high resistance and is ready for another discharge. The wiring diagram and lamp are shown in Fig. 2.

The image is remarkably steady with high power objectives (×62) and we have obtained photomicrographs with the microscope-centrifuge, using a ×62 objective, of bacteria and chromosomes in dividing cells which can hardly be distinguished from those taken when the cells are at rest.

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SPECIAL ARTICLES

OBSERVATIONS ON THE GROWTH OF CHILDREN

A CLEAR understanding of the statistics of growth can not be obtained through a study of single measurements taken on masses of children of the same age—by the so-called generalizing method, but requires the study of individual amounts of growth. If the generalized series is considered as representative of individual growth, two assumptions are made; the one that the traits of the population represented by children of different ages remain the same from year to year; the other that all children pass through the period of growth at the same rate. Neither of these assumptions is admissible. Observations in Europe show clearly that the size of the body is undergoing secular changes. From the middle of the past century until the beginning of the present century the average stature in Europe increased in every single country. Recent observations also show that the stature of growing children, comparing the years 1880 and 1921, has considerably increased.[1] Besides these increments, which are probably due to better control of diseases of childhood, perhaps also to general improvement in hygienic conditions, there are minor changes which occur from year to year. I have studied the statures of individuals born during the period from 1870 to 1916 from this point of view. When the general variability of stature is known and the number of individuals of each year is given, it is possible to determine statistically what the variability of average statures from year to year would be if there were only accidental causes at work bringing about variations. As a matter of fact, the variability from year to year is on the whole too large and the calculation shows that a standard variation of about 0.5 cm or more must be assumed for irregular variations of stature. This variability of stature, so far as it is not due to chance, has been calculated from observations of children born in various years. It will be understood that the numbers of cases are observations repeated annually, many taken on the same individuals, not all distinct individuals.

Hebrew Orphan Asylum, N. Y.	2,275 boys	(born between 1894 and 1916)	$\Sigma = \pm$ .51 cm
" " " "	2,178 girls	(" " 1889 " 1916)	± .45 cm
Ethical Culture School, N. Y.	1,248 boys	(" " 1889 " 1916)	± .49 cm
" " " "	1,154 girls	(" " 1891 " 1915)	± .53 cm
Newark Academy	3,817 boys	(" " 1870 " 1898)	± 1.13 cm

The available material is not sufficient to allow us to determine whether there are any cycles of these changes, or what the actual differences of stature from year to year are. We may, however, be certain that variations do exist.

It seems likely that these changes will not influence the course of individual development materially. Much more important is the uneven rapidity with which children pass through the period of development. I have pointed out before[2] that the variability of physiological age increases very rapidly during life. At the time of birth it may be measured by a few days. That is to say, the total period of gestation differs only by a small number of days. The eruption of the first teeth differs by several weeks. The time of eruption of later teeth is even more variable. The time of reaching maturity varies by more than a year and that of senescence by seven or eight years. While it is not admissible to assume that the variability of any one of these phenomena indicates a general variability in physiological age of the whole organism, all the data combined show that the variability of physiological status increases rapidly during the course of life.

The curve of growth for the body as a whole, as

[1] Robert Rössle and Herta Böning, "Das Wachstum der Schulkinder," *Veröffentlichungen aus der Kriegs- und Konstitutionspathologie*, Vierter Band, Heft 1, pp. 24 et seq.

[2] Franz Boas and Clark Wissler, "Statistics of Growth" (Report of the U. S. Commissioner of Education for 1904), Washington, 1905, p. 40.

well as for its parts, is characterized by a gradual decrease in the rate of growth during childhood, followed by a period of increased rapidity of growth during adolescence and final completion of growth when maturity is reached. I demonstrated a number of years ago that, admitting the variability of physiological development and its determinant influence upon growth rates, the actual individual growth rate must show a much more decided decline during childhood and a much more decided increase during adolescence, and that at the same time the period of method is unsatisfactory on account of the asymmetry of the growth curves and because the fundamental questions are not well expressed by the coefficient of correlation. Furthermore, the data did not continue until the adult stage was reached. For this reason I have treated the same material according to another method. I also obtained with the kindly help of Dr. Farrand the adult statures of a fairly large number of the former students of the academy.

In Fig. 1 are given the total increments of stature up to adult stature for each year, beginning with 11

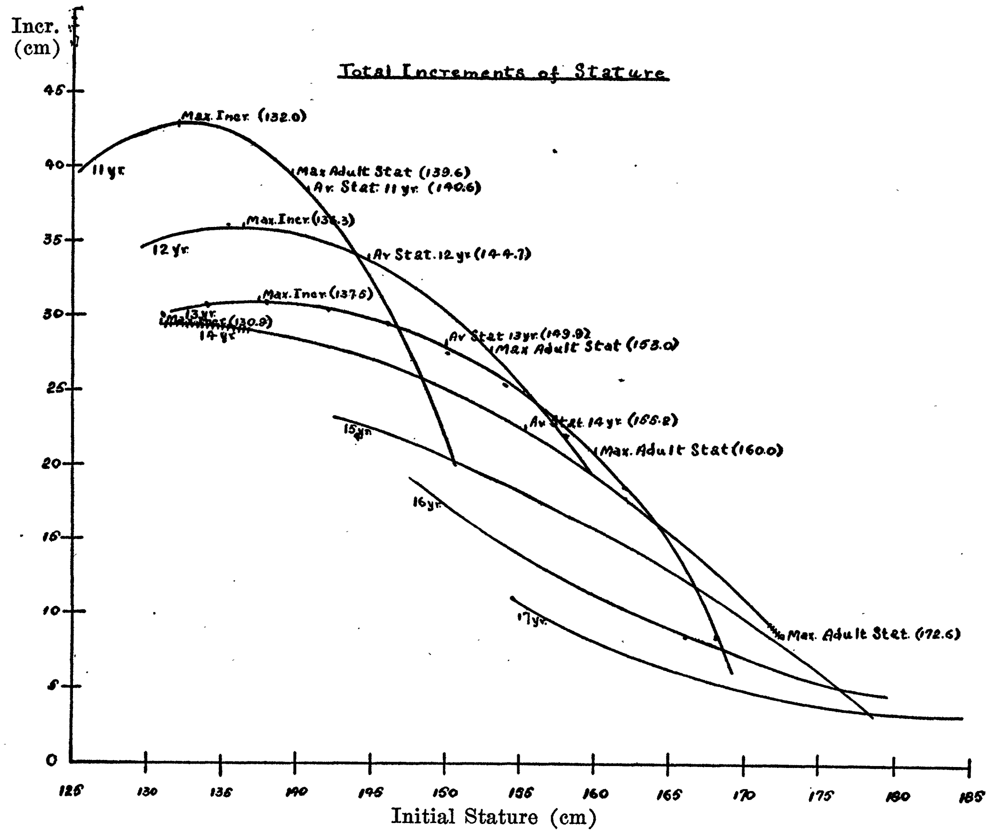

FIG. 1

increased rapidity of growth during adolescence must be much shorter than would appear from the generalized curve.[3]

A number of years ago I obtained, through the courtesy of Dr. Wilson Farrand, continuous measurements of boys in the Newark Academy, a rather uniform social group of almost exclusively northwest European descent. These data were calculated according to my suggestion by the method of correlation by Dr. Clark Wissler.[4] It appeared later that this

[3] *Ibid.*, pp. 42, 48.

[4] *Ibid.*, pp. 43–45; *Amer. Anthropol.*, N. S., 5: 81–88, 1903.

years. The ordinates show the total amount of growth from 11, 12 . . . up to 17 years on to adult stature. The abscissae show the statures at the initial age. The curves have been calculated from the data as parabolas, which seem to render the data adequately. It will be noticed that in early years the maximum total increment does not belong to the shortest individuals. The curves have a maximum and later on drop off very rapidly. From 11 to 15 years the curves are decreasingly concave; from 16 years on, convex. On the curves are indicated the average statures for initial years, the points at which the increment up to adult stature is a maximum and the point for which the adult stature is a maximum. For 11 years the maximum increment is found for children 132 cm tall, the average stature is 140.6 cm, the maximum adult stature belongs to those who have at 11 the stature 139.6 cm.

The general curve of growth of children 12 years old of various initial statures is illustrated in Fig. 2. In this figure the abscissae represent statures at 12 years, the ordinates the growth up to 13, 14, etc., years. In Fig. 3 the annual increments for 14 year

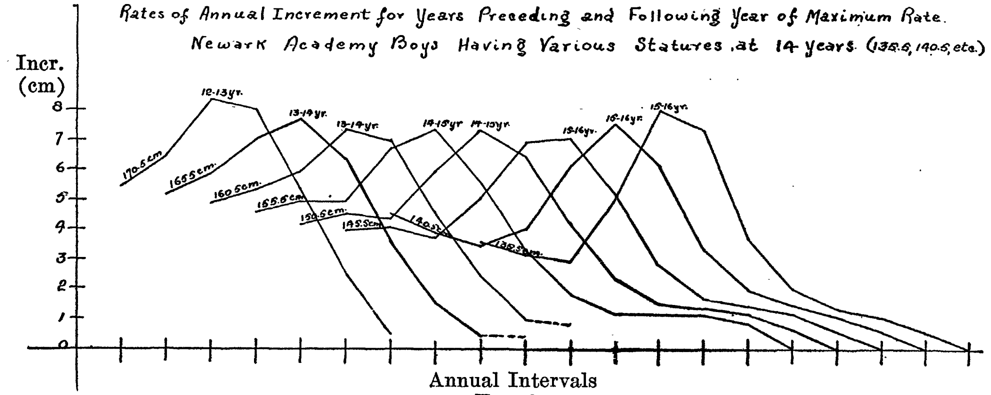

FIG. 3

old boys obtained from these parabolic curves have been so plotted that the maxima are placed side by side. Each curve contains individuals in a group of 5 cm—to the left the tallest (167.5–172.5), to the right the shortest (132.5–137.5). The absolute age to which each curve belongs may be determined from the year indicated at the point of maximum annual rate. It will be noticed that among the shortest children the pre-adolescent decrease in the rate of growth continues. It appears also that the maximum rate decreases with decreasing initial stature except for the two shortest groups. I have calculated from these data the time of maximum rate of annual growth for boys of various initial statures at 12, 13 and 14 years.

The following table gives the data.

FOR BOYS OF AGE	11.5	12.5	13.5	14.5
Average stature	140.5	144.7	149.9	155.2
Maximum increment for initial stature at	132.0	136.3	137.5	—
Maximum adult stature for initial stature at	139.6	153.0	160.0	172.6

These values must be considered as approximations, subject to revision when fuller material is available.

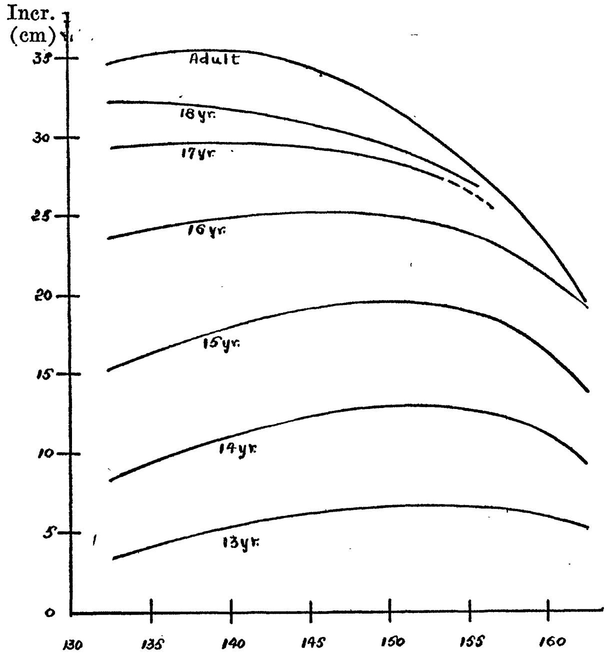

FIG. 2

MAXIMUM RATE OF GROWTH FOR BOYS OF VARIOUS AGES

	Years	Years	Years
Statures	12.5	13.5	14.5
	Maximum Rate at		
132.5	15.8	15.3	16.7
137.5	15.2	14.8	16.0
142.5	14.7	14.7	15.5
147.5	14.3	13.7	14.8
152.5	(12.5)	13.7	14.3
157.5	—	13.2	14.0
162.5	—	11.6	13.4
167.5	—	—	13.1

For the average statures this would give[5]:

[5] The differences between the following averages and those given before are due to the inclusion of additional individuals in the present series.

Age years	Average stature	Age of maximum rate
12.5	145.2	14.5
13.5	149.9	13.7
14.5	155.5	14.1,

approximately the same age. The table shows clearly the acceleration of development with increasing initial stature.

These phenomena may also be approached by a study of the growth of individuals who have their maximum growth at the same period. For the boys of the Newark Academy the average age at which the maximum rate of growth occurs is 14.5 ± .9 years. Fig. 4 indicates the course of actual growth of five groups. The first has its maximum rate of growth between 12 and 13; the second from 13 to 14, and so on up to those in which the maximum growth rate is between 16 and 17 years. It will be seen that the statures of those who have the earliest maximum growth are considerably larger than those of others who have the maximum growth at a later time. The differences naturally increase first, but decrease again considerably later on. The differences among the adults of these various groups are so small and so irregular that, considering the small number of cases that are available, we may well assume that there is no relation between the time when the greatest rapidity of growth sets in and the stature finally

STATURES AND VARIABILITIES OF NEWARK BOYS WHO HAVE THEIR MAXIMUM RATE OF GROWTH IN VARIOUS YEARS (IN CM)

Age	Maximum rate at					Total
	12–13	13–14	14–15	15–16	16–17	
11	142.2 ± 5.1	140.5 ± 5.4	139.5 ± 5.4	135.8 ± 5.4	———	139.7 ± 5.7
12	148.7 ± 5.5	145.5 ± 5.3	143.9 ± 6.3	140.8 ± 6.4	———	144.3 ± 6.3
13	158.7 ± 6.5	151.8 ± 5.2	148.6 ± 6.7	144.7 ± 6.3	———	149.4 ± 7.2
14	165.7 ± 6.4	161.1 ± 5.5	155.1 ± 6.9	150.2 ± 6.8	145.7 ± 7.3	155.7 ± 8.3
15	170.2 ± 5.9	167.2 ± 5.5	164.1 ± 7.0	156.3 ± 7.2	150.5 ± 7.4	162.8 ± 8.4
16	———	170.9 ± 5.7	169.9 ± 6.9	165.1 ± 7.3	157.2 ± 7.5	168.1 ± 7.7
17	———	172.8 ± 5.0	172.6 ± 6.8	170.0 ± 7.0	165.9 ± 8.1	171.2 ± 7.0
18	———	———	174.5 ± 6.8	173.3 ± 7.6	169.0 ± 7.9	173.6 ± 6.7
Adult	(175.7)	174.2 ± 4.6	176.7 ± 5.6	178.9 ± 6.3	(175.4)	176.1 ± 5.9

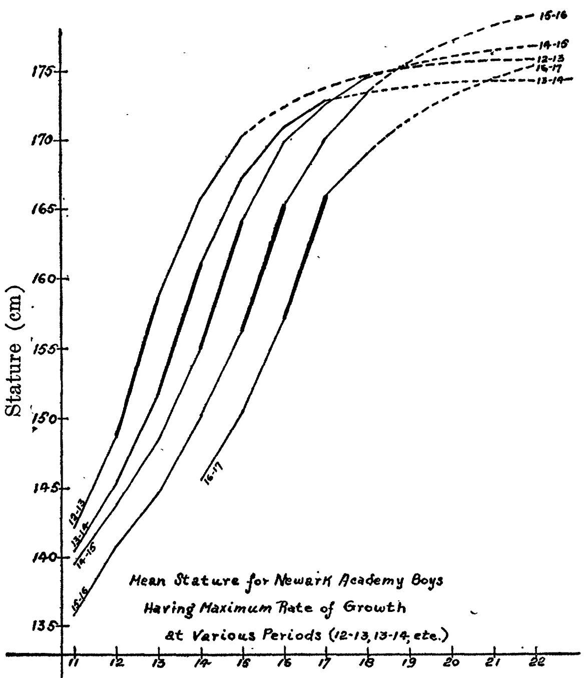

FIG. 4

attained. This conclusion is subject to revision when more material will be available. The averages and various totals for this series are given in the table given above.

It will be remembered that during the period of acceleration of growth the variability of the whole series increases considerably and decreases again later on. I have pointed out at a previous time[6] that this can best be explained as an effect of the difference in period when the greatest acceleration of growth occurs. It is interesting to note that the variabilities of the five curves, just shown, still indicate an increase in variability at the time of most rapid growth. The amount of this variability is considerably less than in the entire series. For boys who have their maximum rate of growth between 13 and 14 years there is practically no change in the variability from 11 years to 17 years. It is quite striking that the variabilities are the greater the later the period of most rapid growth. In our present series the variability of the adult is also the greater the later the period of most rapid growth. It remains to be seen whether this is a significant differ-

[6] "Statistics of Growth," p. 25 et seq.

ence. If it is, we might conclude that environmental conditions have the more effect the longer they exert their influence upon the body.

An analysis of the data also shows that the earlier the most rapid growth occurs, the more intensive is the total amount of increment during the period around the maximum rate. This is indicated in the following table.

INCREMENTS OF STATURE OF NEWARK BOYS DURING INTERVALS AROUND YEAR OF MAXIMUM RATE OF GROWTH

Maximum rate	Intervals in Years			
	− 0.5 to + 0.5	− 1.5 to + 1.5	− 2.5 to + 2.5	− 3.5 to + 3.5
Years	cm	cm	cm	cm
12–13	10.0	23.2	32.2	38.0
13–14	9.2	21.7	30.1	37.0
14–15	9.1	21.5	29.3	35.4
15–16	8.8	20.4	27.8	33.3
16–17	8.7	20.0	27.9	34.5

The intensity of growth during the period of adolescence is the less the later adolescence begins.

The distribution of individual increments in each of these groups is not by any means uniform. To a certain extent this is due to the grouping together of an interval of a whole year, for during this period considerable changes in rate of growth occur. Furthermore, the differences between measurements taken at annual intervals from which growth rates are obtained are always inaccurate, so that their variabilities contain a rather large element due to observational errors. More important, however, are the individual differences in periods of acceleration and of total growth. This is indicated in the following table.

PERCENTAGE OF THOSE WHO GROW LESS THAN 1 CM FROM VARIOUS AGES ON, ACCORDING TO THE PERIOD OF MAXIMUM RATE OF GROWTH

Maximum rate	Age after which growth is less than 1 cm			
	16 yrs.	17 yrs.	18 yrs.	19 yrs. or more
	Per cent.	Per cent.	Per cent.	Per cent.
13–14	5	25	28	42
14–15	1	5	19	75
15–16	0	0	9	91

The distribution of amounts of annual increments for the group with maximum growth between 14 and 15 years is shown in the following table.

INDIVIDUAL INCREMENTS FOR NEWARK BOYS WITH MAXIMUM RATE OF GROWTH BETWEEN 14 AND 15 YEARS

cm	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18
0– 0.9	—	—	1	1	—	1	5	11
1– 1.9	—	1	—	1	—	2	11	14
2– 2.9	—	1	1	—	—	4	25	15
3– 3.9	4	12	17	2	—	6	21	4
4– 4.9	8	27	29	13	—	18	14	—
5– 5.9	7	14	31	22	1	28	2	—
6– 6.9	1	3	11	36	2	34	2	—
7– 7.9	—	—	2	29	15	17	1	—
8– 8.9	—	—	1	16	42	13	—	—
9– 9.9	—	—	—	5	39	1	—	—
10–10.9	—	—	—	1	18	—	—	—
11–11.9	—	—	—	1	7	—	—	—
12–12.9	—	—	—	—	4	—	—	—
13–13.9	—	—	—	—	1	—	—	—

It will be seen that at the time of maximum rate of growth the distribution of increments is quite symmetrical, while at earlier and particularly later periods it becomes very asymmetrical on account of the varying length of the growth period.

These observations may be expressed in a general statement. The life cycle of children between the ages of 10 and 20 years develops with varying rapidity. In some individuals the whole physiological development so far as it is expressed by stature proceeds rapidly and energetically and the whole developmental period is short; in others it is sluggish and occupies a much longer period. The question arises whether this is true for life as a whole. Dr. Pearl has shown that among lower animals there are considerable variations in the life cycles of various lines of the same species, partly dependent upon environment, partly on heredity. Bell's studies of longevity in family lines suggest similar conditions in man. The question arises whether the rapidity with which the individual passes through the stages of early life continues later on, whether the life cycle of rapidly developing individuals is shorter than that of slowly developing ones. I have attempted to find whether a relation exists between the time of first menstruation and menopause. The available material is not satisfactory, but apparently there is no correlation between these two. The solution of the problem requires further and more carefully recorded data than those now available. It will be important to study the rates of the cycle of life in various racial and environmental groups. Available data show a very clear influence of social status upon the rapidity of the life cycle, while the hereditary control is not so clear.

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