Onderstepoort Journal of Veterinary Science and Animal Industry, Volume 4, Number 2, April, 1935.

Studies in Sex Physiology, No. 13.

The Changing Proportions of the Merino Lamb from the Second to the Fifth Month of Prenatal Life.

By

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INTRODUCTION.

THE *situation of the foetus* having been observed in the dead uterus, i.e., after removal from the ewe (Curson and Quinlan, 1934; Curson and Maré, 1934) and the *relationship between the pregnant horn and its corresponding corpus luteum verum* having been ascertained (Curson, 1934; Curson and Maré, 1934), it is possible to continue our investigations *either* by studying the foetus *or* the uterus.

It is proposed now to devote some attention to the *changing proportions accompanying the development of the foetus*, the material being derived from that tabulated in Study No. 10 (Curson and Quinlan, 1934), *viz.*: Nos. 3, 10, 19, 22, 27, 33, 36 and 40, and Study No. 12 (Curson and Maré, 1934), *viz.*: Nos. G (*a*), H, 42, 43, 44 and 45. The ages represented by this series extend from 25 days to 145 days, the interval between each foetus being readily ascertained from a perusal of Plate I, which shows each specimen reduced two-fifths of the original.

For this investigation Hammond's (1932) survey of the problems involved in mutton production and Arey's (1931) textbook of embryology have been consulted.

It is intended to deal now with the *effect of age* on (*a*) general body form, (*b*) weight, (*c*) length, and (*d*) the inter-relationship between weight and length. A comparison is also to be made with the human foetus (*e*).*

* Needham, J. (1931) in "Chemical Embryology" states (Vol. 1, p. 379) "as early as 1847 Gurlt made a study of the increase in length of the foetus of the sheep, but Colin is the only investigator who has ever determined the growth in weight". Their figures are given here as an appendix. Data are also given by Needham for the cow but not for the goat.

(*a*) Effect of Age on General Body Form.

Plate I (showing fourteen foetuses at approximately intervals of ten days) and Plate II (showing the same foetuses with the height at the withers constant) should first be studied.

Remarks on Plate I.—Details concerning the specimens have been arranged in tabular form (see Table 1), so there is no need to amplify their identification. As will be observed, the interval between each foetus is either ten days or approximately ten days. The unnatural posture of the lambs is due to the effect of preservation in formalin. Unfortunately specimen G (*a*) was lost, hence the absence of information regarding weight and length. The relative particulars for a 30 day old foetus H, are, however, given.

Remarks on Plate II.—Here the differences in body proportions are better seen than in Plate I, for the height at the withers is now identical. The Plate should be compared with Figures 2 (p. 92), 3 (p. 154), and 8 (p. 194), featured by Hammond*.

In a comparison of body form, it is striking how the general change becomes less marked as the age increases, e.g. the greatest variation occurs from 25-35 days. Between 35 and 44 days the proportions are markedly altered, but from the 45th day onwards they become less emphasised. From the 96th day there is comparatively little change. It is the apparent decrease in size of the head which is most marked.

Macroscopically, the most important external change between 96 days and 115 days, particularly between 105 and 115 days, is the acquirement of a coat, which by the 125th day is well developed. It is not intended to give more than a general idea of the changing body form, but it may be mentioned that as early as the 40th day† hair buds may be seen with a lens on the lips and eyelids.

The above and other changes, e.g. development of hoofs, will receive more detailed treatment in a subsequent study on the establishment of the external form.

Above have been described and represented pictorially the general changes of body proportions. These are accompanied by a growth in weight, an addition in length and an increase in surface area‡.

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* The Suffolk embryo of two months shown in Fig. 2 of Hammond's book does not agree in regard to appearance with our foetal material. We would estimate this specimen at approximately 5-6 weeks.

† Duerden and Ritchie (1924) write, " Until the foetus is about two months old the surface of the skin is perfectly bare, free from any trace of hair. *By the end of the second month*, however, small light spots appear, easily discernible with a hand lens ". (p. 482.)

‡ As another series of foetuses is to be used for the observation on surface area (see Lines, E. W. & Pierce, A. W. on " Surface area of the Merino sheep in relation to the live weight of the animal ", Bull. 55. Council for Scientific and Industrial Research, Commonwealth of Australia), the Study will be published separately.

(*b*) The Effect of Age on Body Weight.

Table I.

1. Lamb.	2. Age.	3. Weight. (W) gms. (See Chart A.)	4. Crown-Rump Length. (cms.). Observed. (See Chart B.)	5. Crown-Rump Length. (cms.). Expected.	6. $\log_e$ (Weight).	7. $\log_e$ (Length).
H. (Not shown in Plate 1).	30 days.....	0·62	1·6	1·66	$\bar{1}$·5220	0·4700
3	35 days 1 hour	1·9	2·4	2·48	0·6418	0·8755
10	44 ,, 21 ,,	7·8	3·9	4·14	2·0541	1·3610
19	55 ,, 4 ,,	36·5	7·9	7·22	3·5973	2·0669
22	64 ,, 16 ,,	88·4	10·5	9·95	4·4819	2·3514
27	72 ,, 13½ ,,	187	14·1	13·1	5·2311	2·6462
33	84 ,, 19 ,,	414	18·7	17·4	6·0259	2·9285
36	96 ,, 18 ,,	959	23·5	23·5	6·8659	3·1570
40	105 ,, 2 ,,	1,576	25·5	28·2	7·3652	3·2387
42	115 ,, ...	1,490	26·0	27·6	7·3066	3·2581
43	125 ,, ...	2,810	33·0	34·7	7·9409	3·4965
44	135 ,, ...	2,780	35·0	34·6	7·9302	3·5554
45	145 ,, ...	2,790	35·0	34·6	7·9338	3·5554
38138 (Not shown in Chart B.)	At birth. 16/6/33	3,700	37·0 (at withers.)	—	—	—

In Table I are given the weights in grams, the C.R. lengths in cm. and the natural logarithms of these weights and lengths (columns 3, 4, 6 and 7, respectively), opposite the corresponding ages (column 2), for the thirteen different foetuses (column 1).

Columns 2 and 3 give a comparative age-weight growth rate, which is illustrated graphically by those points connected by a series of continuous straight lines on Chart A. On the other hand, just as the difference between any two consecutive values of weight in column 3, divided by the time interval between the corresponding ages in column 2, gives the average increase in weight during that period, so the average relative increase in weight is obtained from the logarithmic values in column 6. $\left[\frac{d(\log_e w)}{dt} = \frac{1}{w}\frac{dw}{dt}\right.$, i.e. the change in the natural logarithm of the weight with age is equal to the change in weight with age divided by the actual weight at that age. w = weight and t = time.]

At the early stages, during the first 1½ months, growth in weight takes place at a very low rate, which increases rapidly, however, owing to a considerable acceleration during the first 3 months. At about the age of 100 days an average daily increase in weight of almost 62 gm. was reached as compared with an increase of only about ¼ gm. per day at the end of 30 days. Beyond the age of 100 days strong irregularities will be observed, such as a drop in

CHART A.

Comparative age—weight growth rate of lambs.

Weight (gm.).

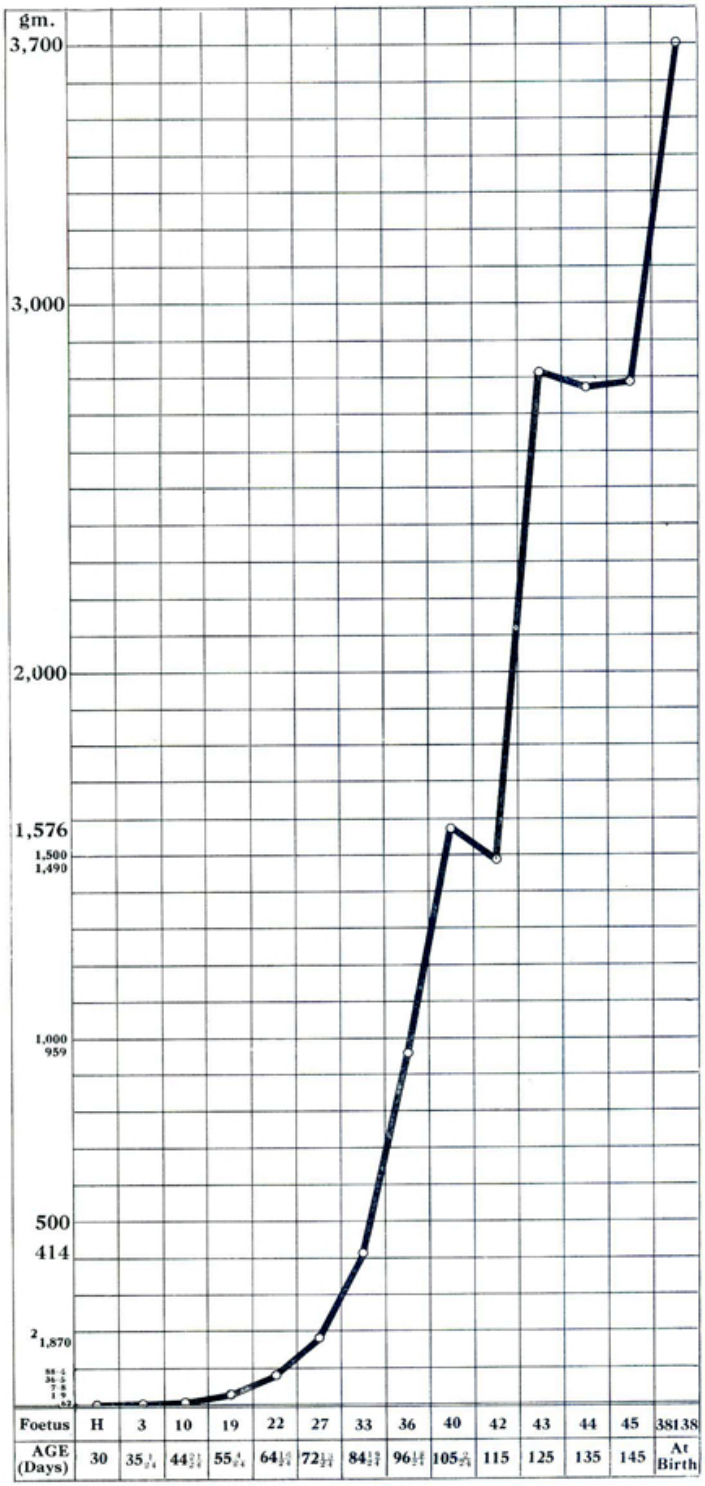
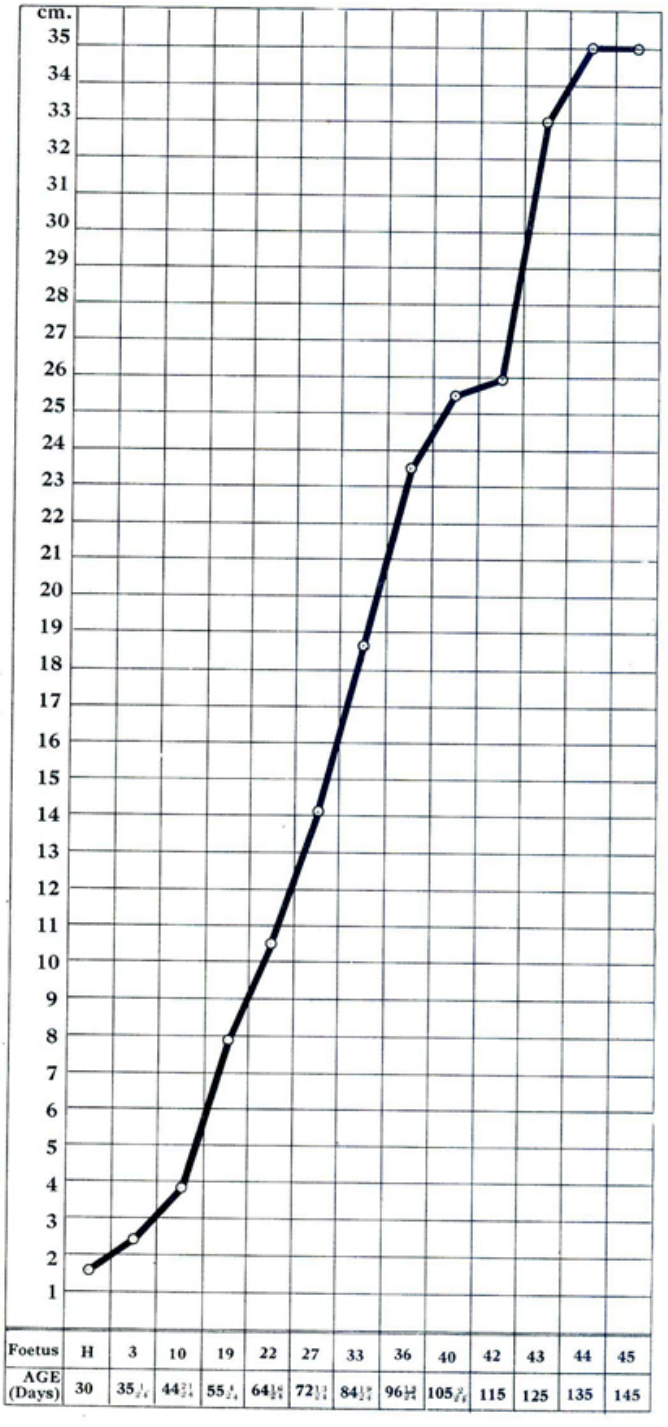


CHART B.

Comparative age—C.R. length growth rate of lambs.

Length (cm.).



weight as regards foetuses 42, 44 and 45. These fluctuations can be well understood, for the series of lambs was taken at random and there is considerable variation in the weight of individuals of the same age. Yet the data seems to indicate a decline in the gains in weight towards the end of the prenatal period. As regards the relative increases in weight $(\frac{1}{w}\ \frac{dw}{dt})$, there appears to be a gradual decline as the weight increases. This relative increase falls from well over 200 per cent. for the early observations to a very small value towards the end.

(*c*) The Effect of Age on Crown-Rump Length.

The particulars tabulated in columns 2 and 4 of Table I have been transposed to Chart B which accordingly shows the increasing length diagramatically. The shape of the curve resembles the integration sign $\int$ or an elongated " S ".

At the end of the first month the rate at which the C.R. length increases is approximately 0·16 cm. per day, slowly accelerating to a rate of just less than 0·5 cm. per day at the age of about 85 days. After this stage (about 85 days of age), a gradual decline in the growth rate again sets in till birth. Obviously the changes in length are much less marked than those in weight as may be expected. Also, inspite of the decreased weights represented by foetuses 42, 44 and 45, there has been no decrease in C.R. length. The relative increase in length $\left[\frac{d\ (log_e\ l)}{dt} = \frac{1}{l}\frac{dl}{dt}\right.$, where l = C.R. length, and t = time or age$]$, shows the same gradual decline with increasing age as was observed in the case of weight, though over a much smaller range. Here, in the case of the C.R. length, the relative growth rate falls from only about 50 per cent. at the end of the first month to a very small value at birth.

(*d*) Relation between the Increases in Weight and C. R. Length.

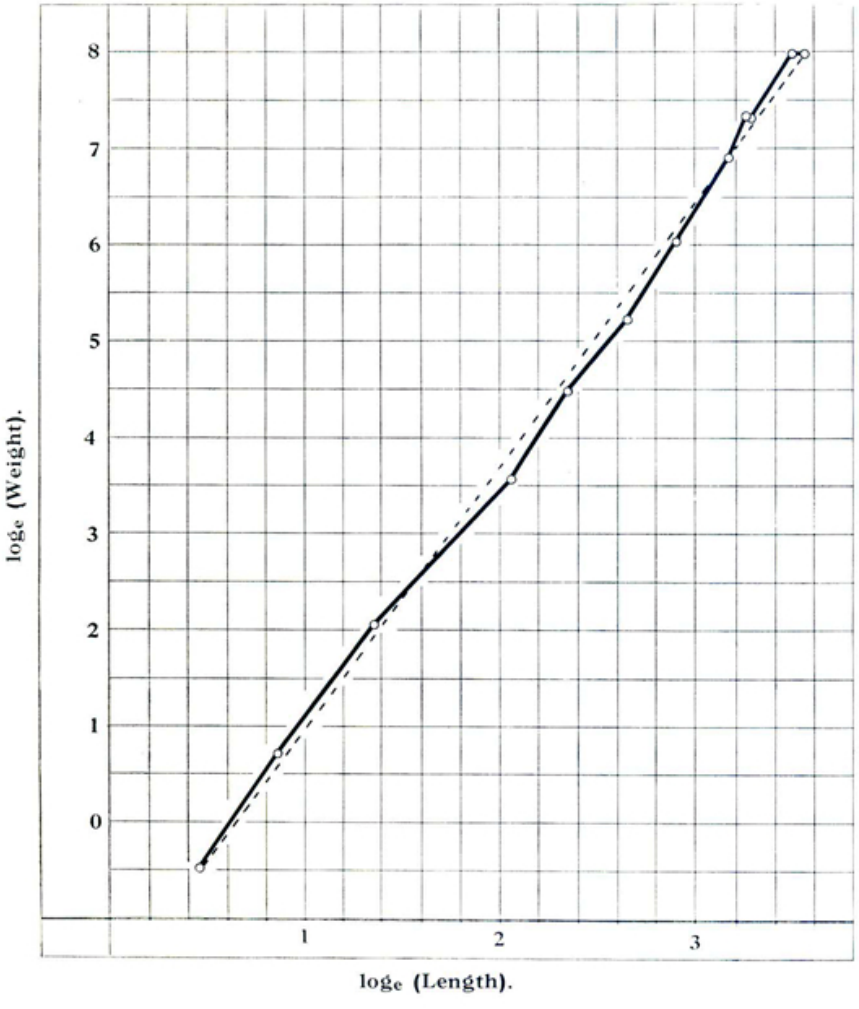
The most obvious feature in the comparison between growths in weight and C.R. length, as shown by the discussions under (*b*) and (*c*) and illustrated by the accompanying Charts A and B, is the much smaller change in the case of length. Thus the average growth rates over the 145 days for foetus 45 were about 9 gm. per day and a little less than $\frac{1}{4}$ cm. per day for weight and length respectively. Moreover the maximum increase in weight (about 62 gm. per day) was not reached before the age of 100 days, which is well after the age, about 85 days, where the maximum gain in length (nearly 0·5 cm. per day) has been reached.

For a direct comparison of relative increases in weight and C.R. length the natural logarithmic values for these two items have been entered in Table I, columns (6) and (7) and also plotted on Chart C. The points are connected by a series of continuous straight lines in order to illustrate more clearly the strong linear relationship which exists. The dotted line, Chart C, represents the " ideal " straight

CHART C.

Comparison of relative increases in weight and C.R. length.

(Dotted line represents $y=0{\cdot}676+0{\cdot}3613x$.)



line for the observed points, obtained by the method of least squares. The equation for this straight line in terms of the logarithmic values is:—

$$y = 0 \cdot 676 + 0 \cdot 3613x \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where y = log (length), and x = log (weight).

In order to represent the above " ideal " relationship in terms of the absolute values for length and weight the transformed equation becomes:—

$$l = 1 \cdot 97 w^{0 \cdot 361} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where l = C.R. length in cm., and w = weight in gm.

NOTE.—Giving the weight in terms of length the above equation (2) becomes: $w = 0 \cdot 154\, l^{2 \cdot 77}$

This equation (2) represents a member of the parabolic family of curves and is shown by the points on the dotted curve of Chart D. These points are observed weights against the corresponding " expected " length as derived from equation (2), and given in Table I, column 5. A comparison between columns 4 and 5 of Table I shows the close agreement between the observed lengths and those " expected " for the corresponding weights in column 3. The discrepancies between the observed and " expected " values in length is also very well illustrated by the curves on Chart D, and equation (2) is, obviously a fair approximation to the actual observed relationship between weight and C.R. length.

(*c*) COMPARISON WITH THE HUMAN FOETUS.

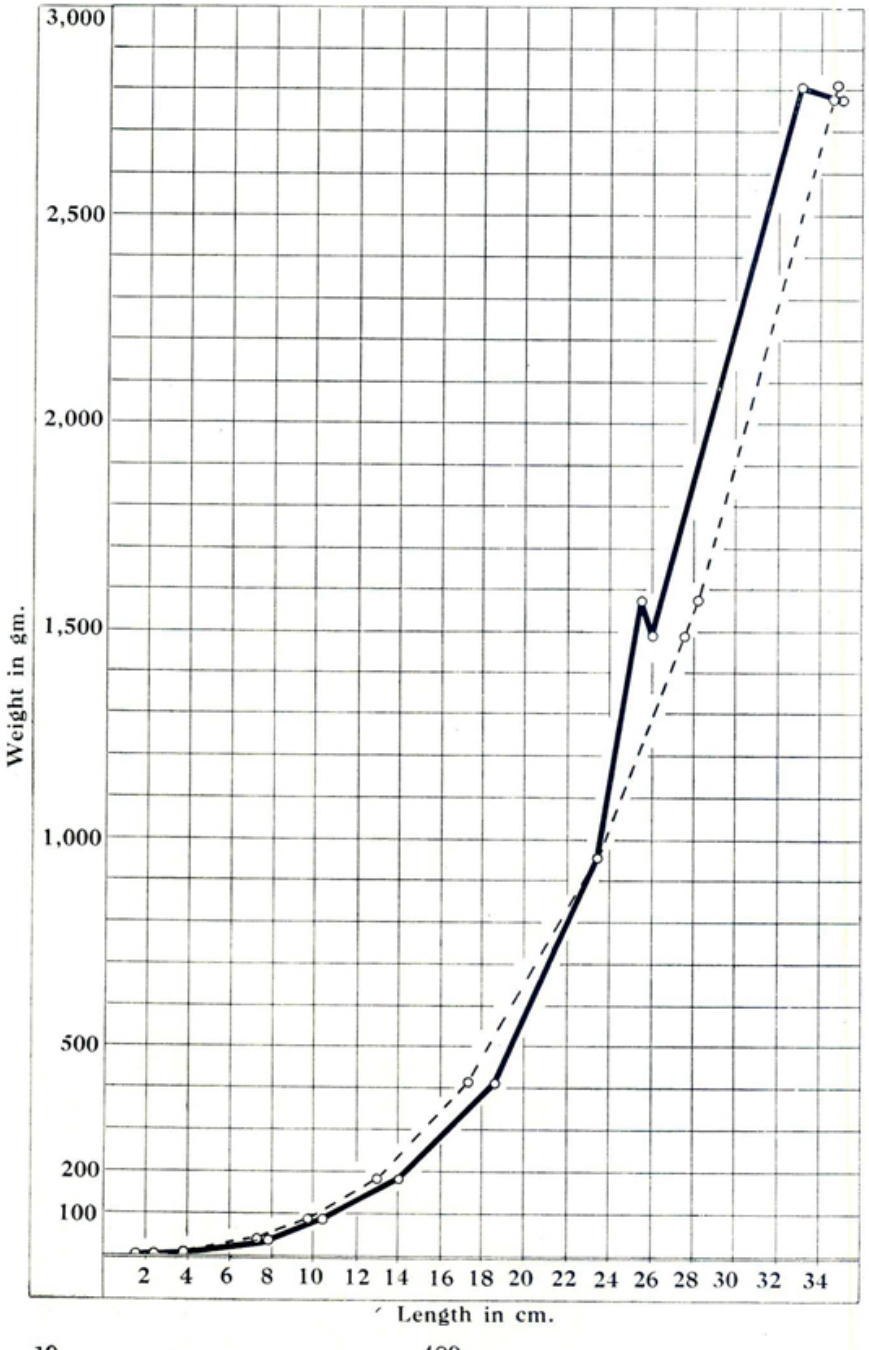
Table II. The Human. (*Arey*, 1931, *p.* 106.)

1. Age (months).	2. Weight (w) gms.	3. Crown–Rump length (l.). Observed (cm.).	4. Crown–Rump length (l.). Expected (cm.).
1.....	0·004	5·5	4·9
2.....	2	25	33
3.....	24	68	66
4.....	120	121	121
5.....	330	167	167
6.....	600	210	202
7.....	1,000	245	237
8.....	1,600	284	275
9.....	2,400	316	313
10.....	3,200	336	342

Table II represents the average weight and C.R. length for the human embryo at monthly intervals as given in the above reference. The general trend in growth for the human embryo agrees well with that of the sheep. Graphically the age-weight growth curve for the human also closely resembles the shape of a hockey stick, as is the case with the sheep data for the main part, Chart A. So the age-C.R.

CHART D.

Relationship between growth in weight and C.R. length for lamb.
(Dotted line represents $l = 1 \cdot 97 w^{0 \cdot 361}$)



length curve for the human embryo may also be compared with an integral sign $\int$ or elongated " S ", with a slight downward bend in the middle. The maximum increases are about 50 cm. in C.R. length at about the age of 5 months, and 800 gm. in weight after the age of 8 months. There is also a decline in the growth rate of C.R. length towards the end of the prenatal period, but no such decline is shown by the weight.

It has been found possible to represent the relation between weight growth and linear growth in sheep during the prenatal period by the equation:—

$$l = Cw^n$$

where l = length, and w = weight.

The fitting of this equation was accomplished by plotting the logarithms of weight against those of length and finding the best fitting straight line by the method of least squares. When the logarithmic values are then transformed to the units of actual observation the above parabolic curve is found. Similarly the corresponding equation for the human was obtained and is represented by:—

$$l = 26{\cdot}65w^{\,0{\cdot}316} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3).$$

This equation is represented graphically by the points on the dotted curve of Chart E, where also the observed points for length and weight are shown on the continuous curve. The discrepancies between the observed and expected lengths for the given weight as shown in Table II, columns 3 and 4 and illustrated by Chart E are also fairly small.

SUMMARY.

This Study, the fourth of a series on merino foetuses, is concerned with the effect of age on (*a*) general body form, (*b*) body weight, (*c*) C.R. length, and (*d*) the relationship between the increases in weights and C.R. length. A comparison (*e*) is also made with the human foetus.

The changes observed are well illustrated in the two Plates and five Charts.

Previous Studies should be consulted for particulars regarding material.

In conclusion, we wish to record our indebtedness to Messrs. T. Meyer and G. C. Walker for their excellent work in regard to the Plates and Charts.

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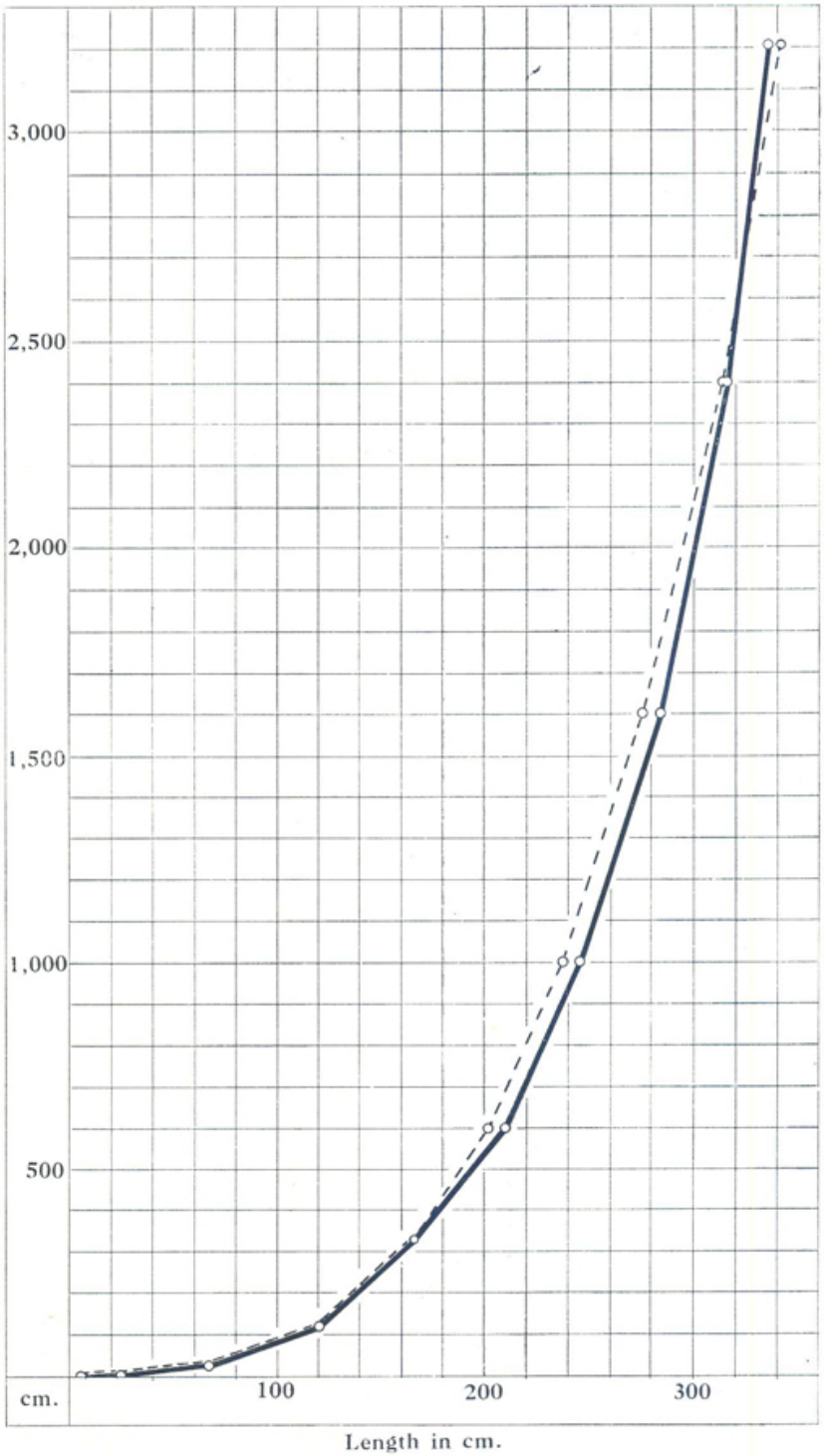
CHART E.

Relationship between growth in weight and C.R. length for the human.
(Dotted line represents $l = 26 \cdot 65w^{0 \cdot 316}$)



Human pre-natal growth.
(Data from Arey, 1931, p. 106.)

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APPENDIX.

(Taken from Needham's Chemical Embryology, Vol. III, p. 1675.)

Table 10.—*Embryonic growth (length) of the sheep.* (Gurlt.)

Week.	Day.	Length (cm.).	Week.	Day.	Length (cm.).
3	21	2·0	13	91	33·5
4	28	3·1	14	98	37·6
5	35	5·5	15	105	41·0
6	42	7·7	16	112	44·0
7	49	10·0	17	119	46·0
8	56	13·4	18	126	49·0
9	63	16·0	19	133	50·0
10	70	21·0	20	140	51·1
11	77	25·0	21	147	51·1
12	84	30·0	22	154	52·0

Table 11.—*Embryonic growth (weight) of the sheep.* (Colin.)

Day.	Weight of embryo (gm.).	Day.	Weight of embryo (gm.).
42	8·5	57	48·5
43	9·5	120	1,910
47	14	129	2,970
49	16	130	2,515
50	19	134	3,310
51	26	137	3,710