THE ANATOMICAL RECORD.

No. 6. AUGUST 1, 1907.

ON MEASURING HUMAN EMBRYOS.

BY

FRANKLIN P. MALL.

WITH 4 FIGURES.

In looking over the literature on human embryology I find that it is not always easy to determine the size and the degree of development of embryos, under consideration, partly on account of the lack of uniformity in measuring specimens and partly because it is not always stated how the measurements were taken. Obstetricians uniformly give as the standard measurement the greatest length of the fœtus after it has been straightened more or less, and this measurement is a most useful one for it can be compared directly with the standing height after birth. This standard measurement is used quite frequently by embryologists, Toldt being one of the most recent who has employed it, but on account of the difficulty in making it upon young specimens without injuring them, Arnold and many others, including His, measured young embryos from the top of the head to the breech. This gave us the well known vertex-breech measurement, which corresponds with the sitting height after birth. To these two measurements His has added a third, which he makes from the projection on top of the neck (over the medulla) to the breech, the neck-breech or *Nackenlinie,* which is a very useful measurement for embryos of the first and second months; in general it measures the length of the spinal column. However, from my own experience, as well as from that of others, this measurement is difficult to make accurately and therefore it has not proved to be of general value.

During the past few years I have remeasured all of the human embryos

in my possession, as well as the profile illustrations of embryos which have been published during the last 100 years and I have found that very often the measurements published by various authors do not correspond with their illustrations. The one marked exception to this statement is made by His, whose measurement always correspond with the pictures of the embryos which he has published. Other writers are often inexact, not

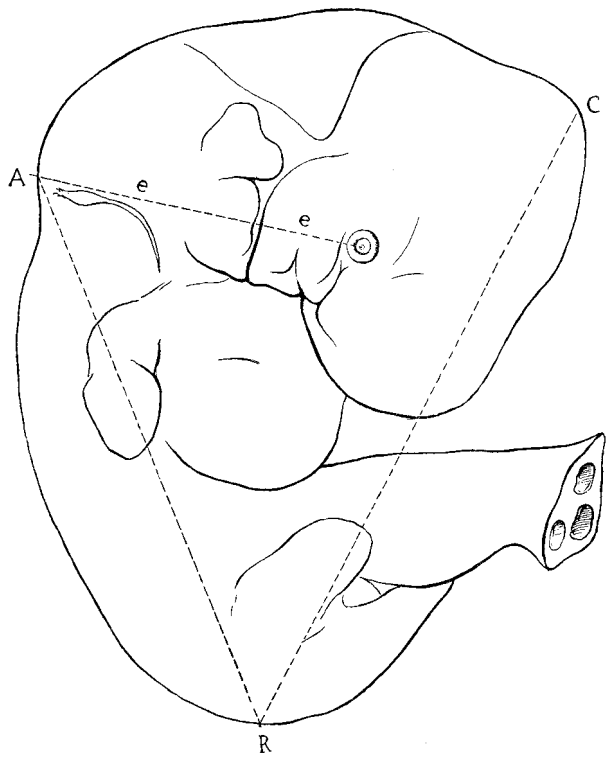

FIG. 1. Embryo No. 163, × 10 diameters. *C*, crown immediately over the mid-brain; *R*, rump; *A*, point between the occipital bone and the first vertebra; *ee*, eye-ear line.

stating from what part of the top of the head they measured, and in case they give His' *Nackenlinie* they usually place its upper end too low down, sometimes as low as the shoulder. The same criticism of this measurement may be made of the records of embryos found in my own note-book. When I began to collect embryos in 1890 the *Nackenlinie* was properly taken, as defined by His, but as the specimens increased

in number I now find that I gradually placed the upper point from which to measure lower and lower until it finally became fixed at a point between the head and the shoulders. It had really become the "neck-breech" measurement.

In measuring my own specimens, as well as all of those I have found suitably pictured in the literature, my attention was called to the neck-

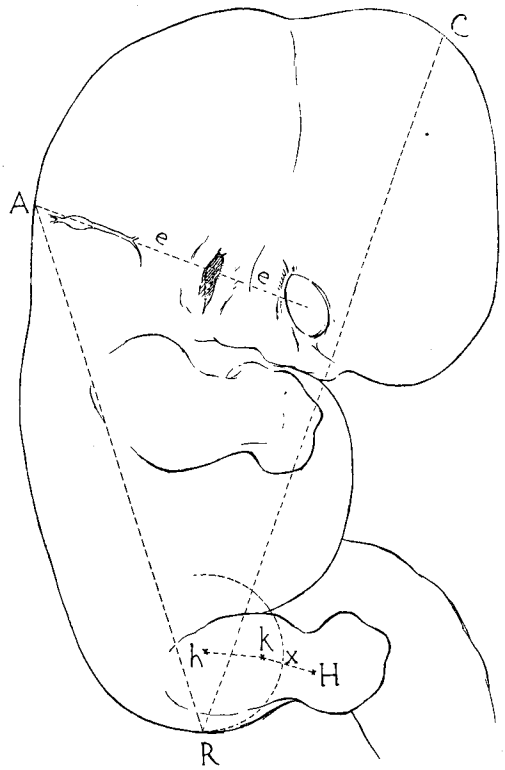

FIG. 2. Embryo No. 144, × 7 diameters. Letters as in Fig. 1. *H*, heel; *h*, hip joint; *K*, knee joint; *x*, point in leg which equals the distance from *h* to *R*. By adding *xH* to *CR* the standing height of the embryo is obtained.

breech measurement and its meaning. As it is usually taken it is of value from the time the embryo is well-curled upon itself until the neck is fairly well developed, that is, from the second to the sixth week. During this period this measurement is the longest, or is as long as any other that can be made upon the embryo without stretching the

legs. In later stages it equals practically the length of the vertebral column.

The object of this note is to suggest three measurements for all human embryos which can be compared with those usually made by anthropologists on infants and on adults. The outlines of embryos, which I give, will enable others to criticise the measurements and will also aid those

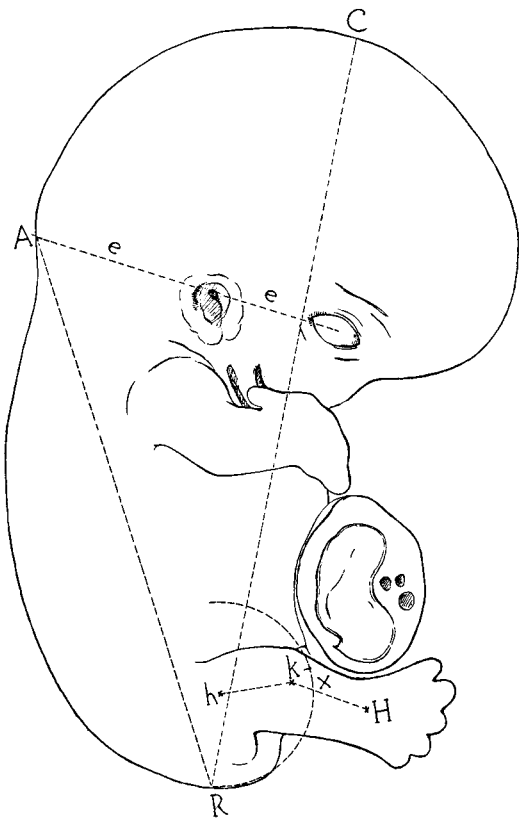

FIG. 3. Embryo No. 22, × 5 diameters.

who are willing to send me data, to make them upon embryos in their possession. In addition to such measurements I desire also menstrual histories of specimens, which are determined by subtracting the date of the beginning of the last menstrual period from that of the abortion. It will be impossible for me to construct a satisfactory curve of the age and size of embryos until a much larger number of menstrual ages and

measurements of embryos are obtained than I now possess. Up to the present time I have collected the measurements of over 600 embryos of which only 200 are accompanied with menstrual histories.

In order to make satisfactory measurements upon the bodies of young embryos it is necessary to measure them from more fixed points than is usually done. According to the position of the head the upper end

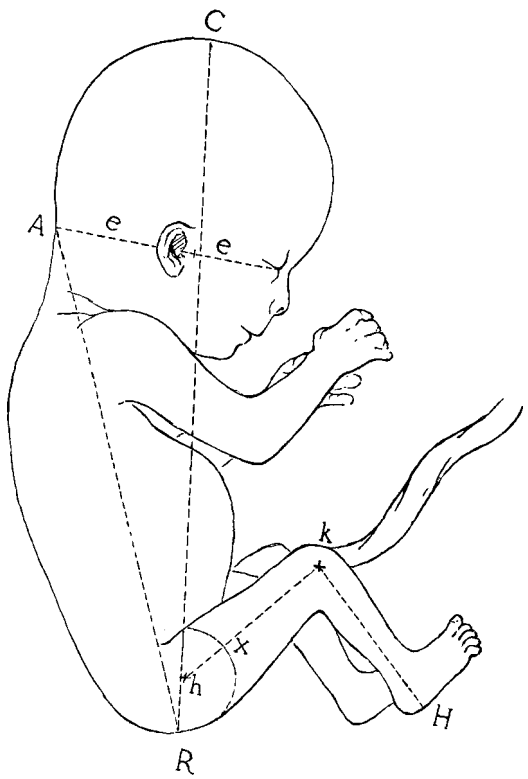

FIG. 4. Embryo No. 131, natural size. Length of "vertebral column," 68 mm.; sitting height (crown-rump or vortex-breech length), 90 mm.; standing height (90 + 21 + 23), 134 mm.

of the longest measurement of an embryo may fall over any portion of the brain, and from a study of numerous specimens I find that the middle of the mid-brain is usually just below the highest point of the head, but whenever this is not the case, as it is found to be in young embryos, I think the measurement should still be taken from a point immediately over the mid-brain as is shown in Fig. 1, *C*. The other point, which I

suggest as a desirable one to measure from, lies in the mid-dorsal region just above the first cervical nerve, as shown in Figs. 1 and 2, which have the outlines of this nerve drawn in. In Figs. 3 and 4 this point is marked by passing a straight line from the middle of the lens through the external auditory meatus to the back of the head. In both of these specimens this line passes between the atlas and the occipital bone. This gives an upper point, between the skull and the vertebral column, which is below the one from which His drew his *Nackenlinie* and above the depression in the neck from which a number of embryologists make their neck-breech measurements.

I have found from numerous measurements of embryos, fœtuses, infants, and adults that a line drawn from the middle of the eye through the middle of the ear and extended to the back of the neck, always passes just below the foramen magnum, or slightly higher. For practical purposes it cuts the skull from the body, and according to our knowledge of the position of the eye and ear this should be the case. This line which I shall term the *oculo-auricular* or eye-ear line, is of fundamental importance in measuring the length of the spinal column in embryos. Anthropologists obtain the same point between the skull and vertebral column by extending the plane between the two rows of teeth to the back of the head; while artistic anatomists determine it by projecting a horizontal line through the nasal spine, just below the nares, to the back of the head; in both cases the skull is cut off. All three of the lines meet in the adult at the foramen magnum, but in the embryo only the eye-ear line is of practical use for it can be determined early and with certainty. The height of the skull, which forms the submodulus in the Fritsch-Schmidt canon, can be obtained in any embryo by measuring the distance at right angles from the above-mentioned horizontal line through the nasal spine, to the crown, *C*, that is, the point immediately over the mid-brain.

The two upper points from which to measure being fixed just above the atlas, and just over the mid-brain, it is necessary to have a lower point in order to measure the length of the head and trunk. All embryologists agree that it be placed at the lowest point of the breech. The line *AR* approximates the length of the spinal column and the line *CR* equals the sitting height of the embryo. These two lines mark respectively the atalanto-sacral and the mesencephalo-sacral measurements. In Figs. 1 and 2 the point *R* is exactly below the sacrum, but as the embryo grows longer (Figs. 3 and 4) the ischium gradually recedes; at birth it is considerably below the level of the sacrum. For practical purposes, therefore, the line from the foramen magnum to the rump, *AR*, equals the length

of the spinal column. In the adult the tip of the sacrum is at the level of the middle of the acetabulum, and this latter point is naturally chosen by Fritsch in the construction of the canon. On account of the high position of the ilium in both the embryo and the fœtus, and an account of the close relation between the lower end of the sacrum and the rump in them I believe it most desirable to measure to the rump and not to the acetabulum. Furthermore, it makes one of the measurements, *AR*, equal the length of the spinal column, and the other, *CR*, the sitting height of the embryo.

A comparison of these two lines upon all four figures shows that in all cases they are the longest lines that can be drawn from the mid-brain and atlas to the rump in each case. Furthermore, as the embryos increase in size the angles they form at the rump becomes more and more acute. In Fig. 1 the crown rump line falls far in front of the eye; in Fig. 2 it is just in front, and in Fig. 3 just behind the eye; in Fig. 4 it nearly strikes the ear.

The entire length of the body, the mesencephalo-calcanean line, or the standing height of the embryo, is really the best single measurement of the embryo, for it is the one usually made by obstetricians as well as by anthropologists. It has been said that the standing height of the embryos and fœtuses is an unsatisfactory measurement on account of its uncertainty, but my experience obtained from the measurement of 600 embryos shows that it is no more variable, probably less so, than either the sitting height or that of the spinal column. In Fig. 1 the sitting and the standing heights still equal each other for, as is easily seen, the leg bud cannot be stretched beyond the rump. The other figures show that by extending the legs the standing height becomes greater than the sitting. In each of the figures the hip and knee joints and heel are indicated by letters. If a circle is described, as has been done in the figures, the portion of the length of the leg to be added to the sitting height in order to obtain the standing height is easily ascertained. In Figs. 2 and 3 this amount is only a portion of the leg, while in Fig. 4 it includes most of the thigh and all of the leg. A number of fresh embryos were measured in this way, the legs were then straightened and specimens were again measured from crown to heel and it was found that the two measurements agreed exactly. By this method, then, the standing height of an embryo can be determined without stretching a fresh specimen or injuring a valuable one after it has been hardened.

By making a large number of measurements of the human body, Pfitz-

ner[1] has demonstrated that the most constant ratio of any is obtained by dividing the breadth of the head by its length. The mean index for individuals of every year, from birth to old age, is 83 in males and 82 in females. I gather from the figures of embryos and fœtuses, published by Retzius[2] that in all months of uterine life the index is the same as after birth, for in the individual cases given it ranges between 80 and 85. Were it possible to apply these measurements to all fœtuses I think either the length or the breadth of the head would prove the best standard, and all other measurements could be adjusted to it as the artistic anatomists has adjusted all proportions to the submodulus. That other measurements are required of the body of the embryo than those that are usually made, including that of entire length of the body, is indicated by various writers, including His,[3] who was the first to use the *Nackenlänge.* More recently he employed a new measurement which he calls *Kopftiefe,*[4] and which he says corresponds about to the height of the head, measured from the chin to the crown. The *Kopflänge* is the length of the head, a measurement which can easily be obtained if this part of the embryo is not distorted. The point between the occipital bone and atlas having been determined, as is done by the eye-ear line, a second line may be introduced connecting the spine of the nose with it. The longest line within the head of the embryo parallel with this measures the length of the head and a line at right angles to it extending to the crown measures the height of the head. Thus it is seen that it is possible to make some of the ordinary head measurements of the adult upon the head of the embryo. It may be that the submodulus of Fritsch-Schmidt[5] may yet prove to be the standard measurement in human embryology, comparing all of the other measurements of the body with it, as is the case in the Fritsch-Schmidt canon of the adult. However, this possibility appears to be remote.

It seems to me, that for the present we must continue to employ the sitting height or the crown rump measurement as the standard. Next in importance is the standing height, and judging by the form of a curve made by abscissas and ordinates to determine the means by the graphic

[1] Pfitzner, Zeit. f. Morph. u. Anthropol., I, 1899.
[2] Retzius, Biol. Untersuch., XI, 1904.
[3] His, Anat. Mensch. Embryonen.
[4] His, Entwikl. d. Mensch. Gehirns, 1904.
[5] Fritsch, Die Gestalt des Menschen, 1899.

method, I do not find that one is more variable than the other. The sitting height is the measurement most easily, and, therefore, the one usually made upon young specimens, and the standing height upon older ones. These two measurements can be compared directly with the two standard measurements made after birth. By means of the eye-ear line the point between the head and neck can be marked and from it the length of the head, and of the skull, may be obtained. That the standing height is just as good a measurement as the sitting height is further found by the experience of Pfitzner,[6] who was at first opposed to it, but after having made many more measurements he selected it as the best standard measurement with which to compare all others. This last statement is based upon the careful measurements of 5000 cadavers.

The measurement from the foramen magnum to the lower part of the body, the rump, does not include all of the spinal column in young embryos, equals it in length in embryos up to the eighteenth week, and exceeds it somewhat from the eighteenth week to birth. This point is well illustrated by Merkel[8] in a series of sagittal sections of the fœtus. In relation to the transverse section of the body the lower end of the sacrum falls considerably below the pubis at birth, but in the adult it is on a level with the top of the symphysis. So the measurement from the atlas to the rump includes more or less of the spinal column according to the age of the embryo. To include in this measurement the hump on the back of the head, that is, part of the occipital region, as is the case in His' *Nackenlänge,* seems to me to be enough to exclude this measurement altogether. If it were possible to find the lower end of the sacrum in each case I would prefer to measure to it rather than to the rump, but this seems to be out of the question at the present time. The acetabulum is not quite so difficult to locate, but on account of its wandering during development the objections to it as a fixed point are as great or greater than those to the rump. A measurement to the perineum has less objections to it than any other, and this point was selected by Pfitzner rather than the tuberosity of the ischium, and therefore his measurement of the head and trunk are a little shorter than the sitting height and considerably longer than the combined height of the skull

[6] Pfitzner, l. c., I.

[7] Pfitzner, l. c., VI.

[8] Merkel, Mensch. Embryonen, etc., Abhandl. d. k. Gesell. d. Wiss., Göttingen, XL, 1894.

and length of the spinal column. Beyer[9] has found that the sitting height is but 3 cm. greater than the distance from the crown to the perineum by measuring over 4500 cadets from 15 to 23 years of age. It seems to me that the advantages to the rump as a point to measure to are so decided and the objections to it are so small—embryologists and anthropologists have been compelled to accept it—that we should not try to establish a new point as Fritsch and Pfitzner have done.

The preliminary list of proportions I have made is based upon the measurement of 140 embryos less than 20 mm. long, 200 between 20 and 100 mm. long, and a large number of older fœtuses. Many of the measurements were obtained from illustrations to scale, found in the literature; some of them, like those of Retzius, have been published by others, and a large number of them were obtained from specimens in my own collection. In each case the sitting height was obtained by direct measurement from the crown to the rump, and the standing height by direct measurement of the specimen after it had been straightened or by the method indicated in the figures. The length of the spinal column was obtained by extending the eye-ear line to the dorsal midline behind the foramen magnum, and from its intersection with the skin a line was drawn to the rump, that is, to a point immediately over the tuberosity of the ischium. The individual measurements were then tabulated, using those of the sitting height as abscissas and those of the standing height, and those of the spinal column, as ordinates. Thus, two curves of a series of dots, representing the specimens, were obtained. By dividing each of the rows into fourths the two middle fourths containing half of the cases gave the probable deviation, and a line midway between them gave the probable mean. In the near future, when more records have been obtained, I shall publish these records in the form of charts, and from the means thus obtained I shall construct a curve, giving the probable age of embryos based upon actual histories of the specimens. The mean measurements of embryos less than 20 mm. based upon 140 specimens are as follows. The figures are in millimeters:

Vertebral Column	1.3	2.3	3.5	4.5	5.5	7	8	9	9.5	9.8
Sitting Height	2	3	4	5	6	7	8	9	10	11
Standing Height	2	3	4	5	6	7	8	9	10	11
Vertebral Column		10	10.5	11	11.3	12	12.5	13	14	15
Sitting Height		12	13	14	15	16	17	18	19	20
Standing Height		12	13	14	15	16.5	18	20	21.5	23

[9] Beyer, Proceed. of U. S. N. Inst., XXI, 1895.

It is seen that the length of the legs is added to that of the body in embryos over 15 mm. long. From now on the measurements are given for every 5 mm. of sitting height until the embryos are 50 mm. long and then for every 10 mm. until birth.

Vertebral Column	15	18	22	26	30	34	38	45	51	58
Sitting Height	20	25	30	35	40	45	50	60	70	80
Standing Height	23	30	39	47	54	62	69	84	98	114
Vertebral Column		65	71	78	83	90	98	107	115	120
Sitting Height		90	100	110	120	130	140	150	160	170
Standing Height		130	145	162	175	187	200	214	240	255
Vertebral Column		128	135	142	150	157	165	172	180	188
Sitting Height		180	190	200	210	220	230	240	250	260
Standing Height		267	282	300	315	332	347	360	375	392
Vertebral Column		195	202	208	215	224	234	243	250	259
Sitting Height		270	280	290	300	310	320	330	340	350
Standing Height		410	425	440	455	475	490	510	530	550

It may be seen by looking over this table that the spinal column increases 7 mm. in length, and the standing height 15½ mm., every time the sitting height increases 10 mm., in embryos over 20 mm. in length. This continues until the sitting height has reached 300 mm. As the fœtuses become larger and larger the growth of the legs is slightly more marked than before, and during the last month or six weeks of pregnancy the standing height increases 20 mm., while the sitting height increases 10 mm. The statement may therefore be made for embryos and fœtuses from the end of the second month to the end of the eighth month, that the spinal column increases 7 mm. and the sitting height 10 mm., while the standing height increases 15½ mm. This reduced to a formula reads as follows:

$$\frac{\text{Spinal Column} - 15}{7} = \frac{\text{Sitting Height} - 20}{10} = \frac{\text{Standing Height} - 23}{15\frac{1}{2}}$$

The figures I have given make it possible to convert the standing height into the sitting height, an obstacle which has been difficult to overcome in estimating the age of embryos. When the figures are converted into curves it is readily seen that Toldt in making his estimate has confused these two measurements, for in embryos under four and one-half months old he has used the sitting height and in those over six months

the standing height, connecting the two during the fifth month. Hecker's curve is much more nearly the correct one, but it begins only with the tenth week. At the present time I do not wish to add another curve to Hecker's because my data are accumulating rapidly and I prefer to withhold it until the number of records is large enough to give the curve a final form.