shorter, and had smaller heads than the Oxford children. Nevertheless the sex differences in head circumference, the smoothness and general shape of the head growth curves, and the range of variation in the individual measurements are strictly comparable in the two series. It is a moot point whether the differences in absolute size are racial in origin, or whether they are due to secular changes in body size (Clements, 1953), or to different standards of nutrition.

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PART II: CHANGES IN HEAD SHAPE

BY

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In Part I the increase in head circumference which occurs during the first seven years of life is described; Part II is based on the same children and compares the contributions made by growth in the transverse and longitudinal diameters to the overall increase in head circumference.

The "transverse skull diameters" correspond to caliper readings of the maximum distance between the parietal eminences, and the "longitudinal diameters" to caliper readings of the maximum distance between the frontal and occipital eminences. These two measurements were taken five times during the first year, and thereafter at six-monthly

intervals to the age of 5 with one additional measurement at 7 years. On average, just under 300 children of each sex were measured at each age.

Mean values for the transverse and longitudinal diameters by sex and age are shown in Table 1 and Fig. 1. In both diameters and at each age the boys' heads were significantly larger than the girls' but the mean differences never exceeded 0.5 cm. and the total increments for the whole seven-year period were virtually identical in the two sexes. (The boys actually gained 1 mm. less in the transverse and 1 mm. more in the antero-posterior diameter.) In both sexes, but particularly in girls,

TABLE

MEAN TRANSVERSE AND LONGITUDINAL SKULL DIAMETERS AND CEPHALIC INDICES OF OXFORD BOYS AND GIRLS AGED 1 MONTH TO 7 YEARS

Age	Boys						Girls					
	No.	Transverse		Longitudinal		Cephalic Index	No.	Transverse		Longitudinal		Cephalic Index
		Mean (cm.)	S.D.	Mean (cm.)	S.D.			Mean (cm.)	S.D.	Mean (cm.)	S.D.	
1 month	297	10.2	±0.62	13.0	±0.80	78.6	299	9.8	±0.54	12.7	±0.76	77.7
3 months	308	11.0	±0.49	13.9	±0.71	79.5	307	10.9	±0.53	13.7	±0.77	79.0
6 "	310	12.0	±0.64	14.8	±0.77	81.3	317	11.8	±0.56	14.7	±0.81	80.0
9 "	284	12.6	±0.59	15.5	±0.69	81.3	298	12.4	±0.59	15.4	±0.78	80.0
12 "	332	12.9	±0.58	16.0	±0.75	80.9	331	12.8	±0.54	15.9	±0.83	80.0
1½ years	318	13.2	±0.58	16.6	±0.70	79.6	329	13.0	±0.54	16.3	±0.68	79.7
2 "	328	13.5	±0.59	17.0	±0.72	79.5	325	13.2	±0.51	16.7	±0.66	79.7
2½ "	283	13.8	±0.55	17.3	±0.69	79.8	295	13.5	±0.51	16.9	±0.69	79.7
3 "	281	13.8	±0.56	17.3	±0.70	79.6	290	13.6	±0.53	17.0	±0.65	80.0
3½ "	268	13.9	±0.57	17.6	±0.65	79.1	272	13.7	±0.53	17.2	±0.59	79.6
4 "	269	14.0	±0.56	17.7	±0.62	79.1	267	13.8	±0.50	17.3	±0.60	79.6
4½ "	250	14.1	±0.54	17.9	±0.60	78.8	256	13.9	±0.51	17.4	±0.60	79.0
5 "	260	14.1	±0.56	18.0	±0.59	78.7	265	13.9	±0.52	17.5	±0.58	79.3
7 "	186	14.4	±0.55	18.2	±0.61	79.4	199	14.1	±0.53	17.8	±0.63	79.0

FIG. 1.—Mean transverse and longitudinal skull diameters of Oxford children by sex and age.

the percentage increase over the seven-year period was slightly greater for the transverse than for the longitudinal diameter.

This last finding implies that the girls, and to a lesser extent the boys, were more brachycephalic at the age of 7 than they were at birth. It was decided therefore to establish, for each sex, the relations between age and cephalic index i.e.,

$$\frac{\text{Transverse diameter}}{\text{Longitudinal diameter}} \times 100,$$

thus in Table 1 and Fig. 2* it will be seen that in both sexes the cephalic index increased rapidly during the first six months of life and achieved a maximum value shortly before the age of 9 months. Thereafter there was a difference between the two sexes. Thus the index for boys declined fairly rapidly and by the age of 5 had almost regained its original level. For the girls, however, the ratio of breadth to length declined more slowly, and by 3 years of age these children were already showing the relatively

able growth phenomena and shown that an empirical rule governs such situations. This so-called law of allometric growth may be stated as follows. Let B and L represent two cognate measurements of a growing body (in this case breadth and length of skull). The instantaneous growth rates of these measurements may be written as $\frac{dB}{B}$ and $\frac{dL}{L}$ and we may define a

coefficient b as $b = \frac{dB}{B} \cdot \frac{L}{dL}$. This coefficient, which

is sometimes known as the "growth partition coefficient", is often found to have a constant value throughout each of a small number of distinct "phases" in the growth of the body. Provided, therefore, that the law applies to the particular case, it is only necessary to plot the logarithms of B and L against one another for it to become apparent that the points lie close to (say) two straight

FIG. 2.—Cephalic index of Oxford children by sex and age.

* The points plotted in this figure are derived from the mean diameters at each age and are therefore not identical with the mean cephalic indices, though they certainly follow the same course with respect to age. Estimates were also made, for each age, of the standard deviation of the cephalic index, from which it appeared that the range of fluctuation shown in Fig. 2 was eight to 10 times as great as the standard error of a mean index based on 300 children.

lines, the slopes of which are equivalent to the coefficient *b* as defined above.

The logarithms of skull breadth and length at each of the 14 ages are plotted for boys and for girls in Fig. 3, and it is clear that for each sex the distribution of points accords with expectations based on the law of allometric growth. To obtain estimates of *b*, the whole period was divided into two parts which, according to the graph, appeared to represent different phases of growth. The first of these runs from 1 to 9 months, i.e., covers four points on the graph, and the second, 1 year to 7 years, i.e., covers 10 points. Straight lines were then fitted to each set of points by the method of least squares† and the values of *b* obtained (see Table).

It is particularly interesting to note that the growth partition coefficients for the first nine months turned out to be identical for the two sexes.

FIG. 3.—Comparative growth of longitudinal and transverse diameters of the skull in Oxford boys and girls aged 1 month to 7 years.

	Sex	1 month–9 months	1 year–7 years
Growth partition Coefficients (<i>b</i>)	Boys	1.21	0.84
	Girls	1.21	0.92

Comparison with Other Surveys

The results of two other longitudinal growth surveys are available for comparison with the Oxford children, one describing American and the other Scottish children (Simmons, 1944; Low, 1952). In all three surveys the mean skull diameters are slightly greater for boys than for girls, but compared with the two British series, the American children have rather small, brachycephalic heads. In all three groups the mean cephalic indices are greater for girls than for boys and reach peak values before 12 months.

† Cawley, Waterhouse, and Hogben (1949), in a similar study, advocate a fitting procedure in which the perpendicular deviations are minimized. The need for this did not arise in the present case since the smallest of the four correlation coefficients was +0.992 and hence the slopes of the conventional regression lines were indistinguishable.

Summary

The growth of the skull during early childhood may be divided into two phases. During the first of these the rate of increase of the transverse diameter exceeds that of the longitudinal diameter by approximately 20% and both boys and girls become increasingly brachycephalic. During the third trimester of post-natal life a second phase is initiated in which the growth rate of the transverse diameter is less than that of the longitudinal diameter. By the end of the first year this trend towards dolichocephaly (which is more marked in boys than in girls) is firmly established.

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