and the mouth closed firmly by the patient, bronchial breath sounds which sounded typical were heard over the left lower lobe. The breath sounds over the other lower lobe were normal. This would seem to show that the vocal cords play no very large rôle in the formation of the bronchial breath sounds, but that the bronchial breath sounds are formed by the passage of air through the bronchial tubes much after the manner of the formation of sound in lip pipes.

A patient who had loud bronchial breath sounds over the right lower lobe came to autopsy. A rubber tube was passed through the vocal cords and air was periodically allowed to enter the lungs from an oxygen tank. There was a side tube for allowing the egress of air and by alternately closing the outflow and inflow tubes, artificial inspiration and expiration could be produced. Auscultation over the right lower lobe produced bronchial breath sounds resembling fairly closely those heard over the same area by the intern and resident physician before the death of the patient. The trachea was now cut off below the larynx and the same rubber tube was inserted down just beyond the bifurcation. On auscultation the breath sounds were still bronchial and apparently were a little higher pitched than when the tube was passed just beyond the vocal cords. This experiment shows that the components of the bronchial breath sounds are formed largely in the bronchial tubes below the vocal cords and that some of the bronchial breath sound is formed apparently beyond the primary bronchus.

Conclusions: The vocal cords play only a very small part in the formation of the bronchial breath sounds. Bronchial breath sounds are not formed on the principle of the reed pipe; more probably on the principle of the lip pipe.

4807

Relations Between Surface Area, Weight and Length of the Human Body in Prenatal Life.

ALBERT D. KLEIN AND RICHARD E. SCAMMON.

From the Department of Anatomy, University of Minnesota.

The growth in surface area of the body in prenatal life has received little study. Valentine,[1] Ssytscheff,[2] Lissauer,[3] Kastner,[4] and Pfaundler[5] have included some determinations of the surface area of premature infants among their observations but most of these were of children who had lived several days or weeks after birth. Sandiford[6] has estimated the surface in prenatal life by the application of the formulae of Lissauer, and of Du Bois to the data of Mall on the length and Jackson on the weight of the fetus at various ages.

We have determined the surface area of the body in a series of 12 fetuses ranging from 2.68 to 31.98 cm. in crown rump length and from 1.26 to 2463.00 gm. in weight. All specimens but one (the largest) were preserved in formalin prior to measurement. The largest specimen was a fresh cadaver and the measurement of its surface was made from a plaster of Paris cast of the body. Our method was as follows: The specimen was first covered with 2 thin coats of lacquer by dipping it in a lacquer solution. When the second lacquer coat was almost dry the specimen was dipped in a hot mixture of water (15 parts by volume), gelatin (5 parts by weight), and glycerin (1 part by volume). This coat hardened into a pliant but non-elastic film which was removed and cut into small pieces. The outlines of these pieces were traced on celluloid and their areas determined from weight by the methods described by Boyd and Scammon,[7] and Scammon and Scott.[8] This method was used for

TABLE I.—Surface area in prenatal life.

Specimen number and sex	Crown-rump length (cm.)	Crown-heel length* (cm.)	Weight† (gm.)	Observed surface area (sq. cm.)	Surface area (sq. cm.) Calculated by formula:		
					(1)	(2)	(3)
1 (m)	2.68	3.27	1.26	5.82	4.17	4.85	6.17
2 (m)	6.02	8.28	11.33	32.37	34.64	33.83	32.04
3 (m)	6.64	9.21	16.15	47.22	44.15	42.81	41.79
4 (m)	10.36	14.79	72.17	129.66	129.88	124.57	128.47
5 (f)	15.32	22.23	221.00	277.70	328.60	318.66	297.34
6 (f)	18.04	26.31	348.50	421.57	482.36	471.79	418.42
7 (f)	18.63	27.20	462.00	602.86	520.12	509.68	516.94
8 (m)	21.14	30.96	664.00	715.90	698.84	690.37	678.57
9 (m)	23.51	34.52	937.20	854.42	895.16	891.02	878.68
10 (f)	26.69	39.29	1428.20	1083.67	1202.20	1208.30	1205.10
11 (m)	29.17	43.01	2075.00	1510.27	1477.40	1495.70	1594.90
12 (f)	31.98	47.22	2463.00	1759.72	1828.20	1865.30	1813.70

*Calculated from crown-rump by empirical formula
$CR = 0.66CH + 0.5$ mm.
†After preservation in formalin.

1 Valentine, *Lehrbuch der Physiologie des Menschen*. Braunschweig, 1851.
2 Ssytscheff, A. I., *Diss.*, St. Petersburg, 1902.
3 Lissauer, W., *Jhrb. f. Kinderheilk.*, 1903, lviii, 392.
4 Kastner, O., *Z. f. Kinderheilk.*, 1913, iii, 391.
5 Pfaundler, M., *Z. f. Kinderheilk.*, 1916, xiv, 48.
6 Sandiford, I., *J. Biol. Chem.*, 1924, lxii, 323.
7 Boyd, E., and Scammon, R. E., *Anat. Rec.*, 1927, xxxv, 5.
8 Scammon, R. E., and Scott, G. H., *Anat. Rec.*, 1927, xxxv, 269.

all parts of the body except the fingers and toes. These digital areas were computed geometrically from their lengths and diameters. The major dimensions and observed surface areas of these specimens are shown in the first columns of Table I.

Considering the body as an approximation to a simple geometric form, the relation of its surface area to its length is written:

$$S = aL^b, \text{ or, } \log S = \log a + \log L \cdot b$$

where a and b are constants, the latter of which is expected to approach the second power. A curve, fitted by the method of averages, to our twelve observations gives the formula:

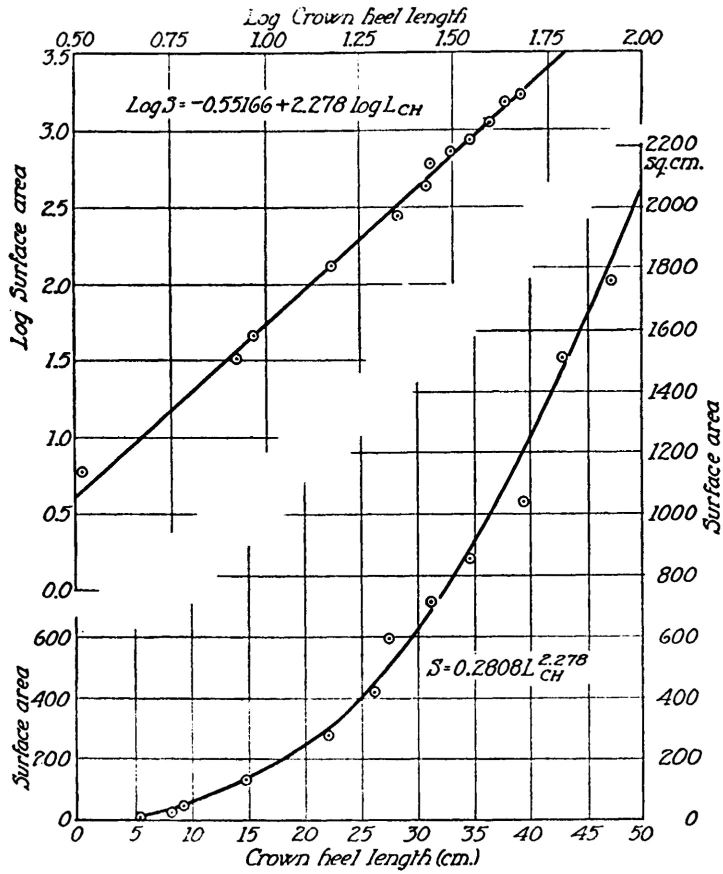

FIG. 1.

Crown heel length and surface area in prenatal life. Upper graph shows relation of logarithms of surface area to logarithms of total or crown heel length. Lower graph shows relation of surface area to crown heel length. Individual observations represented by circled dots. Analytic expressions represented by solid lines.

$$S = 0.2808 L_{ch}^{2.278} \quad (1)$$

The mean absolute deviation of the observed from the calculated values obtained from this expression is 39.86 sq. cm. and the mean relative deviation is 9.4%. (See Fig. 1.)

Applying the same analysis to surface and crown rump length we obtain the expression:

$$S = 0.4545 L_{cr}^{2.401} \quad (2)$$

The mean absolute deviation of the observed from the calculated values is 41.94 sq. cm. and the mean relative deviation is 8.7%. (See Fig. 2.)

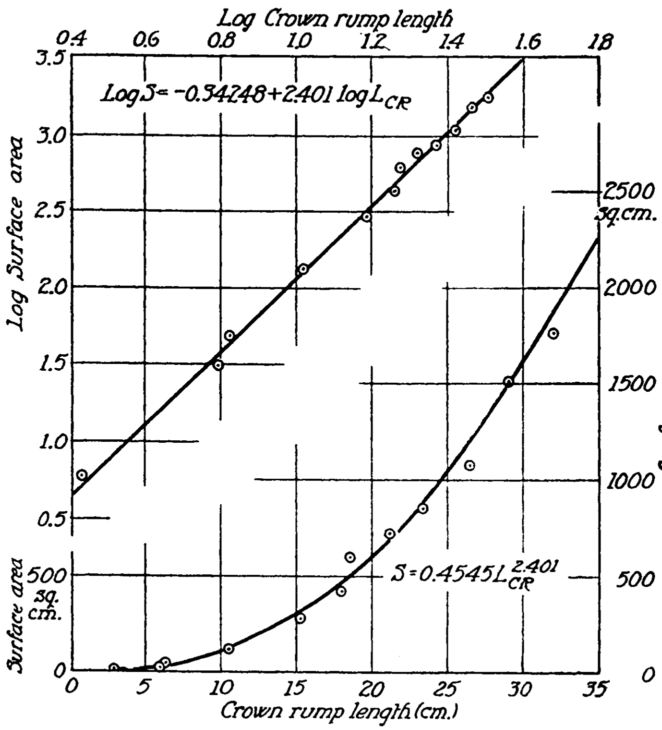

FIG. 2.

Crown rump length and surface area in prenatal life. Lower graph shows relation of the logarithms of surface area to logarithms of crown rump length or sitting height. Lower graph shows relation of surface area to crown rump length.

Similarly, from geometrical considerations, the expression for the relation of surface to weight would be:

$$S = aW^b, \text{ or, } \log S = \log a + \log W \cdot b,$$

the constant b approximating the 2/3 or 0.667 power.

Fitting a curve to the observations by the method of averages, we obtain

$$S = 5.188W^{0.750} \quad (3)$$

where S is the surface in square centimeters and W is the weight of the body in grams. The mean absolute deviation of the calculated from the observed values is 36.39 sq. cm. and the mean relative deviation is 5.8%. (See Fig. 3.)

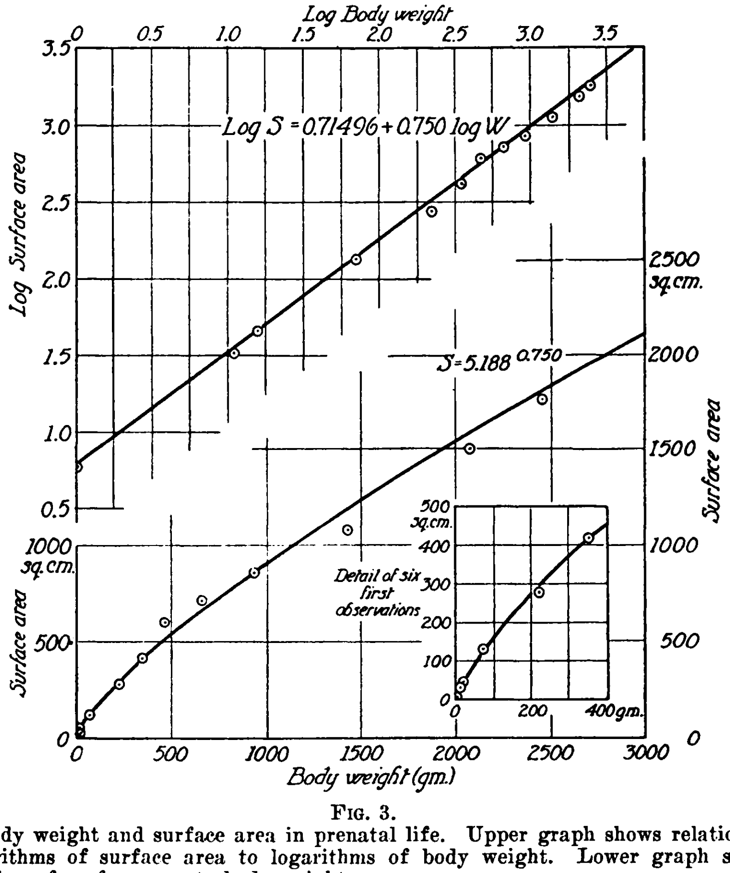

FIG. 3.

Body weight and surface area in prenatal life. Upper graph shows relation of logarithms of surface area to logarithms of body weight. Lower graph shows relation of surface area to body weight.

We have also applied the classic weight-length formula of Du Bois and Du Bois[9] to these data. The mean absolute deviation of calculated from observed values is 40.37 sq. cm. and the mean relative deviation is 21.3%. But it is obviously uncritical to adjudge the Du Bois' formula, which was developed for adults of diverse build by its application to the human body in its early stages of growth.

[9] **Du Bois, D., and Du Bois, E. F., *Arch. Int. Med.*, 1916, xvii, 863.**

We have, therefore, developed new expressions involving height and weight, using the Du Bois method of determining constants. We have obtained a number of expressions showing about equal measures of goodness of fit. Among the best are:

$$S = 113.48 \cdot W^{13/27} \cdot H^{5/9} \quad (4)$$
$$S = 452.40 \cdot W^{11/18} \cdot H^{1/6} \quad (5)$$

The mean absolute deviation of the calculated values by (4) from the corresponding observed surfaces is 71.63 sq. cm. and the mean relative deviation is 15.4%. The corresponding deviations of (5) are 70.2 sq. cm. and 15.8%.

4808

Surface Area and Age in Prenatal Life.

RICHARD E. SCAMMON AND ALBERT D. KLEIN.

From the Department of Anatomy, University of Minnesota.

In a preceding paper we have given a series of empirical formulae for the relation between the surface area and some of the major dimensions of the human body in prenatal life. These formulae are as follows:

$$S = 0.2808 L_{ch}^{2.278} \quad (1)$$
$$S = 0.4545 L_{cr}^{2.401} \quad (2)$$
$$S = 5.188 W^{0.750} \quad (3)$$

In these expressions S is the surface area of the body in square centimeters, L_{ch} is the total or crown heel length in centimeters, L_{cr} is the sitting height or crown rump length, and W is body weight in grams.

The increase in surface area with respect to age in the fetal period may be estimated by the substitution of expressions for time in terms of body length or body weight in this period. We have done this using the empirical formulae of Scammon and Calkins.[1, 2] In these expressions age is given in lunar months (of 28 days) dated from the first day of the last menstruation. These expressions only hold for the fetal period proper (from 3 lunar months to birth).

[1] Scammon, R. E., and Calkins, L. A., PROC. SOC. EXP. BIOL. AND MED., 1923, xxi, 253.

[2] Scammon, R. E., and Calkins, L. A., PROC. SOC. EXP. BIOL. AND MED., 1924, xxii, 157.