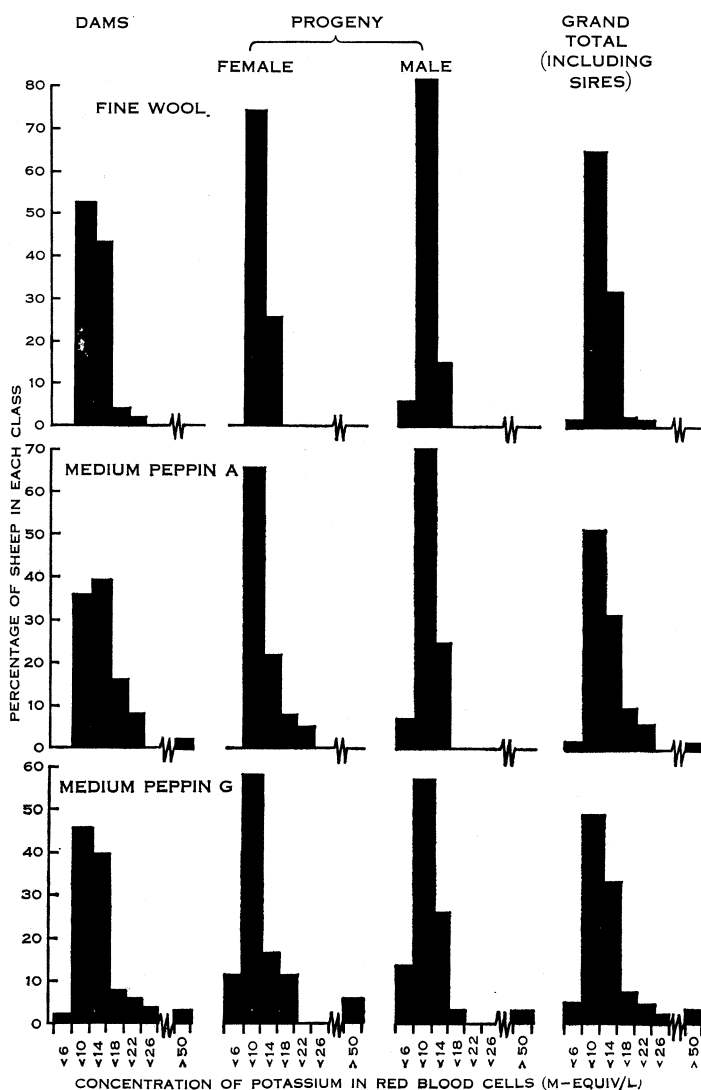


Fig. 1.—Frequency distribution of adult ewes and progeny of all sexes according to their  $[K^+]$  values.

variations. Significance tests including these extreme values were carried out by  $\chi^2$  tests of the frequency distributions over class intervals of  $[K^+]$  values. In most cases the groupings under 10, 10–14, and 14 or over were used.

Differences between ewes within a strain, classified according to their reproductive history in 1956, were analysed by testing weighted mean differences between subgroups within each sire group (Yates 1933). In this case original data were used, without transformation, as no unequal variances were involved.

TABLE 2  
MEAN VALUES OF  $[K^+]$  FOR PROGENY IN EACH SIRE GROUP  
Original data

Strain	Sire	Number of Progeny		$[K^+]$ Values		
		Females	Males	Sire	Progeny Means*	
					Female	Male
Fine wool F	F1	5	2	6.8	9.8	7.0
	2	6	5	9.4	8.5	7.2
	3	4	4	7.1	10.3	9.6
	4	6	5	9.0	7.7	8.4
	5	5	5	7.3	8.0	7.1
	6	1	—	8.7	8.0	—
Medium Peppin A	A1	4	8	10.7	8.9	9.2
	2	9	5	14.1	11.2	9.5
	3	8	7	12.3	9.6	7.4
	4	2	—	20.6	7.7	—
	5†	4	9	11.2	7.4	8.6
	6†	10	1	70.0	12.9	12.6
	7	4	3	6.9	7.7	7.2
Medium Peppin G†	HB†	5	5	11.6	8.9	8.8
	LB	5	5	8.1	8.9	7.9
	HN	9	4	18.4	9.0	7.6
	LN	8	7	10.3	9.7	10.7
	HL†	5	8	13.3	10.1	8.9
	LL	4	9	19.4	6.8	8.8

\* Excluding outlying values.

† Families selected for high and low body weight (HB and LB), fibre population density (HN and LN), and staple length (HL and LL).

‡ Outlying values: A6, the sire; HB, one female progeny; HL, one female and one male progeny. Four dams (not shown above) also had outlying values (1 in A5, 1 in HN, 2 in HL).

### III. RESULTS

#### (a) Differences between Sexes, Sire Groups, and Strains

Frequency distributions of sheep are shown in Table 1, grouped in intervals of 4 m-equiv/l of potassium in the packed red blood cells. This interval was chosen because it appeared to give a smooth distribution. The four types of animals sampled

(adults and progeny of two sexes) are shown separately for each strain, together with the strain total. Only animals with complete data for  $[\text{Na}^+]$  and  $[\text{K}^+]$  have been included, a few with missing  $[\text{Na}^+]$  values having been omitted. The frequencies, expressed as a percentage of the total number of sheep of the strain and sex under consideration, have been plotted in Figure 1.

Values of  $[\text{K}^+]$  up to approximately 20 occurred in most subgroups in a continuous distribution, while in some subgroups of the two medium strains there were outlying values of over 50. Means including and excluding these outlying values are shown in Table 1, together with the standard deviations excluding them.

TABLE 3  
VARIANCES OF  $[\text{K}^+]$  WITHIN SIRE GROUPS FOR PROGENY OF EACH SEX IN EACH STRAIN\*  
Original data

Strain	Females		Males	
	Degrees of Freedom	Variance	Degrees of Freedom	Variance
Fine wool F	21	3.26	16	3.02
Medium Peppin A	34	9.76	27	3.39
Medium Peppin G	30	9.73	32	5.59

\* Excluding three values over 50 m-equiv/l in the G strain.

The male progeny in the G strain were all rams, while all but five in the F and all but eight in the A strain were wethers. No differences between wethers and rams were apparent in these strains, and all male progeny were considered together.

The number of adult rams sampled was too small for an examination of sex differences, but this can be made in the progeny. Table 1 indicates that within each strain the female progeny show more of a "tail" than the male, the difference being expressed in a higher mean or variance, or both. As the sex ratio varied between sire groups, the comparison of sexes should be made within sire groups, and the mean value of  $[\text{K}^+]$  for each sex in each sire group is shown in Table 2, together with the sire's own value. The within-sire variances are shown in Table 3.

On Bartlett's test (1937) the six variances in Table 3 differ significantly (corrected  $\chi^2_5 = 18.64$ ,  $P < 0.01$ ). The sex variances differ significantly (corrected  $\chi^2_1 = 8.29$ ,  $P < 0.01$ ) as do those for strains (corrected  $\chi^2_2 = 8.76$ ,  $P < 0.02$ ).

Table 4 shows the between- and within-sire analyses on the logarithms of the  $[\text{K}^+]$  values. The within-sire variances no longer differ significantly ( $\chi^2_5 = 9.03$ ,  $0.2 > P > 0.1$ ), the pooled value over all sexes and strains being 0.0121.

Weighted mean differences between the sexes within sire groups, on logarithms, are  $0.044 \pm 0.026$ ,  $0.032 \pm 0.026$ , and  $-0.004 \pm 0.031$  for the F, A, and G strains, respectively, the pooled value being  $0.021 \pm 0.016$ .

The sex difference in variance indicated in Table 1 can therefore be regarded as significant, but the difference in mean values is not.

Strain differences can be examined both in adult ewes and in both sexes of the progeny. As indicated in Table 3, there were significant between-strain differences in variance of the original data in the progeny; as these were also present in the ewes (see Table 1), analyses of variance were carried out on logarithms (Table 5).

TABLE 4  
ANALYSES OF VARIANCE OF LOGARITHMS OF  $[K^+]$  VALUES† BETWEEN AND WITHIN SIRE GROUPS

Strain	Source of Variance	Adult Ewes		Progeny			
		Degrees of Freedom	Variance	Females		Males	
				Degrees of Freedom	Variance	Degrees of Freedom	Variance
Fine wool F	Between sire groups	5	0.0197	4	0.0148	4	0.0131
	Within sire groups	59	0.0094	21	0.0073	16	0.0090
Medium Peppin A	Between sire groups	6	0.0296	6	0.0433**	5	0.0173
	Within sire groups	55	0.0140	34	0.0118	26	0.0079
Medium Peppin G	Between sire groups	5	0.0635**	5	0.0148	5	0.0141
	Within sire groups	129	0.0150	30	0.0192	32	0.0140

† Excluding those values over 50 m-equiv/l.

\*\*  $P < 0.01$ .

Table 5 gives pooled overall variances within strains, as well as a separation of these into between-sire and within-sire terms. Table 4 had indicated significant between-sire variances only for the ewes of strain G and the ewe progeny of strain A. For strains F and A the ewes were allotted to sires at random, and sire group differences among the dams would not be expected. In strain G, however, each sire group belongs to a separate closed family, and the ewes within one sire group are genetically related. Almost all progeny within one sire group are half-sibs, a very small number of full-sibs being included with them.

The pooled between-sire term over the three strains was significant for the adult and progeny ewes, but not for the males. It seemed reasonable to test the between-strains term against the overall variance rather than the between-sire

term, however, regarding all animals as the strain sample. This was done in each set of data (Table 5). The strain differences are then significant at the 1% level in the adult ewes, but not significant for the progeny, though for the ewe progeny the variance ratio was approaching significance ( $0.1 > P > 0.05$ ).

Strain differences can also be assessed by means of  $\chi^2$  tests of the frequency distributions of Table 1, and in this analysis the outlying observations can be included. For the dams, there are significant strain differences ( $\chi^2_4 = 11.06$ ,  $P = 0.02$ ) arising chiefly from a marked difference between the F and the two medium strains. Each of the latter shows a "tail" to the right (Fig. 1) and contains

TABLE 5  
ANALYSES OF VARIANCE OF LOGARITHMS OF  $[K^+]$  VALUES† BETWEEN STRAINS

Source of Variance	Adult Ewes		Progeny			
	Degrees of Freedom	Variance	Female		Male	
			Degrees of Freedom	Variance	Degrees of Freedom	Variance
Between strains	2	0.0825**	2	0.0381	2	0.0155
Within strains	259	0.0149	100	0.0152	88	0.0114
Between sire groups within strains	16	0.0371**	15	0.0262*	14	0.0149
Within sires	243	0.0134	85	0.0133	74	0.0108

\*  $P < 0.05$ .

\*\*  $P < 0.01$ .

† Excluding values over 50 m-equiv/l.

a few animals with  $[K^+]$  values in excess of 50. The F strain has only three ewes with values over 14, and none over 20. In all three strains, at least 75% of the ewes have  $[K^+]$  values between 6 and 14.

For the progeny, the same trends in strain differences are present in both sexes, but in neither sex did the distributions differ significantly. [ $\chi^2_4 = 5.09$  for females,  $\chi^2_2$  (grouping into under and over 10) = 2.04 for males,  $P = 0.3$  approximately in each case.]

#### (b) Differences between Adult and Progeny Groups

In all three strains in Table 1, the ewe progeny show a lower mean for  $[K^+]$  than the corresponding adult ewes. The weighted mean difference, on logarithms, is  $0.073 \pm 0.014$ , giving a  $t_{358}$  value of 5.21 ( $P < 0.001$ ).



The adult and progeny ewes of Table 1 are not all paired, since some adults failed to raise a lamb at all while others had male lambs, and additional progeny were sampled in some strains. To eliminate this source of variation, the daughter's value was compared with the mid-parent value in all dam-daughter pairs, which totalled 68 over the three strains. In 52 of these the daughter's value was lower than the mid-parent value, which confirms the discrepancy noted in Table 1.

This lowering of the average value in the progeny has not been explained. The progeny were approximately 10 months old, while the adults ranged in age from 2 to 10 years. Observations in the Merino by Koch and Turner (1961) indicated that  $[K^+]$  values fell with age after birth, and appeared to reach a limit early in life, while Evans (1957) has always considered that a stable adult value for the sodium-potassium balance is reached before 6 months of age. Age differences thus do not seem to be a likely explanation of the fall in the progeny values.

The estimates on the two groups of animals were made at different times a year apart, and one possible explanation is some undetected difference in the technique on the two occasions. Such a difference, even if present, would not invalidate comparisons made within any one set of data.

(c) *Association between  $[K^+]$  Values and Reproductive Performance of Ewes*

Evans and Mounib (1957) suggested that the sodium-potassium balance might have some bearing on survival in different environments. The number of ewes in the present series which fell into Evans' *HK* category (the over 50 class in Table 1) was too small to be informative; of the four ewes concerned, one raised a lamb to weaning in 1956 while the other three bore one lamb each but failed to rear it.

The strain differences in variance of  $[K^+]$ , even when the outlying observations are omitted, and the sire group differences in some strains, indicate additional genetic variation, however, and it seemed worth while to examine the possibility that differences in  $[K^+]$  level, even within the range of the lower population, might have some bearing on survival. Since the lambs themselves could not be examined, the alternative was to compare the reproductive performance of ewes with different  $[K^+]$  values.

Semen testing of rams is carried out each year just prior to mating, and in 1956 the semen pictures were much worse than usual; those for the G strain, which was mated a month later than the F and A strains, were slightly better but were still poor. From among the chosen sires and reserves those with the best semen pictures were finally mated, but even these were below the standard accepted in previous years, and the poor pictures were confirmed by a lowered lambing percentage. One factor contributing to the atypical ram performance might have been the weather conditions, the preceding summer having been a period of abnormally heavy rains and floods.

As a first step, however, the results of the 1956 matings were examined, ewes being classified on their 1956 performance as having raised (R) or failed to raise (N) at least one lamb to weaning. The N group included ewes which were dry, with or without a record of service at mating, as well as those which bore one or more lambs

but raised none. Ewes which were dry with a recorded service could have failed because of poor semen or because of intra-uterine loss, while ewes which were dry with no service recorded could have failed to come on heat through poor adaptation. To eliminate the influence of the sire, the means of  $[K^+]$  values for R and N ewes within each sire group were compared, but the weighted mean difference over all strains was negligible.

TABLE 6

REPRODUCTIVE PERFORMANCE AND  $[K^+]$  VALUES OF EWES PRESENT FOR FOUR OR THREE MATINGS

Strain	Number of Matings	$[K^+]$ Class* (m-equiv/l)	Number of Ewes which Raised:		Total No. of Ewes
			2 Lambs or Less	3 Lambs or More	
F	4	6 < 8	4	2	6
		8 < 12	11	15	26
		12 +	15	2	17
Total			30	19	49
A	4	6 < 8	3	2	5
		8 < 12	11	16	27
		12 +	11	11	22
Total			25	29	54
G	3	6 < 8	11	4	15
		8 < 12	20	19	39
		12 +	13	6	19
Total			44	29	73

\* Excluding four ewes with values over 50 m-equiv/l. Their performance in lambs raised for a given number of matings was: strain A, 1/4; strain G, 0/3, 1/2, 0/1.

The results of further matings are now available for some of the sampled ewes, the F and A strains having been mated in three and the G strains in two later years.\* Fresh sires were used in each strain each year, and the semen pictures since 1956 have improved considerably. The ewes in each strain were therefore classified according to the number of lambs raised in the total years of mating (4 or 3), disregarding sire groups.

Although there were differences between strains in mean  $[K^+]$  values, there was a high concentration of values within a narrow range, and this gave rise to the idea that animals with a value within this range might have an advantage in fitness over those lying outside the range. To isolate these "tails" more precisely, ewes with records for the full 4 or 3 years were regrouped into  $[K^+]$  classes of 6 and under 8,

\* Drought precluded matings in the G strain in 1958.

8 and under 12, and 12 or over. Two-way tables for these  $[K^+]$  values and reproductive performance are given in Table 6, the two "tails" being summed in Table 7 for comparison with the modal class.

Table 7 indicates that in all three strains more animals in the modal class than in the tails raised three lambs or more. The three 2 by 2 tables yielded  $\chi^2_1$  values of 6.74 ( $P < 0.01$ ), 0.30 ( $P = 0.60$ ), and 2.07 ( $P = 0.15$ ) for the F, A, and G strains respectively, the summed value of  $\chi^2_3$  being 9.11 ( $P < 0.05$ ).

The mean numbers of lambs raised per ewe per year are also shown in Table 7. The value for the modal class is higher in the F and A strains, but not in the G.

TABLE 7  
REPRODUCTIVE PERFORMANCE FOR EWES IN THE MODAL CLASS\* AND THE TAILS† OF TABLE 6

Strain	$[K^+]$ Class	Number of Ewes which Raised:		Number of Lambs Raised per Ewe per Year
		2 Lambs or Less	3 Lambs or More	
F	Modal class	11	15	0.64
	Sum of tails	19	4	0.38
A	Modal class	11	16	0.71
	Sum of tails	14	13	0.65
G	Modal class	20	19	0.74
	Sum of tails	24	10	0.77

\* 8 < 12 m-equiv/l.

† 6 < 8 and 12 + m-equiv/l.

#### IV. DISCUSSION

The finding of strain differences in the distribution of  $[K^+]$  values is of considerable interest. Evans and King (1955) have previously reported the existence of alleles differentiating the sheep population into classes with high and low values of  $[K^+]$ , the gene for *HK* being recessive to that for *LK*, while Evans and Mounib (loc. cit.) have shown that the gene frequency for *HK* varies from breed to breed. The absence of sheep with *HK* values from the fine wool strain agrees with the earlier conclusions of Bernstein (1954) and Evans (1957) that the Merino is characteristically an *LK* breed. In the two medium strains there is a clear separation into classes corresponding to *LK* and *HK*, the distribution of *HK* animals over sire groups being consistent with the hypothesis that *HK* is recessive to *LK*. The presence of such animals in these strains could be explained by an earlier introduction of animals from British breeds carrying a proportion of *HK* genes. It is of interest that of the six *HK* animals occurring in families of the G strain, four were in the family selected for long staple, which could well be a characteristic contributed by ancestors from a long-wool British breed. Further analyses of the association between the  $[K^+]$  level and various fibre characteristics are planned.

In addition to having *HK* animals which were absent from the F strain, each of the two medium strains had a higher mean  $[K^+]$  value for the *LK* animals than that of the F strain. Evans and Mounib (*loc. cit.*) found differences among the British breeds in the mean  $[K^+]$  value for both *LK* and *HK* groups.

Another point of agreement with Evans and Mounib is the between-sheep variation in  $[K^+]$  values within each *LK* and *HK* group. For the *LK* groups, this variation was greater in the medium strains than in the fine wool. The standard errors of *LK* values quoted by Evans and Mounib for British breeds, however, are comparable with our fine wool estimates. There was no strong evidence in our data for the bimodal distribution of the *Kea* group discussed by Evans (1957); as shown by Table 1 and Figure 1, the histograms are smooth on the classes shown, and very slight variations which appeared with finer groupings were regarded as arising from sampling variation.

The numbers of *HK* animals in our data are too small for a comparison of within-strain variances, but their variability, as indicated by the values listed at the foot of Table 1, appears in general to be greater than that of the *LK* group. This is also the case in the Evans and Mounib data.

One explanation of the variability in the *LK* group could be an incomplete dominance of the *LK* major gene, heterozygotes having a higher  $[K^+]$  value than homozygotes, as suggested by Evans *et al.* (1956), who recorded a difference between known heterozygotes and a group including both hetero- and homozygotes. Approximately 2% of the adult ewes in the two medium strains were *HK*, giving a gene frequency under random mating of 14%, and an expectation of 24% of heterozygous animals. Such heterozygotes would be absent from the F strain, and their presence in the A and G strains could explain the higher variance which was observed; they would also explain Evans' (1957) bimodal distribution. There were no *HK* animals among the progeny of the only *HK* sire (A6, Table 2), so all must be heterozygotes, and their mean  $[K^+]$  value is above that of all other sire groups.

However, variability among the *HK* values can certainly not be explained by the presence of heterozygotes, and in the breed data of Evans and Mounib the mean  $[K^+]$  value of the *LK* group shows no association at all with the expected proportion of heterozygotes. As no haemoglobin analyses were made in our observations, the influence of haemoglobin type on the  $[K^+]$  level could not be checked (Evans, Harris, and Warren 1958). Environmental influences may, of course, be producing variability, but the observed differences between means of breeds, strains, and sire groups indicate that at least some of the variation is of genetic origin, and it seems likely that polygenes are operating on the  $[K^+]$  level as well as the major gene pair, as was suggested by Evans and Phillipson (1957) for cattle. The numbers of observations here are too small for reliable estimates of heritability, but it is hoped that some may be possible later.

There is some indication of an association between the  $[K^+]$  value of a ewe and her reproductive performance. The number of *HK* ewes (four) was too small for any firm conclusions concerning this genotype, but their performance was poor, as indicated by the records of number of lambs raised from a given number of matings (Table 6), the average per ewe per mating being 0.20.

Among the *LK* ewes there is evidence of an optimum level of  $[K^+]$ ; over the three strains, 54% of ewes with values from 8 to 12 m-equiv/l raised three lambs or more from three or four matings, compared with only 32% of ewes with values outside this range. The mean number of lambs raised per ewe per year was 0.70 for those in the modal class and 0.62 for those outside it. The differences are not large, but in view of the poor lambing performance of the Australian Merino any likely source of improvement is worth further exploration. Lambing records for the F, A, and G strains at Cunnamulla and for the F and A strains at other centres are available for a number of years, and analyses at present being made can be interpreted in the light of the observed differences in  $[K^+]$  values between strains.

If, as appears possible, there is an optimum  $[K^+]$  value for the Merino in Australia near the low end of the scale, one would expect, according to Waddington's theory of canalization, that selection would eventually reduce the variability about this mean value. This process may already have started, as there is an indication in Figure 1 that values are concentrated in a narrow range, but this is another point which requires more extensive data before anything definite can be concluded.

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