

## Variations in the Pattern of Pubertal Changes in Boys

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**Marshall, W. A., and Tanner, J. M. (1970),** *Archives of Disease in Childhood*, **45**, 13. **Variations in the pattern of pubertal changes in boys.** Mixed longitudinal data on the physical changes at puberty in 228 normal boys are presented together with normal standards for stages of genital and pubic hair development.

The genitalia began to develop between the ages  $9\frac{1}{2}$  years and  $13\frac{1}{2}$  years in 95% of boys (mean =  $11.6 \pm 0.09$ ) and reached maturity at ages varying between 13 and 17 (mean =  $14.9 \pm 1.10$ ). The age at which pubic hair first appeared was not accurately determined, but its development through the later stages was studied. It reached the equivalent of an adult female distribution at a mean age of  $15.2 \pm 0.01$  years.

On average the genitalia reached the adult stage 3.0 years after they first began to develop; but some boys completed this development in as little as 1.8 years while others took as much as 4.7 years. Some boys complete the whole process in less time than others take to go from Stage G2 to Stage G3. The genitalia begin to develop before pubic hair is visible in photographs in practically all boys.

The 41 boys in whom it could be studied reached their maximum rate of growth (peak height velocity) at a mean age of  $14.1 \pm 0.14$  years.

Very few boys (about 5%) reached peak height velocity before their genitalia were in Stage 4 and over 20% did not do so until their genitalia were adult. Peak height velocity is reached, on the average, nearly 2 years later in boys than in girls, but the boys' genitalia begin to develop only about 6 months later than the girls' breasts. Pubic hair appears about  $1\frac{1}{2}$  years later in boys than in girls.

In a recent paper we described variations in the ages at which girls reached different stages of puberty and in the rates at which they passed from one stage of development to the next (Marshall and Tanner, 1969). We discussed also the degree to which progress in one event of puberty, for example breast development, could normally be out of step with another, such as growth of pubic hair. We now report a similar study of the maturation of boys.

The ages at which Dutch boys reached various stages of genital and pubic hair development in 1965 were estimated in a large cross-sectional study by Van Wieringen *et al.* (1968), but there are no comparable recent data from other parts of Europe. In any case, cross-sectional data cannot tell us how much individuals vary in the rate at which they pass through puberty nor how the

development of the secondary sex characters is related to the adolescent growth spurt.

This information can only be obtained from longitudinal studies in which the same individuals are examined repeatedly. There are reports of such studies of puberty in boys in the United States, but these were all made more than a generation ago (Stuart, 1946; Reynolds and Wines, 1951; Stolz and Stolz, 1951; Nicolson and Hanley, 1953).

In the Harpenden Growth Study, which began 19 years ago in England and is still in progress, the events of puberty have been followed by examinations at three-monthly intervals. Throughout the 19-year period new subjects have constantly joined the study while others have left it, though some subjects have remained under observation for 15 years or more. Anthropometric measurements have been taken, and the development of the genitalia and pubic hair in each subject has been recorded photographically throughout puberty.

Though these data may be subject to certain biases, discussed below, they provide information available from no other source.

This paper describes the extent of normal individual variation in the events of puberty, as observed in these boys.

We discuss: (a) variation in the chronological age at which adolescence begins and different stages of physical maturity are reached; (b) variation in the time taken to pass through the various stages of development of the genitalia and of the pubic hair; (c) variation in the temporal relation between the adolescent growth spurt and the development of the genitalia and the pubic hair.

### Subjects and Methods

The subjects were 228 white British boys participating in the Harpenden Growth Study. They had no physical abnormalities and lived in family groups in a children's home where the standard of care was in all respects excellent. They came mainly from the lower socio-economic sector of the population, and some may not have received optimal physical care before entering the home (usually between age 3 and 6 years). The reason for their admission was usually break-up of the parental home by divorce or by death, illness, or desertion of one parent.

The subjects were seen at 3-monthly intervals during adolescence. Some were followed throughout their whole adolescent period but some through part of it only.

The development of the secondary sex characters was studied in whole-body photographs taken in the nude at each examination by the technique given in Tanner (1962). All the photographs of each boy were later examined together. By comparing each picture with the preceding one, changes in the genitalia and pubic hair could be readily recognized. The genitalia and pubic hair on each photograph were classified into five stages of development as described by Tanner (1969). These are illustrated in Fig. 1 and 2. All the ratings were made by the same observer (W.A.M.). The stages for the genitalia are as follows:

*Stage 1:* Pre-adolescent. Testes, scrotum, and penis are of about the same size and proportion as in early childhood.

*Stage 2:* The scrotum and testes have enlarged and there is a change in the texture of the scrotal skin. There is also some reddening of the scrotal skin but this cannot be detected on black and white photographs.

*Stage 3:* Growth of the penis has occurred, at first mainly in length but with some increase in breadth. There has been further growth of testes and scrotum.

*Stage 4:* Penis further enlarged in length and breadth with development of glans. Testes and scrotum further enlarged. There is also further darkening of the scrotal skin, but this is difficult to detect on photographs.

*Stage 5:* Genitalia adult in size and shape. No further enlargement takes place after Stage 5 is reached.

The pubic hair stages are:

*Stage 1:* Pre-adolescent. The velus over the pubes is no further developed than that over the abdominal wall, i.e. no pubic hair.

*Stage 2:* Sparse growth of long, slightly pigmented, downy hair, straight or only slightly curled, appearing chiefly at the base of the penis. This stage is difficult to see on photographs, particularly of fair-haired

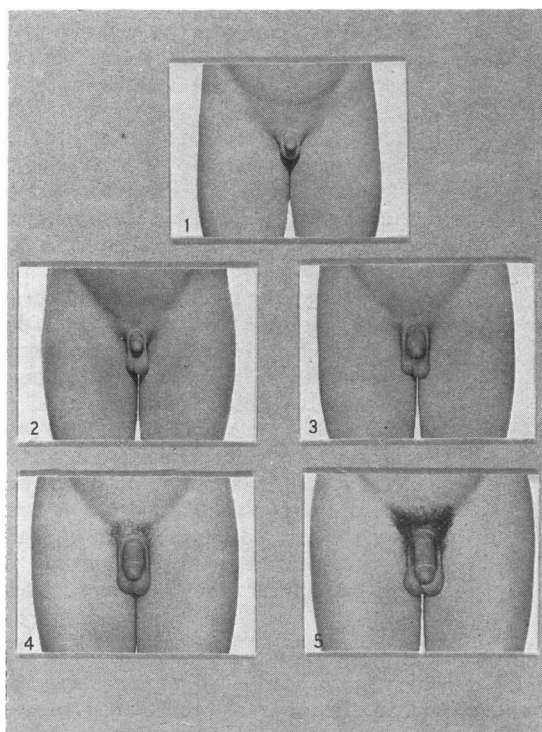


FIG. 1.—Standards for genital ratings (from Tanner, 1969).

subjects. Although the rating 'Stage 2' was used in this study, it cannot be regarded as reliable, and the ages at which subjects are said to have reached Stage 2 are almost certainly too late.

*Stage 3:* Considerably darker, coarser, and more curled. The hair spreads sparsely over the junction of the pubes. This and subsequent stages were clearly recognizable on the photographs.

*Stage 4:* Hair is now adult in type, but the area covered by it is still considerably smaller than in most adults. There is no spread to the medial surface of the thighs.

*Stage 5:* Adult in quantity and type, distributed as an inverse triangle of the classically feminine pattern. Spread to the medial surface of the thighs but not

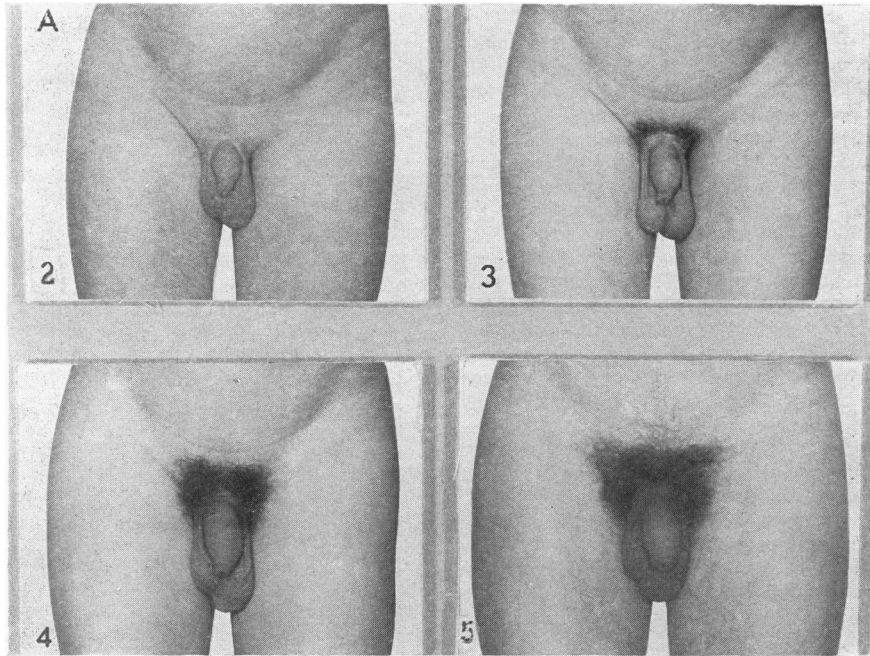


FIG. 2.—Standards for pubic hair ratings (from Tanner, 1969).

up the linea alba or elsewhere above the base of the inverse triangle.

In about 80% of men pubic hair spreads further beyond the triangular pattern (Dupertuis, Atkinson, and Elftman, 1945) but this takes some time to occur after stage 5 has been reached. This more widespread pubic hair may be rated as 'Stage 6', but as this stage is not usually reached before the mid-twenties it occurred in very few subjects in this study: they were rated as Stage 5.

Each subject's stature was recorded at each visit. All measurements were taken by the same observer (R. H. Whitehouse) using the technique described by Marshall (1966). These measurements were used to plot a growth velocity graph for each subject and a curve was fitted to the points by eye (see Tanner, Whitehouse, and Takaishi, 1966). The age at which the peak of this curve was reached was taken as the age at peak height velocity ('Instantaneous PHV'). This was estimated in 45 subjects. A less exact method of estimating age at PHV, which is, however, easier for clinical purposes, is to take the mid-point of the year in which the greatest increment in growth occurred. We have done this in the case of 60 boys including the 41 whose age at 'instantaneous PHV' was known. We refer to the result as 'mid-year PHV'.

**Terminology.** Throughout the paper we have used abbreviations such as 'G3' to represent a point in time; in this case, the moment at which the change from

genitalia stage 2 to stage 3 took place. The period of time during which the subject remains in stage 3 is called the 'interval G3-G4'. G4 is the moment at which stage 4 is reached. G2, G5, PH2, PH3, PH4, and PH5 similarly represent the moments at which the various stages of genital and pubic hair development are reached. The 'interval G2-G5' represents the total time spent in Stages 2, 3, and 4, i.e. the entire duration of genital development.

**Statistical methods.** The data were 'mixed longitudinal', i.e. some individuals were followed continuously from the first sign of puberty to maturity and some for only part of this period. Thus when we consider a single point in development, e.g. G4, some subjects would have been seen only before this point and some only after it, while some would have been seen both before and after. It is unlikely that the exact moment of G4 would ever be observed; it could only be certain that it occurred between two successive examinations on a given subject. Some authors (Nicolson and Hanley, 1953; Barton and Hunt, 1962) have assumed that the change from one stage to another took place at the mid-point of the interval between the last examination at which the subject was seen to be in the earlier stage and the first at which he was seen to be in the later one. Others, e.g. Reynolds and Wines (1951), do not state clearly whether they did this or whether they assumed the change took place at the time the subject was first seen in the later stage. The best

estimate of the population mean and standard deviation from mixed longitudinal data, however, avoids making a choice between these alternatives (Swan, 1969). It gives maximum likelihood estimates of these statistics, making full and appropriate use of the information provided by those subjects who were seen only before or only after a given event, as well as by subjects seen both before and after. This method was therefore used in the analysis of our data. For each calculation the subjects were divided into the following groups:

(1) *Exactly specified*: The age at which the stage was reached was known exactly. This, strictly speaking, does not apply to any of the data in this paper, but the age at peak height velocity (as estimated graphically) was treated as an exactly specified observation.

(2) *Lower bound*: The stage was known to have been reached after a certain age, i.e. the subject left the study while still in an earlier stage.

(3) *Upper bound*: The stage was known to have been reached before a certain age, i.e. before the age at which the subject joined the study.

(4) *Confined*: The stage was reached within a known interval, i.e. between two examinations.

Subjects who gave no useful information in a given analysis were classified as 'missing'.

### Results

In all boys who were seen in more than one stage of genital or pubic hair development, these characters developed progressively from one stage to the next in sequence. No stages were omitted, and there were no reversions to an earlier stage after a later one had been reached.

**Age on reaching stages.** The estimated mean ages at which the various stages of puberty were reached, together with the number of subjects from which each mean was estimated, are shown in Table I. The means are listed in chronological order. The figures for PH2 must be treated with

reserve as the first appearance of pubic hair cannot readily be seen on photographs. The mean given in the Table is therefore almost certainly too high. Note that all the standard deviations are equal to approximately one year.

Fig. 3 indicates diagrammatically the wide variation in the stage of puberty which may have been reached by boys of any given age. The stages are indicated on the vertical axis of the figure. The apex of each triangle represents the mean age at which the corresponding stage was reached and

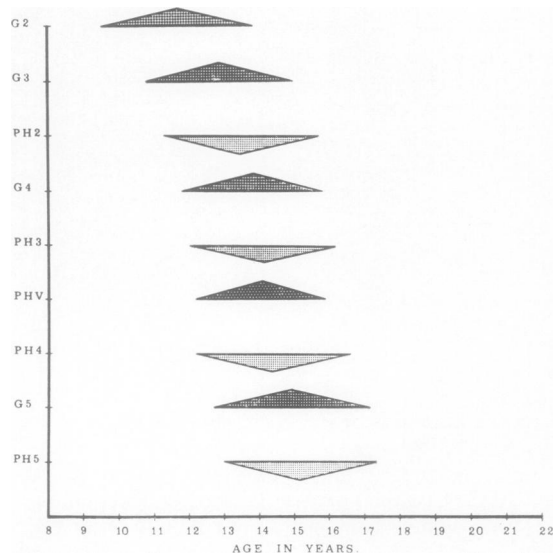


FIG. 3.—Age on reaching each stage of puberty. The centre of each symbol represents the mean and the length of the symbol is equivalent to two standard deviations on either side of the mean (based on the data in Table I).

TABLE I

*Ages (years) on Reaching Each Stage of Genital and Pubic Hair Development and Peak Height Velocity (Last four columns are numbers of boys (see text))*

	Mean	SD	SEM	Exactly Specified	Lower Bound	Upper Bound	Confined
G2	11.64	1.07	0.09	0	35	64	129
G3	12.85	1.04	0.09	0	61	46	121
PH2*	13.44	1.09	0.09	0	70	30	125
G4	13.77	1.02	0.09	0	81	23	124
PH3	13.90	1.04	0.08	0	77	22	126
Mid-year PHV	13.97	1.01	0.13	60	0	0	0
Inst. PHV	14.06	0.92	0.14	41	0	0	0
PH4	14.36	1.08	0.09	0	92	19	114
G5	14.92	1.10	0.09	0	110	10	108
PH5	15.18	1.07	0.09	0	112	7	106

\*See text.

the base of the triangle extends for 2SD on either side of this mean. Thus 95% of subjects reach each stage within the range of ages indicated by the length of the appropriate triangle. Note that between the ages of 13 and 14, normal boys may be found in any stage of sexual development. Some have not yet reached G2 while others may have reached G5 and PH5.

**Variation in duration of stages.** Table II shows the mean intervals between the ages at which the genitalia reached the various stages of

be appropriate. Occasional subjects who gave values exceptionally far from the mean were omitted in order to make the logarithmic transformation effective in creating a Gaussian distribution. Note that the interval PH2-PH5 is much shorter than the interval G2-G5, but the former is probably underestimated.

TABLE III

*Lengths of Intervals (in years) between Ages of Arrival at Different Stages of Pubic Hair Development, Calculated from Logarithmic Transformations of Original Data*

Interval	Centiles		
	2.5	50	97.5
PH2* - PH3	0.11	0.44	0.87
PH3 - PH4	0.31	0.42	0.54
PH4 - PH5	0.20	0.72	1.45
PH2 - PH5	0.82	1.59	2.67

TABLE II

*Lengths of Intervals (in years) between Ages of Arrival at Different Stages of Genital Development, Calculated from Logarithmic Transformations of Original Data*

Interval	Centiles		
	2.5	50	97.5
G2 - G3	0.41	1.12	2.18
G3 - G4	0.24	0.81	1.64
G4 - G5	0.38	1.01	1.92
G2 - G5	1.86	3.05	4.72

\*See text.

Occasional subjects who gave values exceptionally far from the mean were omitted in order to make logarithmic transformation effective in creating a Gaussian distribution.

maturity, together with the 2.5 and 97.5 centiles. Table III gives corresponding means and centiles for the intervals between the stages of pubic hair development. In calculating these means and centiles, logarithmic transformations were used, as the distribution of the data suggested that this would

The mean intervals given in Tables II and III are not identical with the differences between the mean ages at which each of the stages were reached (see Table I). This is because the two estimates are based on slightly different samples. The percentage distribution of the intervals G2-G3 and G2-G5 is shown in Fig. 4. Note that starting

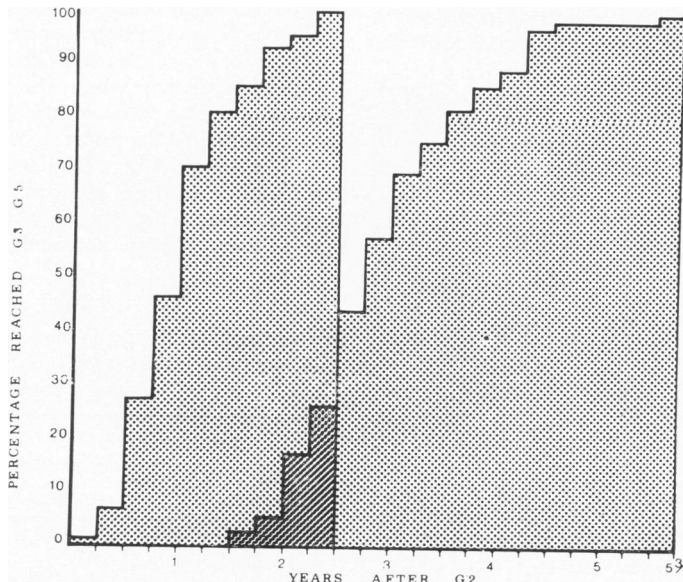


FIG. 4.—Cumulative percentages of boys who had reached G3 (left-hand columns) and G5 (right-hand columns) at given intervals, in years, after reaching G2.

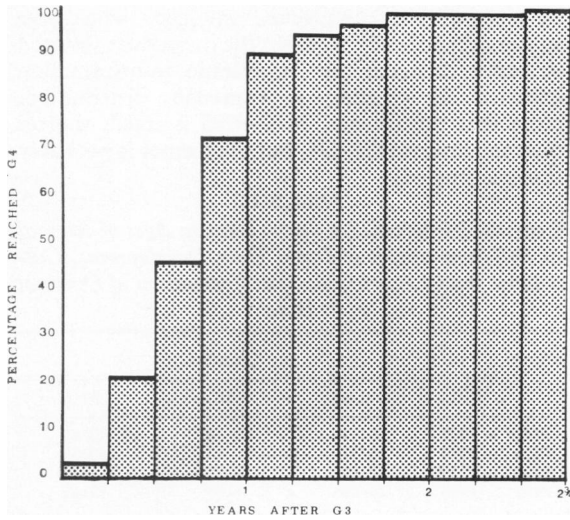


FIG. 5.—Cumulative percentages of boys who had reached G4 at given intervals, in years, after reaching G3.

from G2, some boys reach G5 in less time than others take to reach G3. Fig. 5 and 6 show the distributions of the intervals G3-G4 and G4-G5.

**Interrelationships between events.** Different boys reached a given stage of pubic hair development while they were in different stages of genital development. Similarly, they reached a given genital stage when their pubic hair was in different stages. Peak height velocity was also reached at different

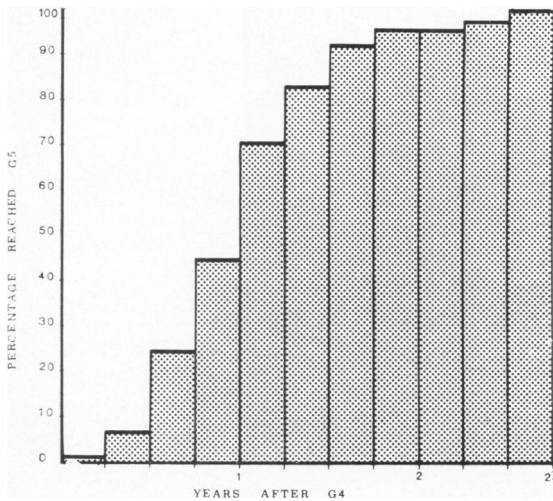


FIG. 6.—Cumulative percentages of boys who had reached G5 at given intervals, in years, after reaching G4.

TABLE IV  
Percentage of Boys in Each Stage of Genital Development when They Reached Each Stage of Pubic Hair Development

Pubic hair stage	2	3	4	5
No. of boys seen entering PH stage	115	115	104	104
% in genitalia Stage				
1	1	0	0	0
2	13	4	0	0
3	45	17	6	0
4	41	75	65	10
5	0	4	29	90

stages of genital and pubic hair maturity in different boys.

Table IV shows the percentage of boys who were in each stage of genital development when they were first seen in each successive pubic hair stage. The Table reads as follows. The changes from pubic hair Stage 1 to Stage 2 and from Stage 2 to 3 were observed in 115 boys. The changes to Stage 4 and to Stage 5 were each observed in 104 boys. The material is mixed longitudinal, thus most but not all of the 115 boys reaching Stage 2 are included in the 104 reaching Stage 4. Of the 115 boys seen on reaching pubic hair Stage 2, 1% were in genitalia Stage 1; 13% were in genitalia Stage 2 and so on. Accumulative percentages of boys who reached each pubic hair stage by the time they reached each genital stage are shown in Fig. 7.

Table V is similarly constructed and gives the number of boys who were in each stage of pubic hair development when they reached successive genital stages. 98% of the boys had no photographically visible pubic hair when development of their genitalia could be seen for the first time, and 16% of those who were seen on reaching genital Stage 4 had still no photographically visible pubic hair. These percentages might have been

TABLE V  
Percentage of Boys in Each Stage of Pubic Hair Development when they Reached Each Stage of Genital Development

Genital stage	2	3	4	5
No. of boys seen entering genitalia stage	126	109	115	101
% in pubic hair Stage				
1	98	72	16	0
2	2	17	37	0
3	0	9	36	8
4	0	2	11	54
5	0	0	0	38

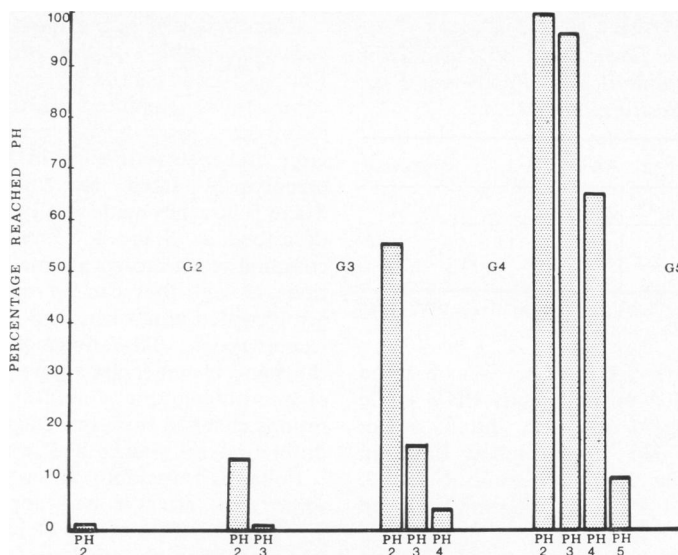


FIG. 7.—Percentage of boys who had reached each stage of pubic hair development before reaching each stage of genital development. G2, G3, etc. represent the moment of reaching the corresponding genital stages. Thus the histogram between G2 and G3 shows the percentage of boys in genital Stage 2 who reached each pubic hair stage before they reached the third genital stage.

lower if the pubic hair ratings had been made from clinical observation of the subjects rather than from photographs.

It is noteworthy (Table IV) that 41% of boys had reached genital Stage 4 by the time their pubic hair first became visible on photographs. (This figure does not conflict with the value of 16% given in Table V for the percentage of boys who were in pubic hair Stage 1 when they reached genital Stage 4. The 41% includes 30 boys who reached G4 and PH2 within the same interval between successive examinations, so that the first time they were seen in genital Stage 4 was also the first time they were seen in pubic hair Stage 2. They are therefore included in the 37% boys who reached G4 in pubic hair Stage 2, not in Stage 1.) At entry to pubic hair Stage 4 most boys were at genital Stage 4 or 5. Pubic hair Stage 5 was not reached by any of the subjects before genital Stage 4. On reaching genital Stage 4, 37% of the boys were in pubic hair Stage 2; 36% were in pubic hair Stage 3; 11% in Stage 4 and none in Stage 5. No boy reached genital Stage 5 before some pubic hair had appeared and only 8% were at less than pubic hair Stage 4.

Table VI shows the percentage of boys in each stage of genital development when they reached instantaneous or mid-year peak height velocity. None of the boys in whom we identified the peak

TABLE VI

Percentage of Boys in Each Stage of Genital Development when 'Instantaneous' and 'Mid-Year' Peak Height Velocity (PHV) was Reached

Genital stage ..	1	2	3	4	5	Total
% boys at inst. PHV	0	0	2	76	22	41
% boys at mid-year PHV .. ..	0	0	5	74	21	60

Based on instantaneous PHV in 41 boys and mid-year PHV in 60 boys (the same 41 and a further 19).

of the height spurt, by either method, had reached this peak before their genitalia were in Stage 3 and very few had done so before they were in genital Stage 4. One-fifth of the boys had still not reached PHV when their genitalia first became adult. The percentage of boys who were in each pubic hair stage when they reached peak height velocity is shown in Table VII.

The data in Tables VI and VII show that boys tended to reach PHV at a later stage in the development of their genitalia than did girls in relation to the development of their breasts (Marshall and Tanner, 1969). 76% of girls reached instantaneous PHV before B4, but only 2% of boys did so before G4. PHV was also later in relation to the growth

TABLE VII  
*Percentage of Boys in Each Stage of Pubic Hair Development when Instantaneous and Mid-year Peak Height Velocity was Reached*

Pubic hair stage . .	1	2	3	4	5	Total
% boys at inst. PHV	0	15	46	36	5	41
% boys at mid-year PHV . . . .	0	32	26	34	8	60

Based on instantaneous PHV in 41 boys and mid-year PHV in 60 boys (the same 41 and a further 19).

of the pubic hair in boys than in girls. We observed that 23% girls reached instantaneous PHV while they were in PH stage 1 and 41% did so before they reached PH3. No boys reached PHV in PH Stage 1 and only 15% did so in Stage 2. 87% of girls reached PHV before they reached PH4 but only 59% of boys had done so. A  $\chi^2$  test, after Yates' correction for continuity had been applied to the original data, showed this difference to be statistically significant ( $p < 0.01$ ).

Regression coefficients were calculated for (a) the length of the interval G2-G5 upon age at midpoint of this interval; and (b) the length of the interval PH3-PH5 upon age at mid-point of this interval.

Neither of these coefficients was significantly different from zero. Our data therefore do not support the hypothesis that the time which boys take to pass through the changes of puberty is related to the age at which puberty occurs. Regression of the interval on its mid-point is a valid test of this hypothesis, which regression of the interval on the age at either of its limits, e.g. (G5-G2) on G2, is not (see Marshall and Tanner, 1969).

### Discussion

#### Validity and reliability of observations.

Our sample of boys is not representative of the British population. Most of the subjects had poor socio-economic backgrounds and had lived in unsatisfactory conditions before entering the home where they were studied. They were, nevertheless, in excellent physical health, well fed, and their growth in stature was well within normal limits.

Boys joined and left the study at different ages but there is no reason to suspect that their coming or going was in any way related to their sexual maturation. The statistical techniques which were used allowed for the fact that many subjects were lost to observation between the ages of 15 and 16 (when children usually leave the home), and bias attributable to this cause should be slight.

Consistency of rating was ensured by comparing each photograph with the others from the same boy. Ratings could then be given with knowledge of the complete development of the child. Thus, for example, a boy whose genitalia were relatively large and mature looking in Stage 4 would not be erroneously rated as Stage 5. Alternatively, Stage 5 in a boy with small genitalia would not be described as Stage 4. Errors such as these are common when ratings are made at clinical examinations, though they can be minimized if the ratings are recorded and taken into account at subsequent examinations. Re-ratings of the photographs by the same observer gave only occasional differences of one photograph (3 months) in the age at which ratings changed from one stage to the next. These differences showed no bias in either direction.

Pubic hair was not seen on the photographs until some time after it had appeared on the body. The estimated mean age of reaching PH2 is therefore later than the true one, and the interval from PH2 to later events is underestimated. Table VIII shows data from other studies; the mean age of reaching PH2 as estimated recently in Holland by Van Wieringen *et al.*, and in the United Kingdom in 1948 by Hogben *et al.*, is considerably earlier than our estimate. These groups of workers made their ratings from live subjects and their estimates of PH2 are probably more accurate than ours. The changes from Stage 2 to Stage 3 and from 3 to 4 could easily be recognized in the photographs, and there is good agreement between ourselves and other authors as to the ages at which these stages are reached. Pubic hair Stage 5 could also be readily seen on the photographs, and where we have compared our photographic ratings made on the live subjects at the time the photographs were taken, there was usually complete agreement. Only occasionally fair-haired subjects were rated photographically at Stage 4 when they were actually in Stage 5. The differences between authors in their estimates of the mean age at PH5 are probably due largely to variations in the exact criteria used to define the stage.

The genital stages could be easily recognized, and Table VIII shows remarkable agreement between authors as to the ages at which they are reached despite the widely different samples studied. Only the estimate of Reynolds and Wines (1951) of the age at reaching G5 is out of keeping with the general pattern.

**Interpretation of results.** The data presented show the approximate range of ages at which each stage of puberty is reached in normal boys (Table I,



TABLE VIII

Mean Ages (years) on Reaching Different Stages of Genital and Pubic Hair Development According to Various Authors

Source	G2	G3	G4	G5	PH2	PH3	PH4	PH5
This paper . . . . .	11·6	12·9	13·8	14·9	13·4*	13·9	14·4	15·1
Van Wieringen <i>et al.</i> (1968) . . . . .	11·0	13·2	14·1	15·8	11·8	13·4	14·4	16·0
Nicolson and Hanley† (1953) . . . . .	11·8	13·1	13·8	15·2				
Reynolds and Wines (1951) . . . . .	11·5	12·7	13·4	17·3	12·2	13·3	13·9	16·1
Barton and Hunt (1962)‡ . . . . .	11·9			14·6	13·4*			14·6
Mulcock (1954) . . . . .					12·2			14·2
Hogben, Waterhouse, and Hogben (1948)					11·0			15·0
Stolz and Stolz (1951)‡	11·8							

\*Photographic appearance only; see text.

†Data from Berkeley (California) 'Guidance' study.

‡These two sets of data are derived from the same group of subjects; viz. the Californian Adolescent Study.

Fig. 3). Enlargement of the genitalia may normally begin at any age after 9½ years. At the other extreme we cannot begin to regard a boy without sexual development as potentially abnormal until he is over 13½ years. In fact, we have observed several boys who went through a perfectly normal puberty, beginning after they were 15. Between the ages of 13 and 15, normal boys may be found in any stage of genital development from infantile to adult.

Pubic hair may develop by the age of 11½ years to the point at which it becomes visible on standard whole-body photographs. The first appearance of pubic hair on the body, however, is presumably earlier than this. Van Wieringen *et al.* (1968), in their large cross-sectional study, found a mean value of 11·75 years, but they do not give a lower limit. If we apply our estimated standard deviation of 1·1 years to their mean, we get a possible value of about 9·5 years for the earliest age at which pubic hair becomes visible on direct examination of normal boys. There is no reason to suspect that Dutch boys are very different from British ones in this respect. According to the cross-sectional study of 642 English boys by Hogben *et al.* (1948), pubic hair had appeared in 25% of the subjects by the age of 10·25 years and in 50% by the age of 11·0 years, when these percentages were calculated by the logistic formula, but estimation by probits gave values approximately 6 months higher. The data were obtained by direct examination of the subjects.

According to our data, the pubic hair may reach Stage 5, i.e. the equivalent of an adult female distribution, at any age between 13 and 17½ years.

Van Wieringen *et al.* give values of 14·3 and 17·7 years for the 10th and 90th centiles.

Only longitudinal studies can give information about the extent to which children vary in the rate at which they pass through puberty. Our data (Table II) show how great this variation may be. Some boys may complete the whole process of genital development (G2–G5) in less time than others take to pass through the second stage (G2–G3). Some boys' genitalia reach the adult state in less than two years after their pubertal development begins while in other boys this development takes more than 4½ years. Thus, once a boy's genitalia have begun to develop, failure to attain complete maturity cannot necessarily be regarded as abnormal before 4½ years have elapsed, regardless of the boy's age.

The intervals PH2–PH3 and PH2–PH5 shown in Table III are biased by our overestimation of the age at PH2 (see above). The best available estimate of the mean age at which pubic hair may first be seen on live European subjects is 11·75 years (Van Wieringen *et al.*, 1968). This is 1·65 years earlier than the mean value obtained by our photographic technique. Therefore, by adding 1·65 years to the intervals given in Table III, a very approximate estimate of the lengths of the intervals PH2–PH3 and PH2–PH5, as seen on living subjects, may be obtained. By this criterion the minimum time for the pubic hair to develop completely (PH2–PH5) would be nearly 2½ years, and the maximum time would be nearly 4 years.

In our study the intervals between genital stages and between pubic hair stages are in good agreement with those reported by Reynolds and Wines (1951)

from their photographic study of 59 American boys in Ohio, except for those intervals bounded by G5 or PH5, which points occurred 2.4 years later and 1 year later, respectively, in their subjects. It may be true that their subjects were genuinely later than ours in reaching maturity but more probably they did not use exactly the same criteria for judging maturity. Barton and Hunt (1962) in their photographic longitudinal study of 62 Californian boys obtained a mean value of 2.8

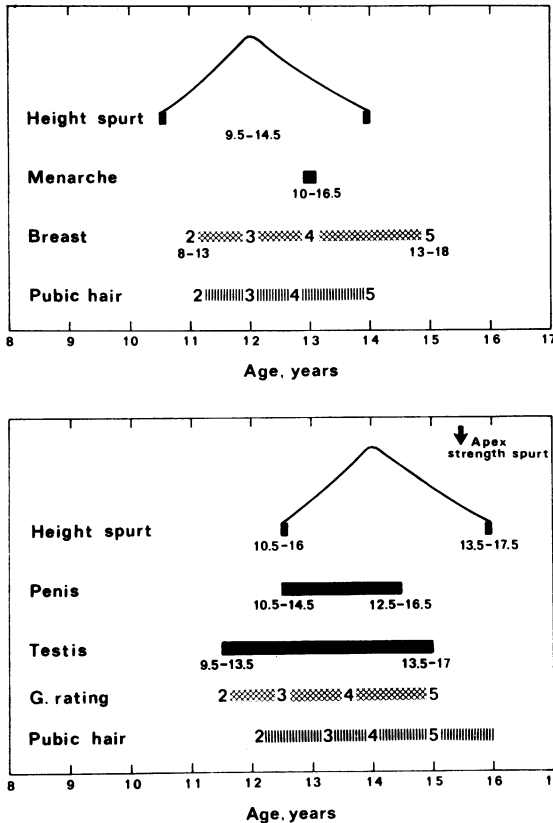


FIG. 8.—Diagrams of the sequence of events at puberty. An average boy and girl are represented in relation to the scale of ages: the range of ages within which some of the changes occur is indicated by the figures below them. (Redrawn from Tanner (1962) to incorporate the data presented in this paper.)

years for the interval G2-G5. This is very close to our value. Their estimate of the interval PH2-PH5 is, however, 2.1 years, which is approximately 1 year shorter than ours and 2 years shorter than that obtained by Reynolds and Wines. Though Barton and Hunt published their work in 1962, their photographs were actually taken before 1950.

In interpreting our data on the relation between genital and pubic hair development in individual boys (Tables IV and V, Fig. 7), it must again be borne in mind that the stages of genital development can be clearly and accurately seen on photographs, but pubic hair Stage 2 cannot. If photographs are used for the clinical assessment of a boy's progress through puberty, our data can be taken at face value and we could expect about 16% of boys in genital Stage 4 to be in pubic hair Stage 1. About double this number would appear to reach PH2 and G4 simultaneously. If the boys themselves were examined, however, this percentage would be much smaller. The figures we give for the relations between pubic hair stages 3, 4, and 5 and the genital stages can be regarded as reliable whether the boys are examined directly or by means of photographs. It is very unusual for pubic hair to develop to the extent at which it becomes visible on photographs before the development of the genitalia has begun. This is in contrast to the situation in girls, where the pubic hair may be well developed before there is any enlargement of the breasts (Marshall and Tanner, 1969).

Another striking difference between boys and girls lies in the relation between the adolescent growth spurt and the development of the secondary sex characters. A significant proportion of girls reach their maximal rate of height growth (PHV) while the breasts are in Stage 2 (i.e. the nipple and areola have enlarged but there is no development of the main part of the breast). It is, however, unusual for boys to reach peak height velocity until their genitalia are quite well developed, usually in Stage 4 (see Table VI). Thus when we see a boy who is small for his age, but whose genitalia are just beginning to develop, we can state with confidence that his growth is about to accelerate. We cannot be so confident when we are faced with the corresponding situation in a girl. The same may be said of the relation between pubic hair growth and PHV in the two sexes.

Though PHV is reached, on the average, nearly two years later in boys than in girls, the boys' genitalia begin to develop only about 6 months later than the girls' breasts. Thus the sexes appear to differ more widely in the time of the adolescent growth spurt than in the age at which these secondary sex characters appear. The pubic hair stages lie between the growth spurt and the genitalia in this respect: PH3 is reached about 1½ years later in boys than in girls (see Fig. 8).

The timing of the adolescent spurt, in relation to genital and pubic hair development, is in keeping with the hypothesis that androgens from the

testes play an important part in accelerating growth. There is no clear evidence as to whether or not growth hormone plays any part in the growth spurt in boys; it is possible that the two hormones act synergistically. Androgens from the adrenals are thought to be responsible for pubic hair growth in girls. This view is supported by the fact that pubic hair may appear before the breasts begin to develop. In boys, however, pubic hair does not begin to grow before the testes enlarge, so that it is not necessary to implicate adrenal androgens in this phenomenon, though they may play a part.

The data in this paper provide a basis for distinguishing normal from abnormal puberty in boys. Genital development cannot be regarded as abnormally early if it begins after the age of 9 or as unduly late so long as it begins before 15. Pubic hair growth in the absence of genital enlargement is sufficiently unusual in boys to raise suspicion of abnormality. It is not, however, abnormal for the genitalia to develop as far as Stage 4 before there is any growth of the pubic hair. A 14- or 15-year-old boy whose stature is below the third centile and whose genitalia are nearly mature, will become a very small adult. If, however, the genitalia are just beginning to develop it can be assumed that the adolescent growth spurt is still to come, and this may bring him to a normal adult height. A formal height prediction, based on the boy's height and skeletal age, should be carried out to confirm this last conclusion in individual cases.

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