ELECTROCARDIOGRAMS OF YOUNG LAMBS.

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SUMMARY.

The heart rate of lambs shows a decrease with age. This decline is rapid for the first five weeks; between the fifth and ninth weeks the rate increases and from then to the twelfth week decreases. There is a tendency for all lambs to have the same proportional decrease by the end of the tenth week, even though the absolute heart rates are dissimilar.

The PR interval is independent of age, and minimum and maximum values show only small differences. Minimum and maximum values for QRS interval are more or less independent of age and show little variation. Variations in QT interval with age are more pronounced in mean, maximum, and minimum values. The value for this interval increases with age. PR and QT intervals vary inversely as the heart rate while QRS interval is fairly constant.

Indices derived from Bazett's systolic formula varied proportionately with heart rate and tended to a constant value with heart rates between 88 and 129 per minute.

Potentials of S, T, R, Q and QS were quite high, exceeding 500 microvolts in many instances. The P wave was much smaller. Instances of the absence of Q, R, S and QS waves were quite common.

Diphasic waves appeared in the T wave and to a lesser extent in P. The percentatge in the T wave was not great. P and R were invariably positive and Q, S and QS invariably negative. Serial changes in polarity of the T wave were mainly diphasic. Lead 1 (left foreleg to right foreleg) in the T wave was invariably positive. All waveforms were of predominant types with the usual exceptions. Transitional stages developed in serial recordings tending to the QS complex, occurring at approximately eight weeks. Lead 3 (left foreleg to left hindleg) was quite stable. Positive waves following the Q wave were not uncommon in Lead 3.

The ST function is discussed.

Average electrical axis changes about 10° every three weeks. Initial mean value for all lambs was —49°. Ten weeks later the mean was —127°. Changes in axis occurred in both directions with gradual progression towards negativity.

INTRODUCTION.

An instrument was designed to record responses from the administration of physiologically active substances to animals. Before any tests could be carried out it was necessary to collect relevant data from normal animals to decide what variations occurred with posture and age.

Merino sheep were selected as they represent the majority of animals subjected to investigation. Lambs were used because of economy and ease of handling. Their use also permitted the study of the effects of rumenal function on recordings at strategic periods.

Waveforms.

The electrical changes which precede auricular and ventricular contractions in the heart may be recorded as a series of waves which vary in frequency, shape, direction and potential. Anatomical variations, such as hypertrophy and position of the heart in the thoracic cavity, appear as corresponding variations in the nature of the waves.

This waveform, existing in its standard form (Plate 1, fig. 1) is divided into five sections designated P, Q, R, S and T. The base line represents the isoelectric line. Waves above and below this line are arbitrarily designated positive and negative, respectively.

The standard form is subject to variations and to avoid confusion the following nomenclature has been adopted throughout. Any downward deflection immediately following the P wave and followed by an upward deflection (however small) other than a T wave is designated as Q (Plate 1, fig. 2). Should an upward deflection (other than P) precede this downward deflection, the downward deflection is designated S (Plate 1, fig. 3). When no upward deflections (other than P or T) precede or succeed this downward deflection, the downward deflection is designated QS (Plate 1, fig. 4).

An appreciation of the differences between Q, S and QS explains the variations which occur in Tables 1-5. Positive and negative amplitudes are measured from the crest of each wave to the top and the bottom of the isoelectric line respectively. In general the PR interval is measured from the beginning of P to the beginning of Q; the QRS interval from the beginning of Q to the end of S; and the QT interval from the beginning of Q to the end of T.

In the study of electrocardiograms the time intervals and potentials of the main complexes, the shape of the waveform and any significant variations are the main concern.

APPARATUS.

The apparatus used in this work was designed by the author in association with T. A. Housley, V. W. Gibbs and I. Hamilton of the Brisbane staff of the Aeradio Division, Postmaster-General's Department, and constructed by the Division's staff.

A high-gain (voltage amplification of 2,000,000) low-frequency amplifier, with relatively flat response from zero frequency to 1 kilocycle, is used to amplify the potentials received. The frequency response and the time constants are such as to ensure faithful reproduction of the waveform which is being presented at the input. The amplified waveform is displayed

PREFACE TO PLATES.

The numerals (1, 2, 3) refer to the lead in question, while the letters (A, B, C, &c.) refer to the lamb used. Records adjoining one another denote the same lamb taken at a later period.

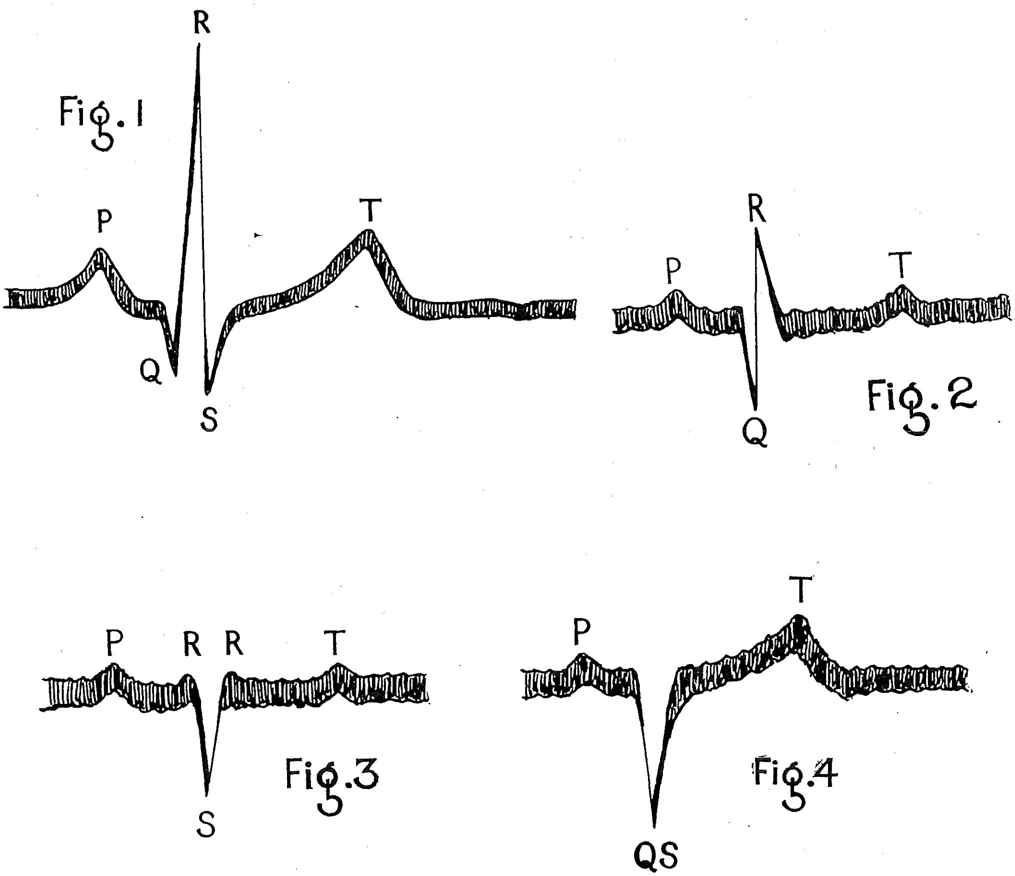


Plate 1.

Showing the standard waveform (Fig. 1) and its variations.

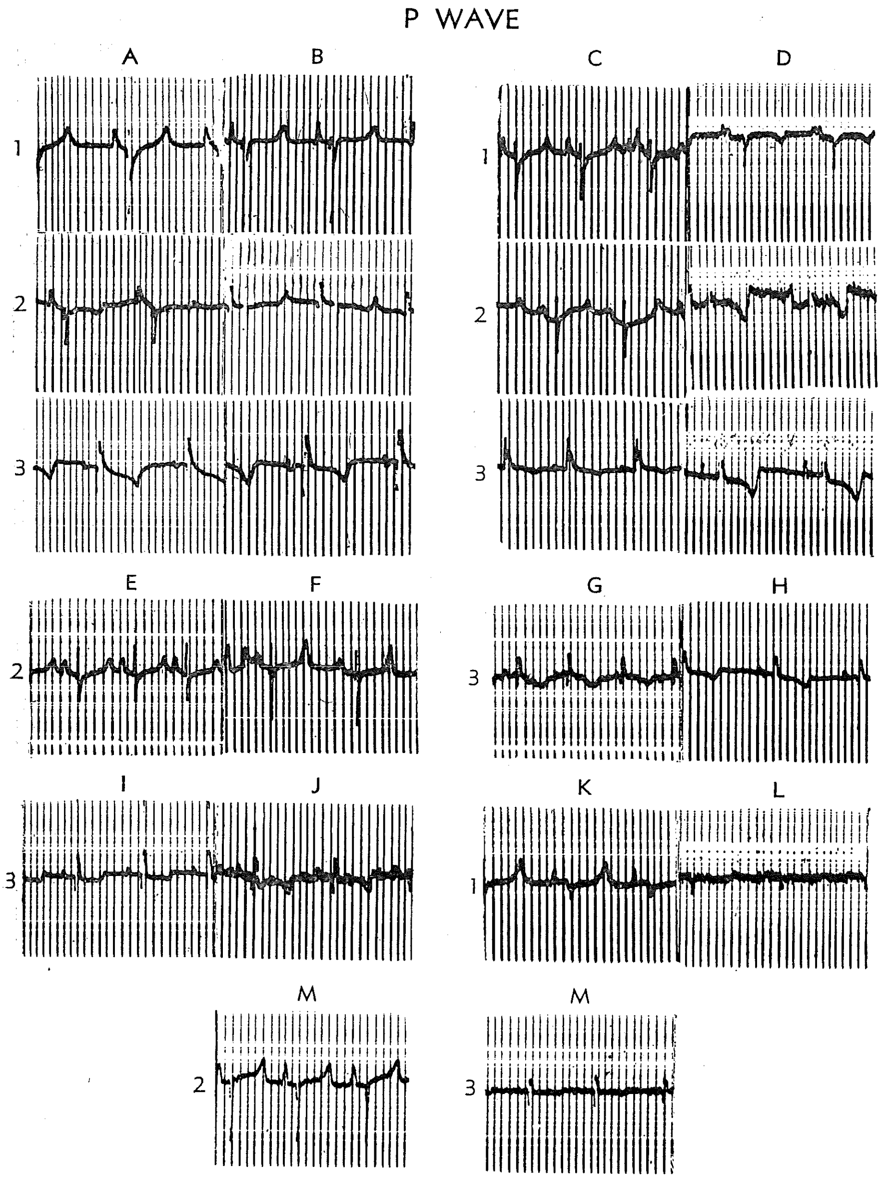


Plate 2.

Showing variations in waveform and amplitude with age, together with extremes of potential.

A, 5 weeks; B, 11 weeks; C, 3 weeks; D, 13 weeks; E, 2 weeks; F, 5 weeks; G, 1 week; H, 11 weeks; I, 1 week; J, 8 weeks; K, 4 weeks; L, 12 weeks; M, 3 weeks.

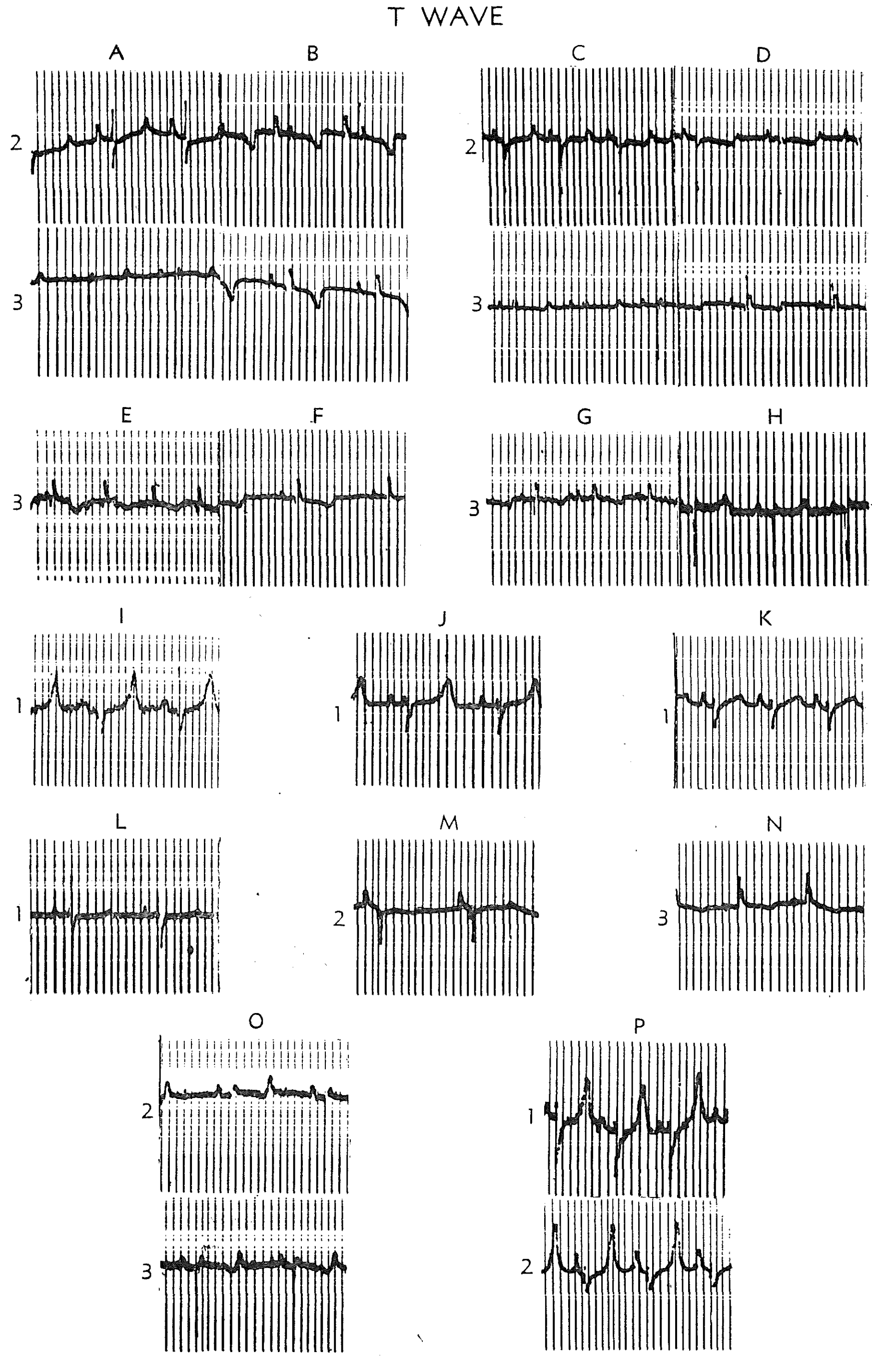


Plate 3.

Showing variations in polarity with age, together with extremes of potential.

A, 4 weeks; B, 15 weeks; C2, 8 weeks; C3, 5 weeks; D, 12 weeks; E, 1 week; F, 11 weeks; G, 2 weeks; H, 6 weeks; I, 5 weeks; J, 12 weeks; K, 2 weeks; L, 3 weeks; M, 5 weeks; N, 3 weeks; O, 10 weeks; P, 8 weeks.

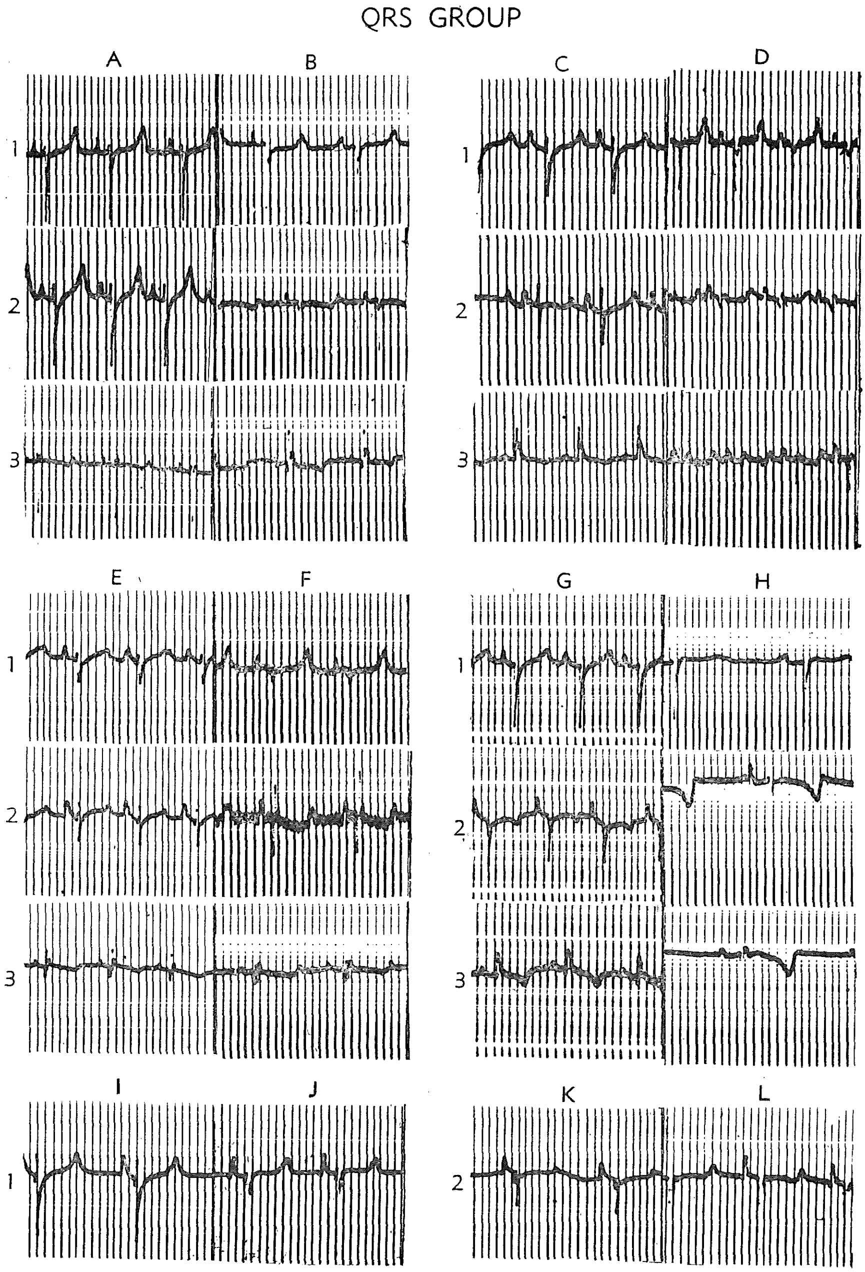


Plate 4.

Showing variations in wave shape with age.

A1, 3, 5 weeks; A2, 2 weeks; B, 12 weeks; C, 3 weeks; D, 9 weeks; E, 2 weeks; F, 12 weeks; G, 2 weeks; H, 12 weeks; I, 5 weeks; J, 12 weeks; K, 5 weeks; L, 12 weeks.

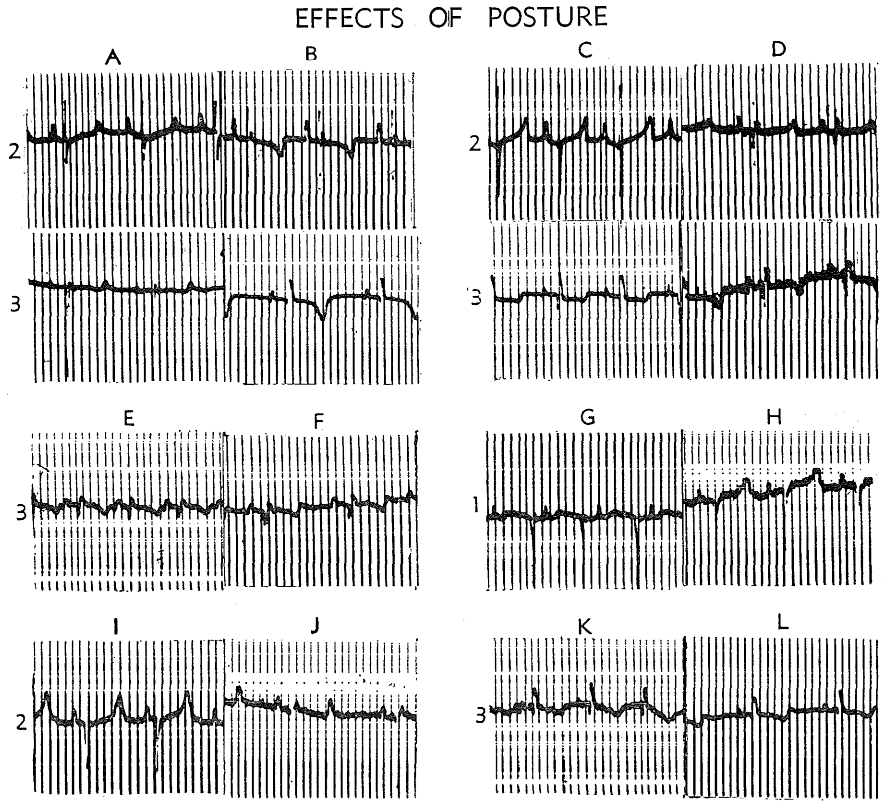


Plate 5.

Showing variations in wave shape with age.

A, 4 weeks; B, 11 weeks; C, 1 week; D, 8 weeks; E, 2 weeks; F, 11 weeks; G, 2 weeks; H, 9 weeks; I, 7 weeks; J, 10 weeks; K, 1 week; L, 11 weeks.

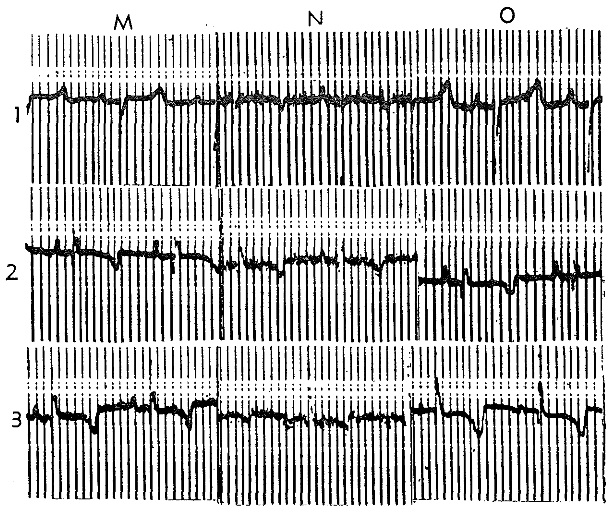


Plate 6.

Showing the same lamb as in Plate 5 (D2, D3), lying on left side, standing, and lying on right side. All 8 weeks old.

on two cathode ray tubes having screen persistencies of the order of one minute in the dark. One cathode ray tube is used for photographic purposes only and the other for monitoring. No time base is used as the spot is photographed in the vertical direction only. The lens (f 4.5, focal length 2 inches) is arranged for a reduction of 2 : 1. Super XX film (35 mm.) moving uniformly at 25 mm. per second is used and the time lines shown thereon are produced by a neon lamp flashing 25 times a second and exposing the film through a slit 1/1,000 inch wide. A tachometer unit is incorporated to measure instantaneous and average heart rates up to 1,000 per minute.

EXPERIMENTAL.

Twelve Merino lambs, consisting of four males and eight females, were selected and recordings were commenced as soon as the lambs could with safety be separated from the mothers for the period necessary to complete all recordings. The number of ewes available for this experiment was fairly small, and since the lambs were born over a period of one month the number appearing in any one age group did not permit of statistical analysis of the data obtained.

Owing to the fact that very small alternating potentials from direct pickup are normally detrimental to the record, the animals were at first placed in an electrostatic shielded cage at earth potential. After a few recordings the animals outgrew the cage and subsequent results were obtained under unshielded conditions with the right hind leg earthed. Plates 2-6 show that the record suffered little distortion.

The animals were carried from their pens to the recording room and after about five minutes' rest the recordings were commenced. Since the procedure was carried out at about the same time each morning, the effect of handling, environmental temperature and humidity was reduced to a minimum. Throughout the recording period the animals were kept lying on the right side in order to prevent fibrillation of the isoelectric line arising from nervousness and muscle tremor. Plate 6 shows the same lamb recorded lying on the left side (M), standing (N) and lying on the right side (O). No marked variation, either in potential or in waveform, is seen in the recordings taken on the left and the right sides. In the standing position fibrillation of the isoelectric line obscures interpretation.

Standard electrode metal was used and contact was made with the skin by medium of sodium chloride jelly. The wool was clipped as short as possible and four electrodes were attached to the limbs, as shown below, to give the standard combinations:—

Lead 1.—Left foreleg to right foreleg.

Lead 2.—Left hindleg to right foreleg.

Lead 3.—Left hindleg to left foreleg.

Earth.—Right hindleg.

All recordings were examined by means of a projector using a magnification of 10; consequently, time intervals and potentials could be measured with a reasonable degree of accuracy. In all leads each determination was carried out 10 times and the mean taken. The vertical lines on the film are spaced 40 milliseconds apart and the calibrating potential appearing at the end of each record is usually 1 millivolt per 10 mm.

Calculation of the average electrical axis of the heart* has been attempted, and while the method employed (Dieuaide; see Ashman and Hull, 1944) is only approximate for absolute values, the comparison afforded some information.

Other methods which could be employed suffer a common disadvantage in that no correlation exists between anatomical structure, position and electrical considerations of the ruminant heart.

Bazett (1920) introduced the formula $K = \frac{QT}{\sqrt{C}}$ (where QT is the interval in seconds between beginning of Q to the end of T and C is the interval in seconds between consecutive R waves) to correlate the QT interval with the average heart rate cycle. Although primarily used to correct the QT interval in humans, in which case K is a constant, the formula is used to show the variation of K for a given QT interval and heart rate cycle.

DATA AND ANALYSIS.

Heart Rate.

Table 1 compares minimum, maximum and mean heart rates per minute with age. The table shows that there is a rapid decline in the mean rate from the second to the fifth week of life; however, between the fifth and ninth weeks the rate is higher than the level of the fifth week, but during the remaining three weeks of the test it is not markedly different from the rate of the fifth week.

The actual normal rates would, of course, be somewhat lower than the recorded rates, since handling would tend to increase the rate. The effect would be expected to decrease with the age of the animal.

No published information on the effect of temperature and humidity on young lambs is known, but Lee and Robinson (1941) in their work on mature sheep found that the heart rate tends to rise with high temperatures. It is also known that heart rate increases during digestion and with the level of the plane of nutrition and the rates for the fifth to the ninth week may possibly be explained as due to the fact that during this period the rumen is developing at the expense of the abomasum because of the larger intake of roughage.

* Determined from the variation in potentials of the QRS complex in Lead 1 and Lead 3. Variations occur mainly from ventricular hypertrophy and positions which the heart adopts in the thoracic cavity.

Table 1.

HEART RATES OF YOUNG LAMBS COMPARED WITH AGE.

Age to Nearest Week.	Number of Lambs.	Heart Rate per Minute. (Mean Value from 3 Leads.)		
		Min.	Max.	Mean.
1	2	183	217	200
2	7	189	231	208
3	3	147	179	161
4	2	141	157	149
5	6	115	160	136
6	1	150	150	150
7	3	131	170	144
8	5	152	192	167
9	3	141	194	163
10	2	114	140	127
11	2	133	141	137
12	5	88	140	122

Plate 5 (D2, D3) shows recordings taken in the morning for a lamb on its right side, after being deprived of food and water for 16 hours.

Plate 6, taken four hours later, shows recordings for the same lamb on its left (M2, M3) and right (O2, O3) sides and standing (N2, N3) after partaking of food and water. The heart rate in the morning is 140 and in the afternoon 115, while the T wave in Lead 2 has reversed its polarity and increased in potential.

Table 2.

HEART RATES OF YOUNG LAMBS SHOWING SERIAL VARIATIONS.

Lamb No.	Age at First Record in Weeks.	Heart Rate Per Min. at First Record.	Percentage Variation in Heart Rate* after—					
			3 Weeks.	4 Weeks.	6 Weeks.	7 Weeks.	8 Weeks.	10 Weeks.
507	1·5	216	−45	..	−22	..	..	−42
508	2·0	204	−32	..	− 6	..	..	−31
509	0·7	217	−35	..	−42	..	..	−35
510	1·4	222	−30	..	−31	..	..	−40
511	2·3	213	−25	..	−13	..	..	−37
512	2·6	179	−16	..	..	..	..	−36
513	2·0	194	..	..	..	−20	..	−37
514	1·7	189	−34	..	..	..	..	−53
521	1·5	231	..	−36	..	..	−34	..
522	3·0	160	..	+ 4	..	−40	..	..
523	1·4	183	..	−36	..	−23	..	..
524	3·0	147	..	−20	..	− 5	..	..
Mean Variation			−31	−22	−23	−22	−34	−39

* Variations are referred to the initial heart rate. Negative variations are decreases, positive variations are increases.

Table 2 shows the variation in heart rate occurring at specified intervals expressed as a percentage of the initial rate. It is seen from the table that, irrespective of age, the mean percentage variation after three weeks and 10 weeks is —31 and —39 respectively. During the period of age from five to nine weeks, five females and one male showed positive variations, one female a negative variation, and two males no variation, while data from three lambs (two females and one male) were not recorded.

Table 3.

SHOWING THE VARIATION OF PR, QRS, AND QT INTERVALS WITH RESPECT TO AGE.

Age to Nearest Week.	Number of Lambs.	PR			QRS			QT		
		Min.	Max.	Mean.	Min.	Max.	Mean.	Min.	Max.	Mean.
		secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.
1	1	·08	·08	·08	·04	·04	·04	·18	·18	·18
2	6	·03	·07	·06	·04	·06	·05	·17	·20	·19
3	3	·03	·07	·05	·04	·07	·05	·20	·22	·21
4	2	·06	·07	·06	·03	·05	·04	·22	·24	·23
5	6	·06	·10	·08	·03	·05	·04	·19	·26	·24
6	1	·08	·08	·08	·02	·04	·03	·12	·20	·17
7	4	·07	·08	·08	·04	·04	·04	·19	·24	·22
8	5	·06	·09	·07	·02	·05	·03	·18	·23	·20
9	2	·08	·08	·08	·03	·03	·03	·23	·23	·23
10	2	·08	·08	·08	·04	·04	·04	·22	·24	·23
11	2	·08	·08	·08	·04	·04	·04	·21	·22	·22
12	5	·08	·12	·09	·04	·04	·04	·22	·28	·25

Table 4.

SHOWING THE VARIATION OF PR, QRS, QT, AND K WITH HEART RATE.

Heart Rate Range.	Number of Lambs.	PR			QT			QRS			Number of Lambs.	K		
		Min.	Max.	Mean.	Min.	Max.	Mean.	Min.	Max.	Mean.		Min.	Max.	Mean.
240–200	18	·04	·07	·06	·15	·21	·18	·04	·08	·05	3	·350	·380	·367
199–170	20	·02	·08	·07	·16	·25	·19	·02	·09	·04	7	·305	·442	·358
169–130	55	·06	·09	·07	·18	·25	·21	·02	·06	·04	20	·288	·383	·336
129– 88	27	·07	·11	·08	·21	·27	·24	·02	·07	·04	10	·326	·379	·341

Intervals.

All intervals are measured in accordance with the procedure given on page 68. Table 3 sets out minimum, maximum and mean values of the PR, QRS, and QT intervals with respect to age. In all cases any one value is the mean of three leads.

Table 4 shows how PR, QRS, QT and K vary with heart rate.

1. PR Interval.

The PR interval remains fairly constant with age. Table 3 shows very little difference between minimum and maximum values. However, the interval was not quite the same for all leads, being greatest in Lead 3 with Leads 1 and 2 about equal. These differences were of the order of 0.01 sec. and instances of Lead 1 being greater than Lead 3 were extremely rare. In very few instances was the Q wave apparent, and, associated with the interrelationship which exists between Q, S and QS, the PR interval (measured from beginning of P to the beginning of the next deflection whether +ve or —ve) was found to be fairly constant as shown from the minimum values for any one age group.

Table 4 shows that the mean value of the PR interval exhibits a regular increase in duration with decreasing heart rates. The same variations apply to the maximum values and to a lesser extent to the minimum values.

2. QRS Interval.

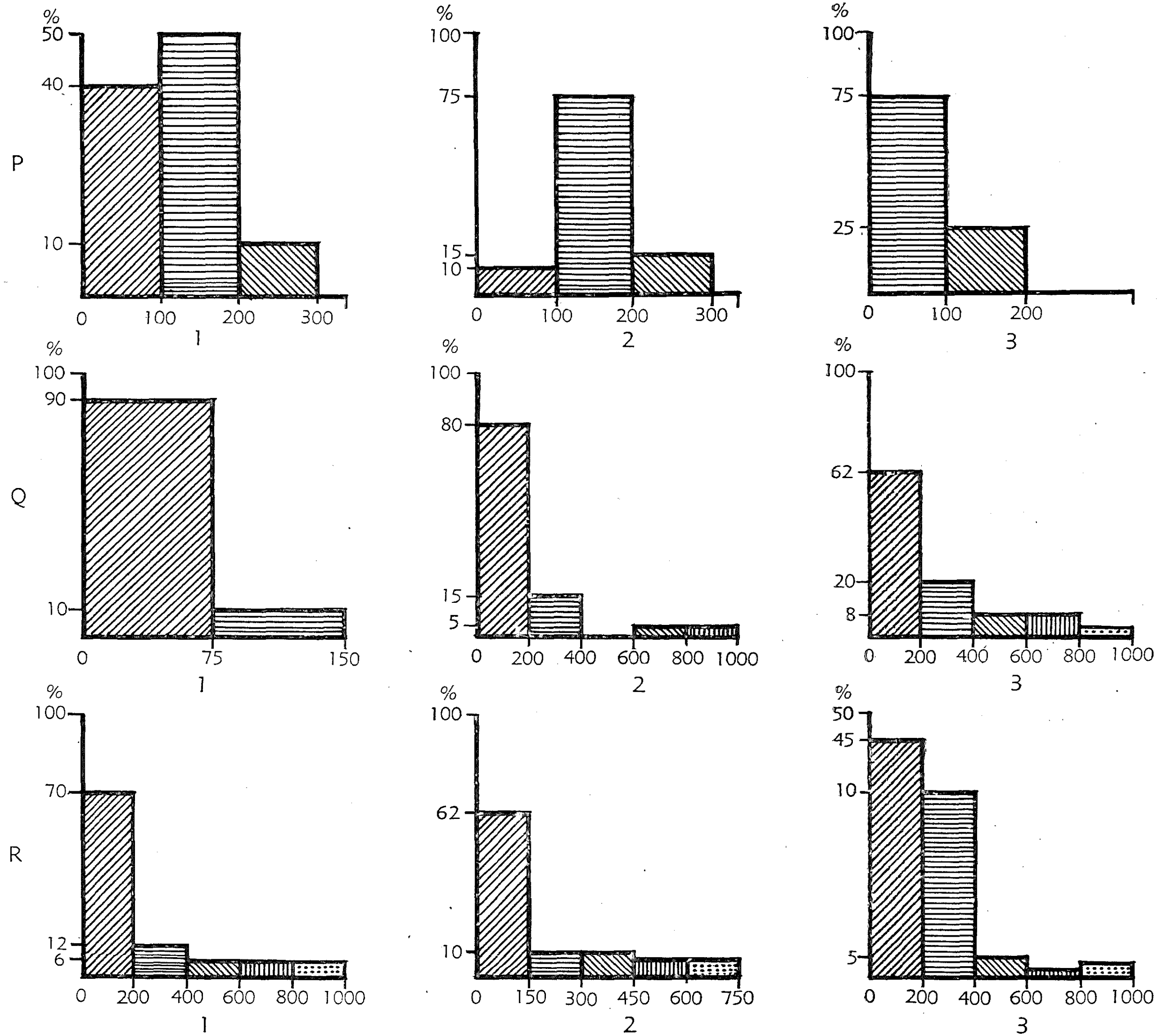
The relative constancy of the duration of the QRS interval should be noted (Table 3). In several instances no difference existed between the minimum and the maximum values. The constancy of this duration exists in spite of the variation in waveform which was manifest from one serial record to another. When transitional waveforms (i.e., interchanging of Q, S and QS) appeared, this interval was measured from the beginning of Q, R and QS to the end of R, S, and QS respectively. When Q waves were in evidence, they were relatively large. In only a few instances did small Q waves exist, and consequently quite a large number of leads showed no Q waves at all. When this occurred the time interval was measured from the first wave following the P wave. As a general rule, the value of the duration was greatest in Lead 1, while Leads 2 and 3 were almost equal.

Table 4 shows that the mean duration of the QRS interval is independent of the heart rate. The minima and the maxima are widely divergent.

3. QT Interval.

A progressive increase with age is noted in the QT interval with the exception of anomalies occurring between the sixth and ninth weeks (Table 3). The minimum and maximum values as a whole show relatively small differences. In general the greatest value was obtained in Lead 1, with Lead 2 greater than Lead 3. Even then the differences between Leads 1, 2 and 3 were proportionately small. The variation between leads was more definite than in the PR and QRS intervals. In the QT interval, as with the QRS interval above, the same problem of transitional Q, S and QS waves is encountered together with the absence of Q waves. Coupled with this measurement there are depressed and elevated ST junctions (Plates 2(A1) and 5(C2)) and also diphasic T waves (Plate 3(O3)). ST junction variations and diphasic T waves

FREQUENCY DISTRIBUTION OF POTENTIAL



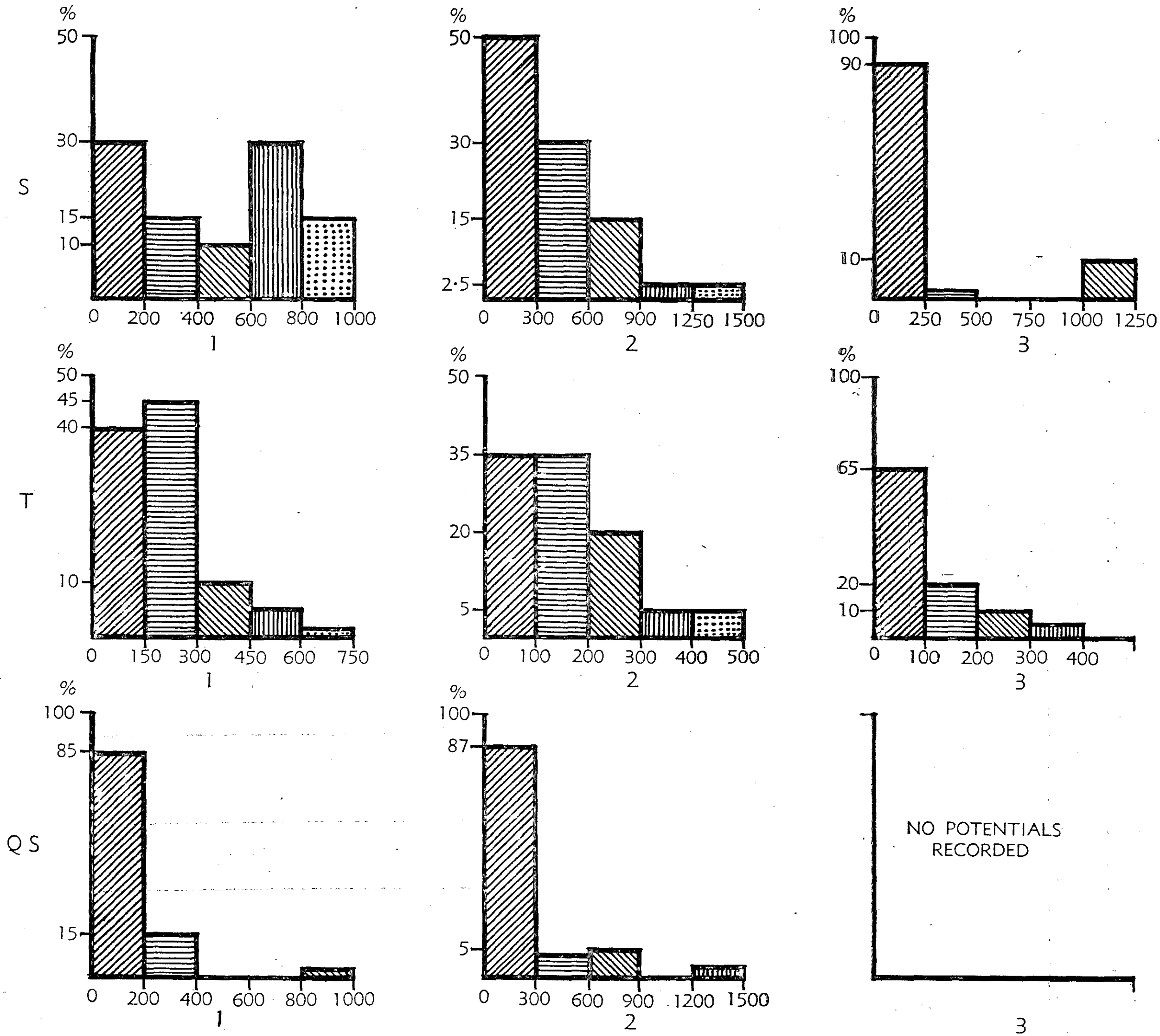


Figure 1.

Showing frequency distributions of potential. All potentials in **microvolts.** **Number** of determinations, 40.

amounted to 25 per cent. and 13 per cent. of the number of records respectively. Serial variations of the T wave from monophasic to diphasic forms were not a predominant feature.

In Table 4, minimum, maximum and mean values are shown to vary inversely with the heart rate in a regular manner. The same result is noticed in humans (Pardee, 1943). The regular variations in this group are more definite than in either of the two preceding groups.

4. K (Systolic Index).

The small potentials which appeared regularly in Lead 3 rendered it unsuitable for calculation of K. In Lead 1 the QRS complex was more stable and subject to less serial variations than in Lead 2, and consequently determinations were made in this lead.

The mean value of K for various heart rate ranges is shown in Table 4. Over the wide heart rate range, the change in the value of K is not large, and there is a tendency to maintain a constant value. It is not possible to state accurately the manner in which K varies with heart rate until the relationship between the QT interval and heart rate is known. Alfredson and Sykes (1942) found K to vary inversely with heart rate. A more detailed mathematical study is necessary to establish the true relationship.

Table 5.

Showing the Potentials in all Leads.

Deflection.	Lead.	Potential in Microvolts.			Deflection.	Lead.	Potential in Microvolts.		
		Min.	Max.	Mean.			Min.	Max.	Mean.
P	1	0	267	118	S	1	0	893	427
	2	60	235	144		2	0	1,400	360
	3	0	180	72		3	0	1,187	88
Q	1	0	135	17	T	1	38	620	202
	2	0	910	107		2	18	540	177
	3	77	1,000	183		3	33	408	112
R	1	0	941	200	QS	1	0	887	120
	2	0	750	163		2	0	1,236	166
	3	Trace	936	233		3	0	996	91

Potentials.

Table 5 shows the variation in potential of P, Q, R, S, T and QS for all leads. The figures show no marked tendency to conform to any general form and wide variations in potential occurred just as in humans. The results are expressed in the tables in microvolts purely for convenience. Effect of position of the animal when the record was taken is not considerable (see Plate 6, M1, M2, M3; O1, O2, O3) and skin contacts should be reasonably constant since standard technique was used throughout. Nil results were prevalent in Q, R, S and QS in nearly all leads, while in P and T deflections measurable values predominated in all leads. Low values are present in Lead 3 in P, S, T and QS deflections. Q, R, S and QS are conspicuous for their large maximum values.

Figure 1 shows the frequency distribution of potential in any one lead. For all leads in the Q, S and QS group a large proportion of nil recordings was obtained. This was brought about in the main by transitional waveforms. P and T waves are singularly free from nil results in all leads.

The potentials of the S and P waves were respectively the largest and smallest recorded. Typical illustrations of the following waveforms are presented:—Large P—Plate 2 (M2); P absent—Plate 2 (M3); large Q—Plate 2 (A1) and Plate 3 (A3); large T—Plate 3 (I1); and large R and S—Plate 5 (C2).

Wave Form Classification.

P Wave.

The P wave is predominantly positive, but a few diphasic waves were encountered (Plate 2 (B1, B3)). The predominant feature is the appearance of this slightly pointed waveform in all leads in 70 per cent. of the recordings. Some waves are relatively small and these occur mainly in Lead 3. Minor variations such as "steep front" and "slurred back" and "sharp front" and "sharp back" amount to about 12 per cent. Illustrations of these various wave forms appear in Plate 2. The variations when present are spread throughout all leads and occur at all ages. Serial records reveal slight changes.

QRS Complex.

From the definition of R, Q and S, 50 per cent. of the waves fall in the very small and nil category. This is the result of the inter-relationship existing within this group. The general wave shape took the form of pointed equal sloped waves, which amounted to about 25 per cent. Leads 1 and 2 were characterized by their number of nil waves. Lead 3 was not predominant in this respect. Positive waves immediately preceding a T wave amounted to 15 per cent. of the total number of recordings. Illustrations of the various waveforms encountered are seen in Plates 4 and 5. In general, the downward stroke is much thicker than the forward stroke. Lead 3 is well represented in the various waveform groupings.

The change in the QRS group with serial recordings is noteworthy. The initial waveform for each animal conforms to the standard P, Q, R, S and T pattern for humans except that the Q wave is not well pronounced and is more often zero. The R wave reduces in amplitude to zero and the original S wave now becomes QS (see Plates 4 (A1, B1; A2, B2; E1, F1; C1, D1). In Lead 1 this QS complex occurs eight times at an average age of eight weeks.

It occurs six times in Lead 2 with an average age of six weeks. QS did not appear in Lead 3 where the predominant feature was the appearance of a +ve wave immediately preceding the T wave. Lead 3 can be regarded as the most stable so far as this experiment is concerned. The QS wave shown in Plate 4 (G2) occurred initially and tended to remain constant throughout. Plate 5 (G1 and H1) and Plate 4 (K2 and L2) show still another variation. In only one instance did a QS wave occurring initially change to another form (see Plate 5 (I2 and J2)).

Miscellaneous variations of the QRS group are illustrated in Plates 4 and 5. The tendency in these changes is towards the QS complex, which appears to be the stable form in all leads. The illustrations are as follows:—Lead 1—Plate 4 (IJ and GH); Lead 2—Plate 4 (EF and CD); and Plate 5 (CD and AB); Lead 3—Plate 4 (AB, EF, CD and GH) and Plate 5 (CD, EF, KL and AB).

T Wave and ST Junction.

Three types of polarity exist, viz., positive, negative and diphasic. Positive waves occur in 64 per cent. of the leads, negative waves in 22 per cent. and diphasic waves in 14 per cent. Lead 1 is composed wholly of positive waves, while in Leads 2 and 3 positive and negative waves respectively predominate. When diphasic waves occur they are always of the negative-positive type. Twenty-three variations, from one form to another, occurred in the serial waveforms. About one-half of these variations were of diphasic type, and only on three occasions did a diphasic wave change to any other form. Two lambs in the initial record had diphasic waves. T waves are characterized by a slurred front and steeper back. Some waves have rounded peaks but the majority are pointed.

Plate 3 shows variations in polarity with age together with extremes of potential. Large potentials are seen in P1 and P2, and small values in L1, M2 and N3. Pointed and slurred waves are illustrated in I1 and J1, respectively. A general feature of the T wave is that its form is determined by the polarity of the preceding wave. If this is positive then the polarity of T is mainly diphasic, with instances of a few negative values. If the preceding wave is negative then the T wave is invariably +ve. These instances have been illustrated in Plate 3.

The ST junction is the mode in which the T wave leaves the isoelectric line. About 75 per cent. of the junctions commence at the isoelectric line, 14 per cent. below and 10 per cent. above. For heart rates of about 200 per minute, the T wave arises from the S wave, there being no isoelectric period (Plate 3 (P1)). Changes in ST junctions occurred 23 times, of which three were double changes. No general principle was involved in the sequence of these changes.

Average Electrical Axis.

Values calculated from the initial record range from −60° to +15°, corresponding to a range of 75° measured in the direction of decreasing negative and positive values. The mean value is −49°. Ten weeks later the minimum and maximuum values were —40° and —168° respectively, with a mean of —127°. With increasing age the general trend is for the axis value to change to a more negative value. So far as the individual lambs were concerned, the serial variations were quite interesting. The change amounted to approximately 10° every three weeks.

All changes did not occur in the same direction and in several instances the variations in any one lamb were such that the ultimate direction was that of decreased negativity. It was possible to calculate the axis in practically all cases.

From Plate 6 it can be seen that position has very little effect on the axis at the age of eight weeks. More marked deviations could be expected in the earlier stages of life.

CONCLUSIONS.

The data suggest that it is unwise to select lambs under the age of three months for the purpose of demonstrating induced electrocardiographic changes. Lambs three months of age and older are relatively stable in behaviour and in addition they lend themselves to experimental procedure with the minimum amount of handling. Recordings can be taken without the aid of a screened room in all positions other than standing, but the use of the room is strongly advisable.

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