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Surface Area in the Foetus of the Merino Sheep.

By A. P. MALAN and H. H. CURSON, Sections of Statistics and Anatomy, Onderstepoort.

Introduction.

In reality this study is a continuation of Study 13 (Curson and Malan) where the effect of age was studied in relation to (*a*) general body form, (*b*) body weight, and (*c*) C.R. length. As the foetuses in question were required for the further investigation of the external body form, another series of foetuses has been obtained through the kindness of Dr. L. L. Roux, M.Sc., of Ermelo, for this observation.

Neither Needham (1931) nor Hammond (1932) has any information bearing directly on the subject.

As the ordinary method of removing the skin and calculating its area on a measuring table was obviously unsatisfactory, we adopted the suggestion of Mr. F. E. H. Appleton of Onderstepoort. This consisted in dipping the foetus in a celloidin solution, allowing the material to dry, removal of the celloidin coat and then measuring this. In this way was obviated the stretching of the skin which would nullify the results obtained.

In Foetuses 32969 (107 days) and 35976 (122 days) and Lamb 45060 (two days plus gestation period 147 days), since the hairy coat was well established, no attempt was made to remove separately the adhering celloidin coat, which in any case, prevented stretching of the skin during removal.

The data obtained from the ten foetuses are tabulated thus:—

TABLE I.

1 Lamb.	2 Age. (Days.)	3 (*w*) Weight. (gm.)	4 (*l*) C.R. Length. (cm.)	5 (*a*) (2) Surface Area. (sq. cm.) (Observed.)	6 (2) Surface Area. (sq. cm.) (Expected.)
No number.....	± 28	—	—	3·1	—
35712.....	31	1	1·9	3·5	3·6
38510.....	55	40	9·8	58	58·3
35659.....	61	70·6	11·0	90	90·9
35592.....	64	82	12·9	98	101·6
33131.....	92	617	25·0	440	485
39904.....	94	680	25·0	522	524
32969.....	107	1,326	29·5	854	875
35976.....	122	2,230	32·0	1,275	1,314
45060.....	147 + 2	2,975	40·0 (1)	1,920	1,644
45023.....	± 149	3,750	45·0	2,100	1,992

(1) Height at withers on second day was 34·5 cm.
(2) The legs below the carpus and tarsus were not taken into consideration.

DISCUSSION.

We shall deal now with the effect of age on (*a*) the increase in surface area and (*b*) the relation between surface area and body weight.

(*a*) *The Effect of Age on the Increase in Surface Area.*

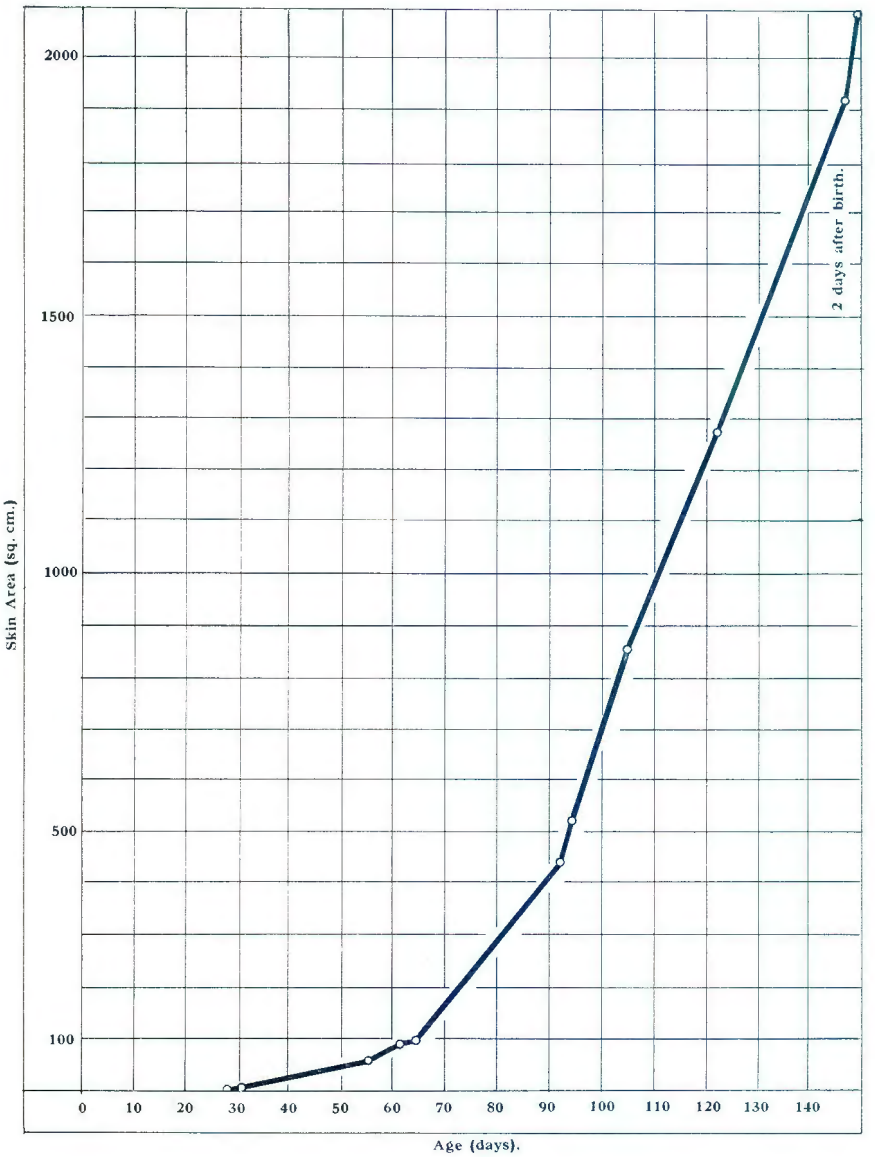
The information available concerning skin area at different ages is contained in columns 5 and 2 respectively in Table I. These particulars are diagramatically shown in Chart A, where surface area is plotted against age and the various points joined by a series of straight lines.

As in other features of prenatal growth, *e.g.* body weight and C.R. length, the increase in surface area with age is exceedingly slow during early pregnancy, but increased rapidly with advancing age. This acceleration in the growth rate has its maximum in the beginning of the gestation period and decreases to a negligible value towards the end.

The average rate of increase in surface area for the whole prenatal period was approximately 13 sq. cm. *per diem*. How this rate of increase, however, varies with age is shown in Chart A, and also if one arbitrarily divides the gestation period into three stages of about fifty days each. The growth rates in surface area during these successive intervals are approximately 1 sq. cm. *per diem*, 15 sq. cm. *per diem*, and 25 sq. cm. *per diem* respectively. It is also obvious that the total increase during the first half of pregnancy is very little in comparison with that during the second half.

CHART A.

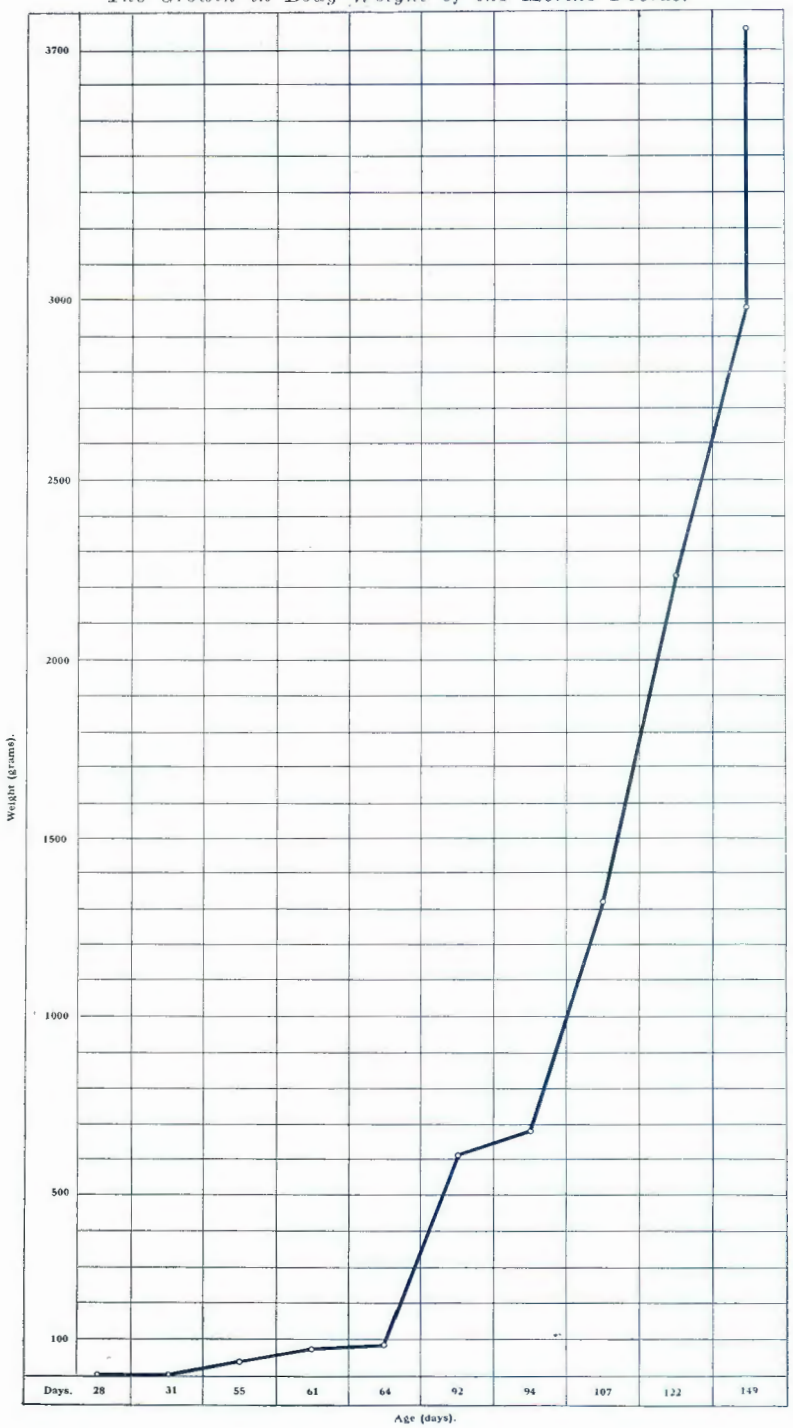
The Increase of the Skin Area of the Merino Foetus.



The surface area is found to double itself during the last forty days of the gestation period, and the skin area of the mature Merino sheep (Lines and Pierce) is approximately five and a half times that of the new born lamb. (The body weight also doubles itself during the last forty days of the gestation period, *but* the mature weight is approximately twelve times the birth weight.)

CHART B.

The Growth in Body Weight of the Merino Foetus.



(*b*) *The Effect of Age on the Relation between Surface Area and Body Weight.*

For the sake of comparison with Chart A (which illustrates the increase of surface area with advancing age), Chart B has been prepared to show the growth in body weight for the same series of foetuses. There is a remarkable resemblance between the two graphs except for a less marked increase of body weight during the first half of pregnancy and a more pronounced growth in weight during the second half. This indicates the relatively greater acceleration of the growth in body weight.

A better picture, however, of the actual relationship is furnished by Chart C where $\log_e$ (weight) is plotted against $\log_e$ (surface area) as tabulated below.

CHART C.

The Relation between the Relative Growths in Weight and Skin Area for the Merino Foetus.

(Dotted line: $x = 1{\cdot}284y - 1{\cdot}530$.)

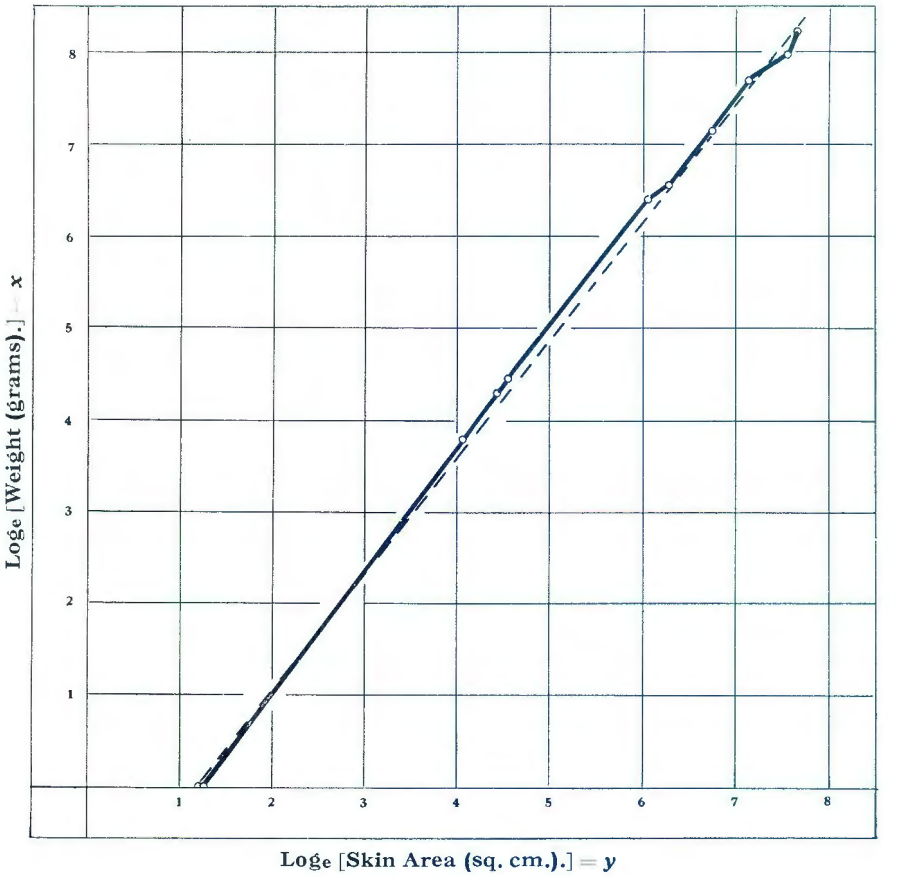


TABLE II (*Logarithmic values*).

Lamb.	$\log_e$ (C.R. Length).	$\log_e$ (Weight). x	$\log_e$ (Skin Area). y
No number.....	—	—	1·1314
35721.....	0·6419	—	1·2528
38510.....	2·2824	3·6888	4·0604
35659.....	2·3979	4·2627	4·4427
35592.....	2·5649	4·4067	4·5850
33131.....	3·2189	6·4249	6·0868
39904.....	3·2189	6·5221	6·2558
32969.....	3·3843	7·1854	6·7499
35976.....	3·4657	7·7098	7·1507
45060.....	3·6888	7·9980	7·5596
45023.....	3·8067	8·2295	7·6497

The strong linear relationship between the logarithmic values is clearly shown by Chart C. This apparent linearity suggests a constant ratio between the relative increases in surface area and those in body weight. $\left\{ \frac{d}{dt}(\log_e w) = \frac{1}{w}\frac{dw}{dt}, \text{ and } \frac{d}{dt}(\log_e a) = \frac{1}{a}\frac{da}{dt}. \right.$

Therefore for a constant relationship between these relative increases, a straight line is to follow when the natural logarithms of the weight are plotted against the natural logarithms of the *corresponding* skin areas. The best fitting straight line to these logarithmic values was obtained by the method of least squares and is shown on Chart C by the dotted line, its equation being:—

$$x = 1{\cdot}284y - 1{\cdot}530 \text{ or } y = 0{\cdot}778x + 1{\cdot}200 \quad \ldots \quad (1)$$

where $x = \log_e$ (*weight*) and

$y = \log_e$ (*area*) as shown in Table II.

When in the above equations the logarithmic values are transformed into units of actual observation the following parabolic relationships are obtained:—

$$w = 0{\cdot}217a^{1{\cdot}284} \text{ or } a = 3{\cdot}320w^{0{\cdot}778} \quad \ldots \quad (2)$$

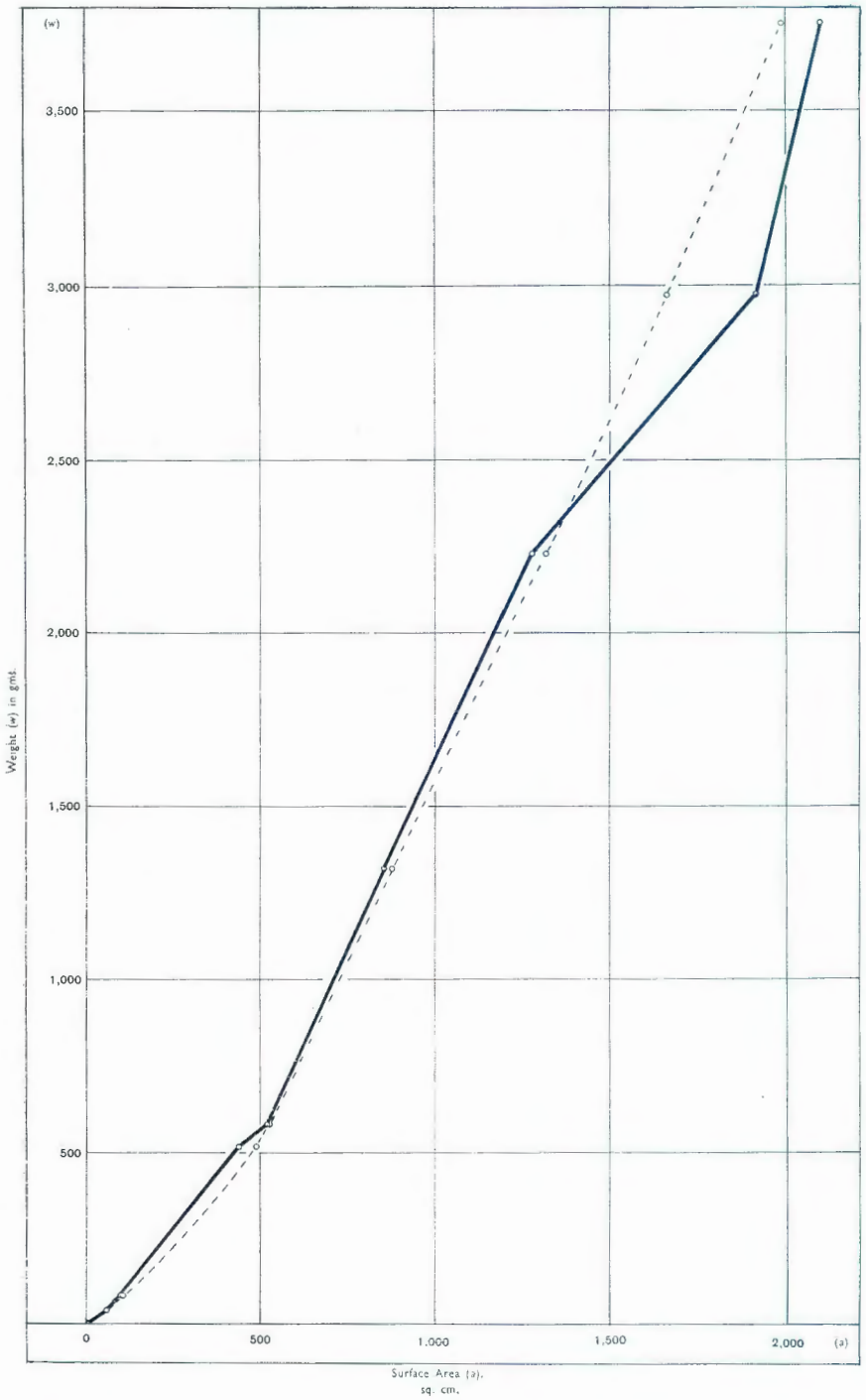
where $w =$ *body weight in gm.* and

$a =$ *surface area in sq. cm.*

This relationship is shown by the dotted line on Chart D. The points joined by a series of continuous straight lines represent the observed values for body weight and surface area, as given in columns 3 and 5 of Table I, while the expected surface areas for the corresponding observed weights are calculated from the above relationship (2) and given in column 6 of Table I. These "expected" values are in fair agreement with those observed. Although the obvious discrepancy of the second last point in chart D is, when expressed as a percentage, not unduly great, some explanation may be given. Lamb 45060 was measured two days after birth and the fact that it was rather thin explains the relatively low weight in comparison with skin area.

CHART D.

The Relation between Body-weight and Surface-area of the Merino-foetus.



In various publications on basic metabolism of sheep (*e.g.* Lines and Pierce, 1931), different values for the constants in the above relationship (2) are given.* A fairly exhaustive review of the literature on the subject is given by Brody (1934) in the *Annual Review of Biochemistry*. The power index in the parabolic relationship between surface area and weight is $\frac{2}{3}$ according to Meeh, whose value is most frequently adopted. Brody, however, suggests 0·70 which is still rather lower than the value for the prenatal stage as shown above.

Although the number of foetuses for which data concerning both weight and skin area exist is only ten, the value for the index is given by the present method of calculation as $0{\cdot}778 \pm 0{\cdot}0104$. This value may therefore not be expected for 1 per cent. probability from an actual value which lies outside the limits 0·75 and 0·81. It is, however, suggested that this value may vary from breed to breed and even differ slightly for different flocks of the same breed.

Another point for consideration was the relationship between surface area and C.R. length and the relationship between surface area and both weight and C.R. length. Since, however, surface area was more accurately expressed in terms of body weight than in terms of C.R. length, and furthermore since the remaining variance in surface area which was not expressed in terms of body weight was of the same order as the accuracy of observation, the inclusion of C.R. length in the present case serves no useful purpose.

Summary.

The increase in surface area of the Merino foetus is discussed.

The relationship between surface area and body weight, as estimated from the present series of foetuses is expressed by the equation $a = 3{\cdot}320\ w^{0{\cdot}778}$.

Several charts are given to illustrate the features described.

Acknowledgment.

We wish to thank Messrs. C. G. Walker and F. D. Horwell for their assistance and interest in the observations.

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* See Section "Heat-production of Mammalian Embryos", p. 732, Vol. II, Needham.

ADDENDUM.

In addition to the observations presented and discussed in the preceding article the following information is now available:—

TABLE.

Foetus of Ewe.	Age of Foetus (days).	(w) Weight in gm.	(l) C.R. length (cm.).	(a) Surface area (sq. cm.).	
				Observed.	Expected.
44803.....	33	1·25	2·4	4·4	4·6
44849.....	60	44·5	10·5	79	71
15337.....	90	530	24	451	472
35821.....	121	2170	36	1353	1387
44397.....	145	3300	37	1930	1911

The data given in the above table should be compared with Table I in the text. (The straight C.R. length is included merely for the sake of completeness.)

The " expected " values for the surface area in the last column of the above table are calculated from the following equations.

$$y = 0{\cdot}765x + 1{\cdot}358 \quad (x = 1{\cdot}307y - 1{\cdot}771),$$

where $y = \log_e$ (surface area),

and $x = \log_e$ (body weight).

These equations are obtained by fitting straight lines to the data in the third and 5th columns.

When these equations are transformed to units of actual observation the following parabolic equations are obtained:—

$$a = 3{\cdot}889\ w^{0{\cdot}765} \quad (w - 0{\cdot}170\ a^{1{\cdot}307}).$$

where $a = surface\ area\ in\ sq.\ cm.$

$w = body\ weight\ in\ gm.$

The agreement between the observed and expected values is obvious.

The numerical coefficients in the above equations are by no means significantly different from those given in the text. Therefore, in order to obtain more reliable estimates of these coefficients all the relevant data given in both Table I (already referred to) and the above table were taken together. The resulting parabolic equations are:—

$$a = 3{\cdot}543\ w^{0{\cdot}771} \quad (\text{and } w = 0{\cdot}196\ a^{1{\cdot}295}).$$