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Studies in Sex Physiology, No. 15.

Further Observations on the Body Weight and Crown-Rump Length of Merino Foetuses.

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In Sex Physiology Study 13 (Curson and Malan, 1935), the effect of age on the weight and C.R. length of the Merino foetus was considered, observations being based on 13 foetuses originally referred to in Sex Physiology Study 10 (Foetuses 3, 10, 19, 22, 27, 33, 36 and 40) and Study 12 (Foetuses H, 42, 43, 44 and 45). The C.R. length was measured in a *straight* line, according to the method described by Keibel and Mall (1910).

In Study 13 an approximate relationship between body weight and C.R. length was given, this being based on an apparent constant ratio between the relative increases in weight and the corresponding increases in C.R. length. Since, however, only 13 foetuses were employed, the estimated relationship was inaccurate due to individual variation in foetal growth. In order, therefore, to improve on the position, more extensive data are used for the results which now appear in this paper.

The data in question are obtained from Sex Physiology Studies 10, 12 and 16(*). The one series of foetuses (mentioned in Studies 10 and 12) was obtained from the same flock, *i.e.* Grootfontein School of Agriculture, Cape Privince, while the other series (mentioned in Study 16) came from Ermelo, Transvaal. These data are tabulated below in Tables I and II.

* See following Study which deals with the effect of age on the increase in surface area. For this a new series of foetuses was obtained.

TABLE I—(*The Grootfontein Series*).

	1 Foetus.	2 Age.		3 Weight. (gm.)	4 C.R. Length. (cm.)
		Days.	Hours.		
1	H	30	—	0·62	1·6
2	1	23	4	1·13	2·1
3	2	33	20	1·56	2·3
4	3	35	1	1·93	2·4
5	4	36	23	1·83	2·5
6	6	39	1	4·08	3·5
7	7	40	8	4·13	3·2
8	8	42	16	2·77	3·3
9	9	43	22	8·06	4·1
10	10	44	21	7·81	3·9
11	11	46	6	13·32	5·1
12	12	46	22	7·87	4·8
13	13	48	8	15·06	5·3
14	14	49	1	17·58	5·7
15	15	49	23	24·2	6·7
16	16	51	1	23·9	6·7
17	17	52	1	25·6	7·2
18	18	53	—	27·8	7·3
19	19	55	4	36·5	7·9
20	22	64	16	88·5	10·5
21	23	65	21	103·0	11·5
22	24	66	18	120	11·9
23	25	68	15	152	12·6
24	26	70	17	178	13·4
25	27	72	13	187	14·1
26	28	80	22	320	20·0
27	29	82	3	400	17·3
28	30	82	23	415	17·4
29	32	84	17	458	19·3
30	33	84	19	414	18·7
31	34	86	20	355	16·5
32	36	96	18	959	23·5
33	37	100	16	988	23·5
34	38	101	15	943	22·9
35	39	102	18	1,011	21·6
36	40	105	2	1,576	25·5
37	41	108	16	1,217	23
38	42	115	—	1,490	26
39	43	125	—	2,810	33
40	44	135	—	2,780	35
41	45	145	—	2,790	35

TABLE II—(*The Ermelo Series*).

	1 Foetus.	2 Age. (days.)	3 Weight. (gm.)	4 C.R. Length. (cm.)
1	35,712	31	1	1·9
2	35,510 Male	55	40	9·8
3	35,659 ,,	61	70·6	11·0
4	35,592 Female	64	82	12·9
5	33,131 Male	92	617	25·0
6	39,904 ,,	94	680	25·0
7	32,969 ,,	107	1,320	29·5
8	35,976 ,,	122	2,230	32·0
9	45,060 ,,	147+2	2,975	40
10	45,023 Female	± 149	3,750	45

CHART A.

Comparison of Relative Increases in Body Weight and C.R. Length of the Murine Foetus.

(The straight line represents $y = 0{\cdot}363x + 0{\cdot}7255$).

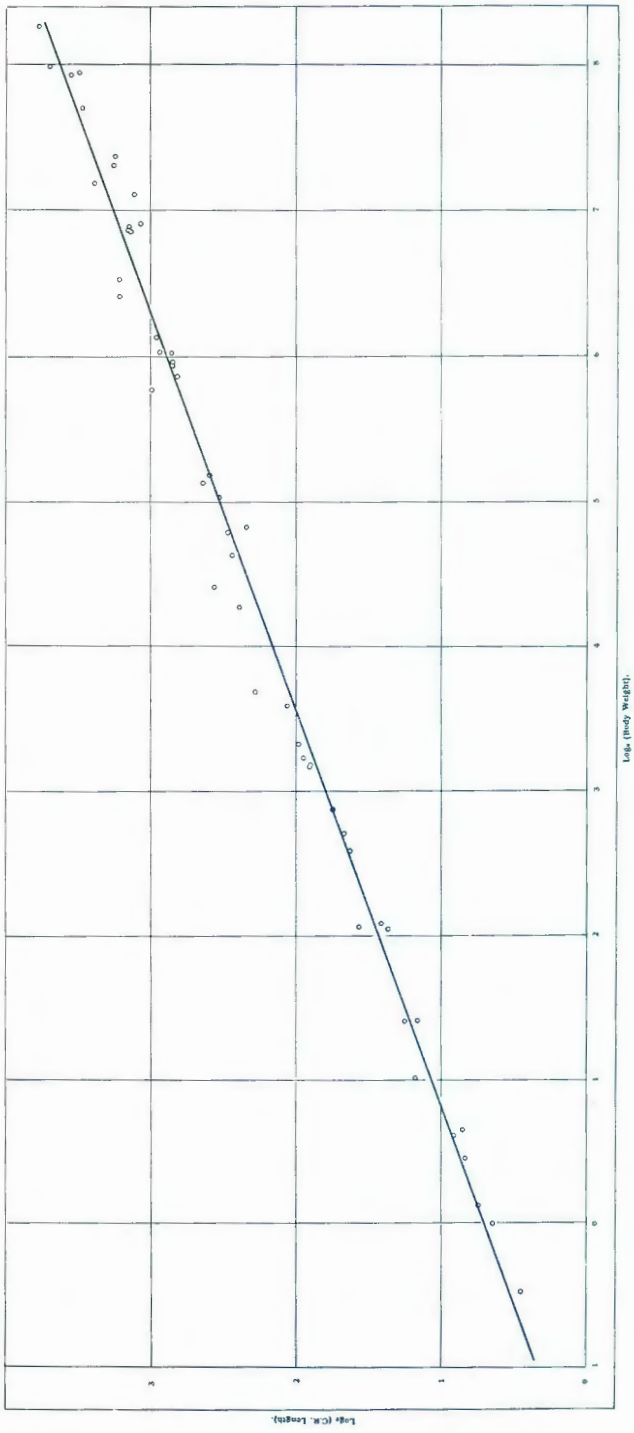
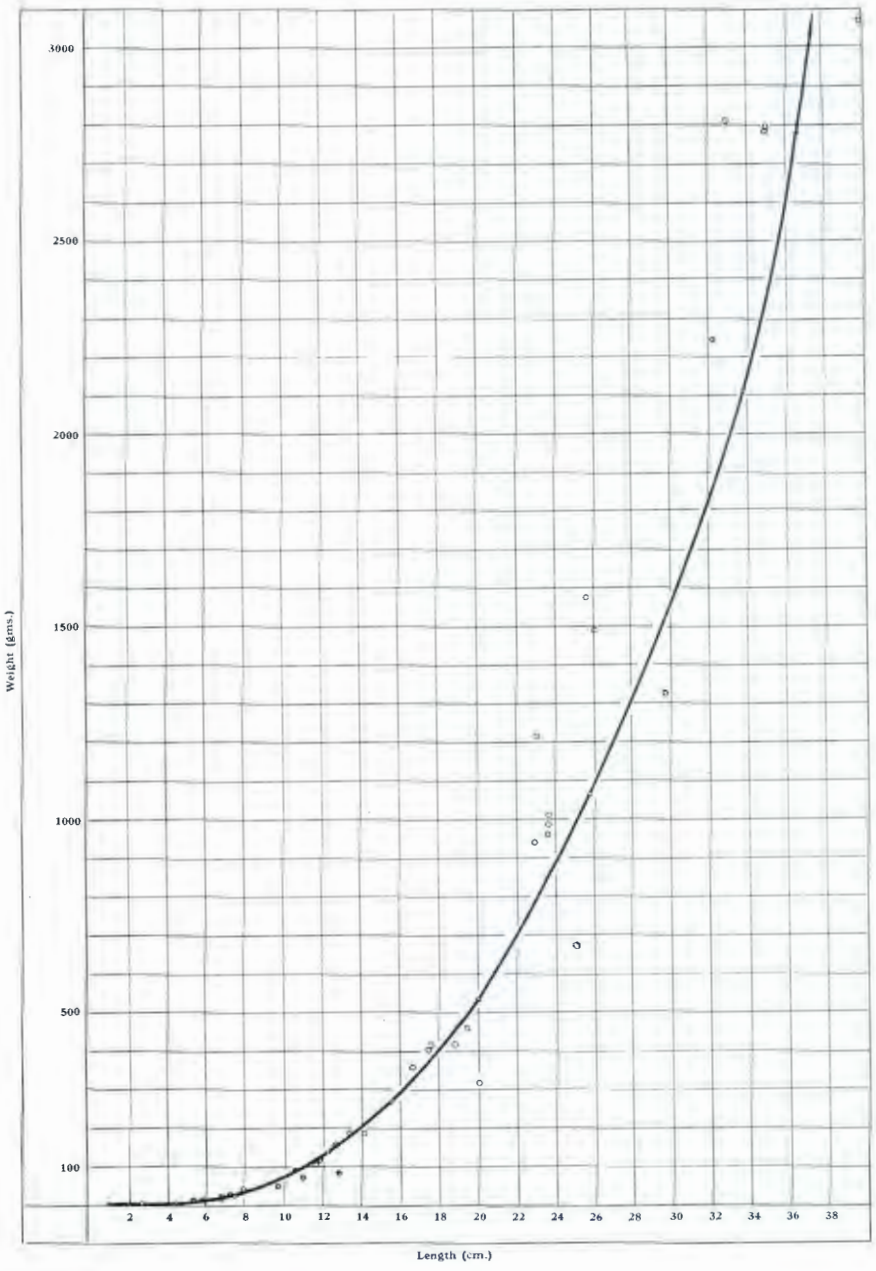


CHART B.

The Body Weight of the Merino Foetus plotted against its (straight) C.R. Length.

(The continuous line represents $w=0{\cdot}147l^{2{\cdot}735}$.)



When the natural logarithms of the weights and C.R. lengths are taken of all the data contained in Tables I and II, columns 3 and 4, and the values for the weight plotted against the corresponding values for length, a strong linear relationship is observed. This relationship is clearly illustrated by Chart A, where the continuous line represents the best fitting straight line.

The equation of this straight line was calculated from the logarithmic values by the method of least squares and is given by:—

$$y = 0 \cdot 363x + 0 \cdot 7255, \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ (1)$$

where $x = log_e$ (*weight*).

and $y = log_e$ (*C.R. length*).

As pointed out in the previous study (Curson and Malan, 1935) the linear relationship between the corresponding logarithmic values indicates a constant ratio between the relative increase in C.R. length and the corresponding relative increase in body weight. Or in other words, that the C.R. length, in units of actual observation, is proportional to a power of the body weight. This power index is represented by the " slope " of the straight line in Chart A and is equal to the coefficient of x in equation (1).

By converting equation (1) unto units of observation the following equation, illustrated in Chart B is obtained:—

$$l = 2 \cdot 066 \ w^{0 \cdot 363} \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ (2)$$

where $l = C.R.$ *length in cm.*,

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

[It is evident that where in the above equations (1) and (2) the C.R. length measurements are expressed as a function of the body weight values, the converse, *i.e.* expressing weight as a function of C.R. length is equally possible. The corresponding equations are:—

$$x = 2 \cdot 759y - 1 \cdot 934 \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ (1)^1$$

and $w = 0 \cdot 147 \ l^{2 \cdot 735} \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \ (2)^1$]

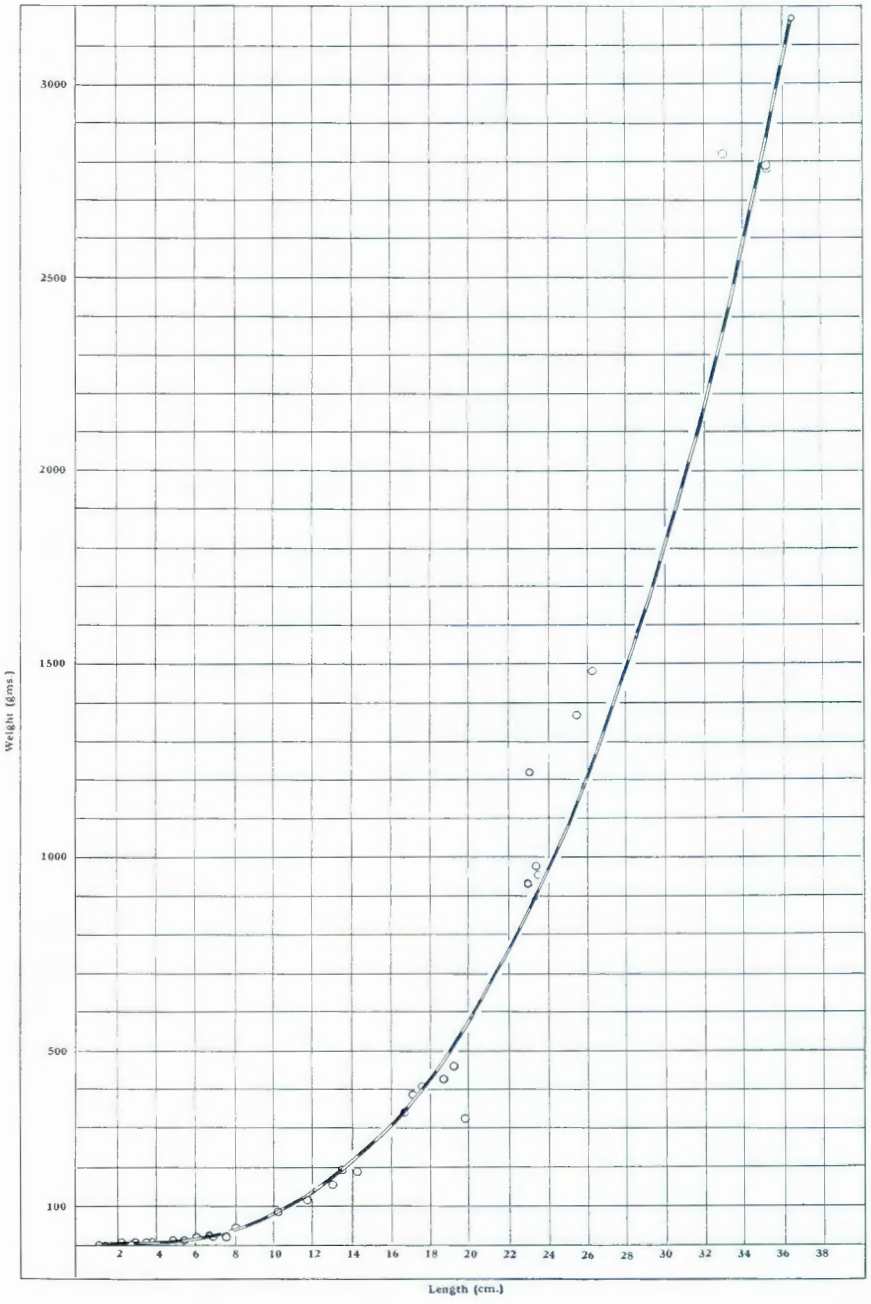
On the assumption of a linear relationship between the natural logarithmic values of weight and C.R. length it is clear that this relationship is uniquely determined by one point on the straight line (Chart A) and its slope. But to determine the accuracy, or standard error of the C.R. length, given by equation (1) for any particular natural logarithmic value of the body weight, one further assumption made in the calculation of this equation, must be adopted, *i.e.* the logarithmic values of all C.R. lengths during the gestation period had to be assumed as " equally variable ". This assumption also seems warranted by the data represented on Chart A.

When the deviation of a particular C.R. length from the corresponding *expected* value on the straight line given by equation (1) is considered, it has a standard deviation of which the estimate is $\pm 0 \cdot 0959$. These deviations, however, are differences between logarithmic values, and expressed in units of actual observation the above value is a ratio and should be interpreted as a standard deviation of 9·59 per cent. of the *expected* value.

CHART C. (GROOTFONTEIN SERIES.)

The Body Weight of the Merino Foetus plotted against its (straight) C.R. Length.

(The dotted line represents $w = 0 \cdot 135 l^{2 \cdot 80}$.)



The fact that the above estimate of the standard deviation is a constant percentage of the *expected* value, or in other words, that the standard deviation from the *expected* value expressed in units of observation is directly proportional to the corresponding *expected* value, is contained in the assumption made that the logarithmic values (of C.R. length and body weight) are equally variable.

[Taking the body weight as the dependent and C.R length as the independent variable and hence using equations (1)[1] and (2)[1] to estimate the standard deviation of an observed value for body weight, $\pm 26 \cdot 36$ per cent is found.]

It is now proposed to briefly deal with the "slope" of the straight line which is given by the coefficient of the independent variable in equation (1) and also by the power index in equation (2). The standard error of the statistic is $\pm 0 \cdot 005328$ and it is therefore *unlikely*† to obtain an estimate from a *corresponding* series of foetuses which will not fall between $+0 \cdot 350$ and $+0 \cdot 377$.

For the sake of comparison the data contained in Tables I and II were taken separately. The parabolic equations obtained from these series, together with the observed data, are graphically represented by Charts C and D. The equation for the Grootfontein series (Chart C) is:—

$$l = 2 \cdot 07 \ w^{0 \cdot 355} \text{ (or } w = 0 \cdot 135 \ l^{2 \cdot 80}) \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \quad (3)$$

and that for the Ermelo series (Chart D) is:—

$$l = 2 \cdot 23 \ w^{0 \cdot 366} \text{ (or } w = 0 \cdot 124 \ l^{2 \cdot 70}) \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \quad (4)$$

Where as before,

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

and $l = C.R.\ length\ in\ cm.$

TABLE III.—(See Sex Physiology Study 13).

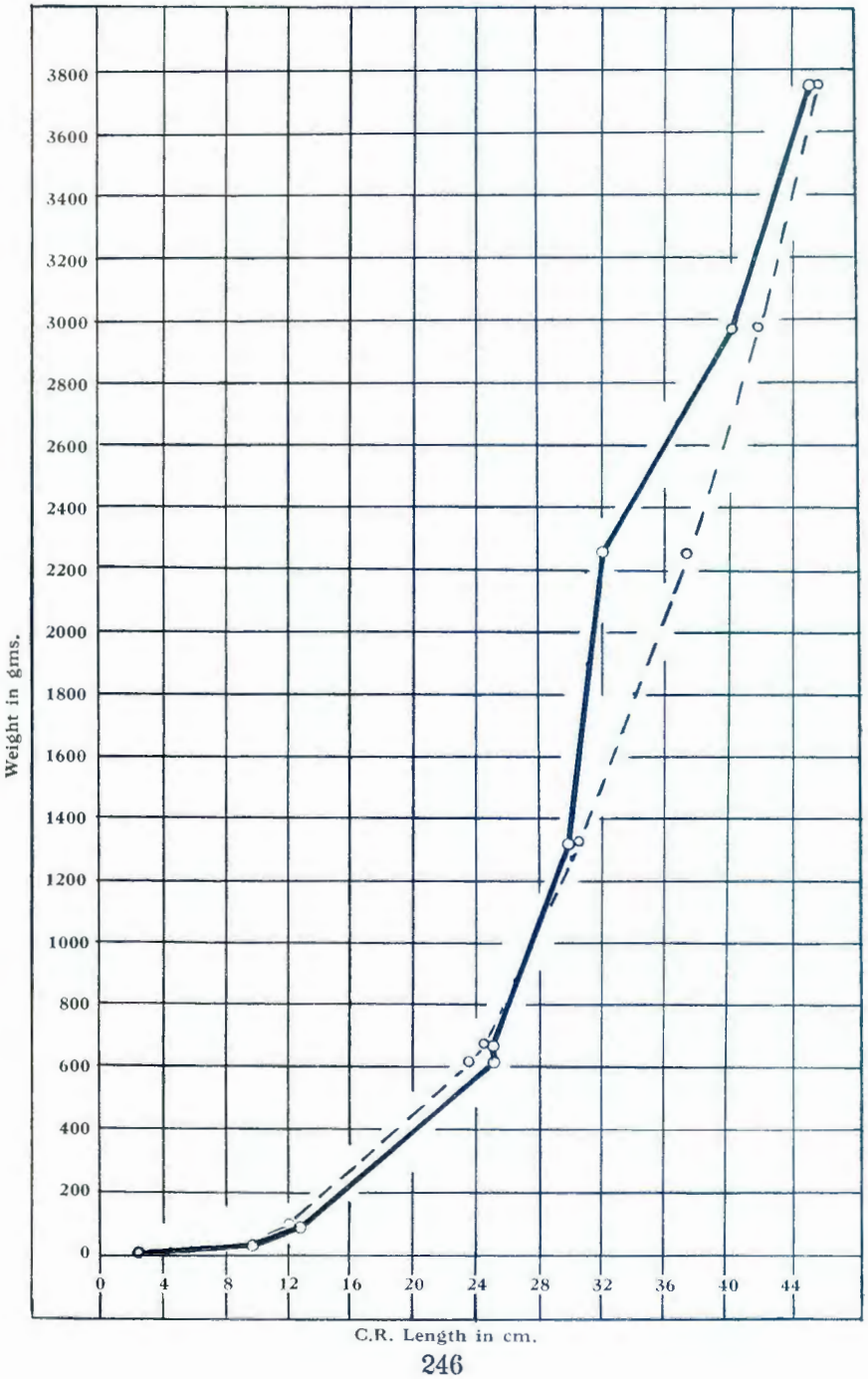
1 Foetus.	2 Age. (days.)	3 Weight. (gm.)	4 Curved C.R. Length (cm.). (observed.)	5 Curved C.R. Length (cm.). (expected.)
H.....	30	0·62	1·7	1·9
3.....	35	1·9	2·5	2·8
10.....	45	7·8	6·0	4·9
19.....	55	36·5	9·3	8·7
22.....	65	88·4	12·0	12·2
27.....	73	187	17·5	16·3
33.....	85	414	22·8	22·1
36.....	97	959	27·3	30·3
40.....	105	1,576	34·0	36·8
42.....	115	1,490	37·5	35·9
43.....	125	2,810	43·8	45·8
44.....	135	2,780	45·3	45·6
45.....	145	2,790	47·5	45·7

† Note that *unlikely* refers to a probability less than 1 per cent.

CHART D. (ERMELO SERIES.)

The Body Weight of the Merino Foetus plotted against its (straight) C.R. Length.

(Dotted line represents $w = 0{\cdot}124 l^{2{\cdot}70}$.)



As it was felt that the C.R. length measurements [given in the above tables and taken as indicated by Keibel and Mall (1910)], depend largely on the posture of the foetus, it was considered possible that a more reliable C.R. length might be obtained by measuring *along the back* instead of taking a straight line from the crown to the rump. Observations of the modified C.R. length were accordingly made, and the thirteen foetuses dealt with in Sex Physiology, No. 13 (Curson and Malan, 1935) were again measured, this time along the back and the results tabulated in Table III.

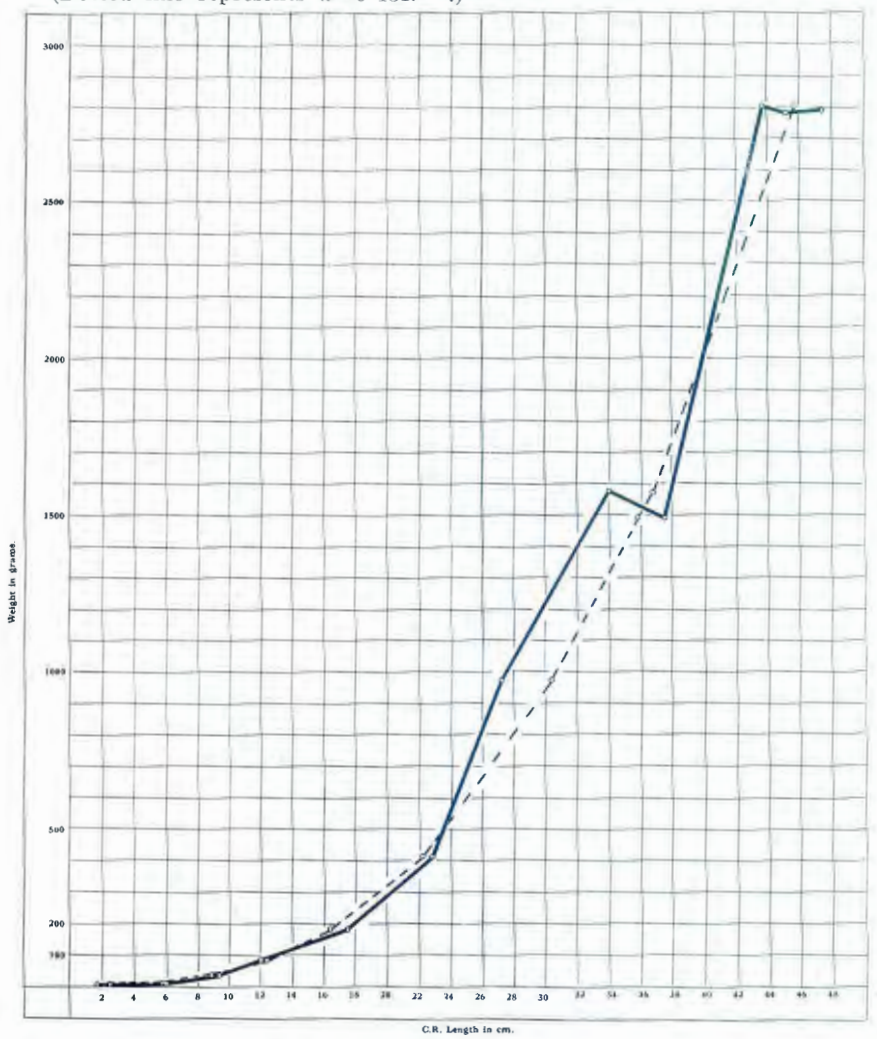
The relationship between the weight and " curved " C.R. length is given by the following equation:—

$$l = 2{\cdot}214\ w^{0{\cdot}382}\ (w = 0{\cdot}131\ l^{2{\cdot}60}) \ \ldots\ \ldots\ \ldots\ \ldots\ \ldots\ (5)$$

CHART E.

The Body Weight of the Merino Foetus plotted against its (curved) C.R. Length.

(Dotted line represents $w = 0{\cdot}131 l^{2{\cdot}60}$.)



The discrepancies between the observed and expected C.R. lengths (Table III) are shown by the points on Chart E, joined by continuous and dotted lines, respectively. Comparing the results obtained here with those in Sex Physiology Study 13, Chart D, the "fit" does not appear to be improved. The data are however too few for a definite conclusion.

It is striking how little information is available regarding C.R. lengths. Needham (1931), in the appendix, giving the normal magnitudes in embryonic growth, gives (Vol. III, pp. 1669-1678), merely the length (except in Table 18 where C.R. length is stated). That this factor should receive more attention and definite details indicated is exemplified in the striking differences to be noted in the length of certain measurements by Galpin (1935) and Curson and Quinlan (1934). The values given by Galpin appear to correspond with the curved C.R. length measurements of Table III, column 4. A comparative table is given hereunder:—

TABLE IV.

Age. (Days.)	Massey Agricultural College.	Onderstepoort.	
		Straight C.R. Length.	'Curved' C.R. Length.
42	6 cm.	3·3	—
43	—	—	6
55	—	—	11
56	11	8·4 (twins)	—
64	14	10·5	—
65	—	—	12
68	15	12·6	—
72	19–20	14·1	—
73	—	—	17·5
83	22–23	18·5 (twins)	—
85	—	—	22·8

SUMMARY.

1. The relationship between C.R. length and weight of two series of foetuses from Grootfontein School of Agriculture, Cape Province, and Ermelo, Transvaal, is considered. The results given below are clearly illustrated by the charts in the text.

(*a*) To series combined:—$l = 2 \cdot 066\ w^{0 \cdot 363}$ $(w = 0 \cdot 145\ l^{2 \cdot 735})$.

(*b*) Grootfontein series:—$l = 2 \cdot 07\ w^{0 \cdot 355}$ $(w = 0 \cdot 135\ l^{2 \cdot 80})$.

(*c*) Ermelo series:—$l = 2 \cdot 228\ w^{0 \cdot 366}$ $(w = 0 \cdot 124\ l^{2 \cdot 70})$.

2. The thirteen foetuses used in Sex Physiology Study No. 13, which is part of the Grootfontein series, were employed to determine

a relationship between weight and C.R. length along the curvature of the back. The result is illustrated by Chart E. The equations for the relationships under discussion are:—

(*a*) Straight C.R. length:—

$l = 1 \cdot 97 \ w^{0 \cdot 361}$ $(w = 0 \cdot 154 \ l^{2 \cdot 77})$.

(*b*) "Curved" C.R. length:—

$l = 2 \cdot 214 \ w^{0 \cdot 382}$ $(w = 0 \cdot 134 \ l^{2 \cdot 60})$.

3. It is suggested that for uniformity more attention be paid towards adopting a definite length measurement as a standard for studies in foetal growth.

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