It must be stressed here that thus far absolute growth has been under consideration. The curves mentioned are of a cumulative nature and indicate at each age the summation of all the gains up to that stage. They illustrate the course of growth in weight. For comparative purposes it is desirable to be able to express these values as relative or percentage figures. In order to avoid the fallacious computations so often encountered in works of this nature, it is essential to remember that, by virtue of the constantly changing mass of the growing foetus, it is impossible to arrive at a true determination of the percentage growth-rate through any calculation based upon the "simple interest" conception. The errors introduced by such methods are exposed by Brody (1927*a*), who shows that the rates mentioned by Minot (1908) are all too high and that the exaggeration is greatest when the rate is highest and when the time interval between successive observations is long.

The growth process is best likened to the increase of capital set out at interest which is being compounded instantaneously, i.e. the increment for one instant forming part of the capital for the following instant. However, the rate of interest (which is the percentage growth-rate) does not remain fixed, but is subject to change during the course of prenatal life.

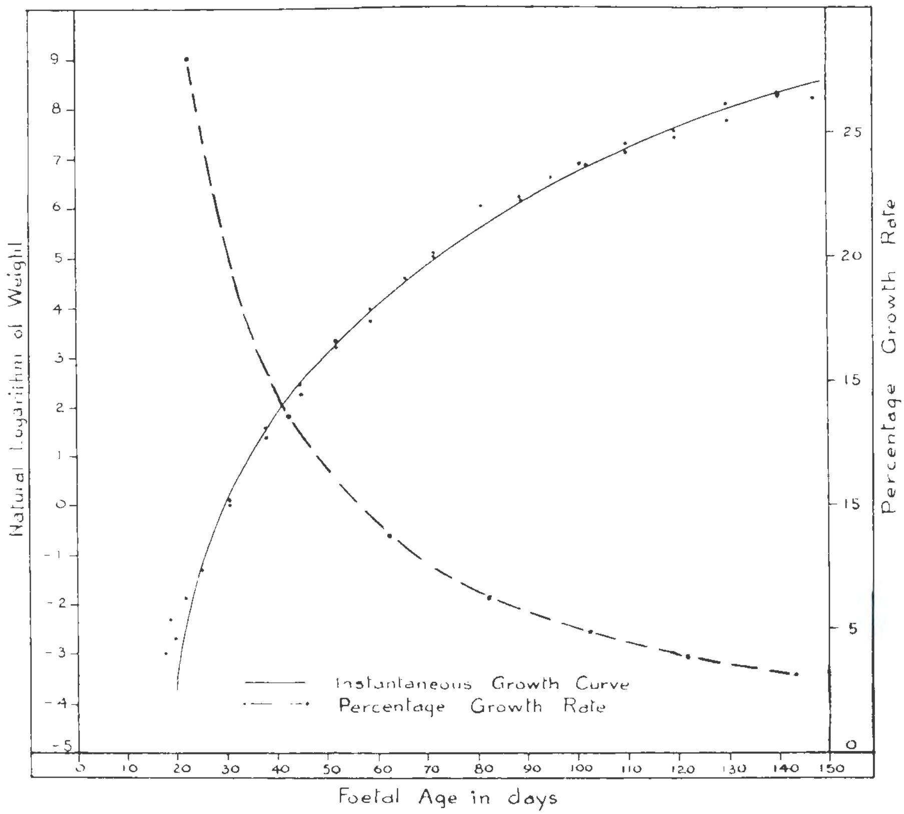
Brody (1927*a*) appears to have been the first investigator to appreciate these facts. By recourse to the calculus he is able to demonstrate that the graph resulting from the plotting of the natural logarithms of weight against age actually represents the trend of the instantaneous growth-rate, and that the slope of the curve at any point is an indication of the growth-rate at that moment.

From the data at his disposal Brody (1927*b*) concludes that such instantaneous growth-rate curves are composed of several segments set at varying and decreasing slope. Thus he maintains that the growth-rate remains steady over a considerable period and then changes abruptly to a lower level.

In Fig. 24 is presented the curve for instantaneous growth-rate of the Merino foetus. The dots represent the actual observations while the continuous line is drawn through points obtained by plotting weight values calculated from the formula previously mentioned. It is observed that the resulting graph is a smooth curve concave to the axis of the figure. This is contrary to Brody's findings, for here there is no evidence of straight segments. Here the decrease in the rate of growth is spread evenly over the entire period and is not limited to certain very short and well defined intervals. It is hardly likely that the difference in these findings is attributable to the species on which the observations have been made. Not only does Brody's work cover a wide range (the rat, the guinea-pig, the chick and man) but also regarding the bovine similar results are claimed by Kislovsky and Larchin (1931). On the other hand, in their work on the mouse MacDowell *et al* (1927) present a curve almost identical with that in Fig. 24. There is much point in these authors' criticism of Brody's work, namely that the data on which he relied were unsatisfactory and that he failed to realise that any curve may be approximated by a series of straight lines.

Both Brody and Kislovsky and Larchin merely plot their data on arithlog paper and then draw their straight lines by inspection. Brody (1927a) actually claims for this method the special merit of keeping the normal trend of the data more prominently under consideration, as compared with the tendency in the method of least squares of stressing the deviations from this normal trend. However, his arguments do not appear to affect the present situation, in which both the actual data and the "fitted" data are plotted. When it is observed that the numbers of observations in Brody's and in Kislovsky and Larchin's works are limited, and that there are fair deviations from the actual lines drawn, then it must be realised that their conclusions are open to criticism.

Fig. 24.—Curves showing Instantaneous Growth-rate and Average Percentage Rate of Growth in Weight.



It is significant that in the present investigation and in MacDowell's work, where efforts have been made to limit the factors likely to cause variations in foetal weight and where relatively large numbers of observations have been recorded, smooth curves are obtained. Further, it is apparent from Fig. 25 that when the chance deviations from the general trend are eliminated then the plotted points all fall directly on a smooth curve.

It must be concluded that the weight of evidence is against the occurrence of abrupt "breaks" in the growth-rate. In the sheep definitely (and most probably in other mammals too) the rate decreases in a steady and regular manner throughout the course of prenatal life.

The instantaneous relative growth-rate (designated K) may be calculated on a daily basis from the following formula:—

$$K = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1}$$

where W_2 and W_1 are the foetal weights at the ages T_2 and T_1 days respectively.

The figure obtained is an average value over the period T_1 to T_2 days. As it has been noted that the rate of growth is changing continuously, the value obtained will vary somewhat with the length of the period ($T_2 - T_1$). The amount of variation will not be large. However, for comparative purposes it will be better to keep the period constant for all such calculations.

By multiplying the value of K by 100, the rate may be expressed as a percentage, thus:—

Instantaneous (Average) Percentage rate per day $= 100 \times K$

$$= \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \times 100$$

In Table 27 are tabulated such percentage rates calculated over periods of five days at twenty day intervals throughout the foetal period.

TABLE 27.

Growth-Rates.—Per Cent. Per Day.

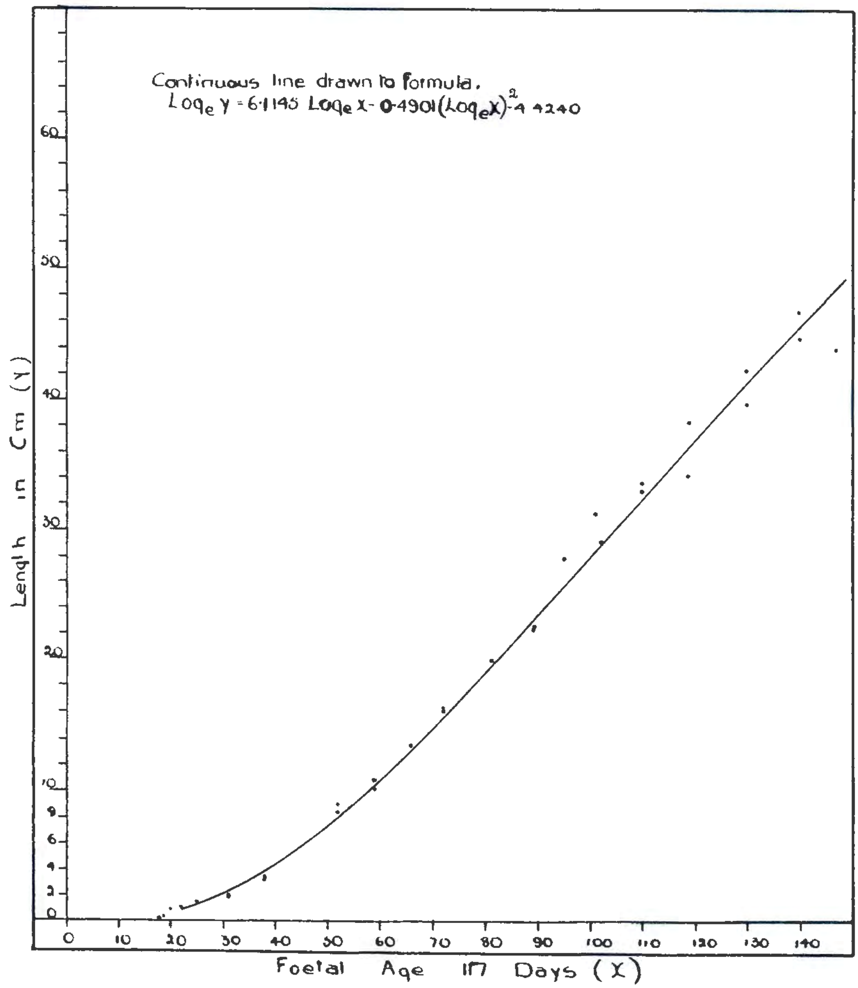
Age.	Value of K.	Percentage per day.
Days		Per cent.
20 to 25	0·2824	28·24
40 to 45	0·1350	13·50
60 to 65	0·0860	8·60
80 to 85	0·0620	6·20
100 to 105	0·0479	4·79
120 to 125	0·0387	3·87
140 to 145	0·0323	3·23

The table indicates clearly that the percentage rates calculated by Minot (1908) and others, which run into several hundred *per cent.*, are excessively high and that the drop in the earlier stages is not nearly as exaggerated as these workers lead one to expect. The rates are comparable with those calculated by Brody (1927*b*) for the rat (53 per cent.), the guinea-pig (10 per cent. to 4·6 per cent.) and the human being (8 per cent. to 1·25 per cent.). It is also interesting to note that Brody (1927*b*) calculates the percentage daily growth-rate of the sheep during the first few weeks of post-natal life to be approximately 2 per cent., which is only slightly lower than that given above for the 140-145 day period, thus lending weight to the contention that the incident of birth is not accompanied by any drastic change in the growth-rate.

2. *Growth in Length.*

In view of the conflicting opinions as to the best method of determining the length of foetuses, and the fact that these opinions all rest upon a theoretical basis, it has been decided to consider here a few of the most usual methods, and from the results of statistical tests to conclude which are the most useful as a guide to foetal linear development. All the dimensions considered are described in Chapter 3.

Fig. 25.—Growth of Straight Crown-rump Length.



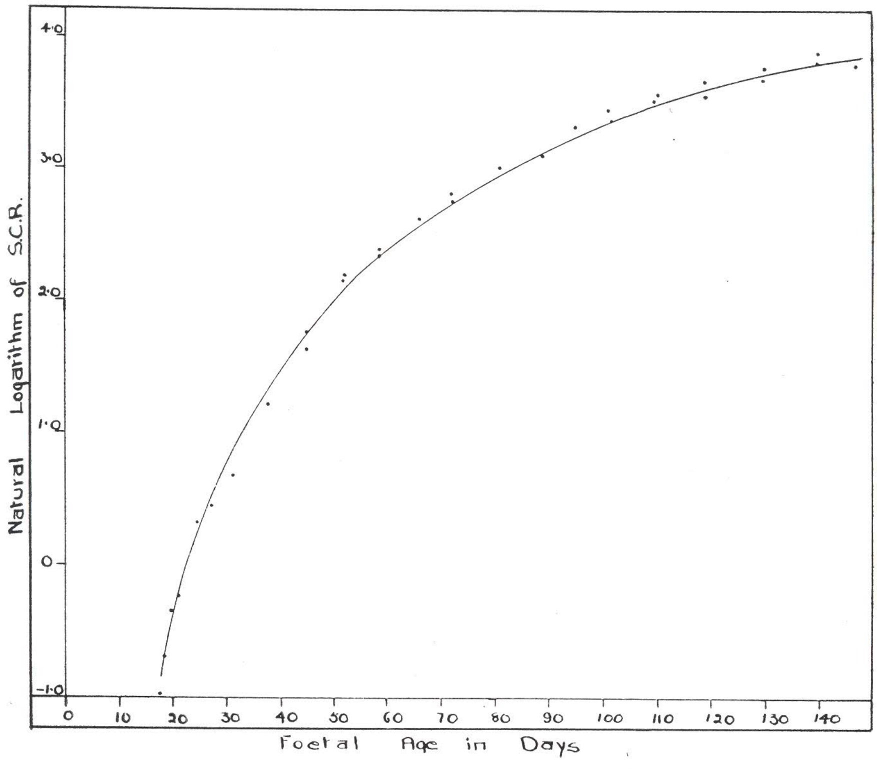
The data for *straight crown-rump length* are best fitted by a curve of the second degree having the formula:—

$$\text{Log}_e \text{ C.R.}(s) = 6 \cdot 1145 \text{ Log}_e \text{ Age} - 0 \cdot 4901 \ (\text{Log}_e \text{ Age})^2 - 14 \cdot 4240.$$

This curve is definitely significant at the 1 per cent. level of probability, while the coefficient of variation is 7·51 per cent. In Fig. 25 it will be seen that the data are well distributed about this line. Further, it is noticed that the second inflection is not very distinct and that the curve does not resemble an elongated "S" as stated by Curson and Malan (1935). However, it approximates fairly closely to Draper's (1920) guinea-pig curve.

In Fig. 26 is presented the instantaneous growth-rate curve of straight crown-rump length. Again the curve is smooth, without any abrupt breaks and lies concave to the axis of the graph. In general shape it conforms closely to that of the weight data.

Fig. 26.—Curve for Instantaneous Growth-rate of Straight Crown-rump Length.



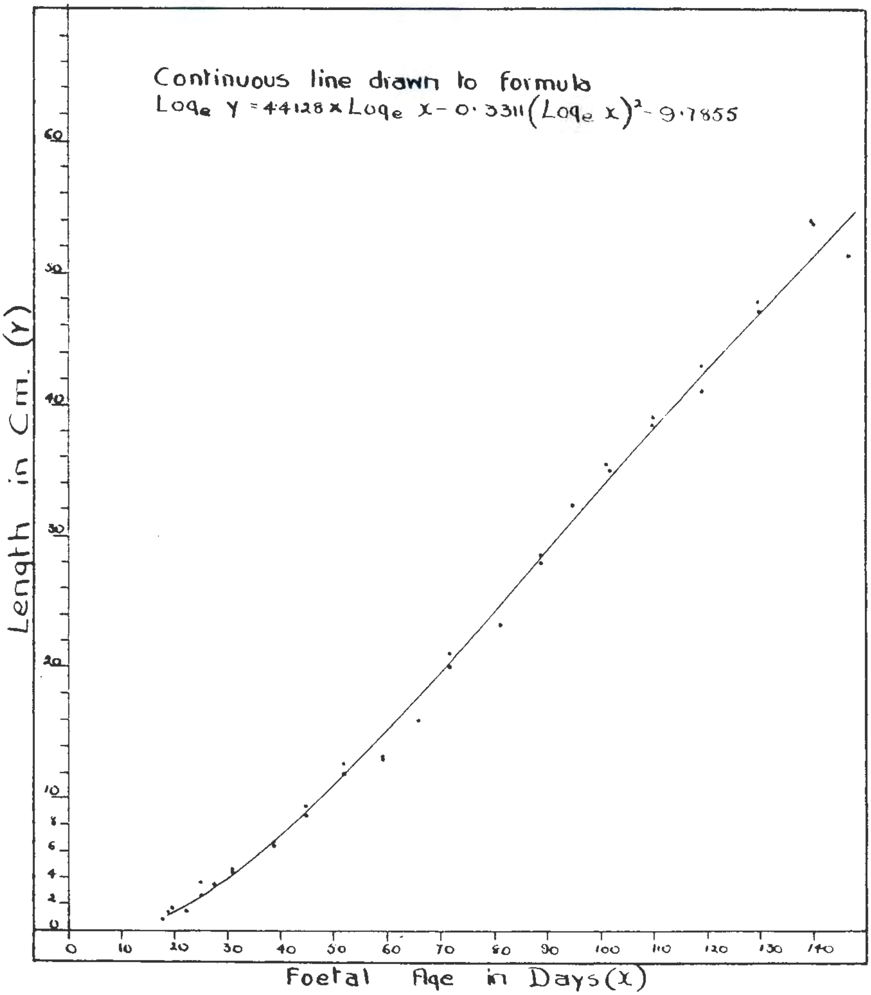
Details of the percentage growth-rate of this dimension are tabulated in Table 28. It is noticed not only that this rate is lower at each stage than that of the weight, but also that the decrease in the rate towards the end of foetal life is much more exaggerated here. As a result of this greater "slowing down" in linear growth the second inflection of the growth curve has been appreciated by workers who have failed to detect its existence in connection with weight data.

TABLE 28.

Growth Rates.—C.R. (s) Per Cent. Per Day.

Age.	Value of K.	Percentage per day.
Days—		Per cent.
20 to 25	·1370	13·70
40 to 45	·0575	5·75
60 to 65	·0330	3·30
80 to 85	·0217	2·17
100 to 105	·0154	1·54
120 to 125	·0114	1·14
140 to 145	·0088	0·88

Fig. 27.—Growth of Curved Crown-rump Length.

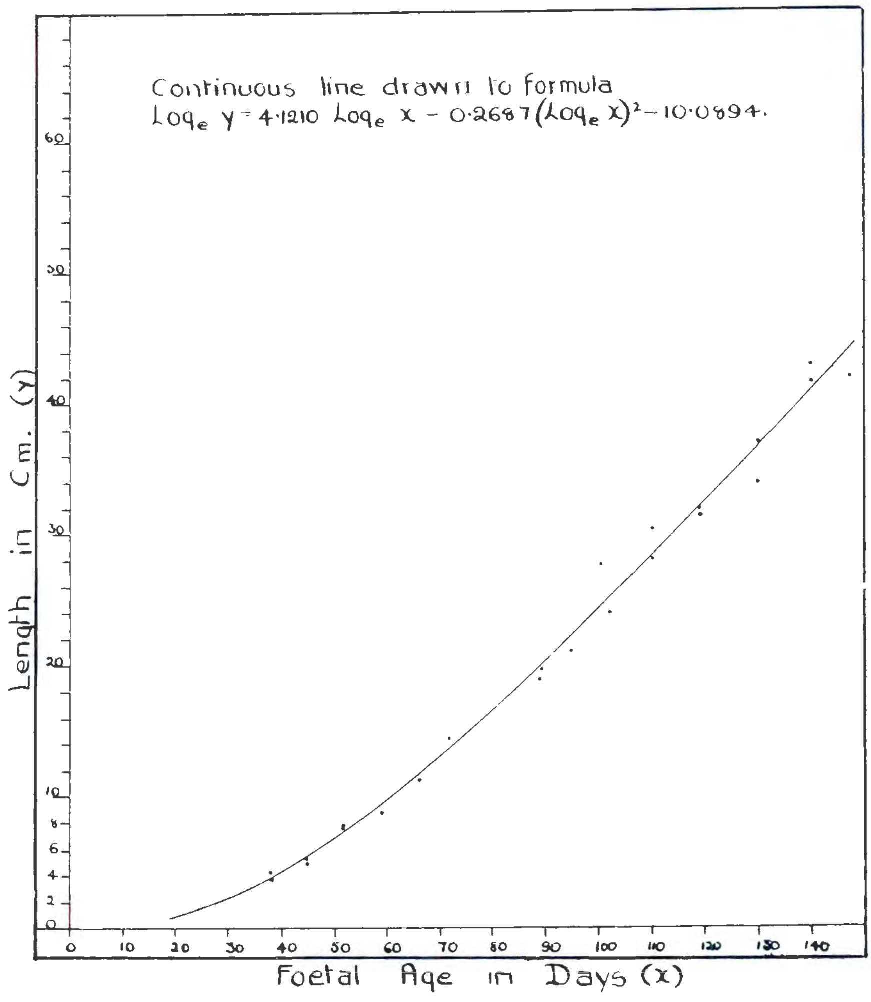


The second dimension to be considered is Curson and Malan's (1936*a*) *curved crown-rump length*. The best-fitting curve is a parabola similar to those already considered. The formula is:- -

$$\text{Log}_e \text{ C.R.}(c) = 4 \cdot 4128 \text{ Log}_e \text{ Age} - 0 \cdot 3311 (\text{Log}_e \text{ Age})^2 - 9 \cdot 7855.$$

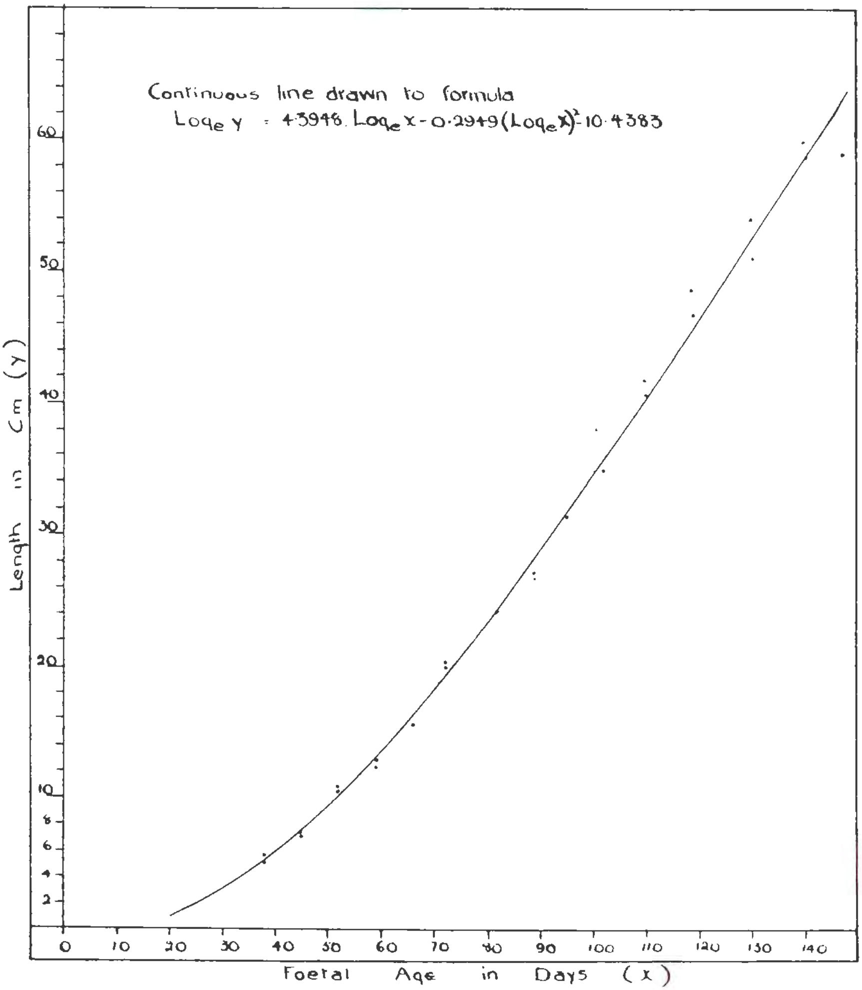
Although the significance is marked, the coefficient of variation is 10·34 per cent. In Fig. 27 the data are less evenly distributed than those of the straight crown-rump length. Thus one concludes that in spite of the theoretical advantages of the curved over the straight line, the latter, when measured according to a set plan, is the less variable and hence the more useful of the two. This had already been indicated in the work of Malan and Curson (1936*a*) in whose weight-length diagrams the curved measurement gave a less satisfactory " fit " than that obtained with the straight line dimension.

Fig. 28. Growth of Length of Back-line.



Undoubtedly a fair proportion of the variation of this measurement is directly attributable to the difficulty of taking precise readings when one of the landmarks is as vague as the "root of the tail". Apart from this technical difficulty there is the fact that this dimension is affected not only by growth in the direction of the long axis of the body, but also by growth at right angles to this axis, i.e. in the length of the head. It is difficult to see how such a "composite" line can be expected to represent satisfactorily the linear enlargement of the body.

Fig. 29.—Growth of Length in the Vertebral Column.



In order to avoid the above criticism the head portion of the curved line has been omitted in the measurement of the *back-line*. The data obtained are plotted in Fig. 28, in which the continuous line has been drawn to the formula: —

$$\text{Log}_e \text{ Black-line} = 4{\cdot}1210 \text{ Log}_e \text{ Age} - 0{\cdot}2687 (\text{Log}_e \text{ Age})^2 - 10{\cdot}0894.$$

This formula is highly significant even at the 1 per cent. level of probability. In this instance the coefficient of variation is 4·93 per cent., which must be regarded as extremely satisfactory. However, in the determination of this dimension the root of the tail is again the caudal landmark. Consequently it is not surprising to find that by measuring the *length of the entire vertebral column* (i.e. the foregoing length plus the tail) the coefficient of variation can be reduced to 3·8 per cent. The formula for this curve, shown in Fig. 29, is:—

$$\text{Log}_e \text{ V.C.} = 4{\cdot}3948 \text{ Log}_e \text{ Age} - 0{\cdot}2949 (\text{Log}_e \text{ Age})^2 - 10{\cdot}4383.$$

The tests for significance yield positive results at the level of $P = {\cdot}01$.

This dimension differs from Mall's (1910) "vertebral column length" for the human being in that in the latter the length of the tail is disregarded. In the sheep foetus the tail is relatively long, hence, perhaps, its greater importance. However, it appears that the slight superiority of the vertebral column length over the back-line is the result of greater accuracy in the measurement of the former, due entirely to the fact that in this case both landmarks are specific.

In Table 29 are tabulated details of the percentage growth-rate of the vertebral column length. The corresponding figures for the back-line resemble these very closely.

TABLE 29.

V.C. Length. Per Cent. Growth-Rate.

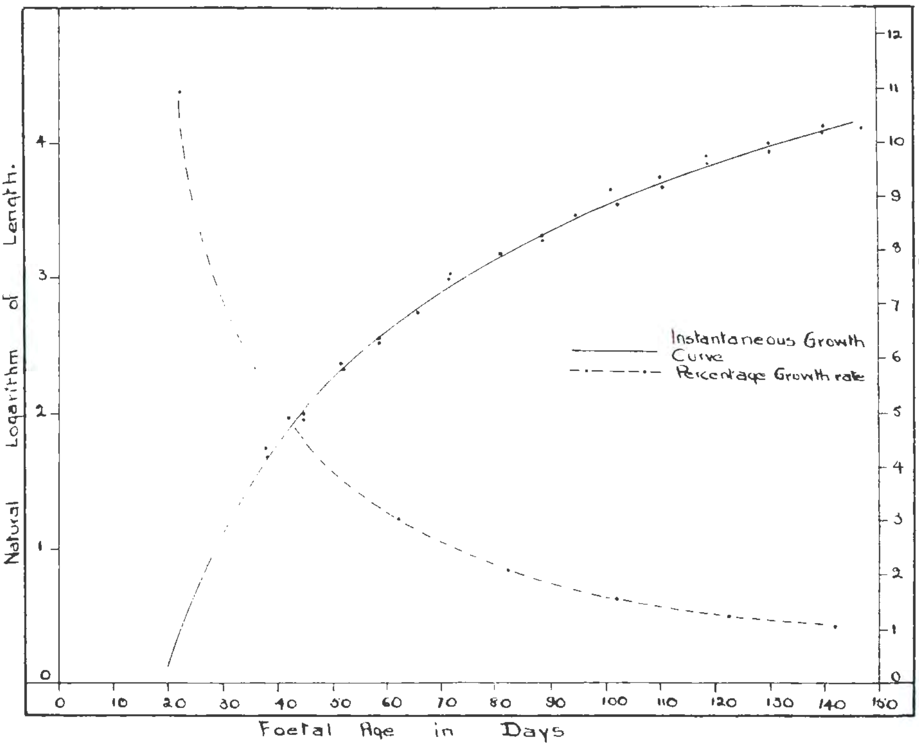
Days.	Value of K.	Percentage per day.
Days—		Per cent.
20 to 25	0·1094	10·94
40 to 45	0·0496	4·96
60 to 65	0·0304	3·04
80 to 85	0·0212	2·12
100 to 105	0·0159	1·59
120 to 125	0·0126	1·26
140 to 145	0·0102	1·02

In Fig. 30 is presented the instantaneous growth-rate curve of this dimension. The actual observations follow very closely the smooth curve drawn from calculated lengths. Again there is no suggestion whatsoever of straight segments with sudden "breaks". The shape of the curve is similar to that obtained with the weight data; so too is the graph of average percentage growth-rates which is also plotted in Fig. 30.

It is found that the trend of growth in all four of these linear dimensions is best represented by curves of the second degree. In no instance is the second inflection at all distinct. There is a fair degree of similarity in the average percentage growth-rates of these dimensions, and at each period they are all well below the rate of growth in weight.

Considering the coefficients of variation of these lines it is found that the vertebral column length and the back-line are the least variable, and hence the most useful dimensions. The straight crown-rump length is slightly inferior to them, but it is especially useful in connection with foetuses younger than 35 days, in which the first two dimensions cannot be determined with any degree of accuracy.

Fig. 30.—Curves for Instantaneous Growth-rate and Average Percentage Rate of Growth of Length of Vertebral Column.



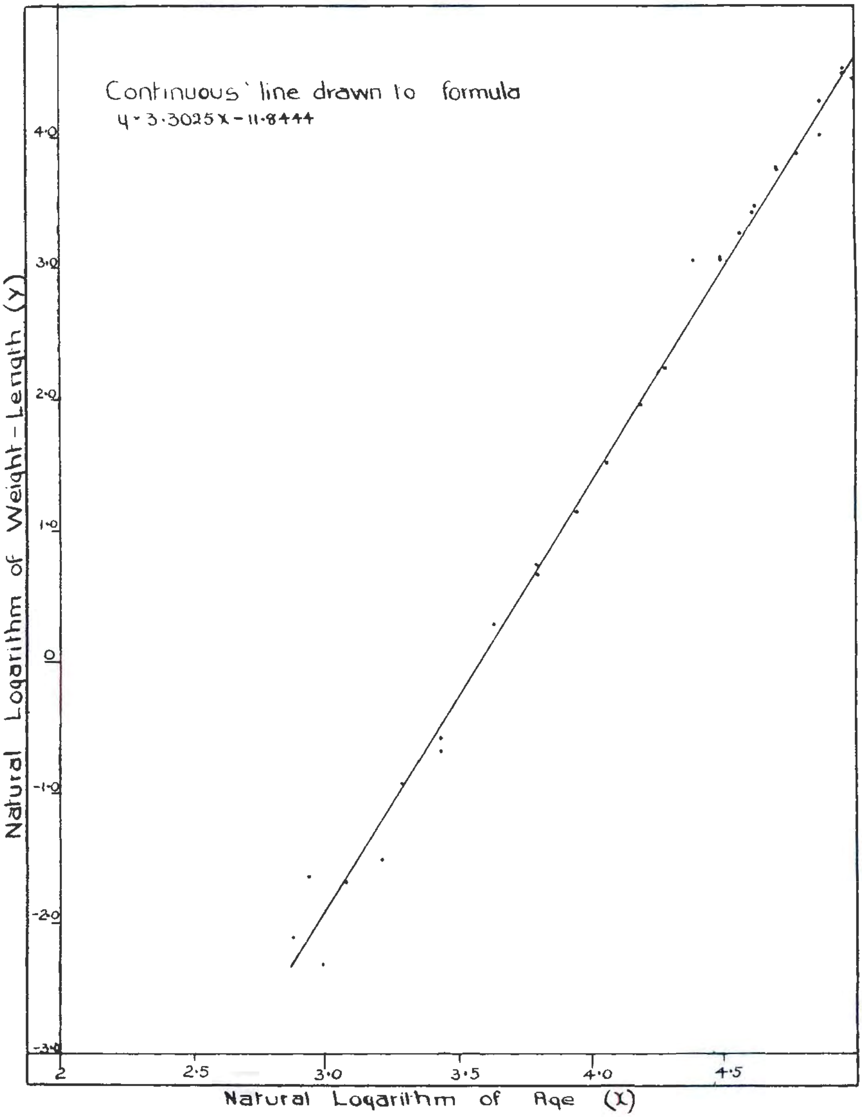
The curved crown-rump length is definitely the least useful of the measurements considered and, remembering the other criticisms of this line, may be discarded.

It is to be noted that the coefficient of variation of this discarded line is only half that of the weight-curve, while regarding vertebral column length this fraction is reduced to one-fifth. These findings are contrary to the assertion of Curson and Malan (1936*a*) that "weight and length are equally variable". Hammond's (1927) statement that "weight is more variable than length" is applicable with equal force to the foetal, as well as the post-natal period of animal life.

3. "*Weight-Length*" *Ratio.*"

In studying the Weight-Age and Length-Age curves just described, it is found that when the weight of a particular foetus lies above the trend line, the point representing the length of that foetus also tends to fall above the smooth curve. This suggests that there may be a distinct correlation between these two characteristics and that it may be profitable to calculate for each foetus the weight-length ratio, and to study the trend of this ratio with a view to determining whether it would not prove less variable than either of the two dimensions from which it is calculated.

Fig. 31.—Relation between Weight-Length Ratio and Age.



Although it has been proved that the length of the vertebral column is the least variable of the length measurements, it is felt that, on account of its total disregard of the head, this dimension is not the most suitable for the purpose of calculating a weight-length index. Consequently, the straight crown-rump length is preferred, and in each instance this measurement in centimetres is divided into the weight in grams.

In Fig. 31 it is shown that the plotting of the natural logarithms of these indices against those of the corresponding ages results in a straight-line distribution. The continuous line in the figure is drawn to the formula:—

$$\text{Log}_e \text{ W. L. Ratio} = 3\cdot3025 \text{ Log}_e \text{ Age} - 11\cdot8444,$$

which is highly significant, but has a coefficient of variation of 17·3 per cent. It is quite evident that the computation of this index will not serve any useful purpose.

Figure 32 is inserted mainly to indicate that the formula mentioned does actually represent the true trend of the data and that the large coefficient of variation is due entirely to occasional marked deviations from this general line.

4. *Regional Growth.*

Growth of the body as a whole is merely the sum total of growth of all its component parts. If the rates of growth of all these parts were identical the body would increase in size without in any way changing its shape or its proportions. However, it is well known that this is not the case, and that growth and moulding of shape proceed hand in hand. Regarding the sheep foetus this is well illustrated in an admirable chart presented by Curson and Malan (1935). Here outline sketches of a series of foetuses have been constructed to such scales that in every instance the height at the withers (i.e. the vertical distance from withers to tip of toe) is identical. With their background of squared paper these illustrations allow of a full appreciation of the changes in proportion which accompany the growth in size of the foetus. It is surmised that such changes must be attributable to differential regional growth-rates.

In an effort to test this hypothesis in a statistical manner, and to obtain some idea of the mode and sequence of operation of these differential rates, a number of linear measurements in different regions of the body have been recorded. When the trends of these data are studied it is found that in each instance the best fitting curve is a parabola with the general formula:—

$$\text{Log}_e \text{ Dimension} = a + d \text{ Log}_e \text{ Age} + c \text{ (Log}_e \text{ Age)}^2,$$

in which a, b and c represent constants which differ for each dimension considered. The values of these constants are tabulated in Table 30, in which are also indicated the coefficients of variation and the results of the tests for significance. Regarding the latter X indicates significance at the 5 per cent., and X X at the 1 per cent. level of probability.

Fig. 32.--Change of Weight-Length Ratio with Foetal Age.

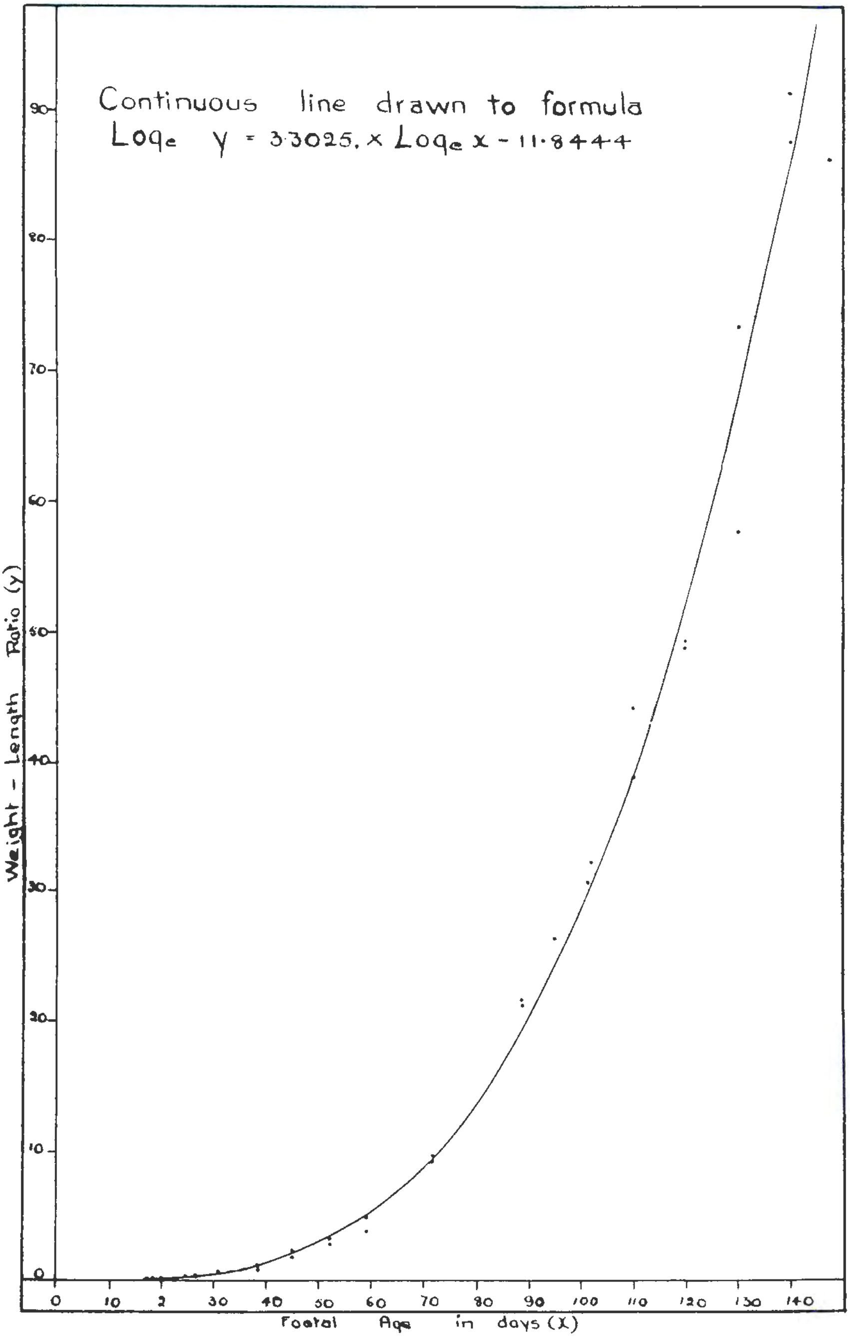
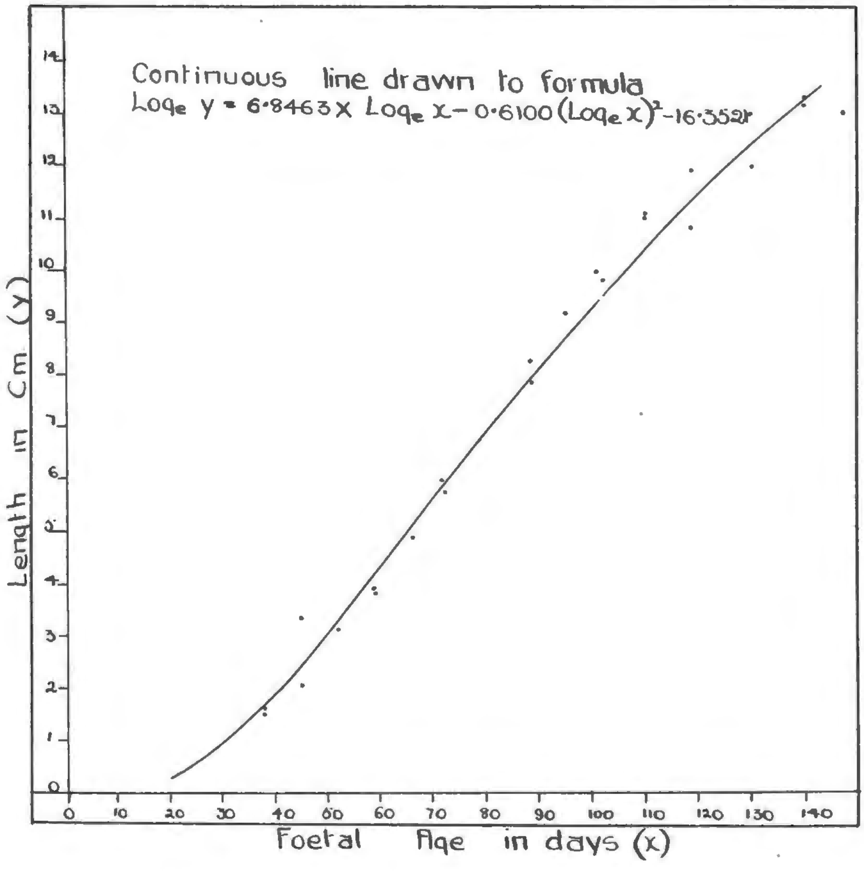


TABLE 30.

Constants for Formulae for Growth of Regions.

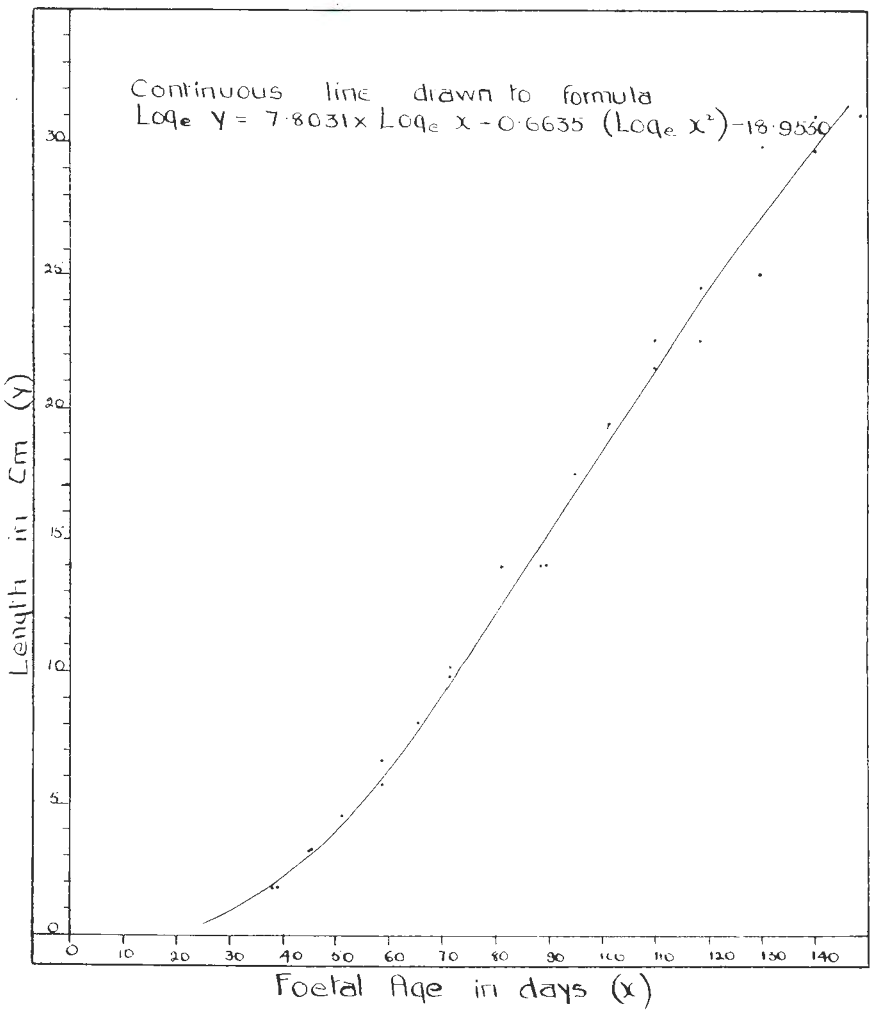
Dimension.	a.	b.	c.	Coeff. Var.	Significance.
Length of head....	−16·3521	+6·8463	−0·6100	8·76	XX
Length of neck....	+ 3·6166	−2·2939	+0·4114	16·71	—
Length of trunk...	−18·9550	+7·8031	−0·6635	4·07	XX
Length of tail.....	−13·4313	+5·0861	−0·3609	9·75	XX
Length of f. limb..	−15·3832	+5·9662	−0·4289	4·72	XX
Length of h. limb..	−17·5845	+6·8646	−0·5128	4·88	XX

Fig. 33.—Length of Head.



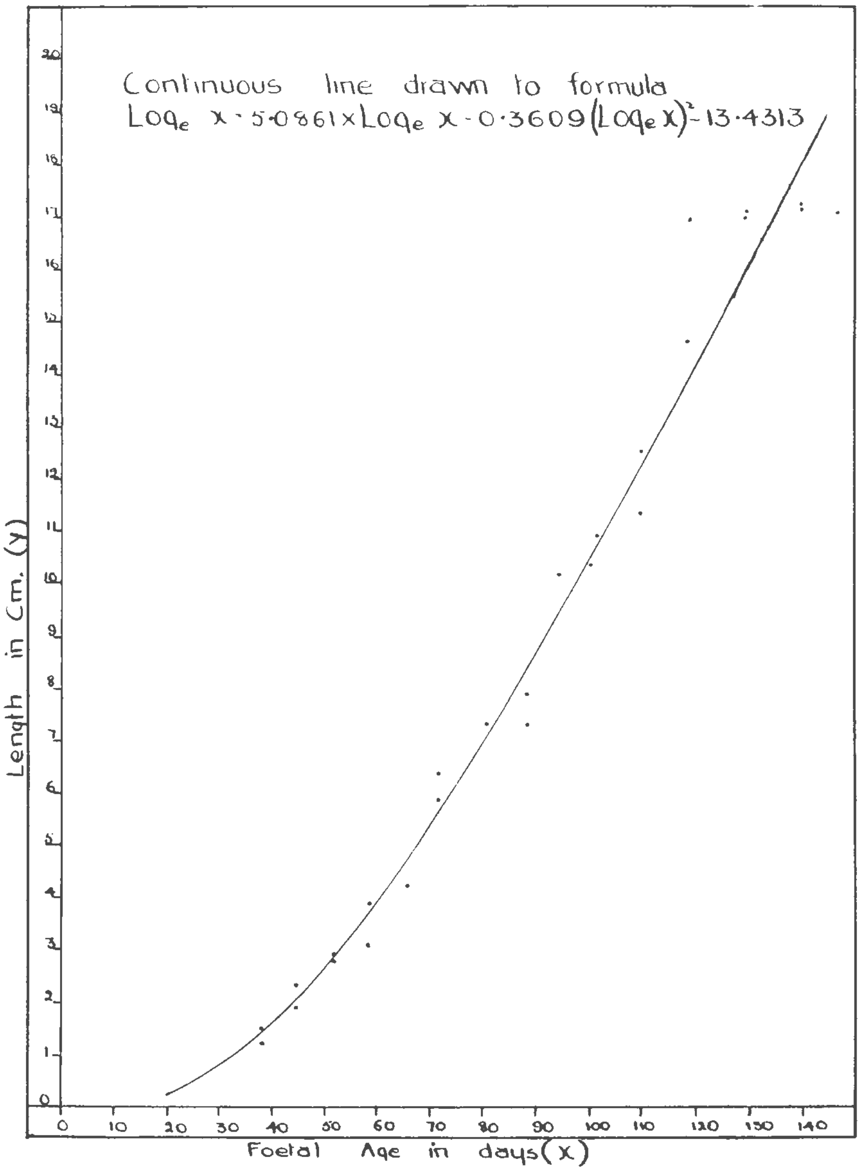
In all but one dimension the values of the constants are strikingly similar, the coefficients of variation are well below 10 per cent., and significance is marked. The curves drawn to these formulae are presented in Figs. 33 to 37. Most of these curves resemble closely those previously encountered. In the case of the head and, to a lesser extent, the trunk, the second inflection is more plainly visible than in any of the previous figures. There is no doubt but that in their growth all these regions follow trends similar to that of the body as a whole.

Fig. 34. -Length of Trunk.



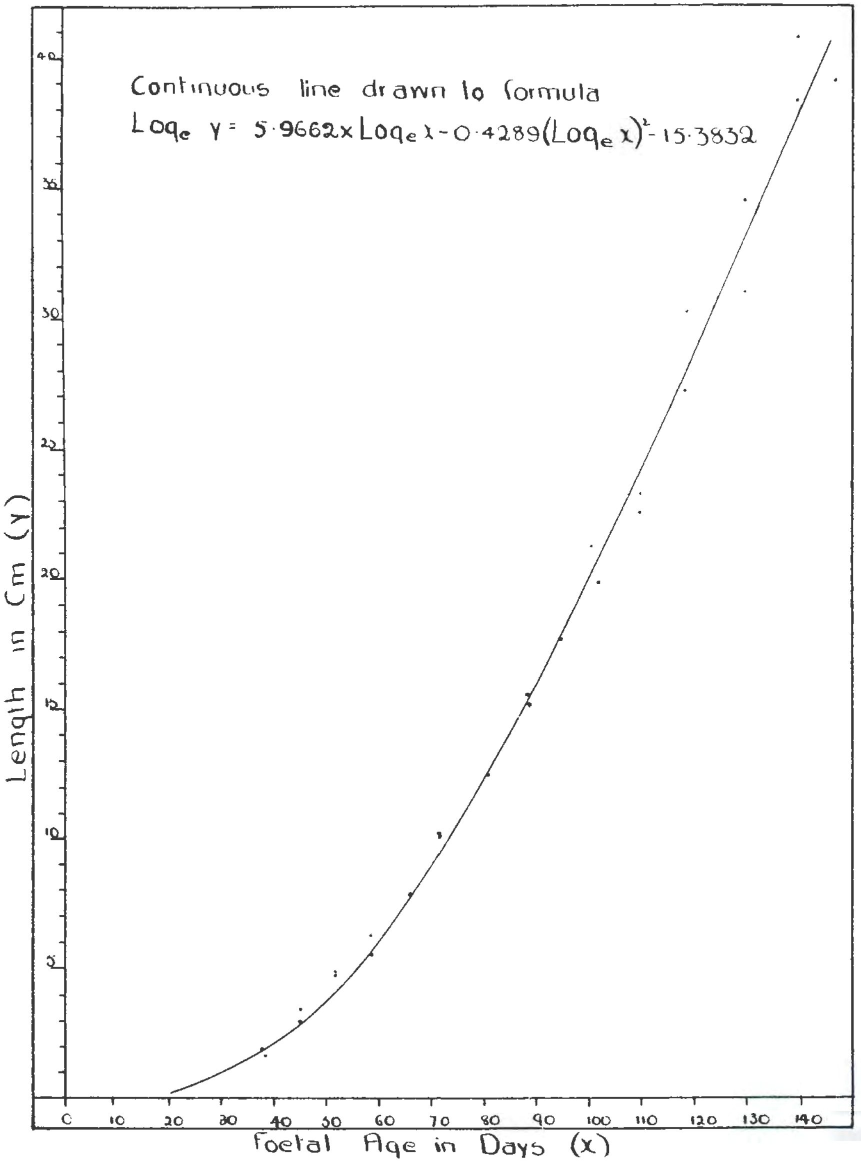
The striking exception is the neck. Here the figures are greatly at variance with those of the other dimensions. The signs of the constants have also been reversed, thus the inflections of the parabola constructed from this formula will be inverted, i.e. the first will be concave, and the second convex to the axis of the figure. Had this curve been significant there would have arisen the difficulty of explaining why of all these regions, the neck should follow such an unique growth-trend. However, it is found that the coefficient of variation is over 16 per cent. and that both factors b_1 and b_2 (see Appendix B) are totally insignificant. This indicates that the degree of variation in the original data is such as to make it impossible to construct a curve which will represent accurately the trend of these data. It must be remembered that the length of the neck was obtained by deducting from the back-line the length of the trunk. From the above results it is concluded that this is not

Fig. 35.- Length of Tail.



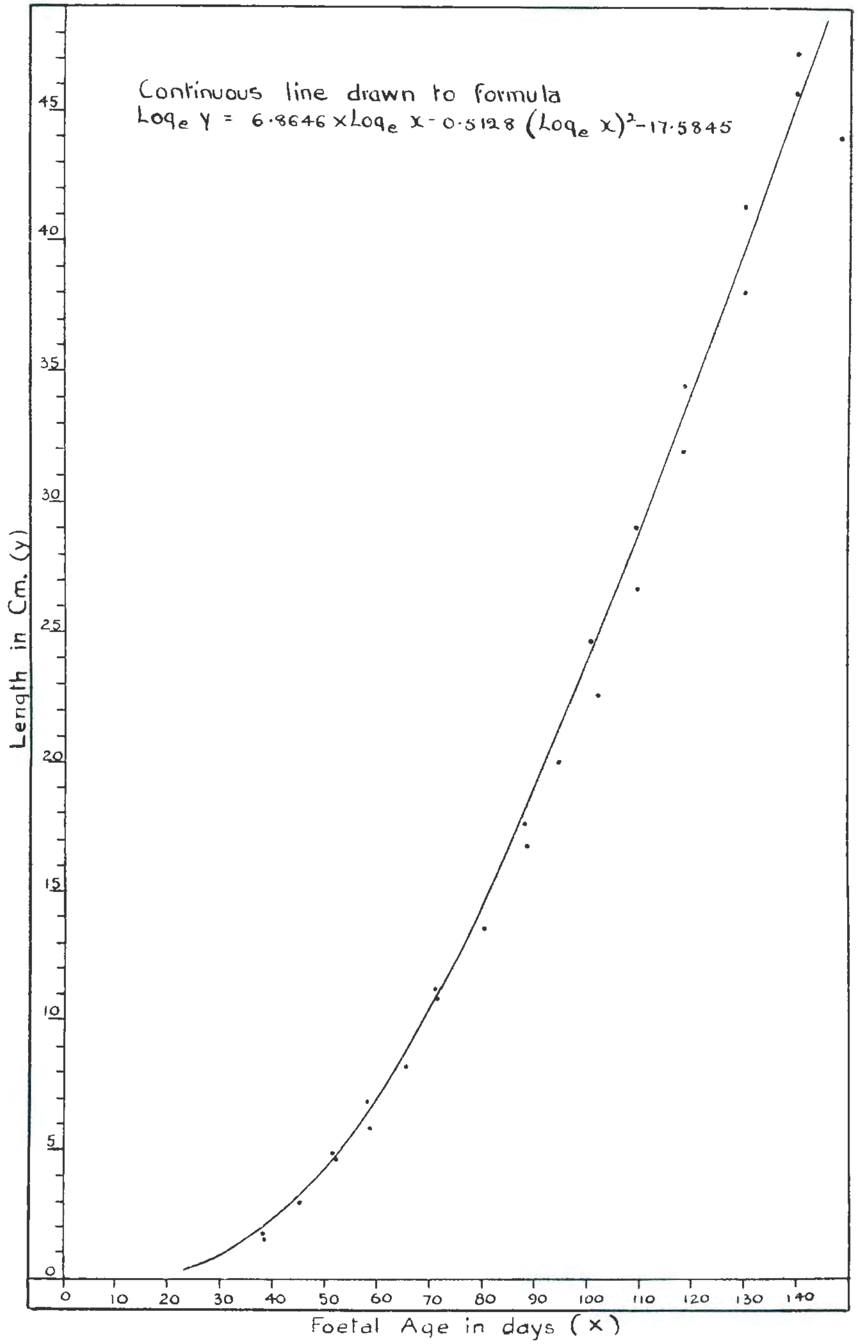
a satisfactory method of estimation. Consequently this apparently conflicting evidence is disregarded, and so far the hypothesis that the growth-trends of all regions follow those of the entire body remains unassailed.

Fig. 36.—Length of Forelimb.



Having found that there is no qualitative difference in the growth processes of the several regions under consideration, we may conclude that the differential nature must consist in the percentage growth-rates, i.e. it must be quantitative. In Table 31 are presented

Fig. 37.—Length of Hindlimb.



details of the average percentage growth-rates of these dimensions, calculated over periods of five days at 20 day intervals. It must here be stressed that the values for the first period (between the ages of 20 and 25 days) are purely theoretical, having been obtained from the formulae by extrapolation. Although the formula may have been proved to hold within the range 38 days to 147 days, this does not necessarily mean that it will furnish correct values when its use is extended beyond either limit of the range. However, these values may serve a purpose provided one does not lose sight of their purely theoretical nature.

TABLE 31.

Percentage Growth-Rates of Regions.

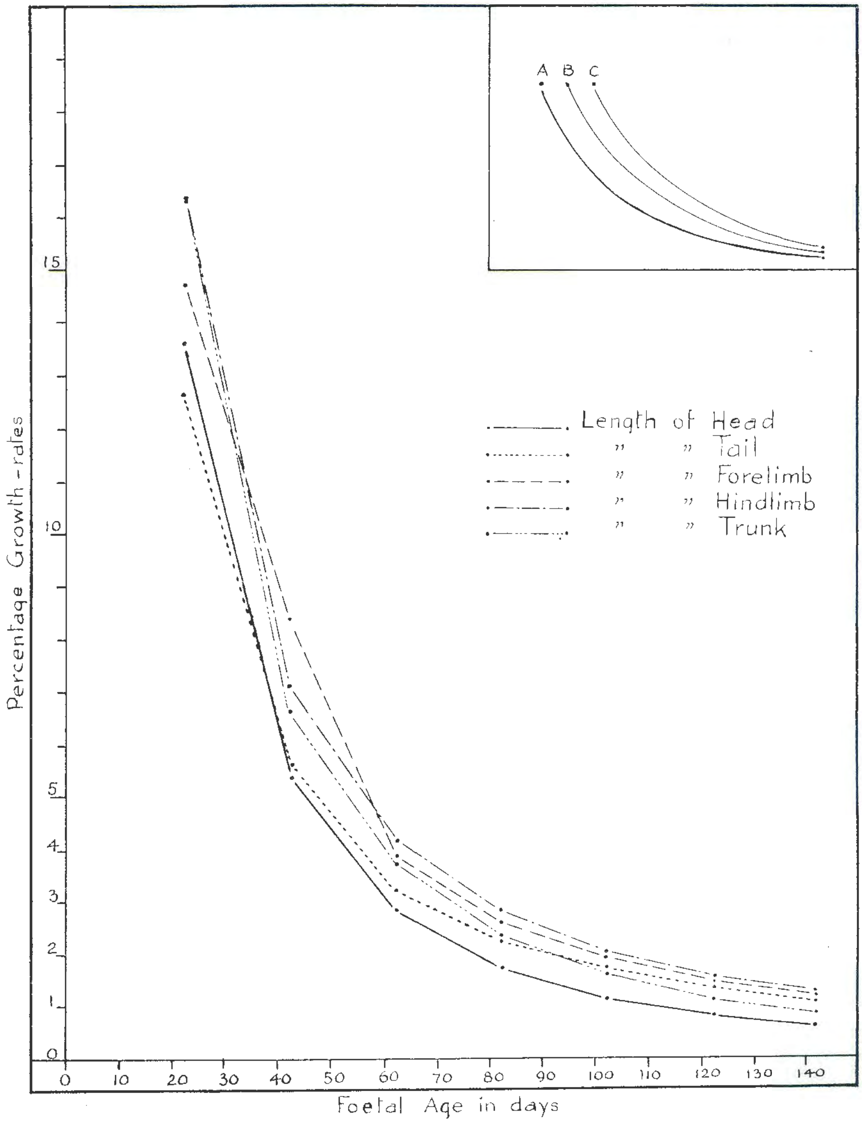
Age.	Growth-Rates.—Percentage per Day.				
	Head.	Trunk.	Tail.	Forelimb.	Hindlimb.
Days—					
20 to 25......	13·64	16·43	12·69	14·73	16·42
40 to 45......	5·36	6·67	5·61	8·48	7·12
60 to 65......	2·89	3·71	3·37	3·88	4·20
80 to 85......	1·78	2·36	2·31	2·65	2·84
100 to 105......	1·17	1·62	1·70	1·93	2·07
120 to 125......	0·80	1·16	1·32	1·50	1·58
140 to 145......	0·56	0·86	1·05	1·20	1·25

In Fig. 38 these percentage rates are all plotted against age, the midpoint of the five day period over which the rate has been calculated being taken for the abscissal reading.

It becomes apparent that in each instance the rate of growth is highest at the earliest stage and then decreases, at first rapidly, but later more gradually. Further, in the earliest period all the rates are roughly of the same order. The lowest rate (tail) is 77 per cent. of the highest one. By the end of prenatal life these rates have all undergone pronounced reduction. At this time the differences between them are much greater, the lowest rate (head) constituting but 45 per cent. of the highest rate (hindlimb). The most cranial portion of the body has the lowest rate, while the highest rate is encountered in the hindlimb—the part most remote from the head.

If the crown of the head is regarded as the starting point of growth, it is found in Table 31 that the more remote the region is from this point the higher is its growth-rate at the end of the prenatal period, i.e. the less has been the retardation to its initial rate. Also, the more distant the region the later (chronologically) will be the moment of inception of growth in that region. From these facts it is concluded that there is a direct relation between the extent of retardation of the growth-rate and the time that has elapsed since the onset of growth in that particular part.

Fig. 38.—Percentage Growth-rates of different regions.



On this basis it is incorrect to look upon the rates tabulated in the first line of Table 31 as representative of the initial growth-rates of the regions under consideration. Obviously in the head region there will already have been a fair degree of retardation, while in the hindlimb this will be at a minimum. To arrive at the true initial or commencing rates of these regions it would be necessary to increase the rates of the first period by amounts varying in decreasing order from the head to the hindlimb. This would have the effect of eliminating the variations encountered in the first line of the table, with the result that all the initial rates would be more or less identical. The rate for the trunk is slightly confusing, yet it must be remembered that this region is large and that while some of its components are in close proximity to the head, others are definitely remote from it. In the latter parts growth will commence some time later than in the former.* This initiation of "new" growth will tend to minimise the extent of the retardation which will already have set in anteriorly. Thus the "slowing down" of the rate for the trunk will not be marked in the earliest stage, placing it in the anomalous position seen in the table. Later in prenatal life this anomaly disappears and the values for its rate of growth fall correctly between those of the head and the tail.

It appears that growth is initiated in the head region and that it spreads wave-like caudally and towards the extremities; in each region the initial or potential growth-rate is the same; from the moment of onset of growth an inhibiting force is at work reducing the rate in a manner proportional to the lapse of time since the commencement of growth in the region concerned. The tendency of this force is to reduce the rate to zero, but in no instance is that level reached during prenatal life. This is only to be expected, since growth ceases only after attainment of full adult size. However, the earlier growth has commenced in any region, the nearer will the rate at the end of prenatal life be on this ultimate zero.

All these points are well illustrated in Fig. 38, the last half of which is very regularly arranged. In the first part of the figure this regularity is slightly disturbed, some of the lines crossing each other. This may be indicative of some inherent differences in the modes of retardation in the various organs. One may be tempted to assume that this is the case and then, by way of explanation, recourse may be had to the expedient of linking up certain points on the curve with certain concurrent events in the development of the foetus. Such reasoning, although not infrequently resorted to, does not appear to be justified. Moreover, having regard to the nature of the data employed in this study, one hesitates to attach great significance to the slight irregularities observed. Indeed, it is suggested that the true state of affairs may be as idealized in the inset in Fig. 38, where points A, B and C represent both the commencing times and rates of growth of three dimensions placed in order according to their antero-posterior sequence.

As a result of the findings recorded in this section it is concluded that during the course of prenatal life the proportions of the body change as the result of differential time rates of retardation of growth in the various regions of the body. Thus the more anterior regions begin growing at an earlier age and obtain a "start" on those parts situated further caudally. As the rates of growth of the former regions undergo retardation, the relatively higher

* Obviously the same applies to any other region, but naturally the effects will not be so marked in a relatively small region as they are in a fairly extensive and elongated region.

rates of the latter regions (consequent upon their more recent entry into the growth process) enable these parts to increase their relative size and thus eliminate the earlier disproportion.

All the dimensions considered above are measurements in the direction of the long axes of the regions concerned. Merely to see whether the trends obtained here are applicable to dimensions measured in other directions, the width of the head and the circumference of the thorax (heart-girth) have been included in this study. The former is measured at right angles to the length of the head, while the latter is a circumferential measurement in a vertical plane. In both cases curves of the second degree are found to represent the trends of the data. The formulae are:—

Width of Head.

$$\text{Log}_e \text{ Width} = 6 \cdot 5252 \text{ Log}_e \text{ Age} - 0 \cdot 5815 (\text{Log}_e \text{ Age})^2 - 16 \cdot 1182.$$

This is definitely significant at $P = 0 \cdot 01$ and the coefficient of variation is 4·75 per cent. This curve is illustrated in Fig. 39.

Heart-Girth.

$$\text{Log}_e \text{ H.G.} = 4 \cdot 9768 \text{ Log}_e \text{ Age} - 0 \cdot 3760 (\text{Log}_e \text{ Age})^2 - 11 \cdot 8658.$$

Again this is significant at the 1 per cent. level of probability, and the coefficient of variation is 5·48 per cent. Graphic representation is given in Fig. 40.

It will be noticed that the first curve (width of head) resembles closely that of the length of head. The second inflection is again distinctly visible. The second curve is of the same shape as those for the trunk and the forelimb.

Thus it is established that dimensions other than those determined in the plane of the long axis of a region also follow the growth-trend of the whole body.

TABLE 32.

Percentage Growth-Rates.

Age in Days.	Rates—Percentage per Day.	
	Width of Head.	Heart-Girth.
20 to 25	13·00	11·79
40 to 45	5·10	5·09
60 to 65	2·75	2·99
80 to 85	1·69	2·01
100 to 105	1·11	1·46
120 to 125	0·72	1·11
140 to 145	0·53	0·88

The percentage growth-rates of these two dimensions are tabulated in Table 32. These, it will be noticed, are comparable with the rates of other dimensions of the same regions. In the case of the head it is seen that length and width have roughly similar rates, but that of the latter is always somewhat lower. In the earlier stages the rate for the heart-girth is slightly confusing, but it soon assumes a close similarity to the rate of linear growth of the trunk.

Fig. 39.—Width of Head.

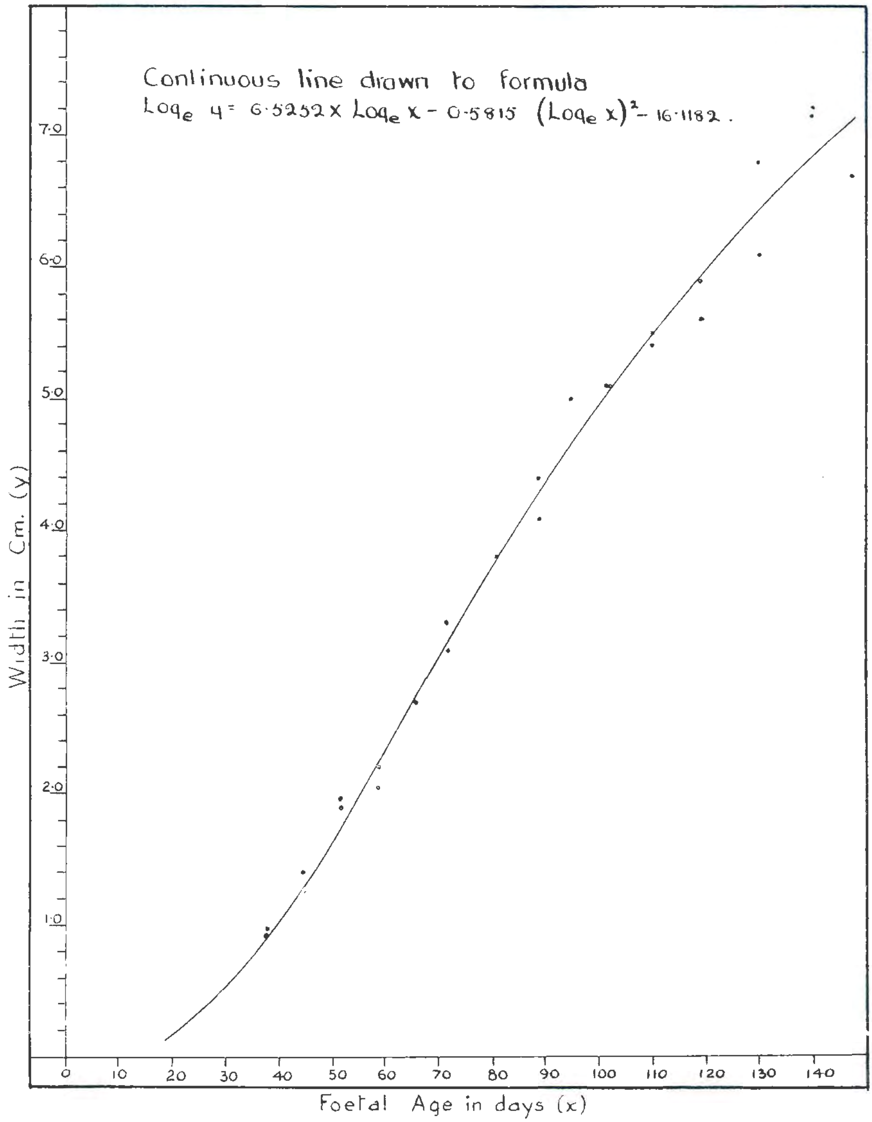
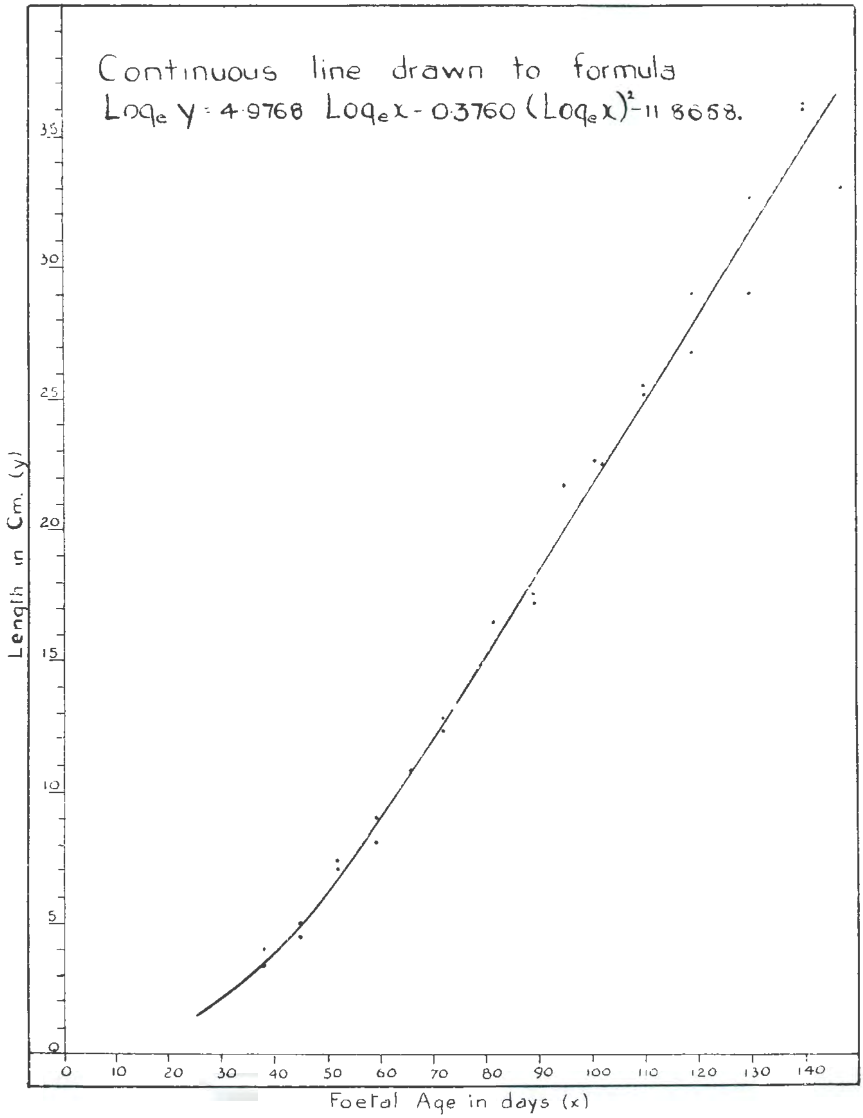


Fig. 40.—Length of Heart-Girth.



5. *Correlation Between Dimensions.*

In the previous two sections it has been found that both the actual observations and the fitted curves of all the dimensions considered exhibit striking similarities. This suggests that between any two of these dimensions there may be some definite relationship. For the purpose of testing the accuracy of this surmise the coefficients of correlation between these dimensions are determined. The method employed is that described by Fisher (1936) for the estimation of "correlation between series".

Since measurements of these variables have extended over a period of growth it is only to be expected that between them there will be a high positive correlation. However, this "total correlation" may be split into two components, one of which, the "trend correlation", measures the relationship between points on the fitted curves of the various dimensions, or, in other words, the correlation between values of the dimensions calculated from their regression formulae. The other component measures the correlation of the deviations of the actual observations from one trend-line, with the deviations of the corresponding observations from any other trend-line. This "residual correlation" is the important one in this work for in its computation the growth-trend has been eliminated, hence it indicates exactly how a deviation of one dimension from the "normal" or "expected" value is likely to be reflected in any other dimension.

Table 33 has been compiled in such a manner that all three correlations between any two variables may be read at a glance. It will be noticed that the portion falling below the diagonal row of blank spaces is an exact repetition of the upper half. Through its inclusion it is possible to read in one straight line, either horizontally or vertically, correlations of a certain dimension with all the remaining variables. Otherwise it would have been necessary to follow a vertical column into the blank space and then to continue along the horizontal column.

In considering the figures presented in the table each of the three types of correlation will be treated separately.

Total Correlation.

It is seen that without exception these figures are highly significant at the level $P = 0 \cdot 01$. Thus there is a very high, positive, direct correlation between all the dimensions under consideration. As explained above, this is only to be expected.

Trend Correlation.

Again there is not a single figure which is not significant at at least the 5 per cent. level of probability. However, it is possible to classify the variables in two groups; in the first are length of head, width of head and length of trunk, while the remainder constitute the second group. The correlation between any two variables of the same group is significant at $P = 0 \cdot 01$, whereas correlations between dimensions of opposite groups are significant only at $P = 0 \cdot 05$. These results could have been anticipated from a study of the continuous curves in Figs. 34-40. Those representing the trends of the dimensions of the first group show much similarity, and in all of them the second inflection is distinct. The remaining curves, while differing from the above, bear a striking resemblance to one another.

Table 33.

Correlation Coefficients.

		Length V.C.	Length Trunk.	Length Head.	Length Tail.	Length Forelimb.	Length Hindlimb.	Width Head.	Heart Girth.
Length of V.C.	1	—	0·9998	0·9966	1·0000	1·0000	1·0000	0·9968	1·0000
	2	—	*0·2111*	*0·1393*	*0·5295*	*0·4416*	*0·4893*	*0·3127*	*0·5887*
	3	—	0·9966	0·9880	0·9956	0·9984	0·9985	0·9937	0·9978
Length of Trunk	1	0·9998	—	0·9999	0·9989	0·9991	0·9994	1·0000	0·9996
	2	*0·2111*	—	*0·3200*	*0·0010*	*0·3132*	*0·4010*	*0·3573*	*0·3586*
	3	0·9966	—	0·9925	0·9915	0·9971	0·9978	0·9317	0·9968
Length of Head	1	0·9966	0·9999	—	0·9971	0·9974	0·9979	1·0000	0·9982
	2	*0·1393*	*0·3200*	—	*0·3987*	*0·3625*	*0·3088*	*0·4943*	*0·3033*
	3	0·9980	0·9925	—	0·9885	0·9903	0·9904	0·9945	0·9901
Length of Tail	1	1·0000	0·9989	0·9971	—	1·0000	1·0000	0·9973	1·0000
	2	*0·5295*	*0·0010*	*0·3987*	—	*0·2946*	*0·1852*	*0·1855*	*0·3010*
	3	0·9956	0·9915	0·9885	—	0·9941	0·9934	0·9899	0·9935
Length of Forelimb	1	1·0000	0·9991	0·9974	1·0000	—	1·0000	0·9975	1·0000
	2	*0·4416*	*0·3132*	*0·3625*	*0·2946*	—	*0·8166*	*0·5979*	*0·3833*
	3	0·9984	0·9971	0·9903	0·9941	—	0·9995	0·9957	0·9972
Length of Hindlimb	1	1·0000	0·9994	0·9979	1·0000	1·0000	—	0·9981	1·0000
	2	*0·4893*	*0·4010*	*0·3088*	*0·1852*	*0·8166*	—	*0·4803*	*0·3262*
	3	0·9985	0·9978	0·9904	0·9934	0·9995	—	0·9957	0·9971
Width of Head	1	0·9968	1·0000	1·0000	0·9973	0·9975	0·9981	—	0·9983
	2	*0·3127*	*0·3573*	*0·4943*	*0·1855*	*0·5979*	*0·4803*	—	*0·5900*
	3	0·9937	0·9317	0·9945	0·9899	0·9957	0·9957	—	0·9960
Heart Girth	1	1·0000	0·9996	0·9982	1·0000	1·0000	1·0000	0·9983	—
	2	*0·5887*	*0·3586*	*0·3033*	*0·3010*	*0·3833*	*0·3262*	*0·5900*	—
	3	0·9978	0·9968	0·9901	0·9935	0·9972	0·9971	0·9960	—

Note.—	$P=0\cdot05$.	$P=0\cdot01$.	
1. Trend Correlation	0·9969	0·9999	Values for Significance.
2. Residual Correlation	0·4227	0·5368	
3. Total Correlation	0·4227	0·5368	

It has been demonstrated that the distinct second inflection is associated with the dimensions of regions which develop early in prenatal life and consequently undergo the greatest degree of retardation of growth-rate. From the above findings one may conclude that "trend correlation" is greatest between dimensions of (anatomically) closely related regions, and lowest between dimensions of regions remote from each other.

Residual Correlation.

Immediately it is noticed that the majority of these correlation coefficients fail to attain significance even at the 5 per cent. level probability. Those that do reach this level may be considered individually:—

> *Length of forelimb—length of hindlimb.*—The correlation between these two variables is the highest obtained. Upon inspection of Figs. 36 and 37 it is seen that there is much similarity not only in the trend-lines, but also in the distribution of the actual observations about these lines. Under these circumstances a high correlation is only to be expected. Moreover, it is fairly obvious why such a definite relationship should exist.
>
> *Length of head—width of head.*—Again it is readily accepted that there should be a definite correlation between these variables. Indeed one is rather surprised not to encounter a higher value than 0·494. In Fig. 39 (width of head) it is noticed that the later points are widely spread, and that due to these marked variations in the actual data, the curve cannot be said to have an exceptionally good fit.* The large variations encountered may be inherent in the material or they may have been artificially exaggerated through the difficulty of making accurate measurements of this dimension.
>
> *Length of vertebral column—length of tail.*—The high correlation present here is easily explained when it is remembered that the latter dimension is contained in the former. But for the difficulty of determining with accuracy the anterior extremity of the tail this correlation may well have been higher.
>
> *Length of vertebral column—heart-girth.*
>
> *Length of vertebral column—length of forelimb.*
>
> *Length of vertebral column—length of hindlimb.*

* Nevertheless it has been proved that with the data available this curve gives the best "fit". What is meant here is that the "fit" of this "best-fitting" curve is not as good as is desirable in work of this nature.

In all these instances the relatively high correlations are understandable. It is quite acceptable that with an increase in the length of the foetus, there should be corresponding increases in the heart-girth and in the length of the two limbs. Thus a longer foetus has also a greater height at the withers and a larger circumference of the thorax.

Width of head—length of forelimb.
Width of head—length of hindlimb.
Width of head—heart-girth.

The definite correlations obtained here are somewhat surprising, especially in view of the fact that other seemingly more apparent correlations prove to be insignificant. However, it must be pointed out that in the method employed the accuracy of the residual correlation is dependent upon the "goodness of fit" of the trend-line. Already it has been indicated that in the case of width of head this fit is not as good as might be desired. It appears reasonable to conclude that this results in the generation of misleading correlations. In consequence of this suspicion attaching to these correlations it is not proposed to consider them further.

To sum up one concludes that between any two of the dimensions considered there is a very highly significant direct correlation. However, the common growth-trend is mainly responsible for this, and in most instances its elimination results in an insignificant residual correlation. The latter is truly significant in but a few cases, and then only when closely associated dimensions are coupled.

6. *External Appearance of the Foetus.*

General Form and Appearance.—Many of the features to be described here are well illustrated in Curson and Malan's (1935) chart to which reference has already been made, and in the series of photographs accompanying this chart.

At the age of 18 days the ovine embryo has the appearance, in profile, of a whitish, translucent comma, the head region being much better developed than the opposite extremity. During the next two days there is an increase in size, especially of the head region, where the primitive brain divisions are already distinguishable. At this stage the heart becomes visible as a reddish, pinhead-sized focus, situated well forward. At the twentieth day the aorta is visible, and from its caudal extremity two vessels emerge at the umbilicus to form the umbilical arteries. At about this time the dorsal region of the body is beginning to assume a more opaque appearance, thus foreshadowing the development of the vertebral column.

During the following few days the cardio-vascular system continues to develop apace, so that at the twenty-fifth day the heart has a diameter of 0·5 cm., and from it the aorta and the carotids can be seen running towards the head and towards the caudal extremity respectively. At this time the curvature of the body is so acute that the future oral regions rest between the two thoracic limb-buds, against what is to be the sternum. The cranial region is relatively large, especially in the vicinity of the vertex, where the main divisions of the brain are plainly visible. By this time the tail has been formed, its length being approximately 2 mm.

By the end of the first month the body has become fairly plump with signs of a definitely solid axial structure in the vertebral region. The colour of the surface of the body has changed from dull translucent white to pink. The heart is still visible through the body wall, and from it vessels are seen to proceed cranially, caudally, and into the developing limbs. The ventral abdominal wall bulges outwards, presenting a herniated appearance. The length of the tail has increased to about 5 mm.

During the following week of its life the foetus undergoes rapid development and at the 38th day most of the main features of the fully developed body may be detected. The body wall becomes opaque, thus obscuring the heart region. The superficial vessels of the head, trunk, tail and limbs are visible. At this stage the cartilaginous models of the vertebrae and the scapulae show up prominently as denser white structures fairly deeply situated. The ventral abdominal bulge has disappeared.

In the middle of the second month the head is still relatively large, its size being accounted for mainly by the prominence of the crown region. At this stage the neck region begins to acquire a more definite shape. However, it is still sharply bent and the face is directed ventrally. This development continues so that at the end of the second month the neck has become fairly long, thin and well-rounded, and its ventral curvature has practically been eliminated. By this time the subcutaneous vessels, which had become very prominent and numerous, are no longer visible.

Throughout the third month the proportions of the body undergo much change, yet at the end of this period the head still appears disproportionately large, whereas the neck is relatively long and thin. However, early in the fourth month the thickness of the neck increases and by the 100th day this disproportion has to a great extent been eliminated. Now the skin over the neck has become somewhat loose and a few transverse wrinkles are to be seen. Ten days later similar wrinkles are present over the brisket and down to the carpus. The spread continues and just before birth the skin, which is now fairly thick, is comparatively loose and wrinkles are evident over the entire body.

The Head and Face.—During the first month of prenatal life the head region undergoes much development both in size and in its proportions. However, it is not until the 38th day that there are signs of facial development. At this time indications of the mouth and nostrils are detected, and by the end of another week these features are plainly visible. Towards the end of the second month the " dished " profile of the early stages (caused by the great prominence of the forehead) has practically disappeared. The facial region has increased in relative size and the mouth and nostrils are well developed. The latter are closed by epithelial plugs.

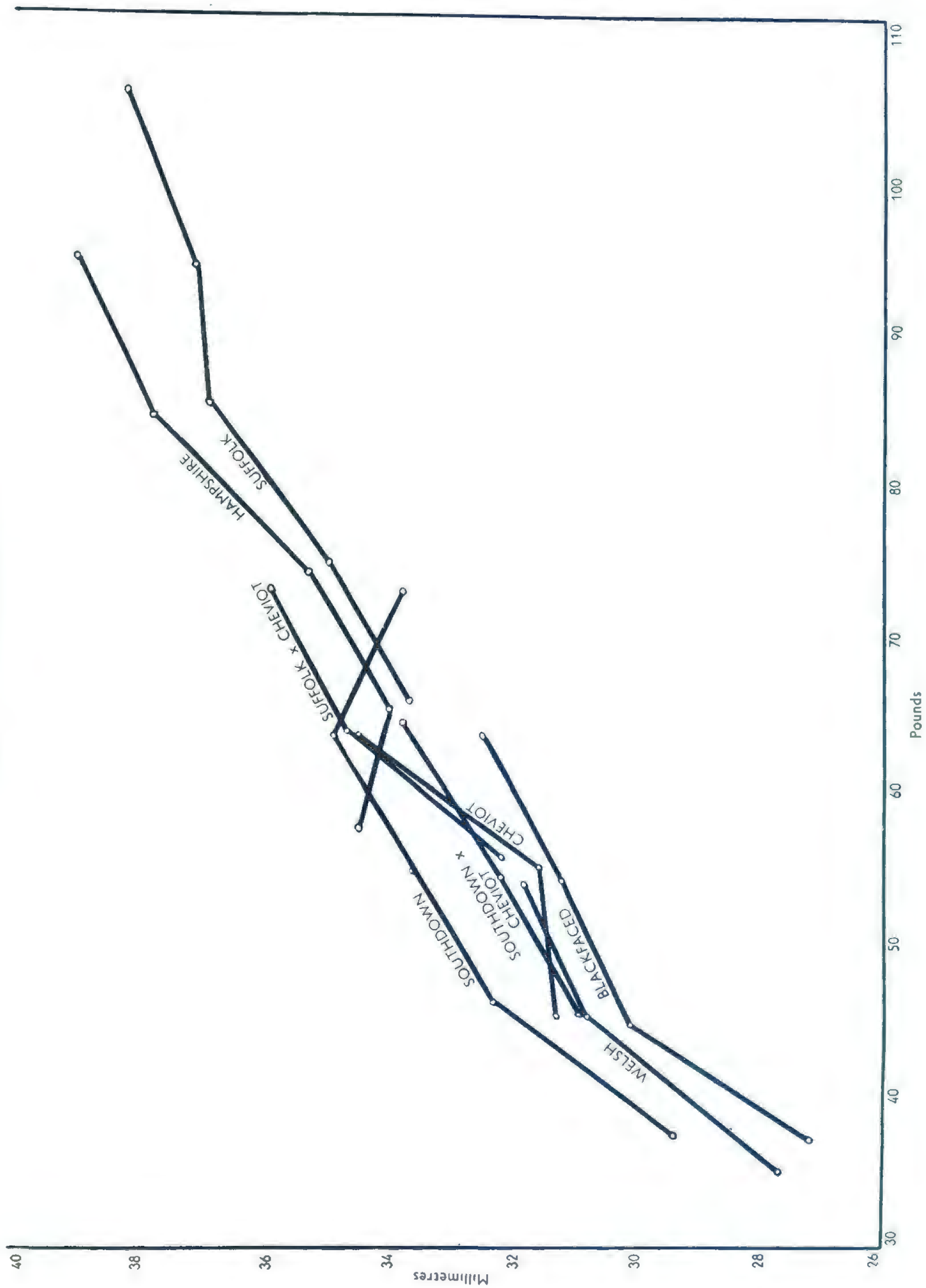
By the middle of the third month the face has come to resemble closely its definitive appearance. However, this region is still relatively small and is overshadowed by the very large and protruding forehead. At this time the rami of the mandible are well-formed, the lips are distinct and the mouth is open. The external nares are deeply excavated but are still " plugged ". The hornbuds become visible as small pinhead-sized elevations equidistant from the lateral canthus of the eye and the base of the ear.

From now on the changes are much less striking than those of the earlier period. Between the 95th and 101st days the nostrils become patent and it also becomes possible to open the mouth and to see the Anlagen of the incisor teeth. Further, the philtrum of the upper lip is distinctly visible. At the 130th day the edges of the nostrils and the upper lip, with the adjacent regions, have become smooth and bare. Ten days later the inner edge of the lower lip is serrated, while on their buccal surfaces the cheeks carry small papillae, these being best seen in the neighbourhood of the commissures of the mouth. In the foetus of 147 the Anlagen of the teeth are very prominent and the first pair of incisors appears to be on the verge of erupting.

The Eye.—At the early age of twenty-five days there is visible on the lateral surface of the head of the foetus a thin black ring 1 mm. in diameter. This is the earliest macroscopic indication of the development of the eye. As a result of the prominence of the forehead and the flexion of the neck, this ring is seen in the vicinity of the anterior limb-buds. At the end of the first month the diameter of the ring has increased slightly and the enclosed area which will later form the lens, is pale, translucent and slightly raised above the surrounding surface. At the 38th day the ring has a diameter of 3 mm., and the eyelids have commenced to grow over the developing eye. The whitish lens area is prominent. The combined effect of the straightening of the neck and the increase in relative size of the face is to place the eye in a more familiar situation. Nevertheless this organ is still somewhat closely related to the nostril and the angle of the mouth.

The black ring continues to increase both in width and in diameter. At the 45th day the latter dimension has reached 5 mm. The eyelids extend over the eye, and although they are transparent the line of fusion of the two is distinct as a denser ridge running across the eye. Just medial to the inner canthus of the eye this line is very prominent and here is foreshadowed the development of the infraorbital pouch, which, at the 52nd day, is rendered much more prominent by the curling over of the upper border of the ridge. By this time the lids have increased in thickness, and although the dark ring is still plainly visible it appears to be more deeply situated. The entire eye region is much enlarged and bulges outward from the side of the head. At the end of the second month the pouch is even more prominent and the pigmented ring has a diameter of 1·5 cm. and a thickness of 0·5 cm. Midway through the following month the ring is still larger, but by now the thickness of the lids makes accurate observation difficult. By the end of the

DIAGRAM I-B.
Depth of Eye-Muscle (B).



divided at the median raphe into two conical lateral halves. The tips of these cones are less dense than the basal part of the sac and they have a translucent appearance. The prepuce and the penis are quite distinct, but the latter does not as yet produce any elevation of the ventral abdominal surface. One week later the length of the scrotum has increased to 2 cm.; the median groove is less distinct; the surface of the sac is smooth. At this stage one or two pairs of small teats are seen just antero-lateral to the base of the scrotum. In the female of this age the mammary region is fairly prominent, and the teats have a length of 3 mm. The labial folds have migrated further towards their definitive position, and only about one-third of the distance remains to be traversed. This is soon accomplished, and at the end of the third month the folds are finally located in the perineal region, and the formation of the vulva is well under way. The anus is well developed and prominent. The main teats are about 4 mm. long; they may be supplemented by two or four smaller, supernumerary teats.

In the male foetus of this age the scrotum is 3 cm. long and is soft and jelly-like. Teats of 2 mm. in length are visible. The prepuce is well developed and soon hairs 3 mm. in length are to be seen around the preputial opening. By the end of the fourth month the length of these hairs has reached approximately 1 cm. The surface of the scrotum, which hitherto has been smooth, becomes wrinkled. This appears to be consequent on the hollowing out and collapse of this previously solid structure.

In the female during the last month the mammae increase in size and the teats reach a length of 5 to 7 mm. The development of the vulva is completed even to the prominent ventral commissure.

The Limbs.—In foetuses of 25 days both sets of limb-buds are clearly visible. The thoracic pair are about 3 mm. in length and the pelvic ones slightly shorter. The former are divided by a central constriction into a proximal rounded, and a distal flattened part. The latter is almost fan-shaped and its surfaces face laterally and medially. In the posterior buds no constriction is evident, but towards the tip there are signs of flattening. Within the next two days these buds reach the stage of development just described for the forelimb.

By the end of the first month the length of the forelimb has increased considerably, and at the distal extremity a central groove indicates the commencing division into two digits. The lower half of the limb has rotated on its long axis in such manner that the two digits are situated medially and laterally, instead of anteriorly and posteriorly. In the posterior limb this stage has not yet been reached; the division into digits is not present, neither has the rotation commenced.

At the 38th day the digits of the forelimb are distinct and there are indications of the accessory digits. The various divisions of the limb (forearm, arm, etc.) are evident and already they have assumed their definitive relative positions. In its development the hindlimb is slightly in arrear of the forelimb.

Within a week the digits have developed considerably and the accessory digits have become plainly visible on both pairs of limbs. Close to the distal extremity of each limb a transverse, ridge-like swelling appears. It is slightly more distinct on the thoracic limb. These swellings represent the coronary bands.

During the next three weeks the fetlock region becomes moulded into shape and the coronary band becomes more prominent. However, the latter is still relatively close to the tip of the limb. By the 66th day the portion distal to the coronet has increased in size and just below the coronary band a bluish-white colouration is detected—undoubtedly this is due to the deposition of horn. The accessory digits are very prominent and are clearly defined.

The limb increases in size and the bluish colour spreads slowly downward over the surface of the third phalanx. At the 89th day the first signs of the interdigital pouches are detected. These are more advanced in the forelimb. By the end of the fourth month they appear to be fully developed.

By this time the major part of the third phalanx has been covered with horn and the line of junction of this horn with the lower dull white surface (which lies parallel to the coronary border) continues to advance distalwards. At the 130th day the horn has reached the heels, and during the next ten days the as yet uncovered triangular portion of the third phalanx becomes progressively reduced, while the horn also encroaches on the sole of the foot, the posterior half of which is covered by the 140th day. At about this time the accessory digits are almost completely covered with the same bluish-white horny substance. At the 147th day the original whitish, friable covering is confined to the tips of the hoofs and the apices of the accessory digits, the remainder of these structures being well covered with horn.

The Hair and the Wool.—Until the 38th day of foetal life there are no signs of development of hair, and the entire body surface is smooth and homogeneous. At about this time pinhead-sized white foci appear just below the surface in the region of the eyelids and the lips. By the 45th day these have increased both in size and number and are recognisable as the follicles of the tactile hairs of the face. Similar, but smaller foci appear immediately above the upper eyelids, and soon they are seen to have spread as far as the crown. These are the follicles of the ordinary hairs of the body.

During the following week the tactile follicles increase in size, while those of the ordinary hairs become more numerous and spread over the crown, but without reaching the upper part of the neck. On the lateral aspect of the shoulder and in the axilla traces of these follicles are encountered. The regions in which follicular development has occurred are not definitely demarcated; the follicles simply become smaller and more isolated towards the outskirts until they are no longer visible. At the 55th day follicles are present over the extensor surfaces of the carpus and the hock. Smaller ones are seen in the region of the flank and over the proximal portion of the thigh.

At the end of the second month the tactile follicles are large and the hairs appear to be on the point of erupting. The ordinary follicles have spread over the entire body, yet in general their distribution becomes more sparse as they are traced caudally and towards the distal ends of the limbs.

At the 66th day the tactile hairs have not yet erupted, but they have become so much increased in size that they cause small elevations on the surface. Six days later these hairs are seen emerging, at a slant, through the skin of the eyelids, the lips and the chin. By the end of the third month the longest of these hairs (on the chin) are 6 mm., while others (on upper eyelid) are only half this length.

All this time the ordinary follicles have been increasing in number and in size. By the 89th day it is possible to detect, by means of a handlens, the presence of very fine downy hairs on the forehead. Around the horn buds these hairs are arranged in whorls. They extend downwards as far as a line joining the medial canthi of the eyes. At this stage the follicles on the dorsal aspect of the carpus and along the coronet, especially close to the interdigital cleft, are large and the hairs contained in them appear to be due to erupt almost immediately. The follicles at corresponding situations on the pelvic limb are much smaller.

By the 95th day the hairs on the forehead are visible to the naked eye. They have spread over the poll and also ventralwards on to the cheeks, to the base of the ear and in the direction of the ramus of the mandible. Over the shoulders, on the lateral surfaces of the arm and forearm, over the dorsal aspect of the carpus and along the coronet, hairs just visible to the naked eye are present. With the lens it is seen that on the remainder of the forequarters, as well as over the loins, the hock and the coronet, fine hairs are just beginning to erupt. In the region of the flank and on the hindlimb (save those parts just mentioned) the follicles are densely packed and fairly large, but no eruption of hair can be detected.

At 100 days the tactile hairs have reached lengths of 0·5 to 0·8 cm. By now the forehead is covered with well-matted hair about 3 mm. long. As this is traced along the neck and back it becomes shorter, until at the loins it is only just visible. Also towards the angle of the mouth the length of the hair decreases, and on the lower part of the face it can only be seen with the help of a lens. Over the shoulders the hair has a length of between 2 and 3 mm., this also being the case on the anterior aspect of the carpus and along the coronets of the forelimb. Shorter hair (about 1 mm.) is seen on the brisket, sternum, loins, tail and proximal portions of the hocks; on the coronets of the pelvic limb it is slightly longer. On the remainder of the surface of the hindquarters hair is just visible. Fine hairs are seen on the inner surface of the ear, where they are confined to the ridges, while the depressions remain smooth and bare.

In the foetus of 110 days the tactile hairs are about 1 cm. long. On the face ordinary hairs are detectable with the naked eye. The hairs on the inner aspect of the ear have become longer and more numerous, while on the outer surface fine downy hairs are appearing.

The entire body is well covered with fairly closely packed hairs. The hairs on the coronets and those around the accessory digits have reached a length of approximately 0·5 cm.

By the end of the fourth month the body is totally covered with fairly long hairs. These are more or less straight, are fairly coarse, and have a glistening white colour. During the last month these hairs continue to increase in length, but gradually it becomes possible to distinguish below them a curly, well-matted coat, the fibres of which are finer and have a dull white colour. This appearance is detected first in the neck region from where it extends backwards over the trunk. At the end of the prenatal period this second coat, which is now recognisable as the woolly covering of the body, has practically replaced the previous hairy coat on all parts of the body excepting the lower portions of the limbs and the face.

7. *Determination of Age.*

As was pointed out in the introduction, one of the main objects of this work is to provide standards for the accurate estimation of age of Merino foetuses collected from uncontrolled sources. The necessary information is already set out in the preceding sections; but, as difficulty may arise in applying this rather detailed knowledge, it is considered advisable to extract the essential facts and to present these in a manner that will facilitate their ready application.

It is obvious that for accurate estimation one has to rely mainly upon quantitative methods. These involve the use of the regression formulae previously presented. In each of these the dimension is given in terms of age. Accordingly, the determination of the age corresponding to a measured value of a dimension necessitates a somewhat complicated calculation, for in the resulting equation the unknown (age) is present in both its first and its second powers. The solution of this equation involves factorization of rather unwieldy numbers. This process is far too elaborate to serve any useful practical purpose.

If the variables be reversed (age in terms of the dimension) the calculation is greatly simplified. From the point of view of growth this is rather illogical, for size is considered to depend on age, not age on size. However, if it will facilitate age-determination there is justification for the calculation of this "illogical" or "theoretical" formula.

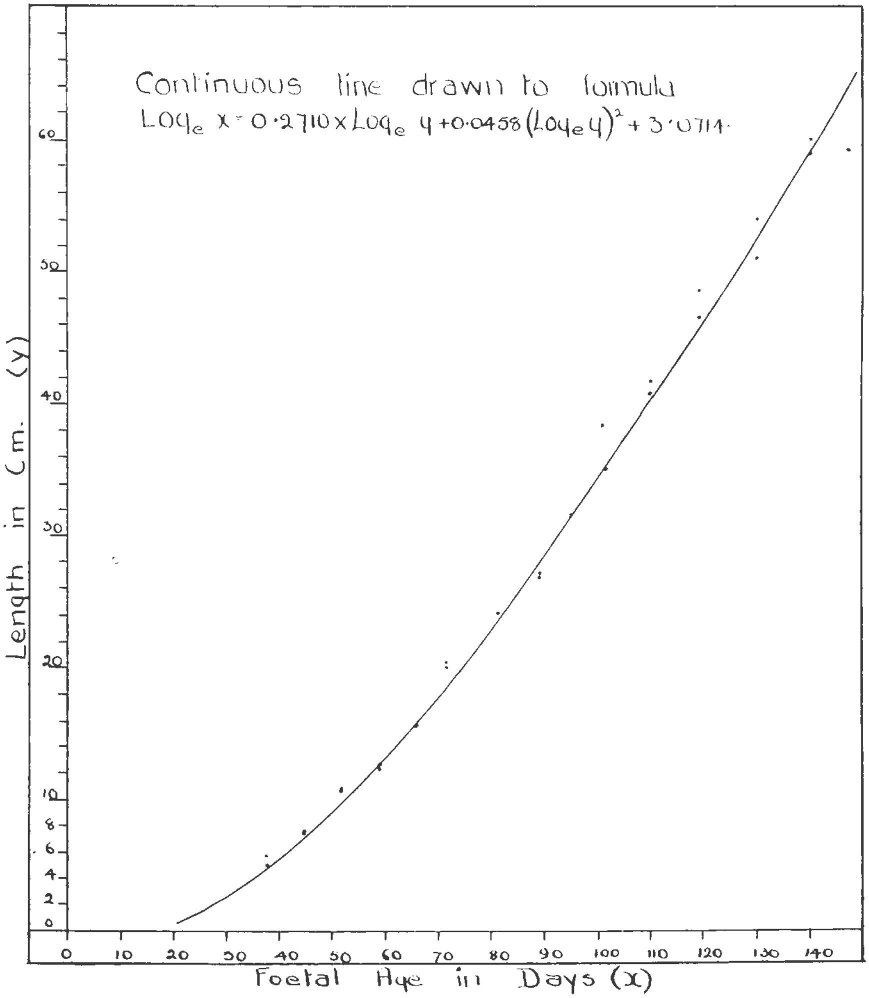
When this is done it is found that again the best-fitting curve is a parabola of the second order. Naturally the constants in the equation differ from those obtained when the same data are employed in the reverse direction. To illustrate this the formulae obtained with the vertebral column and age data are presented:—

(*a*) $\text{Log}_e \text{ Age} = 3 \cdot 0743 + 0 \cdot 2703 \text{ Log}_e \text{ V.C.} + 0 \cdot 0458 (\text{Log}_e \text{ V.C.})^2$

(*b*) $\text{Log}_e \text{ V.C.} = -10 \cdot 4383 + 4 \cdot 3948 \text{ Log}_e \text{ Age} - 0 \cdot 2949 (\text{Log}_e \text{ Age})^2$

The differences are not confined to the actual figures, but are evident also in the signs of these constants. As a result the shape of the regression line differs in the two instances. That obtained with formula (*a*) is illustrated in Fig. 41, while that of (*b*) is presented in Fig. 29.

Fig. 41.—Foetal Age in Terms of Vertebral Column Length.



From equation (*a*) age may be calculated in a direct manner. Nevertheless this computation still involves the use of logarithms and antilogarithms as well as fairly extensive multiplications which, unless a calculating machine is at hand, become very tedious. Consequently it is felt that even this "simplified" equation calls for more arithmetical labour than the average worker in biology will be eager to undertake. Moreover, the estimation of age being in most instances merely a necessary preliminary to further investigation, it is desirable that this process should occupy the minimum of time.

It appears that graphic estimation offers a solution to the difficulties mentioned. In this method direct readings are made on any of the regression curves in Figs. 23, 25, 27, 28, 29, 33 to 37, 39 and 40; thus all calculation is eliminated. It is not necessary to confine oneself to the figures presented in this work. From the regression equation of any dimension, a series of values for this dimension at stipulated ages may be calculated. With these data a graph may be constructed to any suitable scale. Obviously increase of the latter will tend to minimise the possible error of "reading". However, it in no way affects the possible inaccuracy due to the variation inherent in the dimension. The latter error is the more important of the two, and at this stage it may be considered in some detail.

In the preceding sections the coefficients of variation of all the regression equations are stated. For convenience these figures are repeated:

Dimensions.	*Coeff. Var.* Percentage.
Straight C.R. length	7·51
Length of Vertebral column	3·81
Length of trunk	4·07
Heart girth	5·48
Length of tail	9·75
Length of forelimb	4·72
Length of hindlimb	4·88
Length of head	8·76
Width of head	4·75
Weight of foetus	20·07

It must be remembered that these coefficients denote the extent of variation when the dimension is calculated from age. It does not necessarily follow that when the same equation is employed for the purpose of determining age (the dimension being known) the same degree of variation will be encountered. An interesting fact is that the coefficient of variation for equation (*a*) (on page 522) is 2·6 per cent., whereas that for (*b*) is 3·8 per cent. This indicates that owing to the lesser degree of variation in the age data the determination of age from the dimension is more accurate than that of the dimension from the age. This has been proved to hold good when the entire formula is reversed; but the point at issue is whether when age is estimated from formula (*b*) the likely error will be of the order of 3·8 per cent. or of 2·6 per cent. It has been ascertained authoritatively that the exact relationship between these two coefficients of variation has not yet been solved mathematically, but it is known that this error will lie *between* 2·6 per cent. and 3·8 per cent. Visually this may be verified by noting that the horizontal deviations of the plotted points (the variation of age about the trend line) in Fig. 29, are less than the vertical deviations (the variation of vertebral column length about the same line).

It may be assumed that the same applies in the case of all the other dimensions, and that the likely error in age determination will be less than the coefficients of variation presented above. As most of these already lie well below 10 per cent. it is evident that by this graphic method age may be determined with considerable accuracy.

Naturally the dimension with the least variation will be selected for such determinations. This is the vertebral column length. However, it is suggested that the accuracy of the determination may be improved by using more than one dimension and then arriving at an "average" age. This method certainly eliminates the possibility of being misled by an extreme variation in any one dimension. Nevertheless, it would be inadvisable to determine the age of a foetus from, say, its vertebral column length and its weight, and then to take as the most likely age the exact arithmetical mean of the two values. This method would entirely lose sight of the fact that the coefficient of variation of weight is five times as large as that of the vertebral column length. It is essential that more importance be attached to the value obtained through the use of the less variable dimension. It is suggested that the relative importance of two dimensions be apportioned in the inverse ratio of their coefficients of variation. Thus, in the above example, if the age obtained by the use of weight is higher than that obtained from the vertebral column length, then the final age would be taken as the vertebral column length value plus one-fifth, or the weight value less four-fifths of the difference between these two values.

e.g.—If age from weight $= x$
& age from V.C. $= y$
& $x > y$
then "true" age

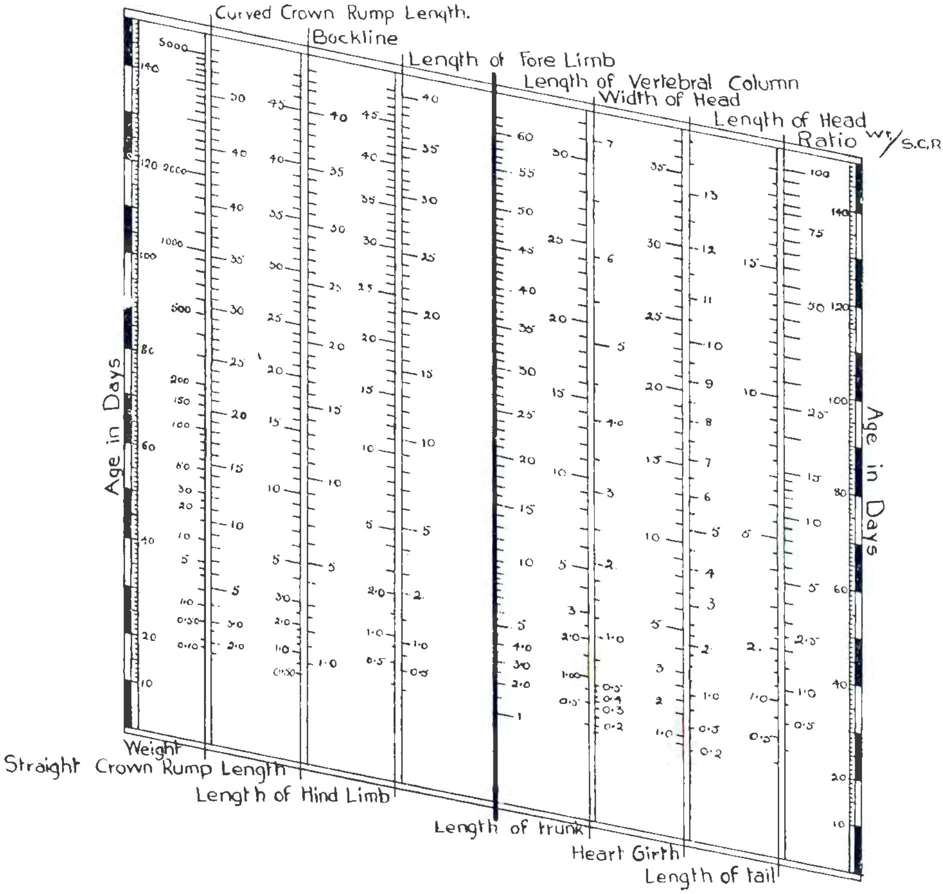
$$= x - \frac{4(x - y)}{5}$$

$$\text{or} = y + \frac{(x - y)}{5}$$

A further point to be mentioned is that in the choice of dimensions for ageing consideration be given to the correlation coefficient table (Table 33). Preference should be accorded to dimensions which have the least correlation with each other. Naturally their coefficients of variability must also be borne in mind, as it would be of little avail to select a highly variable dimension merely on the ground that it is not significantly correlated with any other dimension.

Although the way has now been cleared for the application in a fairly simple manner of the known quantitative data, there is still the possibility of further simplification. This is achieved by the construction, on the lines suggested by Scammon (1937), of a simple normograph (Fig. 42) in which the "expected values" of all dimensions at any age may be read in one straight line parallel to the base of the figure. This normograph may be used for the estimation of age from one or more dimensions.

Fig. 42.—Normograph for purpose of determining either foetal age from one or more dimensions, or the values of dimensions from those of other dimensions or from foetal age.



The following procedure may be recommended:—

(1) Determine the values of the dimensions. The measurements should be made in accordance with the details supplied in Chapter 3. For each dimension two or three readings should be taken and the average of these employed. The number of dimensions to be measured should be decided by the investigator. Naturally the length of the vertebral column will be the first to receive consideration. Others suggested are trunk, heart-girth and straight crown-rump length.

Age in Weeks.	External Appearance.	Head and Face.
3rd	Whittish, translucent comma-shaped. Brain regions developing. Heart pinhead-sized focus. Aorta and umbilical vessels visible	—
4th	Heart 0·5 cm. diameter. Aorta and carotids visible. Cranial region large. Tail 2 mm.	—
5th	Vertebral column foreshadowed. Surface pink. Heart still visible. Ventral abdominal bulge	—
6th	Definitive mammalian features evident. Heart invisible. Cart. models of vertebrae and scapulae seen	Mouth and nostrils distinguishable
7th	Head large, crown prominent. Neck still sharply bent	Mouth and nostrils plainly visible
8th	Neck long, thin and straight. Subcut. Vessels no longer visible	—
9th	Proportions of body become improved. Head still large	"Dished" profile less exaggerated
10th	—	Face increased in relative size
11th	—	Face has its definitive appearance. Horn buds visible
12th	—	—
13th	Head still relatively large. Neck thin	—
14th	Thickness of neck increasing. Skin on neck wrinkled	External nares open. Teeth Anlagen visible
15th	Similar wrinkles on brisket, and extending towards forearm	—
16th	Wrinkles visible on forearm	Philtrum of upper lip distinct
17th	Wrinkled appearance extending over forequarters	—
18th	—	Edges of nostrils bare and smooth
19th	Most of skin appears loose and wrinkled; less so posteriorly	—
20th	Skin over entire body extremely loose and wrinkled	Inner edges of lips serrated
21st	—	1st pair Incisors about to erupt

527-528b

527-528a

TABLE 34.

Correlated Development.

Eye.	External Ear.	Genitalia.
—	—	—
Thin black ring 1 mm. diameter	—	—
Diameter of ring 1·5 mm. Pigment more distinct	Triangular flap, 1 mm. in length	—
Diameter 3 mm. Lens opaque. Lids become visible	Length of flap increased to 1·5 mm.	—
Diameter 5 mm. Lids over eye. Signs of infra. obr. pouch	About 2 mm. in length	—
Eye protruding from head. Pouch distinct	Flap 3 mm. Central longitudinal ridge present	Scrotal and labial swellings visible; also penis and sheath
Ring wide and more deeply situated	—	Slight advance on above
Diameter 1·5 cm. Width 5 mm. Lids plain	Appear. of ext. meatus. 3 ridges present	Labial swellings migrated analwards
Ring no longer clearly visible	—	Penis and prepuce fairly well developed
Ring only faintly visible. Lid thick	—	Labial swellings fairly near anal region
Ring invisible	Flap length 2·5 cm.	Folds in definitive position
—	—	—
Lids well developed, still fused		3 mm. hairs around opening of prepuce
Infra-orbital pouch well developed	—	Preputial hairs 3 cm. Scrotum wrinkled
—	Flap 4·5 cm. 5 longitudinal ridges	Teats 6 mm. in length
Eyelids no longer fused	—	—
—	—	Scrotum collapsed
—	—	Prepuce well covered with hair
—	Flap 6 cm. in length.........	Vagina well developed

← 527–528a

527–528c →

527–528 b

Limbs.	Hair and Wool.
—	—
Both pairs of buds seen. Thoracic 3 mm. long	—
Cent. constriction. Division into digits. Distal part rotated	—
Digits distinct. Signs of access. digits. Division of limb plainly visible	Pinhead-sized white foci on eyelids and lips.
Coronary bands seen as transverse ridgelike swellings	Above foci recognisable as follicles of tactile hairs. Similar foci above eyes and spreading on to crown region.
Fetlock region taking shape. Coronet more prominent	Ordinary hair follicles over fore-arm and in axilla. Also seen on anterior aspect of carpus. Little later also on posterior surface of hock.
—	Tactile follicles large. Ordinary ones over whole body; sparser towards caudal extremity.
Horn deposited just below coronary band	Tactile hairs not erupted, but elevate surface.
—	Tactile hairs just emerging at a slant. Ordinary follicles closely packed over fore-quarters.
—	—
Appearance of interdig. pouch	Tactile hairs up to 6 mm. long. Ordinary hairs erupting on crown. Whorls round horn-bud.
—	Hairs on forehead visible to naked eye. Those on coronet and forearm seen with lens.
—	Forehead covered with well-matted hair. That on hindquarters just visible.
—	Tactile hairs up to 1 cm. in length. On lower part of face hair just visible with the naked eye.
Interdigit pouches well formed	Entire body well covered with white, glistening hair. Shorter posteriorly.
Horn deposition as far as heels	In neck region a dull white curly coat appears below the hairy covering.
Horn present on sole and access. digits	Curly coat more distinct on neck and also detected on anterior half of trunk.
Deposition of horn farther advanced	Curly "under-coat" on entire trunk. Straight hairs sparser and fairly loose.
Hoof and access. digits covered with horn	Hair present only on lower face and distal halves of limbs; remainder of surface has woolly coat.

527–528b

(2) Mark off lightly in pencil on the respective scales the the values of the dimensions.

(3) Stretch a thread across the normograph in such a way that it lies parallel with the base, i.e. so that it intersects identical age readings on each of the vertical sides of the normograph.

(4) Keeping the thread parallel, move it either upwards or downwards until it cuts the vertebral column scale exactly at the mark indicating the value of this dimension. This scale is accorded special prominence in the centre of the figure.

(5) Observe the distribution about the thread of the points indicating the values of the other dimensions. If the majority of them display either an upward or a downward tendency, the thread should be moved slightly in the appropriate direction. Again it must be remembered that to the dimension with the lowest coefficient of variation most weight should be attached. Hence, in the example previously quoted (V.C. length and weight), the thread would be moved roughly one-fifth of the distance towards the level of the weight mark. A further mark (say trunk length), lying somewhat below the level of V.C., might tend to draw the line downward again, probably restoring it to its original position, i.e. on the V.C. mark. In the normograph the arrangement of the scales is such that the most important dimensions are closest on either side to the vertebral column scale, while farthest away are those which carry least weight.

In this way the thread is manoeuvred until the points are well distributed about it.

(6) Make sure that the line is still parallel; i.e. note the age readings on both sides. The reading on the age-scale gives the age of the foetus in days.

Some details of the above procedure may appear over-elaborate, but in actual practice it will be found that unless the majority of the other points deviate considerably (and in the same direction) from the level of the vertebral column reading, the latter will be taken as indicating the most likely age.

Having fixed the age in this quantitative manner, one would scarcely expect that any improvement would result from the use of the descriptive data listed in Table 34. However, it is recommended that in all cases one should refer to this table, if only as a safeguard against incorrect estimation of the age of an exceptionally large or small foetus. In such a case it will be found that the external appearance does not correspond with that described for a foetus of the estimated age.

In this section full directions have been given for ageing foetuses. It rests with each worker to decide for himself in how far these are to be supplied. In his decision he will be guided mainly by the nature of his investigation and the degree of accuracy considered advisable. It is suggested that for most purposes the use of the vertebral column length supplemented by a rapid reference to Table 34, will give sufficiently accurate results.

(*d*) The Maternal Mammary Gland.

For the purpose of studying the growth of this organ during the course of pregnancy the data have again been placed in monthly groups. The differences between the various groups are studied by Fisher's (1936) "analysis of variance" method. Details are presented in Table 35 and Fig. 43.

Table 35.

Weight of Mammary Gland.

Groups of Ewes.		No. of Observ.	Mean Weight.	Significance Tests.	
No.	Class.			W. Group 1.	W. Preced. Group.
			Gm.		
1	Non-pregnant..............	10	199·90	—	—
2	1st month..................	10	122·60	—	—
3	2nd month.........	8	180·13	—	—
4	3rd month..................	6	203·33	—	—
5	4th month............... .	7	314·71	—	—
6	5th month..................	5	806·00	XX	XX

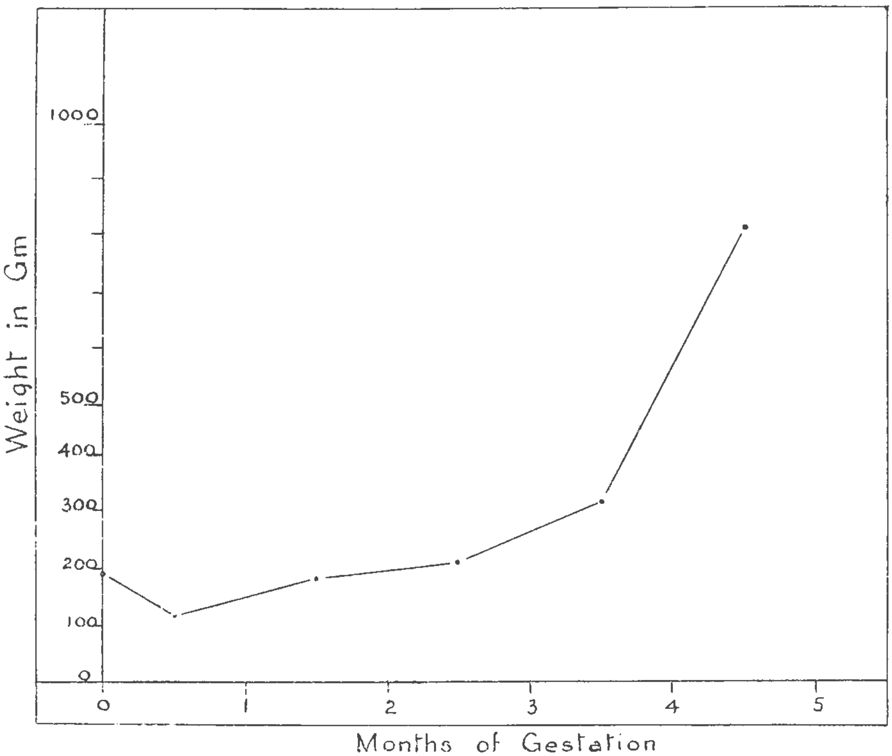
XX Significance at P = 0·01.
X Significance at P = 0·05.

The mean of the second group falls well below that of either the first or the third. This may be associated with the somewhat poorer condition at the time of slaughter of the sheep constituting this group. Nevertheless the drop is insignificant.

It is concluded that until the end of the third month there is no upward trend in the weight of the mammary gland. At about this time the weight does begin to increase, yet when the weight in the non-pregnant group is taken as the standard, this increase does not reach the level of significance until the last month of gestation. When the figure for the first month of pregnancy is employed for the purpose of comparison then the increase by the end of the fourth month is found to be just significant at $P=0\cdot05$. The increase during the last month is highly significant, and by the end of gestation the initial weight has undergone a fourfold increase.

Descriptive.—During the first two months of pregnancy the appearance of the gland changes but little. In the living animal the organ can be felt as a slight swelling under the rather loose inguinal skin. The teats are small and soft. The extirpated organ has the appearance of adipose tissue and it " sets " rapidly. The organ is flattened, with a greater depth at the caudal extremity than in the cranial portion. The depth in the former region is due in part to the presence of the supramammary lymph glands which are situated here, embedded in the adipose tissue.

Fig. 43.—Weight of Maternal Mammary Gland.



Towards the end of the second month of gestation it is noticed that the diameter of the mammary bloodvessels (external pudic arteries and veins and subcutaneous abdominal veins) has been doubled. At about this time it becomes possible to withdraw from the teats small quantities of clear, watery fluid.

During the following month the size of the gland increases slightly. This increase is reflected mainly by the greater depth of the cranial part of the organ. The vessels continue to enlarge, while the teats increase in length and become very soft and flabby.

Early in the fourth month there is much more noticeable enlargement of the gland, so that the increase is evident even in the living animal. To the touch the organ is somewhat elastic, apparently on account of the accumulation of secretion within it. At this time the fluid which can be withdrawn from the teats has become "syrupy".

By the end of the fourth month the gland is greatly enlarged and the parenchyma has a brownish colour, which contrasts with the white of the adipose tissue. The former is predominant especially in the region of the bases of the teats. The depth of the cranial part of the gland exceeds that of the caudal extremity. At this stage it is noticed that the gland does not "set" well, remaining soft and pliable for a long time after extirpation.

By the 140th day there has been even greater enlargement and the teats have become long and fairly well distended. The fluid which can be "milked" from the teat is viscid and has a creamy colour.

Just before birth this fluid becomes honey-like as regards both consistence and appearance. At this stage the bloodvessels are prominent, the veins especially being large and distended. The parenchyma of the organ is roughly cubical in shape, while adipose tissue forms but a narrow peripheral rim.

Thus it is found that the mammary gland undergoes most of its macroscopic development during the second half of pregnancy. This is in agreement with the findings of Hammond (1927) in the case of the cow, i.e. that during the first half of pregnancy there is first an organization of the collecting system, and then growth of the secreting tissue, while during the second half secretion commences and, as a result of the accumulation of the secretory product, the size of the organ is increased.

(e) MATERNAL ENDOCRINE GLANDS.

It is of interest to investigate the possibility of detecting in these glands macroscopic changes which may be associated with the physiologic state of pregnancy. Attention has been directed mainly to the changes in weight. This is due to the fact that in most of these organs linear measurements are impracticable, while volume determinations (by the displacement method) on these small glands call for more time than could be allowed to lapse before sectioning and the initiation of fixation for later histological examination.

In view of the desirability of having in Group 1 only ewes in the same phase of sexual life, all data from sheep judged to have been in anoestrum have been excluded. Thus this group comprises only ewes at various stages of the dioestrus cycle.

Hypophysis.—Details of the mean weights of the various groups are presented in Table 36.

TABLE 36.

Weight of Hypophysis.

Groups of Ewes.		No. of Observ.	Mean Weight of Hypophysis.
No.	Class.		
			Gm.
1	Non-pregnant..............	8	0·8125
2	1st month.................	11	0·6682
3	2nd month.................	8	0·7438
4	3rd month.................	5	0·7700
5	4th month.................	7	0·7286
6	5th month.................	5	0·9600

It is found that none of the differences between groups is significant even at the 5 per cent. level of probability. When the data are placed in two groups only (pregnant and non-pregnant) the differences are still insignificant.

In view of these findings no attempt has been made to analyse the data relating to length, width and depth of this organ.

Thyroid, Adrenals and Epiphysis.—For these organs fewer data are available, hence the method of grouping has been altered, group 2 comprising the former groups 2, 3 and 4, while the former nos. 5 and 6 have been amalgamated to form the third group of this section.

Details of these glands are tabulated below (Table 37). Not in a single instance is the difference between groups significant at $P = 0 \cdot 05$. Even reduction of the number of groups to two (pregnant and non-pregnant) fails to disclose any significant difference.

TABLE 37.

Weights of Thyroid, Adrenal and Pineal.

Groups of Ewes.		No. of Observ.	Mean Weight.		
No.	Class.		Thyroid.	Adrenal.	Pineal.
			Gm.	Gm.	Gm.
1	Non-pregnant..................	5	2·82	3·24	0·11
2	1st, 2nd and 3rd month........	8	1·98	2·93	0·14
3	4th and 5th month.............	12	2·42	3·52	0·14

Corpus Luteum.—For the study of this temporary endocrine gland recourse is had to a rather indirect method. The weights of the ovaries have been recorded, and by studying these it is hoped to gain some information regarding the changes in weight of the corpus luteum. Again the sheep are placed in six groups and in each of these two sub-groups are formed, comprising respectively the data of the ovary with the corpus luteum (C.L.) and those of the ovary without this body (N.C.L.). In Table 38 details will be found.

TABLE 38.

Weights of Ovaries.

Groups of Ewes.		No. of Observ.	Mean Ovarian Weight.	
No.	Class.		Ovary with C.L.	Ovary without C.L.
			Gm.	Gm.
1	Non-pregnant..............	9	1·40	0·69
2	1st month.................	12	1·38	0·66
3	2nd month.................	8	1·44	0·73
4	3rd month.................	6	1·33	0·67
5	4th month.................	7	1·14	0·61
6	5th month.................	5	1·00	0·58

On analysis it is found that none of the differences between groups of the C.L. series is significant. In view of the fact that the corpus luteum accounts for practically half the weight of the ovary in which it is located (see difference between the two ovaries of the same sheep), it is maintained that any change in size of the corpus will be reflected in the weight of the ovary. Consequently the above finding suggests that throughout pregnancy there is no significant change in the weight of the corpus luteum. However, there is the possibility that changes of a compensating nature may occur in both the corpus and the remainder of the ovary. However, reference to the N.C.L. series shows that here no significant changes have occurred. Moreover, the downward trend in the last two groups is well reflected in both series. This may be ascribed to progressive atresia of Graafian follicles, and the somewhat greater drop in the C.L. series may be attributed to this effect being more marked in the ovary carrying the corpus luteum (Hammond, 1927).

From the above reasoning it is concluded that, at least in the present data, there is no evidence of any change in the weight of the corpus luteum throughout the course of pregnancy.

Regarding all the endocrines it must be stated that no significant differences have been demonstrated. Probably the reason for this is that, considering the great variations encountered, the numbers of observations were too limited to allow of the detection of any changes that might have taken place. Probably the main value of this section lies in the fact that it demonstrates the futility of such studies on any but very extensive groups of animals.

(*f*) GENERAL.

1. In the review of the literature it has been pointed out that the ovum may either become implanted in the horn on the same side as the ovary from which it originated, or it may migrate to

the opposite side. Attention is directed to the statement of Clark (1936) that in the bovine more foetuses are carried in the right horn than in the left, and that this is not due to more frequent functioning of the right ovary, but to more frequent migration from left to right. Considering the topography of the rumen one might conclude that the pressure exerted by this organ has an important bearing on these findings. The same would be expected to apply to the sheep.

The data collected during the course of the present work are presented in Table 39.

TABLE 39.

Situation of Foetus and Corpus Luteum.

	No Migration.	Migration.	Total.
Foetus in Right Horn................	18	3	21
Foetus in Left Horn..................	10	5	15
TOTAL................	28	8	36

By means of the X^2 test it is possible to compare with each other migration and non-migration; migration to the right and migration to the left; foetus in right horn and foetus in left. Only in the first instance (migration and non-migration) do the observed figures differ significantly from their expected values. Thus it is seen that there is a very definite tendency for the ovum to become implanted on the side on which it is liberated. In fact, the odds are more than 100 to 1 against its migration. There is no significant difference regarding the number of foetuses carried in each horn, nor is migration more likely to occur in one direction than in the other.

In view of the relatively small number of animals employed it has been decided to include here the data supplied by Curson (1934). The details for the combined group of 72 ewes are set out in Table 40.

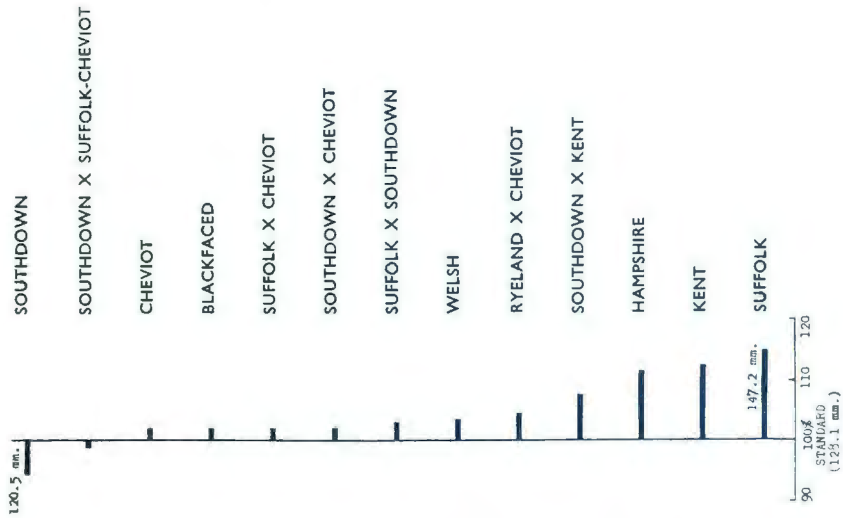
TABLE 40.

Situation of Foetus and Corpus Luteum.

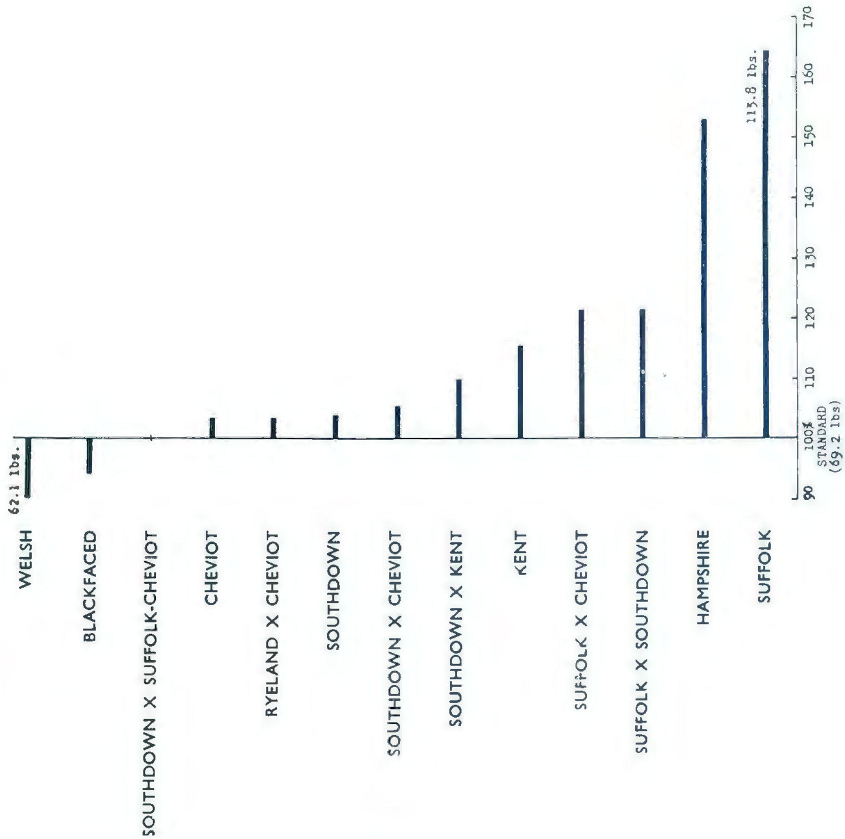
	No Migration.	Migration.	Total.
Foetus in Right Horn................	37	5	42
Foetus in Left Horn..................	25	5	30
TOTAL..................	62	10	72

DIAGRAM VII.

(g) Length of Cannon Bone.



(h) Carcass Weight.



As only data relating to sheep pregnant for 31 days or longer have been employed, the above equation holds good only from the beginning of the second month of gestation. During the first month the weight of the foetal system is negligible.

CHAPTER 5.—SUMMARY.

Attention is directed to the paucity of information regarding prenatal growth of domesticated mammals and to the fact that much of the available knowledge is rendered practically valueless through lack of accurate definition. The importance of accurate standards for ageing foetuses is stressed. The present investigation aims at providing such standards for the Merino sheep. In addition, during the course of the work valuable data have been collected concerning those maternal systems which are chiefly associated in the reproductive process, i.e. the genitalia, the endocrines and the mammary glands. Wherever possible, changes of a qualitative nature have been described in detail, while quantitative data have been subjected to statistical analysis.

In the sheep it is found that, with the exception of the Fallopian tubes, the entire genital tract undergoes extensive enlargement during pregnancy. In the horns and the body of the uterus a significant enlargement is evident sooner than in the vagina and the cervix. Whereas the former have to carry the developing foetal system, increase in the latter merely anticipates the needs of parturition. In all these organs the enlargement observed is the result of active growth of the regions concerned, not of mere passive stretching.

By about mid-term the placenta has reached its maximum development. After this there is a fall in weight, while the individual cotyledons tend to become flattened. Throughout pregnancy the weight of the foetal membranes increases steadily.

The total volume of foetal fluid increases rapidly until the third month, remains practically unchanged during the fourth, and then again increases. The first increase is the result of rapid accumulation of amniotic fluid, while the second is due entirely to the allantoic fluid; for during the second half of gestation the volume of amniotic fluid becomes decreased. During the fourth month a balance is attained between allantoic increase and amniotic decrease. This flattening of the curve is reflected in most of the weights and measurements of the uterus. Although specific gravity and hydrogen-ion concentration of the fluids were considered, no important changes were detected.

The weight of the maternal mammary gland begins to increase in the fourth month of gestation, but the major portion of the increase occurs only in the last month. The watery secretion observed at mid-term changes gradually into the yellowish honey-like cholostral milk.

Regarding the maternal endocrine glands it is concluded that as a result of large individual variations no significant macroscopic changes can be demonstrated. For such studies very large groups of animals would be necessary.

With reference to the foetus it is found that growth both in weight and in length follows a double parabolic trend represented by the formula

$$\text{Log}_e \text{ Dimension} = a + b \text{ Log}_e \text{ Age} + c\ (\text{Log}_e \text{ Age})^2.$$

The coefficient of variation for weight is over 20 per cent., whereas that of the most satisfactory length measurement (length of the vertebral column) is under 4 per cent.

The percentage growth-rates of both length and weight decrease steadily and continuously throughout prenatal life. There is no evidence of abrupt "breaks" in these rates.

The weight-length ratio of the growing foetus follows a simple logarithmic trend. The coefficient of variation is high, namely about 17 per cent.; hence this ratio has little value as an index of age.

In connection with regional growth it is found that with the exception of length of the neck (which is highly variable) all the dimensions considered are capable of representation by parabolae such as described for growth of the entire body. From a consideration of the percentage growth-rates of these dimensions the theory is formed that changes in the proportions of the growing foetus are the result of differential rates of retardation of regional growth. The degree of retardation in any region appears to be proportional to the lapse of time since the inception of growth in that region.

In one comprehensive table are set out the total, trend and residual correlation coefficients for each pair of dimensions. In all instances the total correlation is highly significant, but only between closely related dimensions is there a significant residual correlation. Thus in most instances the high total correlation is due almost entirely to the common growth-trend.

As the object of the work is to provide ageing standards, details are furnished as to the manner in which the above knowledge is to be applied. Special mention is made of a simple normograph so constructed as to allow of the straightforward reading of age from one or more measured dimensions.

In a supplementary section are considered the relation between the pregnant horn of the uterus and the situation of the corpus luteum, and the growth of the entire foetal system. In connection with the former it is concluded that there is a significant tendency for the foetus to be carried in the horn on the same side as the ovary containing the corpus luteum. The numbers of foetuses carried in each horn do not vary significantly, neither is there evidence of any tendency towards migration of the ovum in one special direction.

Knowledge of the weight of the foetal system is of importance to workers wishing to adjust the live weights of pregnant ewes. In this investigation the nett weight of the ewe (i.e. gross weight less weight of foetal system) is found to have no significant effect on the weight of the foetal system. Hence an equation is presented in which the weight of the foetal system (i.e. the correction to be applied) is given in terms only of the length of gestation. However, as the coefficient of variation is over 26 per cent., the correction must be regarded as very approximate.

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APPENDIX "A".

Details of Experimental Animals.

Serial Number of Ewe.	D.O.B. Number of Ewe.	At Slaughter.			Previous Sexual History.			Experimental Treatment.				Foetus.
		Age Years.	Body Wt. Kg.	Brain Wt. Gm.	Oestrum, 1936–37.	Service, 1936–37.	Parturition.	Detect. of Oestr. Date.	Detect. of Oestr. Hour.	Slaughter. Date.	Slaughter. Hour.	Age in Days.
1	48110	4·00	36·50	126	×××	×	—	19/7	9·30	4/8	14·00	15
2	44846	4·00	29·50	87	×××	—	—	14/7	9·30	31/7	9·00	16
3	29324	3·50	41·50	112	××××	×	8/ 8/36	29/4	9·00	17/5	14·25	17
4	44496	3·50	36·50	110	××	—	—	29/4	9·00	18/5	9·15	18
5	48117	3·50	36·50	101	××	—	—	5/5	9·00	25/5	9·30	19
6	44811	3·75	28·00	95	—	—	—	13/4	10·00	4/5	9·15	20
7	39887	3·75	36·50	114	×	—	—	13/4	10·00	5/5	9·15	21
8	44413	4·00	34·50	101	××	×	—	22/7	7·30	14/8	9·15	22
9	32668	4·00	36·00	100	××××	×	2/11/36	15/7	9·00	10/8	9·20	25
10	41614	4·00	44·00	101	××	—	—	19/7	9·30	16/8	9·15	27
11	44816	3·75	28·50	109	×××	×	—	17/4	8·00	19/5	9·30	31
12	48131	3·75	28·00	97	××	—	—	18/4	8·00	20/5	11·00	31
13	44444	3·50	35·50	102	×	—	—	17/4	8·00	26/5	9·40	38
14	40632	3·75	34·00	100	×	—	—	18/4	8·00	27/5	11·30	38
15	40663	3·50	33·00	108	×	—	—	17/4	7·50	2/6	9·45	45
16	44347	3·75	32·00	97	×××	×	—	18/4	8·00	3/6	11·30	45
17	44490	3·75	43·00	102	—	—	—	18/4	8·00	10/6	9·15	52
18	32490	3·75	34·00	104	×××	×	—	17/4	7·50	9/6	9·45	52
19	38347	3·75	42·00	113	××	×	1/ 7/36	17/4	7·50	16/6	9·50	59
20	35711	4·00	36·50	100	××	×	—	18/4	8·00	17/6	11·40	59
21	44519	3·75	43·50	108	×	×	12/ 7/36	16/4	7·50	22/6	9·45	66
22	47664	4·00	43·50	110	×	—	—	16/4	7·50	28/6	9·50	72
23	44759	3·75	37·50	101	×	—	—	17/4	10·30	29/6	9·25	72
24	42642	4·25	34·02	102	××××	×	6/ 1/37	15/7	9·00	5/10	9·10	81

Explanation :—

In connection with previous oestrum the number of observed occurences are indicated as follows—

×××× .... Very frequent.
××× .... Less frequent.
×× .... Occasional.
× .... Only one or two.

The dates and times in the 9th and 10th columns refer to the detection of the oestrum during which the ewe was successfully served. In these columns, and the following two, only the day and month are indicated as all this work was carried out during the course of one year, i.e. 1937.

APPENDIX "A".

Details of Experimental Animals—(*continued*).

Serial Number of Ewe.	D.O.B. Number of Ewe.	At Slaughter.			Previous Sexual History.			Experimental Treatment.				Foetus.
		Age Years.	Body Wt. Kg.	Brain Wt. Gm.	Oestrum, 1936–37.	Service, 1936–37.	Parturition.	Detect. of Oestr. Date.	Detect. of Oestr. Hour.	Slaughter. Date.	Slaughter. Hour.	Age in Days.
25	44371	3·75	44·50	110	××	×	—	15/4	7·20	14/7	9·10	89
26	36165	3·50	45·00	106	××	×	—	14/4	8·30	13/7	9·15	89
27	44332	3·75	41·50	109	×××	—	—	15/4	10·30	20/7	9·50	95
28	42605	4·00	46·50	105	××	×	—	15/4	7·30	26/7	9·35	101
29	47666	3·75	30·50	102	×	—	—	15/4	7·50	27/7	9·20	102
30	44683	4·00	46·50	113	×	—	—	15/4	7·20	4/8	9·15	110
31	47665	4·00	36·50	105	×	—	—	14/4	8·50	3/8	9·15	110
32	32489	4·00	46·50	109	××	×	—	15/4	7·50	13/8	9·30	119
33	36084	4·00	48·00	109	××	—	—	13/4	8·30	11/8	9·25	119
34	44326	4·25	39·50	113	××	—	—	14/4	8·30	23/8	9·15	130
35	44408	4·00	40·00	96	××	—	—	15/4	10·30	24/8	9·15	130
36	38540	4·25	54·50	106	××××	×	—	13/4	7·15	1/9	9·25	140
37	48123	4·25	51·50	106	×	—	—	15/4	7·50	3/9	9·20	140
38	44338	4·00	46·50	102	×	—	—	15/4	10·30	10/9	9·05	147
39	44643	3·75	25·58	102	—	—	—	13/4	8·30	24/4	9·30	—
40	36417	3·75	38·10	116	×	×	—	9/5	9·00	22/5	9·15	—
41	44835	3·75	30·62	108	×	—	—	13/4	7·15	27/4	9·20	—
42	25948	4·25	30·84	94	××	×	1/7/36	14/7	9·30	7/8	9·00	—
43	44823	4·00	35·38	94	×	×	—	17/4	7·50	7/7	9·15	—
44	35719	4·00	34·47	111	×	×	24/6/36	15/7	9·00	12/8	9·00	—
45	48113	4·25	42·18	102	×××	×	—	15/7	9·00	20/9	9·10	—
46	44737	4·25	44·45	118	××××	×	—	22/7	7·30	12/10	9·35	—
47	47668	4·00	61·24	119	××	—	—	—	—	2/11	9·05	—
48	44401	4·25	36·29	103	××	—	—	—	—	3/11	9·00	—
49	44651	4·25	43·55	118	×××	—	—	—	—	4/11	9·00	—

Explanation :—

In connection with previous oestrum the number of observed occurences are indicated as follows—

×××× .... Very frequent.
××× .... Less frequent.
×× .... Occasional.
× .... Only one or two.

The dates and times in the 9th and 10th columns refer to the detection of the oestrum during which the ewe was successfully served. In these columns, and the following two, only the day and month are indicated as all this work was carried out during the course of one year, i.e. 1937.

APPENDIX "A".

Details of Genital Tract.

Serial Number of Ewe.	Weight in Grams.	Vagina.			Cervix.			Fallopian Tubes.						Body.		Wall of Cornua.	
		Dimensions.			Dimensions.			Length.		Diameter.		Weight.		Dimensions.		Thickness.	
		L.	W.	T.	L.	W.	T.	P.	N.P.	P.	N.P.	P.	N.P.	L.	T.	P.	N.P.
1	22	10	3·2	0·30	4·0	2·1	0·30	16·5	16·0	0·20	0·20	0·50	0·50	1·5	0·40	0·40	0·40
2	18	10	3·5	0·20	5·0	1·5	0·35	17·0	15·0	0·15	0·15	0·30	0·30	2·5	0·40	0·40	0·40
3	35	13	3·7	0·40	7·0	2·5	0·40	15·0	15·5	0·20	0·20	0·70	0·75	2·5	0·50	0·40	0·40
4	17	11	3·5	0·30	5·0	2·5	0·40	17·0	15·0	0·15	0·15	0·50	0·60	2·0	0·40	0·40	0·40
5	17	10	3·0	0·30	5·0	2·0	0·25	15·0	15·5	0·15	0·15	0·45	0·40	1·5	0·25	0·25	0·25
6	17	10	2·7	0·40	4·5	2·5	0·40	16·0	15·6	0·30	0·30	0·50	0·50	2·0	0·40	0·40	0·40
7	35	11	4·0	0·40	4·8	3·0	0·40	18·5	18·5	0·20	0·20	0·65	0·70	3·0	0·40	0·40	0·40
8	22	12	4·5	0·25	6·0	1·5	0·20	17·5	17·0	0·20	0·20	0·40	0·50	1·5	0·40	0·40	0·40
9	26	10	3·5	0·40	6·0	1·8	0·40	15·0	15·0	0·20	0·20	0·48	0·40	2·0	0·40	0·40	0·40
10	15	12	3·2	0·20	6·0	1·5	0·30	16·0	15·0	0·15	0·20	0·45	0·40	1·8	0·40	0·40	0·40
11	26	13	3·5	0·25	4·5	3·0	0·40	15·6	15·0	0·20	0·20	0·50	0·60	2·5	0·40	0·40	0·40
12	17	11	2·4	0·25	5·0	1·5	0·35	11·5	13·5	0·20	0·20	0·40	0·40	2·0	0·30	0·25	0·25
13	13	11	2·8	0·35	6·5	1·5	0·40	19·0	20·0	0·20	0·20	0·60	0·70	2·5	0·30	0·30	0·30
14	22	12	3·2	0·30	5·5	1·8	0·30	16·5	18·0	0·15	0·15	0·45	0·45	3·0	0·20	0·20	0·25
15	22	12	2·6	0·35	6·5	1·7	0·40	18·0	18·0	0·20	0·20	0·70	0·70	2·5	0·40	0·40	0·40
16	10	10	2·2	0·25	5·5	1·6	0·35	18·0	19·0	0·20	0·20	0·50	0·50	2·5	0·40	0·40	0·40
17	22	11	2·8	0·25	5·5	1·6	0·30	17·0	18·0	0·20	0·20	0·60	0·60	3·5	0·25	0·30	0·25
18	23	13	3·5	0·20	5·5	1·6	0·40	18·5	18·0	0·20	0·20	0·60	0·55	2·5	0·25	0·25	0·25
19	22	14	3·5	0·30	6·5	1·8	0·30	16·0	17·0	0·20	0·20	0·45	0·45	5·0	0·25	0·25	0·25
20	17	11	3·0	0·30	6·0	1·8	0·30	14·0	16·0	0·20	0·20	0·45	0·45	4·0	0·30	0·30	0·30
21	18	14	3·0	0·30	7·0	1·5	0·20	17·0	18·5	0·20	0·20	0·50	0·50	4·5	0·25	0·20	0·25
22	22	15	3·5	0·20	7·0	2·0	0·20	17·0	17·5	0·20	0·20	0·50	0·50	5·0	0·20	0·20	0·20
23	25	11	4·0	0·20	6·0	2·0	0·30	14·5	15·0	0·20	0·20	0·50	0·50	6·0	0·30	0·30	0·30
24	32	14	5·0	0·20	5·5	1·5	0·39	16·0	15·5	0·15	0·15	0·25	0·25	7·5	0·25	0·25	0·25

N.B.—All measurements given in centimetres.

Abbreviations as follows :—

L. .... Length.
W. .... Width.
Wt. .... Weight.
T. .... Thickness.
P. .... Pregnant Side.
N.P. .... Non-pregnant Side.

In the case of Ewes No's 39 to 49 (i.e. the non-pregnant group) the left side measurements are tabulated under "P" (pregnant side at 0 days) while the measurements on the right hand side are regarded as those of the non-pregnant side at 0 days, and are given under "N.P.".

APPENDIX "A"

Details of Genital Tract—(*continued*).

Serial Number of Ewe.	Weight in Grams.	Vagina.			Cervix.			Fallopian Tubes.						Body.		Wall of Cornua.	
		Dimensions.			Dimensions.			Length.		Diameter.		Weight.		Dimensions.		Thickness.	
		L.	W.	T.	L.	W.	T.	P.	N.P.	P.	N.P.	P.	N.P.	L.	T.	P.	N.P.
25	28	13	5·0	0·35	8·5	2·5	0·30	18·0	17·5	0·20	0·20	0·45	0·45	5·0	0·20	0·20	0·20
26	24	13	3·5	0·25	7·2	2·0	0·40	20·0	19·0	0·20	0·20	0·65	0·57	5·0	0·20	0·15	0·20
27	18	15	3·5	0·15	7·0	1·8	0·30	19·0	18·5	0·15	0·15	0·40	0·30	7·0	0·20	0·20	0·20
28	23	13	3·2	0·25	7·5	2·0	0·30	18·0	18·5	0·20	0·20	0·65	0·65	6·0	0·25	0·25	0·25
29	23	13	4·0	0·20	7·5	2·5	0·30	16·0	16·0	0·20	0·20	0·50	0·50	5·0	0·20	0·15	0·20
30	29	15	4·0	0·20	8·0	2·4	0·40	20·0	19·0	0·20	0·20	0·62	0·62	5·5	0·25	0·15	0·15
31	36	12	4·5	0·20	8·0	2·3	0·30	17·0	18·0	0·15	0·15	0·50	0·50	6·5	0·20	0·15	0·15
32	34	14	7·0	0·15	9·0	2·5	0·30	14·5	15·5	0·20	0·20	0·40	0·40	7·0	0·15	0·15	0·15
33	28	13	4·0	0·25	8·5	2·5	0·40	18·5	18·0	0·20	0·20	0·60	0·60	10·0	0·15	0·15	p·15
34	33	18	6·0	0·15	9·0	2·6	0·50	17·5	18·0	0·20	0·20	0·50	0·50	6·0	0·20	0·15	0·15
35	29	14	5·5	0·15	8·5	2·3	0·40	16·0	18·0	0·20	0·20	0·40	0·50	10·5	0·25	0·15	0·15
36	32	16	6·0	0·20	8·0	3·0	0·55	19·0	20·5	0·20	0·20	0·40	0·50	8·0	0·20	0·15	0·15
37	43	14	7·0	0·20	8·5	3·0	0·60	19·0	18·5	0·20	0·20	0·60	0·50	7·5	0·20	0·15	0·15
38	39	16	7·5	0·15	10·0	4·0	0·70	18·0	18·0	0·20	0·20	0·60	0·60	11·5	0·50	0·30	0·50
39	30	10	3·0	0·30	4·0	2·0	0·30	13·0	13·0	0·20	0·20	0·60	0·50	2·0	0·50	0·50	0·50
40	29	12	3·2	0·30	6·0	1·3	0·35	16·0	15·0	0·30	0·25	1·10	0·90	2·5	0·30	0·30	0·30
41	20	10	3·0	0·20	4·0	2·0	0·30	15·0	16·0	0·20	0·20	0·75	0·70	2·0	0·40	0·30	0·30
42	18	10	3·5	0·20	5·5	1·5	0·30	14·0	12·0	0·20	0·20	0·40	0·40	1·5	0·40	0·40	0·40
43	16	11	3·0	0·20	5·0	1·8	0·30	13·5	14·0	0·20	0·20	0·50	0·40	2·5	0·30	0·50	0·50
44	28	11	4·5	0·30	4·5	2·5	0·40	14·0	13·0	0·20	0·20	0·40	0·40	3·0	0·50	0·50	0·60
45	23	13	4·8	0·15	6·5	1·8	0·30	19·0	18·5	0·20	0·20	0·60	0·50	3·0	0·40	0·40	0·40
46	24	10	4·0	0·40	6·0	1·5	0·30	15·5	16·5	0·20	0·20	0·30	0·35	2·0	0·60	0·60	0·60
47	24	11	3·3	0·50	5·5	1·6	0·70	18·0	17·5	0·20	0·20	0·50	0·50	2·0	0·50	0·50	0·50
48	18	10	3·5	0·60	4·5	1·7	0·50	16·0	15·5	0·20	0·20	0·30	0·30	1·5	0·50	0·50	0·50
49	17	10	2·4	0·50	5·0	1·5	0·50	15·5	14·5	0·20	0·20	0·30	0·30	1·8	0·50	0·50	0·50

N.B.—All measurements given in centimetres.

Abbreviations as follows:—

L. .... Length.
W .... Width.
Wt. .... Weight.
T. .... Thickness.
P. .... Pregnant Side.
N.P. .... Non-pregnant Side.

In the case of Ewes No's 39 to 49 (i.e. the non-pregnant group) the left side measurements are tabulated under "P" (pregnant side at 0 days) while the measurements on the right hand side are regarded as those of the non-pregnant side at 0 days, and are given under "N.P.".

APPENDIX " A ".

Details of Genital Tract—(*continued*).

Serial Number of Ewe.	Uterus.									Plac.	Cotyledons.					
	Weights in Grams.			Greater Curv.		Lesser Curv.		Circumference.		Weight in Gram.	Number.		Diameter.		Height.	
	D.	E.	W.	P.	N.P.	P.	N.P.	P.	N.P.		P.	N.P.	P.	N.P.	P.	N.P.
1	45	44	—	19·0	18·0	12·5	13·0	5·0	5·0	—	36	37	0·40	0·40	0·15	0·15
2	37	36	—	21·0	18·0	16·0	13·0	5·0	5·0	—	51	45	0·40	0·40	0·15	0·15
3	60	58	—	16·0	15·5	14·5	14·0	5·0	5·0	—	47	45	0·30	0·30	0·10	0·10
4	27	25	—	15·5	14·0	14·0	13·0	5·2	5·0	—	45	45	0·30	0·30	0·15	0·15
5	31	27	—	16·0	15·5	14·0	15·0	5·2	4·3	—	49	48	0·30	0·30	0·10	0·10
6	23	14	—	16·0	15·0	14·0	13·0	5·2	4·4	—	36	35	0·40	0·40	0·15	0·15
7	53	39	—	17·5	16·0	15·0	14·0	6·0	4·8	—	41	39	0·40	0·40	0·15	0·15
8	47	37	—	17·5	18·0	11·0	13·0	7·0	4·5	—	44	44	0·40	0·40	0·15	0·15
9	72	51	—	19·0	18·0	11·0	12·5	7·5	6·0	—	43	44	0·40	0·40	0·10	0·10
10	91	39	—	26·0	22·0	15·0	13·0	9·0	7·0	—	49	49	0·50	0·40	0·20	0·15
11	163	59	—	21·0	18·5	16·0	17·0	11·5	9·0	—	38	37	0·60	0·50	0·20	0·20
12	142	47	—	25·0	22·0	14·5	13·0	10·8	8·7	—	51	47	0·60	0·50	0·30	0·30
13	134	58	—	23·0	21·0	14·5	16·5	11·0	8·0	—	45	38	1·00	0·80	0·30	0·30
14	173	60	—	28·0	24·0	16·5	15·0	11·0	9·5	—	30	32	0·90	0·70	0·30	0·30
15	350	123	—	36·0	35·0	21·5	19·0	13·5	11·0	—	41	36	1·75	0·85	0·50	0·40
16	388	116	—	37·0	36·0	24·0	22·0	16·0	11·5	—	42	35	1·00	0·70	0·40	0·30
17	635	305	—	40·0	31·0	21·0	23·0	23·5	17·0	—	47	40	2·50	2·20	0·80	0·70
18	625	200	—	50·5	45·0	25·0	30·0	30·0	20·0	—	33	42	2·00	1·75	0·60	0·50
19	1,100	473	149	46·0	48·0	32·0	29·0	24·0	20·0	324	47	46	2·75	2·50	1·00	0·90
20	753	287	119	44·0	34·0	28·0	25·5	21·5	15·0	168	42	32	3·00	2·25	1·10	1·00
21	1,545	735	190	60·0	46·0	27·0	29·0	29·5	18·0	545	53	45	4·00	3·50	1·30	1·00
22	3,124	1,120	275	74·0	65·0	38·0	50·0	34·0	25·0	845	49	42	4·00	3·50	1·40	1·40
23	1,488	567	165	50·0	52·0	30·0	24·0	24·0	27·0	402	33	32	3·00	3·00	1·60	1·60
24	1,932	627	195	59·0	43·0	30·0	31·0	33·0	22·0	432	38	32	3·25	3·00	1·50	1·50

Abbreviations as follows:—

D. .... Dressed Uterus.
E. .... Empty Uterus.
W. .... Uterine Wall (Empty Uterus less Placenta).
Plac. .... Placenta.
P. and N.P. .... As explained previously.

Non-pregnant Group treated as indicated on previous page.

APPENDIX "A".

Details of Genital Tract—(*continued*).

Serial Number of Ewe.	Uterus.									Plac.	Cotyledons.					
	Weights in Grams.			Greater Curv.		Lesser Curv.		Circumference.		Weight in Gram.	Number.		Diameter.		Height.	
	D.	E.	W.	P.	N.P.	P.	N.P.	P.	N.P.		P.	N.P.	P.	N.P.	P.	N.P.
25	2,281	700	248	56·0	46·0	32·0	27·0	30·0	29·0	452	45	50	3·25	3·25	1·50	1·50
26	2,402	692	252	77·0	49·0	42·0	36·0	36·0	17·0	440	45	35	3·20	3·20	1·20	1·20
27	2,750	826	230	71·0	60·0	34·0	28·0	34·0	25·0	596	40	40	3·75	3·50	1·75	1·60
28	2,640	682	255	70·0	48·0	31·0	28·0	41·0	22·0	427	42	36	3·75	3·50	1·75	1·60
29	2,600	474	187	57·0	41·0	36·0	28·0	37·0	21·0	287	38	33	3·25	3·10	1·50	1·50
30	3,521	685	309	81·0	60·0	38·0	40·0	40·0	22·0	376	46	39	2·75	2·75	1·40	1·40
31	2,675	480	238	72·0	55·0	36·0	32·0	34·0	20·0	242	25	27	3·00	3·00	1·30	1·30
32	3,950	570	260	89·0	59·0	43·0	34·0	40·0	24·0	310	41	45	2·50	2·50	1·30	1·30
33	3,050	465	260	84·0	59·0	40·0	32·0	37·0	20·0	205	32	36	2·25	2·25	1·50	1·50
34	4,448	467	387	82·0	62·0	54·0	39·0	43·0	23·0	280	45	37	3·00	3·00	1·50	1·50
35	5,296	680	342	108·0	66·0	43·0	40·0	45·0	22·0	338	41	42	3·00	3·00	1·40	1·40
36	6,728	870	480	118·0	72·0	40·0	43·0	40·0	20·0	390	51	51	3·00	3·00	1·00	1·00
37	6,512	860	523	97·0	58·0	47·0	44·0	52·0	24·0	337	39	35	3·00	3·00	1·10	1·10
38	6,420	667	477	95·0	55·0	35·0	33·0	47·0	27·0	190	39	39	3·00	3·00	0·80	0·80
39	32	32	—	17·0	18·0	13·0	14·0	4·5	4·5	—	48	48	0·20	0·20	0·10	0·10
40	71	71	—	16·0	15·5	13·0	12·0	6·0	5·5	—	58	55	0·25	0·25	0·20	0·20
41	30	30	—	16·0	15·0	11·0	10·5	5·0	5·0	—	46	46	0·30	0·30	0·10	0·10
42	49	49	—	17·0	16·0	12·5	12·5	5·5	6·0	—	44	45	0·20	0·20	0·15	0·15
43	30	30	—	14·5	14·0	10·0	9·5	4·0	4·5	—	40	42	0·20	0·20	0·15	0·15
44	64	64	—	14·0	14·5	11·5	9·5	6·5	7·5	—	47	41	0·30	0·30	0·15	0·15
45	38	38	—	14·5	15·0	11·0	11·0	5·0	5·0	—	47	44	0·30	0·30	0·20	0·20
46	53	53	—	20·0	17·0	14·5	14·0	5·0	5·0	—	44	40	0·40	0·40	0·20	0·20
47	54	54	—	18·0	18·0	13·0	12·0	5·5	5·5	—	44	40	0·30	0·40	0·15	0·20
48	22	22	—	11·0	11·0	9·0	9·0	3·5	4·0	—	44	46	0·30	0·30	0·10	0·10
49	27	27	—	13·5	13·0	9·0	9·0	5·0	5·0	—	51	51	0·30	0·30	0·20	0·20

Abbreviations as follows:—

D. .... Dressed Utorus.
E. .... Empty Uterus.
E. .... Empty Uterus.
W. .... Uterine Wall (Empty Uterus less Placenta).
Plac. .... Placenta.
P. and N.P. .... As explained previously.

Non-pregnant Group treated as indicated on previous page.

APPENDIX " A ".

Foetal Fluids and Membranes—(*continued*).

Serial Number of Ewe.	Foetal Memb.		Foetal Fluids.							
	Weight in Grams.	Volume in C. cm.	Volume in C. cm.		Spec. Gravity.		Hydr. Ion. Conc.		Appearance.	
			All.	Amn.	All.	Amn.	All.	Amn.	Allantoic.	Amniotic.
22	330·0	300·0	600·0	500·0	1·005	1·002	7·0	7·1	Lemon colour; turbid......	Less distinct amber.
23	50·0	46·0	—	—	—	—	—	—	—	—
24	80·0	79·0	40·0	750·0	1·015	1·004	6·8	7·2	Lemon colour; turbid......	Lemon colour.
25	85·0	82·0	65·0	820·0	1·013	1·002	6·8	7·3	Lemon changing to amber..	Slightly viscid.
26	88·0	85·0	115·0	940·0	1·015	1·007	7·2	7·2	Amber; fairly turbid.......	Amber; more viscid.
27	122·0	120·0	71·0	750·0	1·016	1·011	7·2	7·4	Dark amber; more viscid..	Amber; more viscid.
28	110·0	105·0	215·0	480·0	1·016	1·066	6·6	6·8	Dark amber; more viscid..	Amber; more viscid.
29	112·0	110·0	390·0	590·0	1·010	1·004	7·2	7·0	Dark amber; more viscid..	Lemon; fairly cloudy.
30	155·0	150·0	535·0	550·0	1·011	1·003	6·6	7·0	Dark amber; more viscid..	Lemon fairly cloudy.
31	139·0	136·0	370·0	360·0	1·012	1·003	7·0	7·2	Dark amber; less cloudy...	Pale lemon; very cloudy.
32	147·0	140·0	500·0	620·0	1·013	1·003	6·6	7·4	Dark amber; watery.......	Deeper shade lemon.
33	115·0	113·0	350·0	330·0	1·011	1·000	6·6	7·2	Dark amber; watery.......	Deeper shade lemon; very viscid.
34	162·0	158·0	725·0	295·0	1·010	1·002	6·6	7·4	Dark amber; watery.......	Deeper shade lemon; very viscid.
35	225·0	220·0	685·0	275·0	1·011	1·004	7·0	7·0	Dark amber; not turbid...	Pale lemon; creamy.
36	230·0	225·0	770·0	375·0	1·012	1·003	6·9	6·8	Dark amber; not turbid...	Pale lemon; less viscid.
37	185·0	180·0	550·0	350·0	1·015	1·002	6·6	6·8	Dark amber; not turbid...	Pale lemon; less viscid.
38	162·0	160·0	1,080·0	350·0	1·009	1·002	7·2	7·4	Distinct amber colour, almost clear and watery	Very pale lemon, cloudy and fairly viscid.

Abbreviations as follows:—

All............................ Allantoic fluid.
Amn.......................... Amniotic fluid.
Hydr.-Ion Conc................. Hydrogen-Ion Concentration.
Memb......................... Membranes.

APPENDIX "A".

Endocrines, Ovaries and Mammary Gland.

Serial Number of Ewe.	Hypophysis.				Ovaries.								Pineal.	Adrenal	Thyroid.	Mam Gld
	Weight Gram.	Dimensions.			Length.		Width.		Depth.		Weight.		Weight in Gram.	Combd. Weight.	Weight in Gram.	Weight in Gram.
		L.	W.	D.	C.L.	N.C.L.	C.L.	N.C.L.	C.L.	N.C.L.	C.L.	N.C.L.				
1	0·60	1·4	1·1	0·8	1·9	1·5	1·5	0·9	1·2	0·9	1·6	1·0	0·10	3·10	2·60	182
2	0·55	1·2	1·0	0·8	1·3	1·0	1·3	0·9	1·0	0·8	1·0	0·3	0·10	3·00	2·00	122
3	—	—	—	—	1·9	1·3	1·6	1·3	1·3	0·8	1·7	0·9	—	—	—	110
4	0·75	1·4	1·0	0·8	1·8	1·3	1·5	1·1	0·9	0·6	1·2	0·6	—	—	—	72
5	0·60	1·3	1·1	0·8	1·6	1·0	1·1	0·9	1·0	0·7	1·2	0·6	—	—	—	—
6	0·60	1·4	1·1	0·5	1·6	1·2	1·3	1·0	0·9	0·6	1·1	0·5	—	—	—	33
7	0·55	1·5	1·0	0·6	1·3	1·3	1·3	1·1	1·3	0·8	1·2	0·7	—	—	—	93
8	1·00	1·3	1·0	1·0	1·8	1·1	1·1	1·0	0·9	1·0	1·1	0·7	0·10	3·30	2·30	124
9	0·60	1·4	1·0	0·8	1·5	1·6	1·2	1·2	1·2	0·6	1·3	0·7	0·10	3·00	2·50	168
10	0·60	1·3	1·1	0·8	1·3	1·3	1·4	0·9	1·0	0·9	2·0	0·7	0·20	0·60	0·50	160
11	0·80	1·5	1·1	0·6	1·8	1·5	1·5	1·1	1·1	0·6	1·6	0·7	—	—	—	—
12	0·70	1·4	1·0	0·9	1·7	1·3	1·2	0·9	1·0	0·6	1·3	0·5	—	—	—	62
13	0·85	1·4	0·9	0·9	1·6	1·1	1·2	1·1	1·1	0·8	1·4	0·7	—	—	—	155
14	0·60	1·3	1·0	0·8	1·6	1·5	1·2	0·9	1·1	0·7	1·3	0·7	—	—	—	167
15	0·60	1·3	1·0	0·8	1·7	1·6	1·4	1·1	0·9	0·7	1·2	0·7	—	—	—	157
16	0·60	1·2	1·0	0·8	2·0	1·5	1·3	0·9	0·9	0·8	1·6	0·8	—	—	—	134
17	1·00	1·7	1·1	1·0	1·8	1·5	1·5	1·1	0·9	0·5	1·7	0·7	—	—	—	212
18	0·80	1·3	1·2	0·8	1·7	1·5	1·2	0·8	1·0	0·6	1·4	0·5	—	—	—	279
29	0·80	1·5	1·0	0·9	1·5	1·6	1·4	1·2	1·0	0·8	1·4	1·1	—	—	—	187
20	0·70	1·4	1·1	0·8	1·8	1·5	1·3	0·9	1·0	0·8	1·5	0·6	—	—	—	150
21	—	—	—	—	1·8	1·7	1·4	1·0	0·8	0·4	1·1	0·6	—	—	—	195
22	0·95	1·5	1·2	0·8	1·8	1·6	1·3	0·9	1·0	0·5	1·6	0·7	—	—	—	237
23	0·60	1·5	1·1	0·8	1·8	1·2	1·2	1·0	0·8	0·6	1·4	0·6	—	—	—	175
24	0·70	1·4	0·9	0·8	1·6	1·0	1·4	0·9	0·9	0·6	1·2	0·5	0·11	2·70	1·80	150
25	0·90	1·4	1·2	0·8	1·9	1·7	1·5	1·0	1·0	0·6	1·5	0·9	0·20	3·70	2·50	183

Abbreviations as follows:—

L. .... Length.
W. .... Width.
D. .... Depth.
C.L. .... With Corpus Luteum.
N.C.L. .... Without Corpus Luteum.
Mam. Gld .... Mammary Gland.

APPENDIX "A".

Endocrines, Ovaries and Mammary Gland—(*continued*).

Serial Number of Ewe.	Hypophysis.				Ovaries.								Pineal.	Adrenal.	Thyroid.	Mam Gld
	Weight Gram.	Dimensions.			Length.		Width.		Depth.		Weight.		Weight in Gram.	Combd. Weight.	Weight in Gram.	Weight in Gram.
		L.	W.	D.	C.L.	N.C.L.	C.L.	N.C.L.	C.L.	N.C.L.	C.L.	N.C.L.				
26	0·70	1·5	1·1	0·7	1·7	1·7	1·3	1·1	0·9	0·5	1·2	0·7	0·20	4·05	1·60	280
27	0 80	1·3	1·2	0·9	1·5	1·5	1·4	0·6	0·9	0·4	1·2	0·5	0·14	3·50	2·50	137
28	0·90	1·4	1·0	1·0	1·8	1·5	1·3	0·9	1·0	0·5	1·3	0·6	0·20	3·80	3·10	294
29	0·55	1·4	0·8	0·9	1·4	1·4	1·2	1·1	1·0	0·5	1·0	0·7	0·10	3·60	3·40	165
30	0·80	1·5	1·1	0·9	1·6	1·4	1·2	1·0	1·0	0·5	1·3	0·6	0·10	3·00	1·60	397
31	0·65	1·4	1·0	0·8	2·0	1·7	1·3	0·9	1·0	0·7	1·2	0·7	0·15	2·50	2·20	295
32	0·60	1·3	1·1	0·8	1·6	1·7	1·1	0·9	0·9	0·5	1·0	0·6	0·15	2·10	0·90	340
33	0·80	1·5	1·0	0·9	1·6	1·3	1·1	1·0	0·9	0·5	1·0	0·6	0·20	3·70	1·80	575
34	0·80	1·4	1·1	0·8	1·5	1·3	1·0	0·9	0·7	0·6	0·7	0·5	0·10	3·00	1·60	365
35	0·80	1·4	0·9	1·0	1·3	1·2	1·1	0·8	1·0	0·6	1·0	0·4	0·11	5·40	3·00	360
36	1·00	1·5	1·0	1·0	1·5	1·5	1·3	1·1	0·9	0·4	0·8	0·4	0·20	4·70	2·90	1,120
37	1·40	1·6	1·3	1·1	2·0	1·7	1·1	1·2	0·9	0·8	1·3	0·9	0·10	3·70	3·70	1,285
38	0·80	1·4	0·9	1·0	1·9	1·5	1·3	1·0	0·6	0·5	1·2	0·7	0·15	3·20	2·30	900
39	0·75	1·3	1·0	0·6	1·5	1·0	1·2	0·9	0·9	0·7	1·1	0·5	—	—	—	80
40	0·60	1·6	0·9	0·7	1·8	1·0	1·1	0·9	0·8	0·5	1·2	0·5	—	—	—	90
41	0·60	—	—	—	1·8	1·4	1·0	1·2	0·8	0·7	1·0	0·8	—	—	—	156
42	—	—	—	—	1·3	1·2	1·2	1·0	1·0	0·5	1·2	0·5	0·10	2·50	3·00	—
43	0·55	1·2	1·0	0·8	1·7	1·2	1·1	1·0	0·9	0·7	1·4	0·6	—	—	—	154
44	1·00	1·4	1·2	0·9	1·7	1·4	1·0	1·0	0·9	0·6	1·0	0·4	0·10	4·50	3·20	254
45	0·70	1·4	1·0	0·8	1·8	1·1	1·3	1·0	1·0	0·6	1·6	0·6	0·15	2·50	3·00	203
46	1·10	1·6	1·2	1·0	1·5	1·3	1·3	1·3	1·5	0·6	2·5	0·8	0·10	2·90	2·00	275
47	1·20	1·8	1·1	1·0	1·6	1·7	1·3	1·2	1·2	1·2	1·6	1·5	0·10	3·80	2·90	351
48	0·60	1·3	1·0	0·8	1·3	1·2	0·9	0·8	0·9	0·6	0·7	0·5	0·10	2·00	2·10	184
49	0·65	1·3	0·9	0·8	1·2	1·2	1·0	1·0	0·8	0·7	0·6	0·6	0·15	3·30	1·60	252

In the case of Ewes No. 48 and 49 no Corpus Luteum was present. In these instances the left ovary is tabulated under C.L. and the right under N.C.L.

Abbreviations as follows :—

L.	Length.
W.	Width.
D.	Depth.
C.L.	With Corpus Luteum.
N.C.L.	Without Corpus Luteum.
Mam. Gld	Mammary Gland.

APPENDIX "A".

DIMENSIONS OF FOETUS.

Serial Number of Ewe.	Age of Foetus Days.	Sex of Foetus.	Weight in Grams.	Crown Rump Str.	Crown Rump Curv.	Back Line.	Tail Length.	Length of Head.	Width of Head.	Heart Girth.	Length of Trunk.	Length of Forelimb.	Length of Hindlimb	Length Vertb. Column.
4	18	—	0·05	0·4	1·0	—	—	—	—	—	—	—	—	—
5	19	—	0·10	0·5	1·4	—	—	—	—	—	—	—	—	—
6	20	—	0·07	0·7	1·8	—	—	—	—	—	—	—	—	—
7	21	—	—	—	—	—	—	—	—	—	—	—	—	—
8	22	—	0·15	0·8	1·6	—	—	—	—	—	—	—	—	—
9	25	—	0·30	1·4	3·8	—	—	—	—	—	—	—	—	—
10	27	—	0·65	1·6	3·7	—	—	—	—	—	—	—	—	—
11	31	—	1·10	2·0	4·4	—	—	—	—	—	—	—	—	—
12	31	—	1·00	2·0	4·5	—	—	—	—	—	—	—	—	—
13	38	—	4·7	3·5	6·9	4·1	1·5	1·6	0·9	4·0	1·9	1·9	1·8	5·6
14	38	—	4·1	3·4	6·5	3·8	1·2	1·6	1·0	3·4	1·9	1·8	1·7	5·0
15	45	—	9·7	5·0	8·9	5·3	1·9	2·1	1·3	4·5	3·2	3·0	3·1	7·2
16	45	—	12·1	5·7	9·3	5·0	2·3	3·4	1·4	5·0	3·2	3·3	3·2	7·3
17	52	F.	27·3	8·5	12·0	7·9	2·0	3·2	1·9	7·1	4·5	4·9	4·9	10·6
18	52	M.	29·6	9·0	12·7	7·8	2·9	3·2	2·0	7·3	4·5	4·9	5·0	10·8
19	59	F.	54·3	11·0	13·2	9·6	3·1	3·9	2·2	9·0	6·6	6·3	6·9	12·7
20	59	F.	39·2	10·2	13·3	8·8	3·8	3·8	2·1	8·1	5·7	5·5	5·8	12·6
21	66	F.	96·6	13·5	16·0	11·3	4·2	4·9	2·7	10·8	8·0	7·9	8·1	15·5
22	72	F.	161	16·5	21·0	14·5	5·8	5·8	3·1	12·3	10·2	10·2	11·1	20·3
23	72	F.	152	16·2	20·0	13·9	6·3	5·8	3·3	12·8	9·8	10·2	10·9	20·2
24	81	M.	427	20·0	23·5	16·9	7·3	7·0	3·8	16·5	12·8	12·5	13·5	24·2
25	89	F.	485	22·5	28·0	19·0	7·8	8·3	4·4	17·5	14·0	15·6	17·6	26·8
26	89	F.	470	22·5	28·5	19·7	7·3	7·9	4·1	17·3	14·0	15·1	16·8	27·0
27	95	M.	737	28·0	32·5	21·2	10·2	9·2	5·0	21·7	17·5	17·7	20·0	31·4
28	101	F.	970	31·5	35·5	27·9	10·3	10·0	5·1	22·6	19·4	21·2	24·7	38·2
29	102	M.	947	29·0	35·0	24·1	10·9	9·8	5·1	22·5	19·1	19·9	22·5	35·0
30	110	M.	1,460	33·0	38·2	30·5	11·3	11·1	5·5	25·5	22·5	22·6	29·0	41·8
31	110	M.	1,205	33·5	39·0	28·3	12·5	11·1	5·4	25·2	21·5	23·3	26·8	40·8
32	120	F.	1,875	38·5	43·0	31·7	16·9	11·9	5·9	29·0	24·5	30·3	34·4	48·6
33	120	F.	1,692	34·5	41·0	32·0	14·6	10·3	5·6	26·8	22·5	27·3	32·0	46·6
34	130	M.	2,310	40·0	47·0	34·0	17·0	12·0	6·1	29·0	25·0	31·0	38·1	51·0
35	130	M.	3,120	42·5	48·0	37·0	17·0	13·0	6·8	32·6	29·9	34·5	41·4	54·0
36	140	M.	4,120	47·0	54·0	41·8	17·2	13·1	7·2	36·0	29·6	40·8	47·4	59·0
37	140	M.	4,120	45·0	54·0	42·9	17·1	13·2	7·2	36·2	31·0	38·3	45·7	60·0
38	147	F.	3,800	44·0	51·5	42·0	17·0	13·0	6·7	34·0	31·0	39·1	44·0	59·0

All length measurements given in centimeteres.

APPENDIX "B".

Comments on the Methods Adopted in Fitting Curves.

As indicated in the text the weight-age data were the first to be considered. The individual observations were translated to logarithmic form. For convenience let x siginfy these values of the age data, and y those of the weight data. It appeared that the plotting of y against x resulted in a straight-line distribution. Consequently the regression coefficient b was determined and a straight line with the formula $Y = (\bar{y} - b\bar{x}) + bx$ was fitted.

Next the standard deviation of a single observation about this line was calculated. Let this be S.

The coefficient of variation = $100 \times S$ %

The significance of the coefficient of regression was tested by calculating

$$t = \frac{6}{S\bar{E}6}$$

Although the significance was high the fact that the coefficient of variation was large and that the actual observations were badly scattered about, the regression line led one to believe that a better "fit" would be obtained by introducing also the square of the age, i.e., fitting a parabola. For this the formula is: —

$$y = \bar{y} + b_1 (x_1 - \bar{x}_1) + b_2 (x_2 - \bar{x}_2)$$

Here x_2 represents the square of the age, and b_1 and b_2 are the coefficients. The former signifies the tendency towards straightness while the latter introduces the curved tendency.

The coefficient of variation is calculated as before, while the significance of both coefficients is tested in the same manner as previously described.

Both on account of the lower coefficient of variation and the improved distribution of the data about the line, it is concluded that this line "fits" the data more satisfactorily than the previous one.

It will be remembered that in the above calculation both age and weight were represented in their logarithmic forms. In order to eliminate these logarithms it is necessary to take antilogarithms on both sides of the question. In this way it is possible to determine for any series of age values the corresponding expected values of weight. The construction of a smooth weight-age curve is then a simple matter. All the curves presented in chapter 4 (in the section concerning the foetus) were constructed in this manner.

In the majority of cases it was obvious from the plotting of the logarithms of the dimensions against those of age that a straight line would not give the best "fit". Therefore, this equation was not calculated. However, in all instances the coefficient of variation of the linear logarithmic trend was determined. This was done in order to establish definitely, in each case, the superiority of the curved logarithmic trend.

It is to be noted that the technique employed in these calculations, and, in fect, throughout the whole work, is that standardized by R. A. Fisher in his "Statistical Methods for Research Workers", from which all basic formulae have been obtained.