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The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Helen Adams Mackeen for the degree of Master of Arts. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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Report
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Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Helen Adams Mackeen final oral examination for the degree of Master of Arts . We recommend that the degree of Master of Arts be conferred upon the candidate.

Minneapolis, Minnesota

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The Growth of the Abdominal Region
in the Human Fetus.

A thesis submitted to the
Faculty of the Graduate School of the
University of Minnesota

by

Helen Adams Mackeen

In partial fulfillment of the requirements
for the degree of
Master of Arts.

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The Growth of the Abdominal Region in the Human Fetus.

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Growth of the Abdominal Region in the Human Fetus.

This work was undertaken with the idea of ascertaining what changes, if any, take place in the form of the abdomen of the human during prenatal development, and of determining the rate of growth of the various parts of the region as compared with the rate of growth of the body as a whole and of the trunk region. The material upon which the measurements were taken was supplied from the fetal anatomy museum of the University of Minnesota by the kindness of Dr. Richard E. Scammon, under whose direction the work was done. All specimens were chosen with regard to the symmetry of the trunk region, any showing distortion or improper fixation being rejected. One hundred and eighty-seven fetuses were measured. These range in length from 28 mm. C.H.¹ to 590 mm. The series is well distributed. In the entire range between these two limits in only two intervals of 1 cm. (that between 8 cm. and 9 cm. and that between 22 cm. and 23 cm.) did no case occur. In all other centimetre intervals there were from 1 to 7 cases. Forty per cent of the total number of cases was distributed between 30 cm. C.H. and 60 cm. C.H., and 60 per cent of the cases had a C.H. measurement less than 30 cm. Of the 187 cases, 75 were male, 87 were female, and the remaining 25 were not sufficiently differentiated externally to allow the determination of the sex.

The linear measurements, including total length in specimens under 20 cm. C.H., were made with a vernier caliper. The lengths and the circumferences of specimens over 20^{cm.}_A C.H. were measured with

¹C.H. is the abbreviation used to designate the total height of the fetus, i.e. the crown-heel length, measured from the vertex to the point of the heel.

a narrow steel tape. A coarse linen thread was used for circumferences of the small specimens. The extent of the measurement was then determined secondarily with the tape. The measurements were recorded on small mimeographed cards on which the museum number, the sex and the length measurements were also kept for identification. These measurements were so chosen that they should end, in so far as possible, on bony points recognized as limits of the abdomen.

The series of measurements were as follows:

1. C.H.= crown heel: from the vertex to the point of the heel.
2. C.R.= crown rump: from the vertex to the tip of the coccyx. (Taken as a check on the C.H.)
3. Sterno-pubic: from the sternal notch to the superior margin of the symphysis pubis.
4. Sterno-umbilical: from the sternal notch to a transverse line bisecting the umbilical cord.
5. Xiphisterno-pubic: from the junction of the xiphoid process and the body of the sternum to the superior margin of the symphysis pubis.
6. Xiphisterno-umbilical: from the xiphisternal junction to a transverse line bisecting the umbilical cord.
7. Umbilico-pubic: from this mid point at the umbilicus to the superior margin of the symphysis pubis.
8. Mammary line: a point on the inguinal ligament half way between the mid sagittal plane of the body and the anterior superior iliac spine. A vertical line from this point on the inguinal ligament extended to bisect the costal arch.

9. Last rib to the crest: the vertical distance between the free tip of the last rib and the iliac crest.
10. Intercristal: the transverse distance between the highest points on the iliac crests?
11. Interspinous: the transverse distance between the anterior superior iliac spines.
12. Intertrochanteric: the transverse distance between the great trochanters.
13. Lumbo-coccygeal spine: the length of the vertebral column from the upper surface of the first lumbar vertebra to the tip of the coccyx.
14. Lumbar spine: the distance from the upper surface of the first lumbar vertebra to the lumbo-sacral junction.
15. Crest above the pubis: the distance above the symphysis pubis of a line circling the body at the level of the iliac crests.
16. 10th rib above pubis: the distance above the symphysis pubis of a line circling the body at the lower border of the 10th rib.
17. External conjugate: the oblique diameter between symphysis pubis and lumbo-sacral junction.
18. Xiphisternal circumference: at the level of the xiphisternal junction.
19. 10th rib circumference: at the lower border of the 10th rib.
20. Umbilical circumference: at the level of the umbilicus.
21. Cristal circumference: at the level of the iliac crests.

A table of each measurement was made from these measurements dividing the cases into intervals of 1 cm. C.H. length, and recording the number of cases, the average length of the measurement in millimetres and the minimum and maximum measurement for that interval. From these tables other tables were made covering 5 cm. intervals, giving the average C.H. length of all cases in that interval, the number of cases, the average length of the measurement in millimetres and the minimum and maximum measurement for that interval. From this second set of tables the curves of the measurements were plotted and the results computed which appear as diagrams and histograms.

The first chart of curves represents the averages calculated on measurements 3, 4, 5, 6, 7 in tables I, II, III, IV and V. The entire series of graphs on this chart show a decided tendency to run in straight lines, indicating that the rate of growth of each, ^{as} compared with the growth in length of the body, remains constant throughout this period. Any deviation from the straight in this series probably can be accounted for by individual variation. The uppermost line shows the change in the length of the trunk, i.e. the sterno-pubic distance. This line measures 20 cm. when the body measures 60 cm. C.H., that is, it equals one-third of the total body length. In other words, the sterno-pubic line has increased at a rate equal to one-third of the rate of growth of the body. That this rate is remarkably constant may be seen at a glance. At 15 cm. C.H. the trunk length is 5 cm.; at 30 cm. C.H., 10 cm.; and at 45 cm. C.H., 15 cm. Taking 50 cm. C.H. as the average length of the newborn, it will be noted that at birth the average length of the trunk equals 17 cm. Friedenthal ('14) who includes in his work this same measurement gets results

consistently lower, but it is evident that he includes only one case in each period, so that little emphasis may be placed on his results.

Similarly, the second line which shows the rate of growth of the region between the sternal notch and the umbilicus, while indicating a lesser rate, shows that this rate is quite as constant as those preceding. At 15 cm. C.H. the line is about 4 cm. long; at 30 cm. C.H. it is 8 cm. long, 12 cm. at 45 cm. C.H., and 16 cm. at 60 cm. C.H. In the newborn the length of the line equals 17 cm. From these figures it will be seen that the sterno-umbilical line increases at slightly more than one-fourth the rate of the body length.

The xiphisterno-umbilical line closely parallels the sterno-umbilical line throughout and increases at one-fourth the rate of the entire body length.

The xiphisterno-umbilical region gains less rapidly than those already described. It reaches a length of 10 cm. while the body is acquiring a length of 60 cm. At 15 cm. C.H. the distance between the xiphisternal junction and the umbilicus is 2.5 cm.; at 30 cm. C.H. it is nearly 5 cm.; and at 45 cm. C.H. it is 7.5 cm. In other words, this region increases at one-sixth the rate of lineal growth of the body.

The umbilico-pubic distance increases the least rapidly of the five measurements in this plane. At 15 cm. C.H. it is 1 cm.; at 30 cm. C.H. it is 2.3 cm.; at 45 cm. C.H. 4.25 cm.; and at 60 cm. C.H. 5.5 cm. This shows the rate to be something under one-tenth that of the body length.

Chart II gives the results obtained in tables X, XI, VI, XIX and IX on the lengths of the lumbo-occygeal spine, the lumbar spine, the

mammary line, the external conjugate diameter, and the distance from the last rib to the crest. In general, the growth rate of the two spinal distances and of the external conjugate may best be expressed by straight lines; the mammary line shows a more rapid rate of growth in the second half of the distance causing the line to curve with the concavity upward. The rate of growth of the last rib to the crest distance is checked apparently after 40 cm. C.H., and the line tends to flatten out.

From the chart it is evident that the lumbo-coccygeal spine increases at about one-fifth the rate of linear body growth. This part of the vertebral column is 3.5 cm. long at 15 cm. C.H.; 6.5 cm. long at 30 cm. C.H.; 9.5 cm. long at 45 cm. C.H.; and 12 cm. long at 60 cm. C.H. At birth it is 10 cm. in length.

The lumbar portion of the spine increases at about one-eighth the rate of growth of the body in length. At 15 cm. C.H. the length of this region is about 2 cm.; at 30 cm. C.H. it is 4 cm.; at 45 cm. C.H. it is 6 cm.; and it is nearly 8 cm. at 60 cm. C.H. In the newborn, the length of the lumbar portion of the spine is 6.3 cm.

The segment of the mammary line between the costal arch and the inguinal ligament is 11 cm. at birth, and 13 cm. at 60 cm. C.H. It is 2.5 cm. long at 15 cm. C.H., and 5 cm. long at 30 cm. C.H., but between 30 cm. C.H. and 60 cm. C.H. the line increases 8 cm. in length, or one and three-fifths times the growth in the first 30 cm. C.H. For the entire fetal period the body length increases about 4.5 times faster than this portion of the mammary line.

The external conjugate diameter is about 5.5 cm. at birth and increases to about 6.5 cm. in this series of measurements. At 15 cm. C.H. the diameter is 1.5 cm. C.H.; it is 3 cm. at 30 cm.

C.H., and 5 cm. at 45 cm. C.H. The rate compared with the rate of growth of the body in length is just one-tenth the latter during the first half of the period, but apparently a slight acceleration appears at about 45 cm. C.H. This throws the curve a trifle higher at this point and although the original rate of increase is maintained, the final result compared with the length of the body shows an increase in the rate of growth of the diameter to about one-ninth that of body length.

The distance from the tip of the last rib to the crest is 1 cm. at 15 cm. C.H., 2 cm. at 30 cm. C.H., and 3.5 cm. at 45 cm. C.H.; thereafter it does not appreciably increase up to 60 cm. C.H. The average rate of growth is something less than one-fifteenth the rate of lineal body growth.

The third chart gives the curves plotted from the averages found in tables 16, 17 and 18, of the three pelvic measurements--the intercrystal, the interspinous and the intertrochanteric diameters. The rate of growth here also is remarkably constant. Up to 10 cm. C.H. the three lines are almost superimposed but at this point they begin to spread slightly, the intertrochanteric distance becomes the greatest, then the intercrystal, and lastly, the interspinous diameter. This relation is maintained throughout the remainder of the period, and they measure 9.5, 9, and 8.5 respectively at 60 cm. C.H. length. A decided increase in the rate of growth takes place in the intertrochanteric diameter at about 45 cm. C.H. and continues until birth or shortly after, at which point it drops back to a lower rate than before the increase. This is the only marked deviation from the straight taking place in any of these lines. The length of the body increases on the average six and one-third times faster than the intertrochanteric

diameter, six and two-thirds times faster than the intercostal, and seven times faster than the interspinous distance.

The last chart of curves deals with the circumferences based upon tables 12, 13, 14 and 15. The circumferential measurement at the level of the tenth rib is greater than any of the others throughout the period covered by the series, though the circumferential measurement at the level of the xiphisternal junction approaches it closely at all points. Each one of the group shows a tendency to lessen the rate of growth about the time of birth. The length of the body increases one and six-tenths times faster than the tenth rib circumference, about the same for the xiphisternal junction level, one and eight-tenths times faster than the umbilical circumference and twice as rapidly as the distance around the body at the top of the crests.

The histograms were developed directly from the tables and not from the curves. They deal with a series of six average lengths, --those between 5-10 cm. C.H., 15-20 cm. C.H., 25-30 cm. C.H., 35-40 cm. C.H., 45-50 cm. C.H., and 55-60 cm. C.H. In all charts in which the absolute measurements for these periods have been included, the relative growth, as compared with some member of the series, has been added. The absolute measurements are of course located on the curves, and no further consideration of them seems necessary at this point.

In the first histogram which includes the measurement of the mammary line, the sterno-pubic line, the xiphisterno-pubic line, the xiphisterno-umbilical line, and the umbilico pubic lines, the xiphisterno-pubic line was used as a constant in computing the relative development of the other linear measurements. There is no appreciable change in the relation of the mammary line. It remains

about four-fifths as long as the xiphisterno-pubic line. The sterno-pubic line makes a slight but constant decrease in relative growth when compared with the xiphisterno-pubic distance. The xiphisterno-umbilical distance remains constant, while there is a slight but constant increase in the relative length of the umbilico-pubic line.

In the second histogram, combining absolute and relative measurements of the length of the lumbo-coccygeal spine, the length of the lumbar spine, the distance of the tenth rib above the pubis, the distance of the crest above the pubis, and the distance from the last rib to the crest, the length of the lumbo-coccygeal spine was used for the constant in computing the relative lengths of the other measurement. The relation of the length of the lumbar spine to the length of the lumbo-coccygeal spine remains constant, the former being about three-fourths as long as the latter. There is a marked increase in the relative distance of the tenth rib above the pubis in these stages; also an increase, not so marked, in the distance of the crest above the pubis. There is a very slight relative increase in the distance between the last rib and the crest.

In the third histogram, a miscellaneous group of measurements are computed against the trunk length (sterno-pubic length) as constancy. With reference to the same measurement at different stages of the umbilico-pubic, the mammary line and the xiphisterno-pubic line show a relative increase. In the four circumferences there is at first a considerable increase and then a more gradual decrease. Both the increase and the subsequent decrease is most marked in the tenth rib and the xiphisternal circumferences.

The interspinous line and the external conjugate also show increase followed by slight decrease.

In relation to the sterno-pubic line, the umbilico-pubic changes from 16 per cent to 28 per cent of the entire trunk distance. The mammary line increases from 40 to 60 per cent to the entire trunk distance, and the xiphisterno-pubic line from 55 to 75 per cent. The tenth rib circumference begins at 171 per cent, reaches a maximum of 223 per cent and decreases to 192 per cent. The xiphisternal circumference begins at 141 per cent, increases to 220 per cent, and decreases to 170 per cent. The umbilical circumference begins at 145 per cent, increases to 181 per cent, decreases again to 166 per cent; and the cristall circumference begins at 110 per cent, increases to 161 per cent, and decreases to 147 per cent.

The interspinous line begins as 33 per cent of the sterno-pubic line, increases to 58 per cent, and decreases again to 44 per cent; while the external conjugate begins as 22 per cent of the trunk length, increases to 36 per cent, and decreases to 33 per cent.

In the histogram of the circumferences alone, plotted against the tenth rib circumference as unity, it will be noted that there is an increase followed by a slight decrease in the xiphisternal relation, a slight decrease followed by an increase in the umbilical relation, and a constant increase in the cristall circumference relative to the tenth rib circumference.

The last histogram depicts the absolute and relative changes and the sexual differences in the pelvic measurements. A number of investigators have worked on this problem in the newborn. Friedenthal ('14) and La Faille ('93) carried some of the

measurements down into the fetal period. The only available measurement by Friedenthal ('14) is the intertrochanteric diameter, which he finds to be 2.2 cm. at 13.4 cm. C.H., 3.9 cm. at 22 cm. C.H., 5.4 cm. at 30 cm. C.H., 6.6 cm. at 36.4 cm. C.H., 8.5 cm. at 37 cm. C.H., 9.5 cm. at 47 cm. C.H., and 11.4 cm. at birth. It is evident that he has included but one case in each of the periods, and his results are subject to criticism because of the individual variation which may obtain. From his cases of 36.4 cm. C.H. and 37 cm. C.H. it is apparent that he has two fetuses of the seventh month, rather than one of the seventh and one of the eighth, as he affirms. The fact that his figures are all higher than those obtained in this study, particularly those gained from the older embryos, may be offset by the fact that there were so few cases.

Klein ('96), who worked on newborns, found that all the pelvic measurements were greater in the male than in the female at birth. Konikow ('93) found that the intertrochanteric distance was greater in the female infant at birth, but that all other measurements gave greater results in the male. Le Damany ('10), on a series of one hundred newborn infants of each sex finds that the intercrystal diameter is equal to 20 per cent of the total body length of newborn male infants, and to 19.7 per cent of the total body length of newborn female infants. Developing this formula it is found that the intercrystal diameter is 10 cm. in males and 9.8 cm. in females,--results that are at least 2 cm. greater than those given by any other writer. In the following table, which summarizes the work of Klein ('96), Konikow ('93), and Tatewosoff ('99), it will be noted that each of the distances is greater in the male than in the female.

	<u>Cases</u>	<u>Ext.Conj.</u>	<u>Int.sp.</u>	<u>Int.cr.</u>	<u>Int.tr.</u>
Newborn M	17	6.6	7.2	7.9	9.1
Newborn F	22	6.2	6.9	7.5	9.0

Fasbender ('78), in measuring 345 newborn male infants and 285 newborn female infants, finds the interspinous diameter to be 71.3 mm. in the former and 69.6 mm. in the latter; and the intercrystal diameter 73.0 mm. in the male and 71 mm. in the female. It is interesting to note that Litzmann ('61) and Fehling ('76), who worked on skeletons, get about the same relative values, but that Fehling's figures are all greater than those of Fasbender, who measured living children. Hennig ('80) finds the external conjugate to be 50 mm. in the newborn male and 53 mm. in the newborn female. Taylor ('19), in a recently published article on newborn measurements, includes two on the pelvis, the intercrystal and the intertrochanteric diameters. He measured 125 newborns of each sex, and finds the average of the intercrystal measurement in both sexes to be 78.5 mm., - 79.7 mm. for males and 77.3 mm. for females. The intertrochanteric diameter was 91 mm. for the males and 89 mm. for females, -- 90 mm. for an average. This last average is exactly what Weisenberg ('06) finds for the same measurement. In my series were six newborn male infants and ten newborn female infants. The results of the pelvic measurements are in the following table.

	<u>Cases</u>	<u>Ext.Conj.</u>	<u>Int.sp.</u>	<u>Int.cr.</u>	<u>Int.tr.</u>
Newborns M	6	56 mm.	72 mm.	75 mm.	84 mm.
Newborns F	10	58 mm.	80 mm.	83 mm.	89 mm.

The last histogram is based upon tables 16, 17, 18, 19 and 20. In all the measurements, except the external conjugate, there is shown a steady increase with very little difference in rate compared with one another and with the total body length. The external conjugate increases less rapidly, as was shown in chart II. Using the average intercrystal measurement of males and females as unity, it will be noted that there is considerable variation in the same measurement at different stages of intra-uterine life, and in different measurements. Up to 50 cm. C.H., the length of these lines on the male equal or are slightly greater than the same measurements on the female. Between 55 and 60 cm. C.H. the female measurements increase over the male in all except the measurement of the interspinous diameter; in this the male maintains the lead. Yet in the series of newborn cases, including only infants with total body lengths between 49 cm. and 52 cm., all the female measurements were greater than the male measurements. This is contrary to the findings of all observers who have worked out these measurements except Hennig. Hennig finds the external conjugate to be 3 mm. greater in the female. In this series the difference is 2 mm. The number of newborn cases measured was small, and it may have been chance that has thrown in only large females. Further investigation may show a change in the relative values of these measurements.

Plates X and XI are diagrams illustrating the form of the abdomen in each of the six periods used in the preceding histograms. They are based upon the average figures for each period. Plate X is based upon the averages of the absolute measurements, and plate XI is constructed upon a relative scale in which the length of the xiphisterno-pubic line is used as unity. Plate X

shows a progressive increase in the size of the abdomen with comparatively little change in form. Length increases slightly more rapidly than breadth, and the lateral lineal measurements grow somewhat more than the mid-sagittal length. These form changes are also seen in Plate X where it will be noted that they are associated with an increase in the angle of the costal arch.

The relative position of the umbilicus changes very slightly, although it appears to shift upward as the fetus grows older. In the youngest group, that is, fetuses between 5 and 10 cm. C.H., the umbilicus lies between the middle and lower third of the xiphisterno-pubic line. It lies closest to the pubis in the group having a C.H. length between 15 cm. and 20 cm., when it is located between the fifth and lower sixth of the xiphisterno-pubic line. It lies farthest from the pubis in the group 45-50 cm. C.H., being then between the third and the fourth fifths on the xiphisterno-pubic line. In the last group (55-60 cm. C.H.) the umbilicus again drops slightly in its relative position. In all except the very youngest group the crest line lies a considerable distance below the umbilicus. The distance between a transverse line at the level of the iliac crests increases with the age of the embryo, or in other words the distance of the crest above the pubis does not increase at as rapid a rate as does the umbilico-pubic distance.

Plate XII shows the differences in form of the male and female abdomen at birth as drawn from average figures obtained on six male infants and ten female infants. In shape there is no relative difference. The female abdomen is the larger, but the series of newborn female infants gave an average C.H. measurement

of 51.2 cm. as against the male measurement of 50.4 cm. C.H., so that it may very well be that the abdomen is larger merely because the cases were larger. In comparing a complete list of figures of average measurements in the two sexes at birth, it is to be noted that the male shows an increase over the female only in the length of the lumbo-coccygeal spine, the length of the lumbar spine, the distance of the last rib above the iliac crest, and in the tenth rib circumference. It would appear that the lumbar section of the vertebral column was increasing more rapidly in length in the male than in the female at birth, and this fact would account for the increased distance between the last rib and the crest.

The last series of plates are of sagittal and coronal contours of the trunk region, and of the transverse contour at the xiphisternal junction. The ten smaller outlines were made from a series of plaster casts of the specimens while the three larger ones were made from the specimens direct. The smallest specimen in this series was 49 mm. C.H.; the largest may be regarded as a newborn infant.

These contours show how slight is the change in the shape of the trunk from early fetal life to birth. The circumference at the xiphisternal junction is circular, except for individual cases of slight distortion in the smaller specimens, but it shows a tendency to become flattened antero-posteriorly toward the end of fetal life.

Summary.

The most striking fact noted in connection with this problem was the uniformity in the rate of growth which takes place in practically every dimension. It is evident that growth rate must have been established very early in fetal life,--before a C.H. length of 28 cm., and this rate maintained throughout the fetal period. Particularly is this true of lineal trunk measurements and those which were frankly based upon the skeleton. Measurements not founded on bony points showed a greater tendency to variation, as for instance two of the circumferential measurements. Two measurements of this kind were made on the entire series; one, the transverse abdominal diameter at the level of the umbilicus, and the other the antero-posterior diameter at the same level, but so great was the variation that no use could be made of the figures obtained. It would seem that growth changes taking place in the abdominal organs were affected by the skeletal rate of growth, rather than that the changes in these organs affected the form of the abdomen.

Lineal growth is more rapid than horizontal growth. The shape of the abdomen at birth is relatively longer and narrower than in early fetal stages.

The abdomen is at first frankly barrel-shaped; the greatest circumference is at the level of the tenth rib and the next greatest is at the level of the umbilicus. The relation changes early in development, however, and the two upper measurements,--the xiphisternal and the tenth rib circumferences,-- have almost the same dimensions; and the umbilical and cristal circumferences being progressively smaller, give the abdomen the form of an inverted cone. Later still the tenth rib circumference again

becomes the greater and a barrel shape, though not so marked as in the earlier stage, holds to the end of intra-uterine development.

The pelvic measurements have already been discussed at some length. The increase in rate of growth of the intertrochanteric diameter is probably due to the rotation outward of the os femora which takes place in the latter part of fetal life. The appearance of sexual differences in the pelvis cannot be said to be settled by the present work, figures here quoted being at variance with all the established ideas.

The change in position of the umbilicus, it will be noted, is comparatively slight. Its relative position in the abdomen may shift slightly cephalad, but this may be subject to variation.

The rate of growth in all save the circumferences, besides being constant throughout intra-uterine development, apparently continues unchecked at least through the first trimester of postnatal development. It would be unreasonable to suppose that all the cases measured above 50 cm. C.H. were large newborn children. The rate of increase of circumferences is checked after the average birth length is reached, though constant up to that point.

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Table I.

Average Length of Sterno-Pubic Line (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No. of Cases	Average	Minimum	Maximum
0 - 50	42	7	15	11	18
50 - 100	77	15	31	17	30
100 - 150	120	24	37	30	47
150 - 200	169	13	50	42	61
200 - 250	221	21	65	56	74
250 - 300	275	21	85	72	107
300 - 350	328	13	105	84	117
350-- 400	373	18	125	101	143
400 - 450	429	9	148	134	160
450 - 500	489	13	161	155	171
500 - 550	523	16	178	165	195
550 - 600	573	25	197	164	210

Table II.

Average Length of Sterno-Umbilical Line (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No. of Cases	Average	Minimum	Maximum
0 - 50	42	7	11	9	13
50 - 100	77	15	19	13	24
100 - 150	120	24	30	22	40
150 - 200	170	13	42	32	49
200 - 250	221	21	52	39	62
250 - 300	275	21	67	51	81
300 - 350	328	13	80	70	95
350 - 400	373	18	99	81	118
400 - 450	429	9	114	105	126
450 - 500	489	13	125	112	135
500 - 550	523	16	139	125	162
550 - 600	573	5	154	134	165

Table III.

Average Length of Xiphisternal-Pubic Line (m m.)

Range of C.H. Length (m m.)	Average of C.H. Length	No. of Cases	Average	Minimum	Maximum
0 - 50	44	6	10	9	11
50 - 100	77	15	17	12	21
100 - 150	120	24	26	20	35
150 - 200	169	13	34	28	41
200 - 250	221	21	44	36	48
250 - 300	275	21	57	42	76
300 - 350	328	13	73	56	84
350 - 400	373	18	88	64	115
400 - 450	429	9	103	95	111
450 - 500	469	13	114	74	132
500 - 550	523	16	133	121	151
550 - 600	573	5	146	122	160

Table IV.

Average Length of Xiphisternal-Umbilical Line (m m.)

Range of C.H. Length (m m.)	Average of C.H. Length	No. of Cases	Average	Minimum	Maximum
0 - 50	42	7	7	5	8
50 - 100	77	15	12	9	14
100 - 150	120	24	19	14	27
150 - 200	169	13	26	20	29
200 - 250	221	21	31	26	36
250 - 300	274	21	39	26	52
300 - 350	328	13	49	39	57
350 - 400	373	18	61	45	87
400 - 450	429	9	68	61	73
500 - 500	469	13	82	72	111
500 - 550	523	16	90	81	103
550 - 600	573	5	97	91	103

Table V.

Average Length of Umbilico-Pubic Line (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	44	6	1	3	5
50 - 100	77	15	5	3	8
100 - 150	120	24	7	5	10
150 - 200	169	13	9	5	14
200 - 250	221	21	14	9	17
250 - 300	275	21	18	9	30
300 - 350	328	13	26	17	32
350 - 400	373	18	31	18	41
400 - 450	429	9	38	31	47
450 - 500	469	13	44	30	68
500 - 550	523	16	50	40	60
550 - 600	573	5	54	36	63

Table VI.

Average Length of Mammary Line (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	44	6	8	6	9
50 - 100	77	15	12	7	17
100 - 150	120	24	21	15	25
150 - 200	169	13	27	21	34
200 - 250	221	21	34	28	44
250 - 300	275	20	45	30	66
300 - 350	328	13	61	51	78
350 - 400	373	18	75	56	90
400 - 450	429	9	88	72	98
450 - 500	469	13	101	76	125
500 - 550	523	16	113	98	126
550 - 600	573	5	121	97	142

Table VII.

Average Distance of 10th Rib Above Pubis (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	40	1	5		
50 - 100	74	5	10	9	14
100 - 150	122	16	17	13	20
150 - 200	177	5	25	18	29
200 - 250	218	9	27	22	31
250 - 300	275	15	35	28	55
300 - 350	328	10	54	38	69
350 - 400	371	14	67	55	82
400 - 450	429	7	76	66	84
450 - 500	474	8	82	64	97
500 - 550	520	15	14	74	124
550 - 600	569	4	105	84	122

Table VIII.

Average Distance of Crest Above Pubis (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	40	1	1		
50 - 100	74	5	3	2	5
100 - 150	122	16	7	4	11
150 - 200	177	5	12	9	15
200 - 250	218	9	13	9	17
250 - 300	275	15	16	11	25
300 - 350	328	10	22	15	30
350 - 400	371	14	25	15	34
400 - 450	429	7	29	25	33
450 - 500	475	8	29	21	33
500 - 550	520	15	34	24	44
550 - 600	569	4	40	29	45

Table IX.

Average Length of Last-Rib to Crest Line (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No. of Cases	Average	Minimum	Maximum
0 - 50	42	7	3	2	5
50 - 100	77	16	5	3	7
100 - 150	121	26	8	5	11
150 - 200	170	15	10	7	13
200 - 250	221	22	15	11	18
250 - 300	275	22	18	12	30
300 - 350	328	13	22	14	32
350 - 400	373	18	28	13	49
400 - 450	429	9	34	17	48
450 - 500	469	13	35	18	55
500 - 550	523	16	35	20	47
550 - 600	573	5	36	28	52

Table X.

Average Length of Lumbo-Coccygeal Spine (m m.)

Range of U.H. Length (m m.)	Average of C.H.Length	No. of Cases	Average	Minimum	Maximum
0 - 50	42	6	11	8	15
50 - 100	77	16	18	14	21
100 - 150	121	26	26	19	35
150 - 200	170	15	36	27	44
200 - 250	221	22	47	35	53
250 - 300	275	22	59	46	72
300 - 350	328	13	70	59	89
350 - 400	373	18	79	64	101
400 - 450	429	9	92	74	112
450 - 500	469	13	96	81	110
500 - 550	523	16	108	93	123
550 - 600	573	5	111	99	123

Table XI.

Average Length of Lumbar Spine (M m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	40	5	6	4	9
50 - 100	78	15	11	8	14
100 - 150	121	26	17	12	24
150 - 200	170	15	24	17	38
200 - 250	221	22	30	22	37
250 - 300	275	22	38	27	51
300 - 350	328	13	49	35	62
350 - 400	371	15	51	39	67
400 - 450	429	7	64	43	86
450 - 500	475	8	61	44	74
500 - 550	520	15	69	50	84
550 - 600	569	4	73	66	80

Table XII.

Average of Xiphi-Sternal Circumference

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	42	7	35	27	42
50 - 100	77	16	44	39	67
100 - 150	121	26	79	64	107
150 - 200	169	17	110	93	125
200 - 250	221	22	142	118	167
250 - 300	275	22	169	140	200
300 - 350	328	13	200	183	224
350 - 400	373	18	228	200	274
400 - 450	429	9	259	232	280
450 - 500	469	13	297	269	328
500 - 550	523	16	336	295	378
550 - 600	573	5	343	312	380

Table XIII

Average of 10-rib circumference. (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	42	7	36	29	44
50 - 100	77	16	53	38	71
100 - 150	121	25	82	66	108
150 - 200	169	16	111	99	128
200 - 250	221	21	144	120	172
250 - 300	275	22	170	140	198
300 - 350	328	13	204	182	231
350 - 400	373	18	230	195	284
400 - 450	429	9	258	230	285
450 - 500	469	13	308	259	352
500 - 550	523	16	345	303	393
550 - 600	573	5	361	345	400

Table XIV.

Average of Umbilical Circumference (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	42	6	32	28	40
50 - 100	77	15	45	32	55
100 - 150	119	22	69	53	98
150 - 200	169	12	90	69	108
200 - 250	221	21	120	99	155
250 - 300	275	21	145	115	180
300 - 350	328	13	174	144	205
350 - 400	373	18	205	155	252
400 - 450	429	5	241	195	271
450 - 500	469	13	283	210	333
500 - 550	523	16	322	273	371
550 - 600	573	5	340	319	385

Table XV.

Average of Cristal Circumference (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	44	5	24	20	32
50 - 100	77	16	34	23	46
100 - 150	121	26	56	44	85
150 - 200	169	17	76	52	90
200 - 250	221	22	102	83	129
250 - 300	275	22	125	100	151
300 - 350	328	13	152	135	175
350 - 400	373	18	176	156	210
400 - 450	429	9	206	188	222
450 - 500	469	13	239	191	280
500 - 550	523	16	275	237	329
550 - 600	573	5	286	265	315

Table XVI.

Average of Intercristal Line (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	44	5	6	5	7
50 - 100	77	16	10	6	14
100 - 150	121	26	17	13	26
150 - 200	169	17	24	21	28
200 - 250	221	22	33	27	41
250 - 300	275	22	41	32	49
300 - 350	328	13	49	41	65
350 - 400	373	18	54	49	65
400 - 450	429	9	63	60	68
450 - 500	469	13	71	60	85
500 - 550	523	16	77	68	102
550 - 600	573	5	87	82	92

Table XVII.

Average Length of Interspinous Line (m m.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	0	0	0	0	0
50 - 100	84	5	11	9	14
100 - 150	121	24	17	13	25
150 - 200	169	17	23	19	27
200 - 250	221	22	31	25	39
250 - 300	275	22	38	32	45
300 - 350	328	13	45	39	60
350 - 400	373	18	51	41	60
400 - 450	429	9	59	56	81
450 - 500	469	13	67	59	81
500 - 550	523	16	72	61	97
550 - 600	573	5	81	73	83

Table XVIII.

Average Length of Intertrochanteric Line (mm.)

Range of C.H. Length (m m.)	Average of C.H.Length	No.of Cases	Average	Minimum	Maximum
0 - 50	43	4	6	5	8
50 - 100	77	16	10	7	13
100 - 150	121	26	17	12	26
150 - 200	169	17	25	20	30
200 - 250	221	22	33	29	40
250 - 300	275	22	43	36	48
300 - 350	328	13	52	46	61
350 - 400	373	17	60	53	71
400 - 450	429	8	69	63	75
450 - 500	472	11	81	69	93
500 - 550	523	16	92	83	111
550 - 600	573	5	95	84	103

Table XIX.

Average Length of External Conjugate (m m.)

Range of C.H. Length (m m.)	Average of C.H. Length	No. of Cases	Average	Minimum	Maximum
0 - 50	42	6	5	4	6
50 - 100	77	16	7	5	10
100 - 150	121	26	13	9	20
150 - 200	169	17	18	13	22
200 - 250	221	22	22	15	31
250 - 300	275	21	26	18	35
300 - 350	328	13	33	28	40
350 - 400	373	18	38	30	51
400 - 450	429	9	47	39	51
450 - 500	469	13	56	41	67
500 - 550	523	16	60	50	75
550 - 600	573	5	63	60	66

Table XX.

Sex Differences in Pelvic Measurements (m m.)

		150 - 200	250 - 300	350 - 400	450 - 500	550 - 600
		m m.	m m.	m m.	m m.	m m.
Intercristal Line	M (6)	24	40	55	72	81
	F (10)	24	42	54	71	92
Interspinous Line	M (6)	22	32	53	69	81
	F (10)	23	39	50	65	78
Intertrochanteric Line	M (6)	24	42	61	83	92
	F (10)	26	43	59	82	98
External Conjugate	M (6)	18	26	40	57	62
	F (10)	18	28	39	54	66

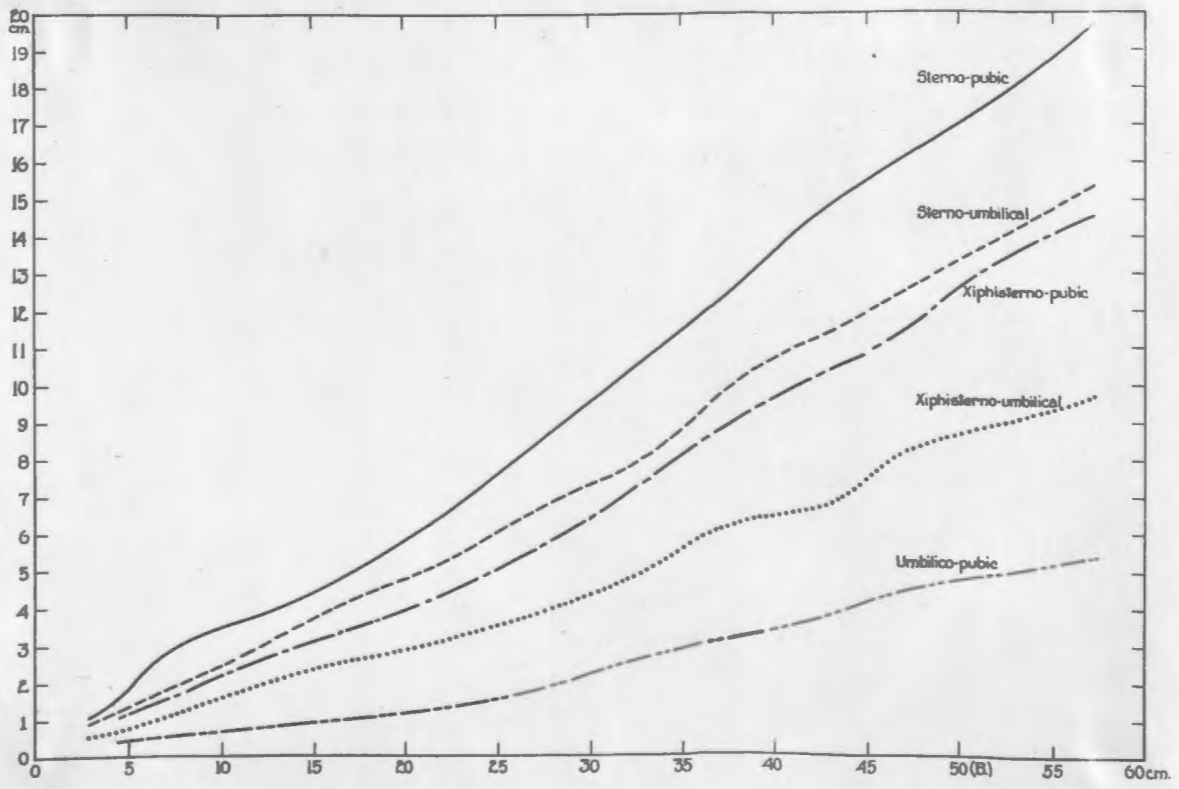


Fig. 1.

Fig. 1. Curves showing rate of growth of the Sterno-pubic, Sterno-umbilical, Xiphisterno-pubic, Xiphisterno-umbilical and Umbilico-pubic lengths.

Abscissae: C.H. length in cm.

Ordinate: length of measurement in cm.

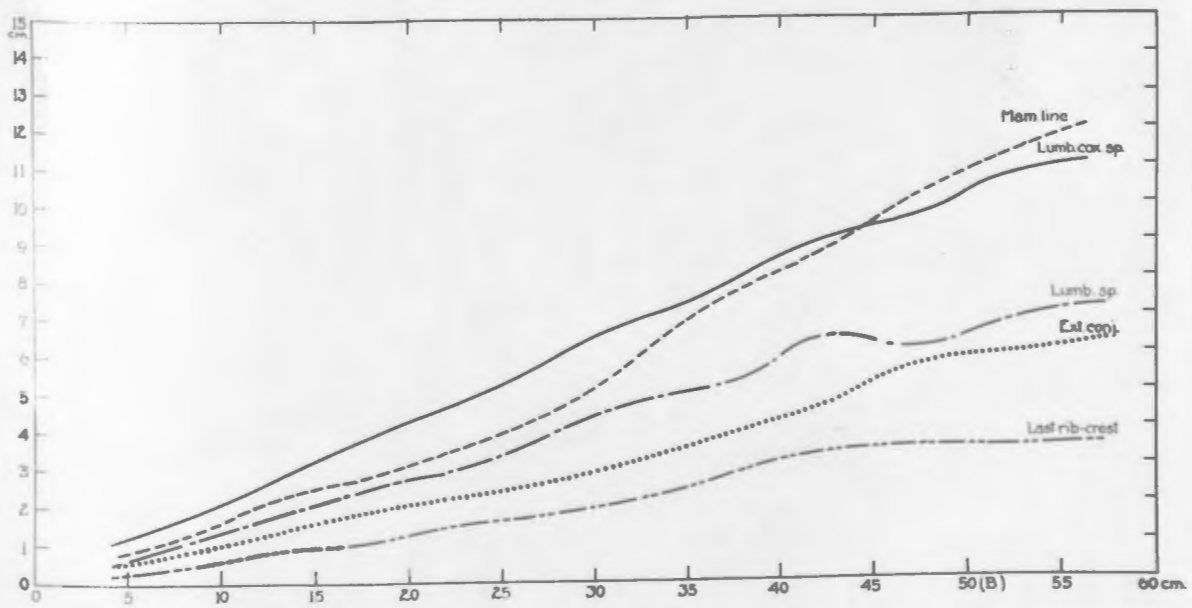


Fig. 2.

Fig. 2. Curves showing rate of growth of Lumbo-coccygeal spine, Lumbar spine, Mammary line, External conjugate and Distance from last rib to iliac crest as compared with total body length.

Abscissae: C.H. length in cm.

Ordinate: length of measurement in cm.

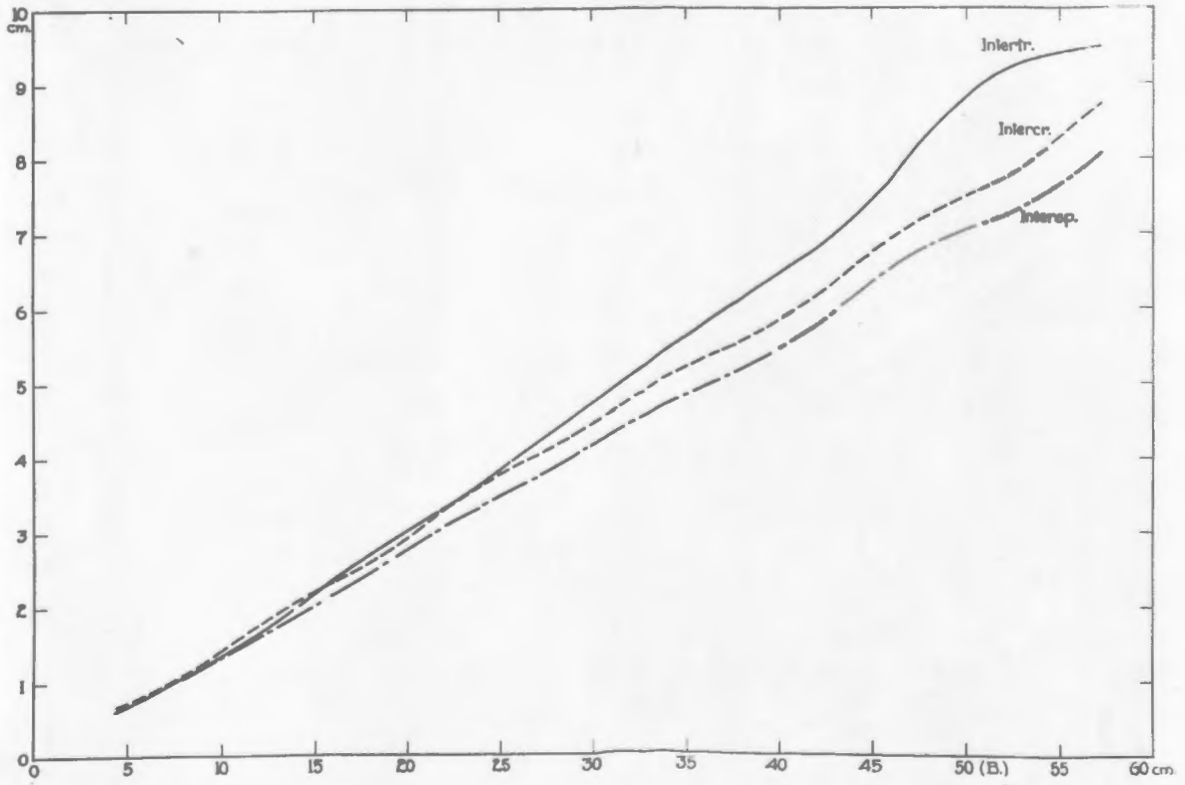


Fig. 3.

Fig. 3. Curves showing rate of growth of Intertrochanteric, Intercristal and Interspinous diameters as compared with total body length.

Abscissae: C.H. length in cm.

Ordinate: length of measurement in cm.

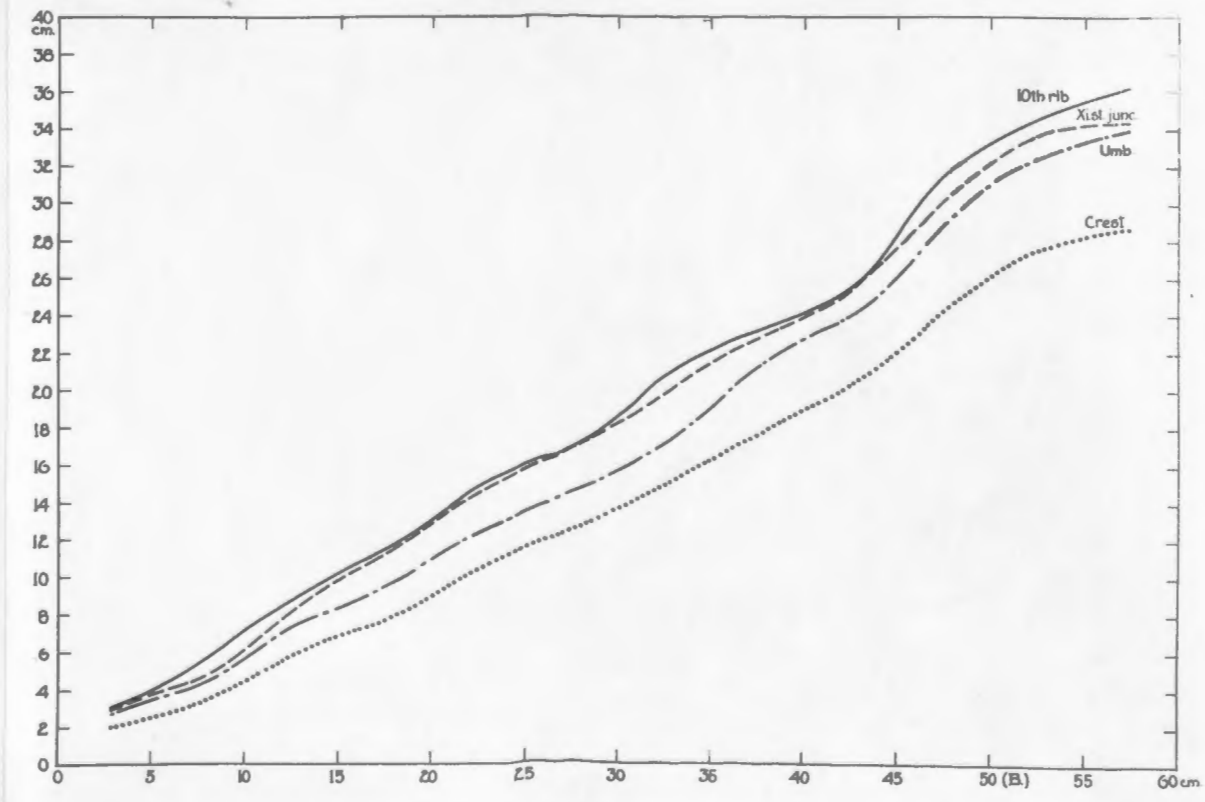


Fig. 4.

Fig. 4. Curves showing rate of increase in circumferences at levels of Tenth rib, Xiphisternal junction, Umbilicus, and Crest, compared with total body length.

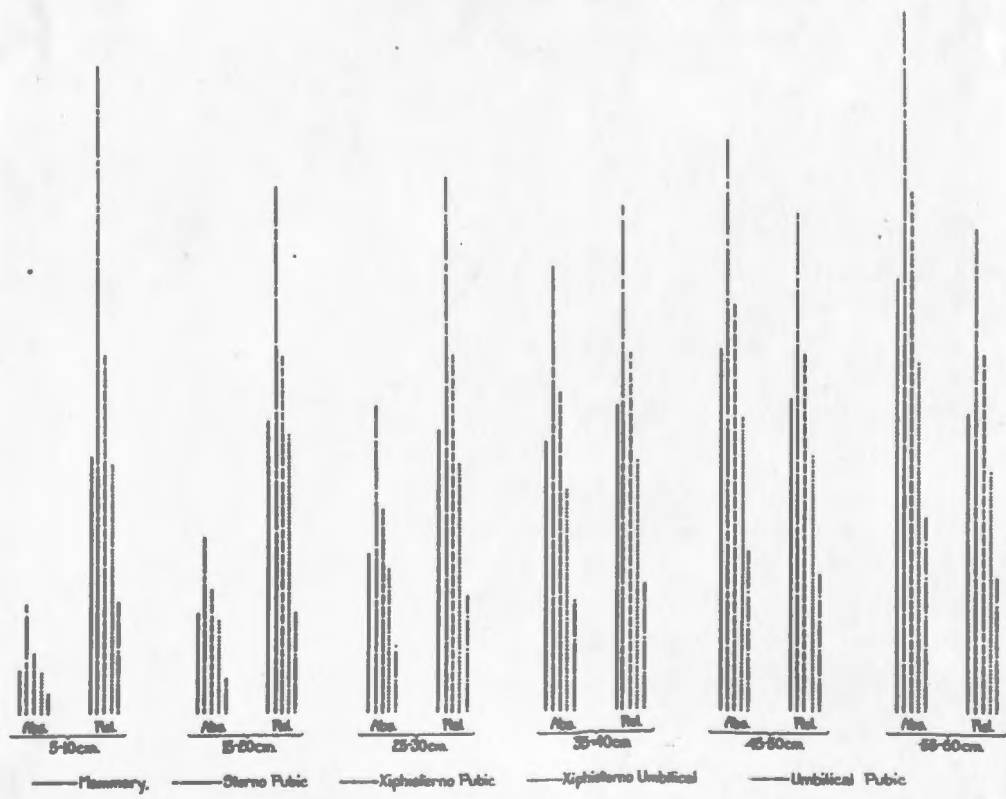


Fig. 5.

Fig. 5. Histogram showing absolute and relative values of the Mammary line, Sterno-pubic, Xiphisterno-pubic, Xiphisterno-umbilical and Umbilico-pubic distances compared to the Xiphisterno-pubic distance as unity.

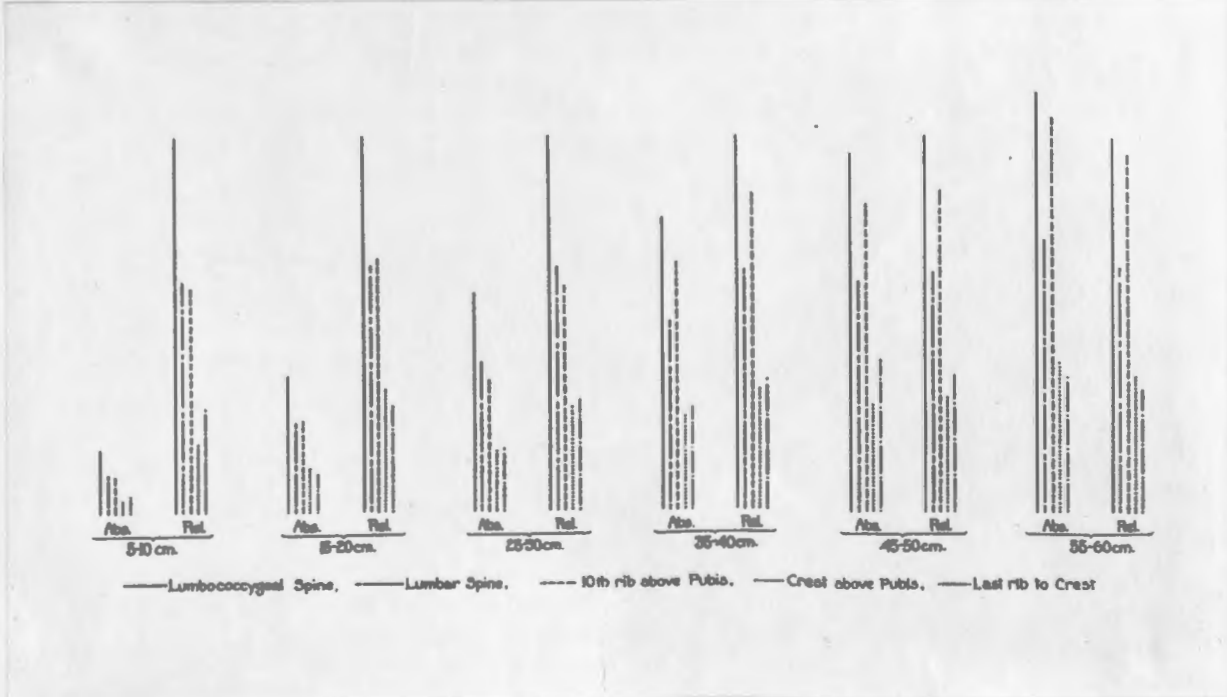


Fig. 6.

Fig. 6. Histogram showing absolute and relative values of the lengths of the Lumbo-coccygeal spine and Lumbar spine; distances of the Tenth rib above the pubis, the Crest above the pubis and the Last rib above the crest. The lumbo-coccygeal spine is used as a constant.

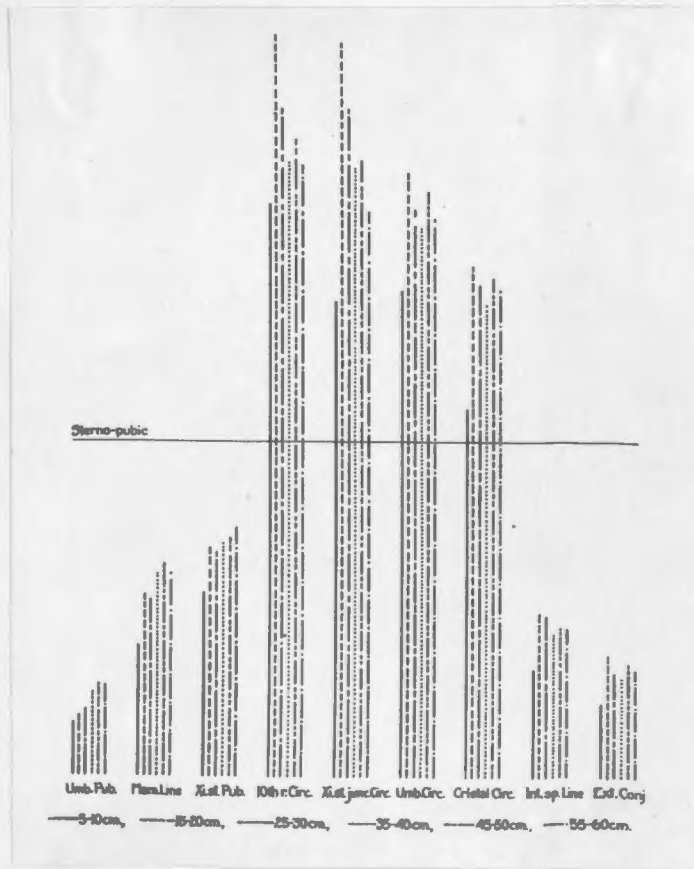


Fig. 7.

Fig. 7. Histogram showing relative values of the lengths of the Umbilico-pubic line, the Mammary line, the Xiphisterno-pubic line, the Tenth rib circumference, the Xiphisternal circumference, the Umbilical circumference, the Cristal circumference, the Interspinous diameter and the External conjugate compared to the Sterno-pubic line as unity.

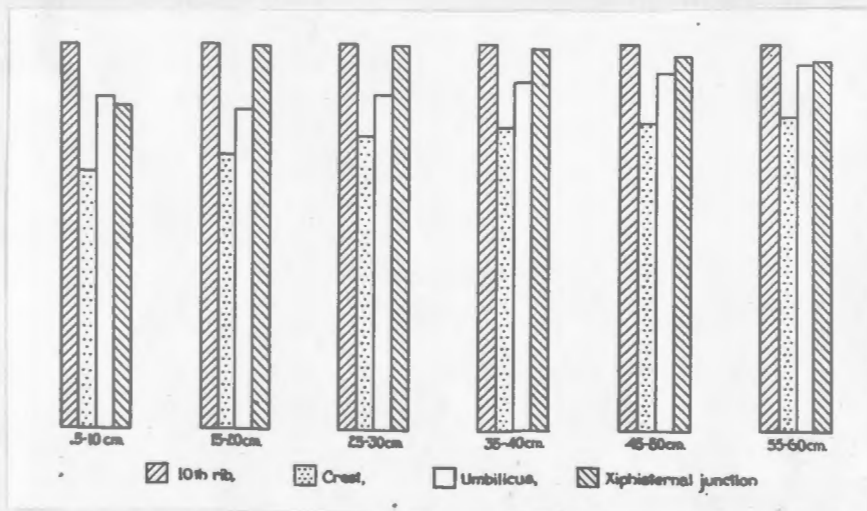


Fig. 8.

Fig. 8. Histogram showing relative values of the Cristal, Umbilical, Xiphisternal circumferences in terms of the Tenth rib circumference.

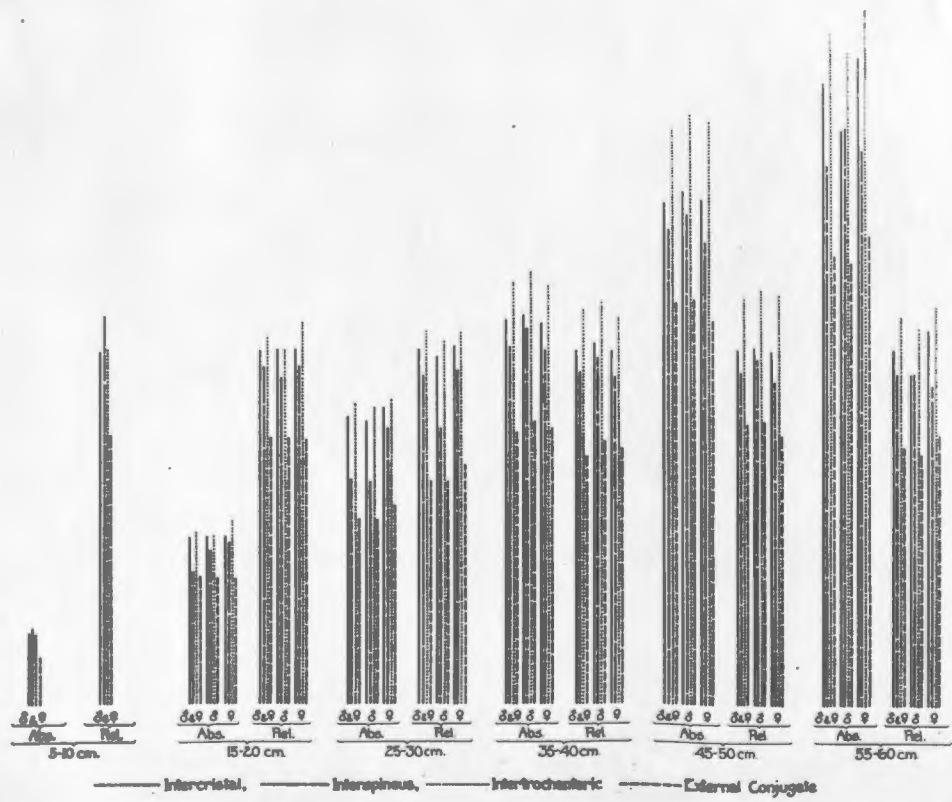


Fig. 9.

Fig. 9. Histogram showing absolute and relative values of the pelvic measurements and the differences between male and female measurement both absolute and relative to the length of the Intercristal diameter.

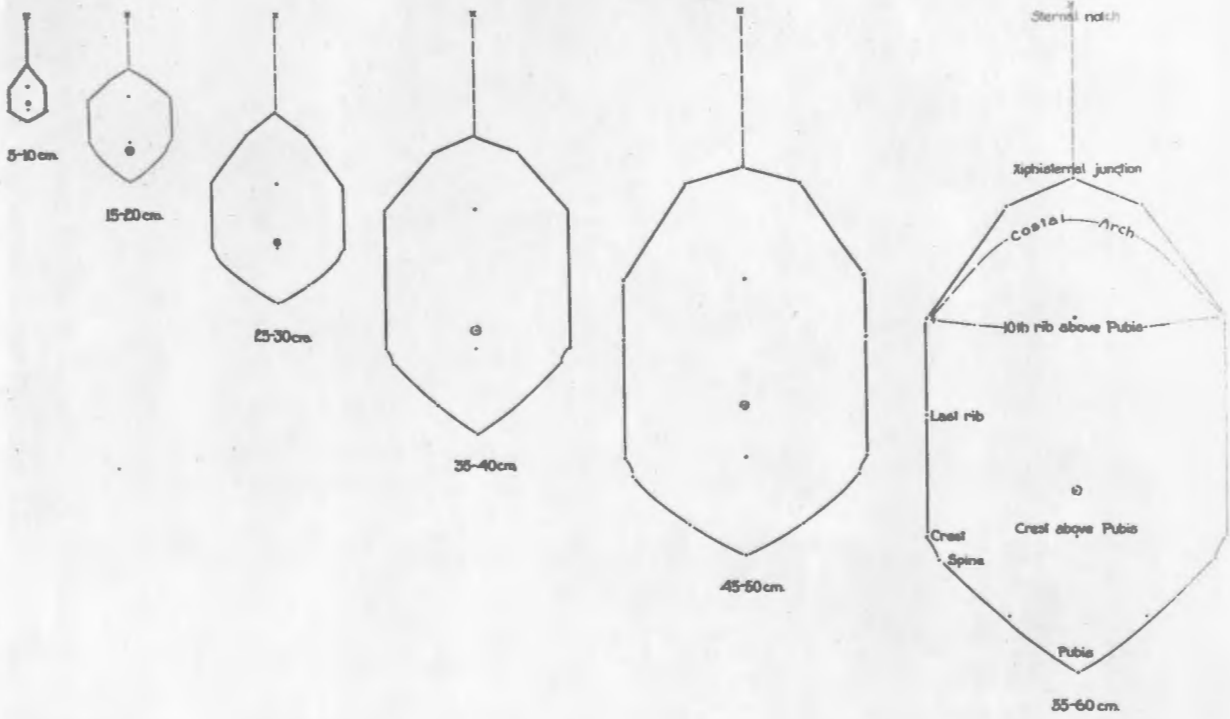


Fig. 10.

Fig. 10. Six Diagrams of abdomens at different periods
drawn in absolute from average measurements.

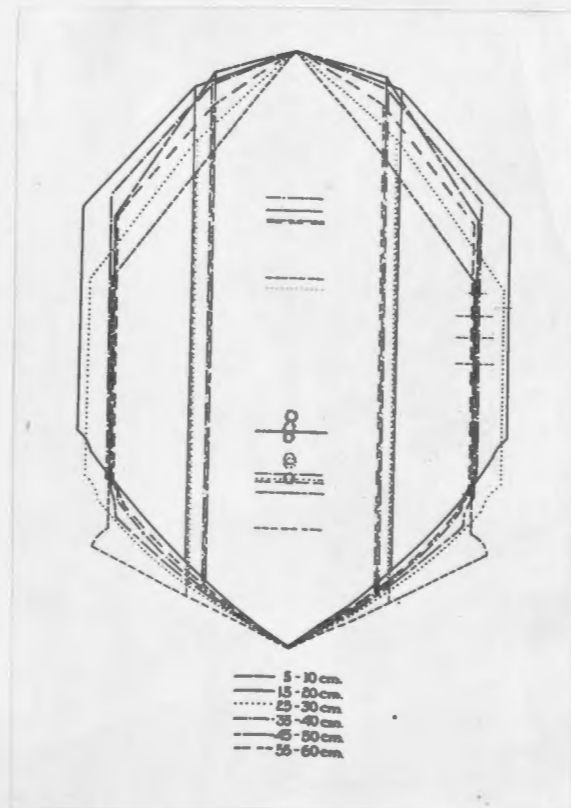


Fig. 11.

Fig. 11. Composite diagram of same six abdomens as in Fig. 10, drawn to relative scale with Xiphisterno-pubic line as one.

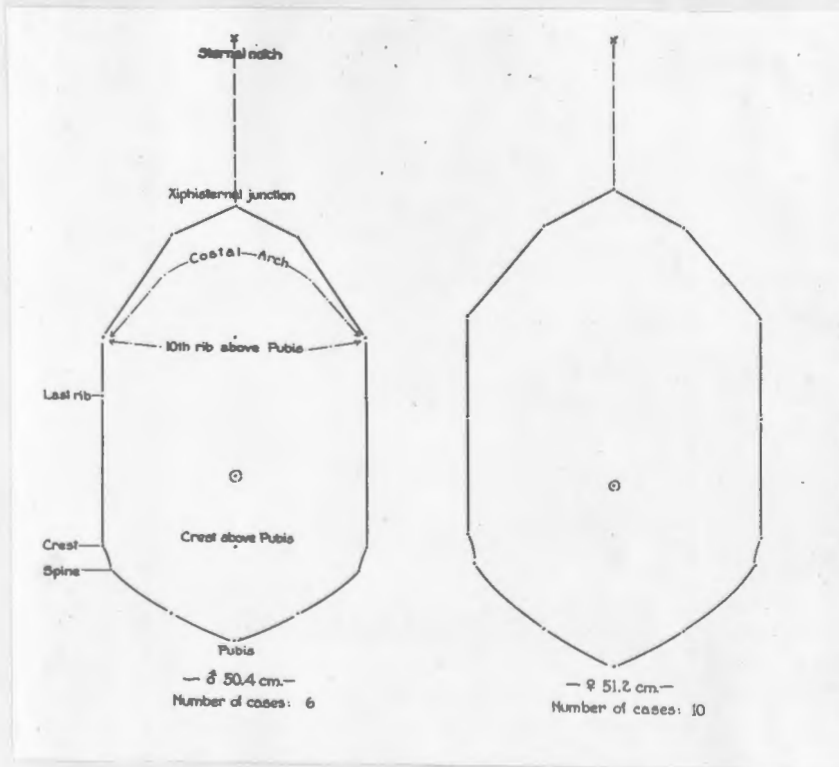


Fig. 12.

Fig. 12. Diagrams of newborn male and female abdomens drawn to absolute scale from average measurements.

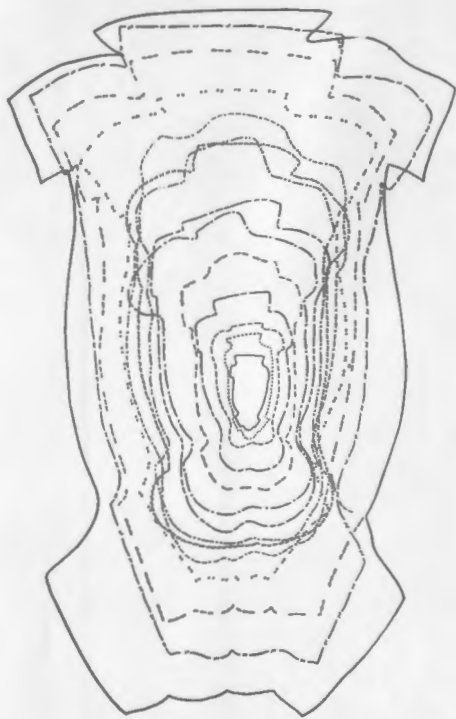


Fig. 13.

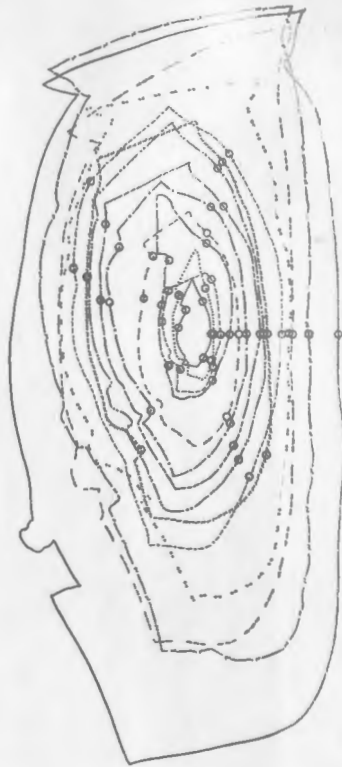


Fig. 14.



Fig. 15.

Fig. 13. Superimposed contours of series of trunks (sagittal view) of embryos of 49 mm. C.H. length to the newborn length.

Fig. 14. Coronal view of superimposed contours. Same series as in Fig. 13.

Fig. 15. Transverse contours at level of Xiphisternal junction. Same series as in Figs. 13-14.