PRIMARY AND SECONDARY SEXUAL CHARACTERISTICS

STUDY OF THEIR DEVELOPMENT IN MALES FROM BIRTH THROUGH MATURITY, WITH BIOMETRIC STUDY OF PENIS AND TESTES

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In view of the complexity of the process of growth and maturation, it is not surprising to find great variations among normal boys as to the time of onset of pubescence, the rate of development and the ultimate size of the genitalia. This study was undertaken in an attempt to ascertain the actual variations among normal boys and men as to the size of the testes and of the penis and the degree of development of secondary sexual characteristics.

The primary sexual organs are essentially the gonads, but we shall accept the broader classification, which includes all the organs required for procreation. These in males are the testes, the epididymides, the seminal vesicles, the prostate and the duct systems. In children these primary sexual organs differ considerably in size and structure from those of adults, since they do not as yet exercise their specific function. They are maintained in a quiescent state, without appreciable growth after infancy, until the onset of pubescence, when there is a rapid growth of the genitalia with production of spermatozoa at puberty. Following this, there is a stage of postpubescent maturation, called adolescence, ending with maturity. The curves for relative weight of the genitalia and of the body during these stages of development have been well presented by Scammon.[1] However, there is a great variation in the age at which the pubescent spurt begins and in the rate of development during pubescence, as well as individual differences in the initial and final sizes of the genitalia. This creates a wide range of normal size and functional state of the gonads in children at any age, particularly between 10 and 18 years. The secondary sexual characteristics, such as deep voice, hirsuties, development of muscles and bones and emotional maturation, which are largely dependent on the function of the testes, begin to develop with pubescence and end with full maturity and thus are also subject to great variation.

To evaluate this variation in the development of normal children, the genital status of about 1,500 normal white boys and men from birth to 25 years of age was studied and the accumulated data were statistically analyzed. The subjects examined were from general pediatric, medical, dental, otolaryngologic, traumatic and special follow-up clinics and wards at the Neurological Institute of New York, Vanderbilt Clinic, Babies and Presbyterian Hospitals of Columbia-Presbyterian Medical Center, Morrisania City Hospital and Mount Sinai Hospital. From this wide source of patients we were assured of a good sample of the general population of all nationalities and economic statuses in New York. The table shows the number of boys and men examined in each age group. The stated age is recorded according to the birthday preceding the examination.

Care was taken to exclude boys known or suspected to be suffering from an endocrinopathy or other abnormality associated with genital development. Although the nationality of each

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Statistical analysis by Gilbert Beebe, Ph.D., New York.

From the Columbia-Presbyterian Medical Center, Morrisania City Hospital and Mount Sinai Hospital.

1. Harris, J. A.; Jackson, C. M.; Paterson, D. G., and Scammon, R. E.: The Measurement of Man, Minneapolis, University of Minnesota Press, 1930, p. 215.

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patient and of his parents was recorded, no attempt was made to analyze the data on a racial basis, because review of the literature (summarized graphically in figure 1) revealed no appreciable variation in the size of the testes in the various nationalities studied and reported,[2] although the age of onset of pubescence probably varies. The only possible exception

Number of Observations for Length and Circumference of the Penis and for Volume of the Testes, by Age

Age	Number of Subjects		
	Penis		Testes,
	Length	Circumference	Volume
0- 5 months	125	125	247
6-11 months	51	51	101
1 year	50	50	98
2 years	50	50	98
3 years	50	50	100
4 years	50	50	98
5 years	50	50	96
6 years	50	50	98
7 years	50	50	98
8 years	50	50	100
9 years	50	50	96
10 years	82	81	162
11 years	91	91	175
12 years	93	92	186
13 years	104	104	204
14 years	121	121	242
15 years	101	100	201
16 years	76	76	150
17 years	61	61	122
18 years	40	40	79
19 years	31	31	62
20-25 years	54	55	110
Total	1,480	1,478	2,923

2. (*a*) Freeman, W.: The Weight of the Endocrine Glands: Biometrical Studies in Psychiatry, Human Biol. **6**:489, 1934. Pearl, R.; Gooch, M., and Freeman, W.: A Biometric Study of the Endocrine Organs in Relation to Mental Disease, ibid. **7**:555, 1935. Pearl, R.; Gooch, M.; Miner, J. R., and Freeman, W.: Studies on Constitution: IV. Endocrine Organ Weights and Somatological Habitus Types, ibid. **8**:92, 1936. Scammon, R. E.: Growth of the Human Reproductive System, Proceedings of the Second International Congress for Sex Research, 1930, p. 118. (*b*) Eberth, C. J.: Die männlichen Geschlechtsorgane, in von Bardeleben, K.: Handbuch der Anatomie des Menschen, Jena, G. Fischer, 1904, vol. 2, pt. 2. Gundobin, N. P.: Die Besonderheiten des Kindesalters, Berlin, Allgemeiner medizinischer Verlag, 1912. Henle, F. G. J.: Handbuch der systematischen Anatomie des Menschen, Braunschweig, F. Vieweg u. Sohn, 1873, vol. 2, p. 362. Leupold, E.: Beziehungen zwischen Nebennieren und männlichen Keimdrüsen, Veröffentl. a. d. Geb. d. Kriegs- u. Konst. Path. **4**:1, 1920. Mühlmann, M.: Wachstum, Altern und Tod. Ueber die Ursache des Alterns und des Todes, Ztschr. f. d. ges. Anat. (pt. 3) **27**:1, 1927. Mita, G.: Physiologische und pathologische Veränderungen der menschlichen Keimdrüse von der fötalen bis zur Pubertatszeit, mit besonderer Berücksichtigung der Entwicklung, Beitr. z. path. Anat. u. z. allg. Path. **58**:554, 1914. Roessle, R., and Roulet, F.: Mass und Zahl in der Pathologie, Berlin, Julius Springer, 1932, p. 83. Schilf, F.: Die quantitativen Beziehungen der Nebennieren zum übrigen Körper, Ztschr. f. Konstitutionslehre **8**:507, 1922. Schultze, W. H.: Männliche Geschlechtsorgane, in Brüning, H., and Schwalbe, E.: Handbuch der allgemeinen Pathologie und der pathologischen Anatomie des Kindesalters, Wiesbaden, J. F. Bergmann, 1913, vol. 2, pt. 1. Sitsen, A. E.: Zur Kenntnis des Normalen, Ztschr. f. Konstitutionslehre (Ztschr. f. d. ges. Anat.) **16**: 308, 1931. Stieve, H.: Harn- und Geschlechtsapparatus, in von Möllendorff, W.: Handbuch der mikroskopischen Anatomie des Menschen, Berlin, Julius Springer, 1930, vol. 7, pt. 2. (*c*) Mackevičaité-Lašiené, J.: Average Weight and Size of Endocrine Glands in Lithuanians, Acta med. Fac. Vytauti Magni Univ. Kaunas **3**:289, 1936. (*d*) Wwedenski, A. A.: Die Hoden und Samenblasen der Kinder, Inaug. Dissert., St. Petersburg, 1900; cited by Wagensteen.[2f] (*e*) Oiye, T.: Statistische und histologische Hodenstudien, Mitt. ü. allg. Path. u. path. Anat. **4**:425, 1928. Morioka, Y.: Position, Diameter and Weight of Human Testes and Certain Observations in Vas Deferens and External Cremasteric Muscles, Okayama-Igakkai-Zasshi **48**:2716, 1936.

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is the Japanese, who seem to have appreciably smaller testes as adults. It must be remembered that the data represented by these curves are not entirely comparable, since some of the authors weighed both testes together, some without and others with the epididymides; so it was necessary to calculate arbitrarily the weight of one testis alone before it could be included in the data. Another experimental factor which may create such variations as are noted in the curves is the degree of drying and fixation of the testes weighed by the various observers, since, as Bischoff [3] has pointed out, by weight a fresh testis is only about 18 per cent tissue and 82 per cent water. It will suffice to state that about 85 per cent of the boys and men were of the first generation, born in the United States and an additional 13 per cent were second generation Americans; the remaining 2 per cent, as well as the ancestors of the American-born subjects, were born in practically every country of Europe, in Canada and in some South American countries. In addition, it was noted that there was a fairly equal distribution among religions.

In presenting the results of this investigation of the normal genital development of boys [4] no attempt will be made to review the extensive literature on the

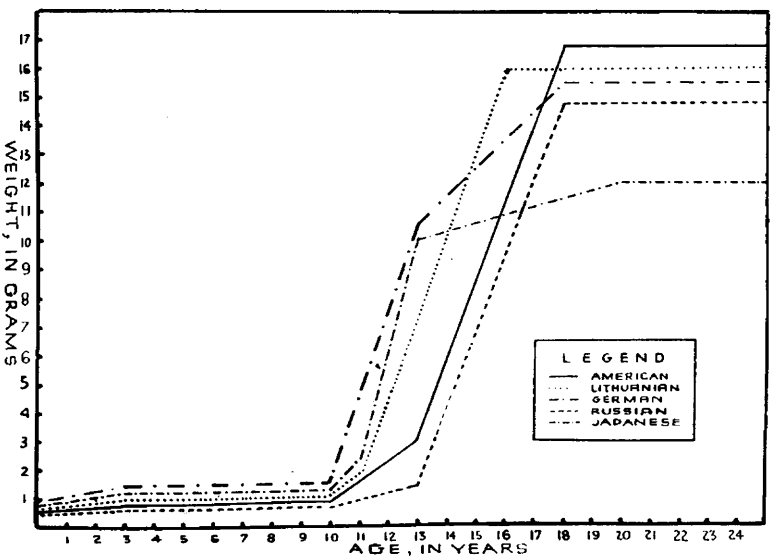

Fig. 1.—Weight of testis according to nationality, based on values obtained from a review of the literature listed in footnote 2 (*a*, American; *b*, German; *c*, Lithuanian; *d*, Russian; *e*, Japanese).

Endo, M.: Ueber das Volumen des Hodenparenchyms bei den japanischen Kindern, Okajimas Folia anat. japon. **17**:451, 1938. (*f*) Vierordt, H.: Anatomische, physiologische und physikalische Daten und Tabellen, Jena, Gustav Fischer, 1906, p. 57. Wangensteen, O. H.: The Surgery of the Undescended Testis, Surg., Gynec. & Obst. **54**:219, 1932. Cooper, A.: Observations on the Structure and Diseases of the Testis, London, J. Churchill, 1830. Smith, G. G., in Cobat, H.: Modern Urology in Original Contribution by American Authors, Philadelphia, Lea & Febiger, 1936, vol. 1, p. 397.

3. Bischoff, E.: Ztschr. f. rat. Med. **20**:75, 1863.

4. (*a*) Greulich, W. W.; Day, H. G.; Lachman, S. E.; Wolfe, J. B., and Shuttleworth, F. K.: Handbook of Methods for the Study of Adolescent Children, Monographs of the Society for Research in Child Development, serial no. 15, 1938, vol. 3, no. 2. (*b*) Peter, K.: Männliche kindliche Geschlechtsorgane, in Peter, K.; Wetzel, and Heidrich: Handbuch der Anatomie des Kindes, Munich, J. F. Bergmann, vol. 2, pt. 1. (*c*) Schmidt-Voigt, J.: Der gegenwärtige Eintritt und die Acceleration der Pubertätsentwicklung dei der männlichen Jugend einer Grossstadt, Ztschr. f. Kinderh. **61**:548, 1940.

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histologic development.[5] I shall merely mention the points which aid in the evaluation of the data accumulated. The reliability and validity of the method of measurements used had been established, and the data accumulated on measuring the testes and penises of about 1,500 boys and men were statistically analyzed in great detail in a previous communication.[6]

PRIMARY SEXUAL CHARACTERISTICS

Testes.—In discussing the growth of the testes, one must consider not only their own change in size but also their relationship to the epididymides. In a newborn boy the epididymis, which is about equal in size to the testis, is completely separated from it, the body being weakly attached while the head is completely free.[7]

At about 2 years of age the epididymis and testis are closer together but the head is still free. During pubescence both grow but the testis grows at a more rapid rate, so that during early pubescence the epididymis may be only one-third or one-quarter the size of the testis; later its relative size decreases, until in adult life it is only one-ninth the size of the testis.[8] During the period of rapid growth the epididymis becomes more closely bound to the testis, so that at times it is difficult to evaluate the exact size of the testicle alone. When this problem arises in the longitudinal study of an individual, no attempt is made to isolate the testis but the volume of the epididymal testicular mass is recorded as a unit.

Fig. 2.—Position of testis in relation to epididymis during pubescence.

In a child the testis is ovoid and about the same shape as in an adult.[4b] As to its position, the literature states that during childhood the testicle is vertical while in adulthood the upper pole is superior and lateral. This is true in most cases, but it is not uncommon to find the testis during pubescence in some unusual position, as noted in figure 2. Latarjet,[9] Poirier and Charpy[10] and Campbell[11] also noted some of these positions in the subjects they studied.

Histologically the testis undergoes several changes during the various stages of development.[12] As the length and diameter of the tubules increase and lumens

5. (*a*) Spangaro, S.: Ueber die histologischen Veränderungen des Hodens, Nebenhodens und Samenleiters von der Geburt an bis zum Greisenalter, Anat. Hefte (pt. 1) **18**:593, 1902. (*b*) Rowlands, I. W., and Brambell, F. W. R.: Development and Morphology of the Gonads of the Mouse: The Post-Natal Growth of the Testis, Proc. Roy. Soc., London, s.B **112**: 200, 1933. (*c*) Greulich and others.[4a] (*d*) Peter.[4b]

6. Schonfeld, W. A., and Beebe, G.: Normal Growth and Variation in the Male Genitalia from Birth to Maturity, J. Urol. **48**:759, 1942.

7. Poirier, P.: Kystes de l'epididyme, Rev. de chir., Paris **10**:861, 1890.

8. Peter.[4b] Poirier.[7]

9. Testut, L., and Latarjet, A.: Traité d'anatomie humaine. Appareil uro-génital. Péritoine, ed. 8, Paris, Gaston Doin, 1931, vol. 5, p. 152.

10. Poirier, P., and Charpy, A., in Testut, J. L.: Traité d'anatomie humaine, anatomie descriptive, ed. 4, Paris, O. Doin, 1901, vol. 5, p. 225.

11. Campbell, M. F.: Pediatric Urology, New York, The Macmillan Company, 1937, vol. 1, p. 310.

12. Jaffe, R., and Berberich, F.: Hoden, in Hirsch, M.: Handbuch der inneren Sekretion, Leipzig, Curt Kabitzsch, 1927, vol. 1, pt. 2, p. 197. Greulich and others.[4a] Peter.[4b] Spangaro.[5a]

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begin to form and eventually spermatogonia are transformed to spermatozoa, there is a relative reduction in the amount of intertubular connective tissue, so that the testis becomes temporarily softer. Interstitial cells of Leydig soon appear in the connective tissue for the first time since infancy, when they were present as a result of the maternal pituitary or chorionic gonadotropic stimulation; they disappear after four to six weeks but reappear at pubescence as result of the boy's own pituitary gonadotropic hormones.

Although the literature [2] contains many reports on postmortem measurements and weights of the testes, they are merely the average values at each age (fig. 1) and thus are of no appreciable help in evaluating the genital status of an individual.[13]

For each of the 1,500 boys and men [14] examined the volume of each testicle was determined by palpating the testicular mass with one hand while the other ran through a graded series of hard rubber models (fig. 3*D*) the volumes of which were known. When a model was found which seemed to have the same volume as the testicle, the observation was recorded. In recording, however, the median, or middle, value of 3 such observations was taken.

In preparing the standards a large number of postmortem specimens were obtained and utilized in the construction of a set of wax models. The volume of each model was then obtained by water displacement and a graded series selected. The volumes of the models used were 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.25, 1.5, 1.75, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 14, 18 and 25 cc. At each point in the range of volume the smallest perceptible difference was taken into account in selecting the models for inclusion in the standard set. These models were then reproduced in rubber and their volumes rechecked by water displacement (fig. 3*E*).

In analyzing the data to ascertain the relative sizes of the right and left testes, it was found that in 23 per cent of the boys the right testis was larger than the left while in 22 per cent the right testis was smaller than the left and in 55 per cent the right and left testes were equal in size. These figures confirm some observations in the literature and contradict others which claim that the right testicle is always larger than the left.

The curves for growth of the testes (fig. 4) were prepared by plotting the tenth, fiftieth and ninetieth percentiles of the cumulative percentage frequency distributions at various ages, as described in a previous communication.[6] The line connecting the fiftieth percentile, or median,[15] points indicates the trend of growth, while the area between the lines joining the first decile points and the ninth decile points indicates the range of size of 80 per cent of the testes measured.

The median growth curve shows a slight growth of the testes during the first two years followed by a prolonged quiescent period until the age of 11 years, when there is a rapid spurt of growth, reaching its maximum at about 17 years. During this period of active growth the vertical distance between the first and ninth deciles lengthens rapidly. This is due, as previously explained, to the wide variation of the date of onset of pubescence and the rate of genital maturation. A realization of this great variation is essential to evaluate the genital status of an individual.

13. (*a*) Reich, H.: Klinische Testikelmessungen bei Kindern, Jahrb. f. Kinderh. **105**:290, 1924. (*b*) Shorohowa, A. A.: Elements of the Study of Sterility in Man, paper read at the Union of Socialist Soviet Republics Congress on Genetics and Selection, Leningrad, Jan. 15, 1929, unpublished paper (courtesy of R. L. Dickinson). (*c*) Shuttleworth, F. K.: Adolescent Period (Graphic and Pictorial Atlas), Monographs of the Society for Research in Child Development, serial no. 16, 1938, vol. 3, no. 3. (*d*) Crampton, C. W.: Physiological Age: A Fundamental Principle, Am. Phys. Educat. Rev. **13**:141, 214, 268 and 345, 1908; (*e*) Influence of Physiological Age on Scholarship, Psychol. Clin. **1**:115, 1907; (*f*) Physiological Age, Pedagog. Seminary **15**:230, 1908. (*g*) Footnote 2. (*h*) Footnote 2 *a*.

14. Although 1,500 subjects were examined, complete data were not obtained on all (details are given in the table).

15. The median of a series of measurements is that point in its frequency distribution where there are equal numbers of members of the series larger and smaller than this measurement.

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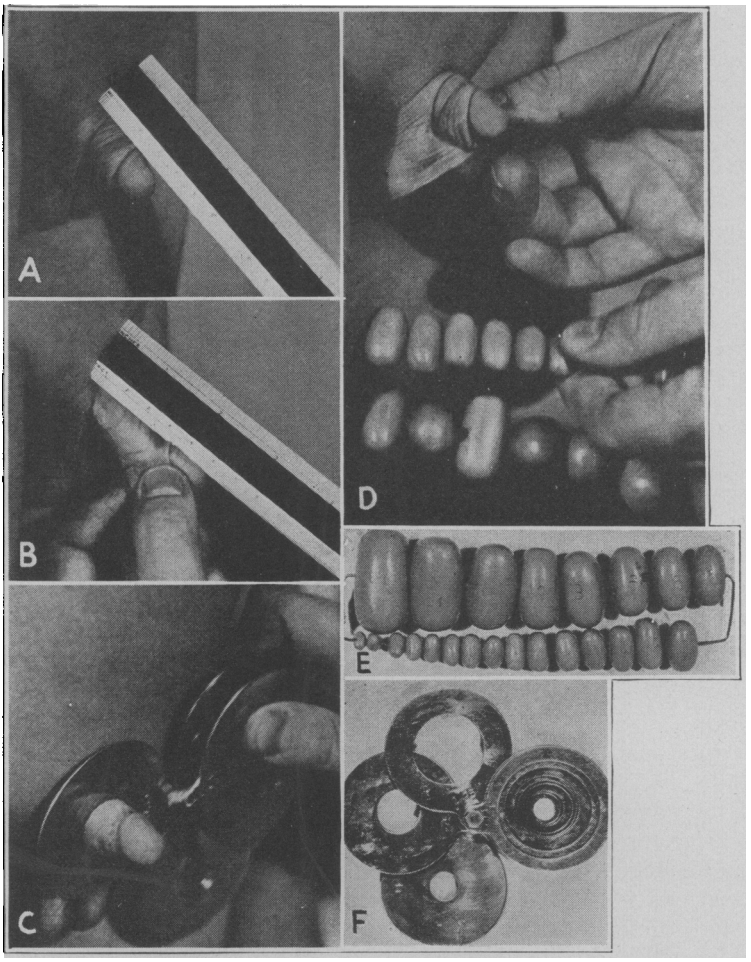

Fig. 3.—Methods of evaluating the genital status. *A*, measurement of length of the relaxed penis; *B*, measurement of length of the stretched penis; *C*, measurement of the circumference; *D*, comparison of a testis with a standard of known volume; *E*, orchidometer; *F*, gage for measurement of circumference.

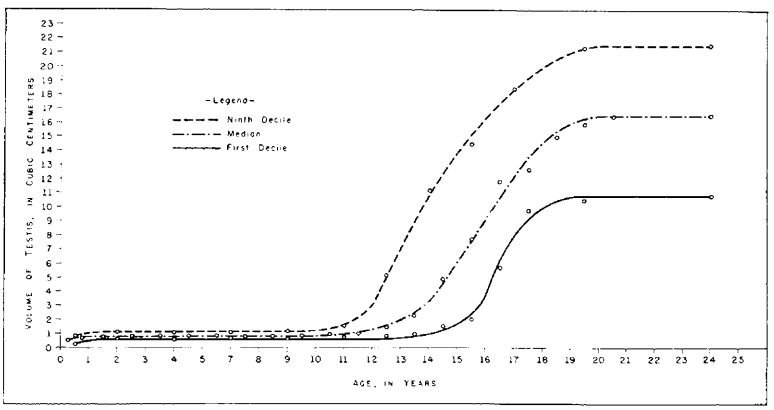

Fig. 4.—Curve for growth of the testis in volume from birth to maturity.

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Through the use of growth curves of the testes or of frequency distribution curves [6] of the various sized testes at each age one may more readily evaluate the genital status of an individual and ascertain whether the volumes of his testicles are within the range of normal for his age.

Penis.—The literature is wholly inadequate as to the normal range of size of the penis, as has been pointed out by Dickinson,[16] who investigated this field thoroughly. The only original measurements on children were published by Zwineff [17] and Kubitschek,[18] and these are inadequate. For adults there are several other references,[19] but the only comprehensive work has been done by Loeb.[20]

There are several references in the literature [21] confirming Piersol's [22] observation that the size of the normal penis is in no way related to the general body build. This is also borne out by our observations on the adolescent boys.

The data accumulated were not adequate to permit any conclusions as to the racial variations in the size of the penis; but one fact that we did ascertain, which was also observed by Dickinson, was that the proportionate lengths of the relaxed flaccid penis and of the erect penis vary in different races.

In a newborn infant the corpus spongiosum urethrae is relatively larger than the corpora cavernosa and continues to grow somewhat in length during the first four or five years of life. During pubescence, accompanying the growth of the testes, there is extensive growth of the corpora cavernosa and of the corpus spongiosum,[23] so that the penis grows not only in length but in girth. Associated with this rapid growth of the penis, the glans becomes turgescent and the long prepuce of infancy frequently recedes.[4a,b]

The penis is primarily an organ of copulation, so that its true physiologic size would be gaged by measurement of the erect phallus. Since it was not feasible to obtain observations on the erect penis on a scale sufficient for this study, my associate and I had to resort to indirect evaluations of these measurements. The dorsal length from the pubopenal skin junction to the tip of the glans was measured with an ordinary centimeter rule, first for the relaxed, flaccid penis (fig. 3 *A*) and then for the fully stretched penis (fig. 3 *B*). Each measurement was taken three times, and the median, or middle, value was recorded. It was soon found that the length of the relaxed flaccid penis varied a great deal as a result of environmental factors and suprapubic obesity and was wholly unreliable as a guide to the genital status [24]; therefore only the length of the fully stretched organ has been extensively studied. In a previous publication [6] it had been ascertained that the length of the fully stretched penis is practically identical with the length of the erect phallus and is thus acceptable as a pertinent measurement.

16. Dickinson, R. L.: Human Sex Anatomy, Baltimore, Williams & Wilkins Company, 1933, pp. 71-84.

17. Zwineff: Die ausseren Geschlechtsorgane der Kinder, Inaug. Dissert., St. Petersburg, 1900; cited by Gundobin.[2b]

18. Kubitschek, P. E.: Sexual Development of Boys with Special Reference to Appearance of Secondary Sexual Characters and Their Relationship to Structural and Personality Types, J. Nerv. & Ment. Dis. **76**:425, 1932.

19. (*a*) Cecil, A. B., in Cabot, H.: Modern Urology in Original Contributions by American Authors, Philadelphia, Lea & Febiger, 1936, vol. 1, p. 115. (*b*) Charpy, A.: Cours de splanchinologie. Organes génito-urinaires, Toulouse, Cassanfils, 1890, p. 344. (*c*) Krause, C. F. T., in Krause, W.: Handbuch der menschlichen Anatomie, Hannover, Hahn, 1876, vol. 2, p. 961. (*d*) Waldeyer, H. W. G.: Das Becken (Topographisch-anatomisch mit besonderer Berücksichtigung der Chirurgie und Gynäkologie dargestellt), Bonn, M. Cohen & Sohn, 1899. (*e*) Testut and Latarjet.[9]

20. Loeb, H.: Harnröhrencapacität und Trippers pritzen, München. med. Wchnschr. **46**: 1016, 1899.

21. Campbell.[11] Dickinson.[16]

22. Piersol, cited by Dickinson.[16]

23. Brack, E.: Anatomische Untersuchungen über den menschlichen Penis, über sein Wachstum und seine Alterserscheinungen, Ztschr. f. urol. Chir. **15**:162, 1924.

24. Schonfeld, W. A.: Management of Male Pubescence, J. A. M. A. **121**:177 (Jan. 16) 1943.

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In evaluating the girth or circumference the same problem arose, to obtain a measurement that would correlate with the circumference of the erect organ. For the purpose of this investigation the circumference of the fully stretched flaccid penis was taken as that of the smallest of a graded series of rings or washers (fig. 3 *C*), which would slip over the glans and shaft with ease. Rings were used rather than a tape to facilitate the determination of this circumference. The rings were 3, 4, 4.5, 5, 6, 7, 8, 9, 10, 12 and 14 cm. in inside circumference (fig. 3 *F*). Again 3 observations were made and the median recorded. The rings were run through in both directions, and their marking is sufficiently unobtrusive to justify the conclusion that the 3 observations were independent in that none was biased by a previous one; and, since the reliability and validity of these measurements have been proved, they may be accepted for statistical analysis. In the previous communication [6] it had been proved that there is a definite correlation between the circumference of the flaccid and erect phallus expressible by a mathematical equation,[25] but practically it was found that the erect penis was about two ring sizes [26] larger than the flaccid penis. Thus, a flaccid stretched penis with a circumference of 5 cm. would be 7 cm. in girth when erect, while a flaccid penis with a circumference of 9 cm. would be about 12 cm. in girth when erect.

The growth curves (figs. 5 and 6) for both the length and the circumference of the fully stretched penis were constructed in the same way as the curves for the testes, on the basis of the cumulative frequency curves of the length and the circumference of the penis for the 1,500 boys and men studied. These curves may be utilized to evaluate the genital status of an individual by comparing the measurements of his penis with that of other normal boys and men of the same age. However, the growth characteristics of the three measurements vary. Although they all show a rapid phase of growth starting at about 10½ or 11 years of age, only the curve for length of the penis shows a period of moderately rapid growth extending from birth to above 5 years of age. This is probably an expression of longitudinal growth of the body rather than a specific genital growth and is due to the growth of the corpus spongiosum urethrae.

Scrotum.—The scrotum of a newborn child is a flaccid, dark red sac with a conspicuous raphe and wrinkled skin covered with a sparse growth of lanugo. This form of scrotum according to Peter [4b] persists until the boy is 7 to 10 months of age, when it becomes less flaccid and the form changes so that the width at the proximal end is greater than at the distal end. There is no further change in the scrotum until the onset of pubescence, when, as a result of the rapid growth of the testes and epididymides, there are a progressive increase in size of the scrotum and distention of the distal portion of the sac to accommodate its contents, so that the proximal end becomes relatively narrower.

We shall not discuss the development of the spermatic ducts, seminal vesicles and ejaculatory ducts,[27] as no attempt was made to evaluate them in this series.

Prostate.—Although the prostate gland is one of the most sensitive indicators as to the presence or absence of androgenic hormone, it is only too rarely examined and evaluated in pubescence. Unfortunately, our data on the development of the prostate are not as thorough as we should like, but such facts as have been accumulated are here presented (fig. 7). During infancy and early childhood no prostate is palpable by rectal examination, but frequently prior to the onset of pubescence or in early pubescence a small, apparently single-lobed structure is

25. Means for the value of the circumference of the erect penis corresponding to those for the circumference of the stretched penis of 5, 6, 7, 8, 9 and 10 cm. are well approximated if the latter values are multiplied by 1.36, 1.28, 1.34, 1.37, 1.30 and 1.30 respectively. For the entire range this ratio is 1.34.

26. Ring sizes are 3, 4, 4.5, 5, 6, 7, 8, 9, 10, 12 and 14 cm.

27. Fischer, A. W.: Nebenhoden, Samenwege, Prostata, akzessorische Geschlechtsdrüsen, in Hirsch, M.: Handbuch der inneren Sekretion, Leipzig, Curt Kabitzsch, 1927, vol. 1, pt. 2 Peter.[4b]

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palpable at the neck of the bladder. It is a spherical body with its width greater than its length. With the advent of pubescence the monolobar organ increases progressively in size as a result of enlargement of the five undifferentiated lobes; but at puberty, because of relatively greater enlargement of the two lateral lobes, a groove appears between them, over which the posterior lobe fits like a thin cap but does not prevent a median furrow from becoming palpable per rectum. The

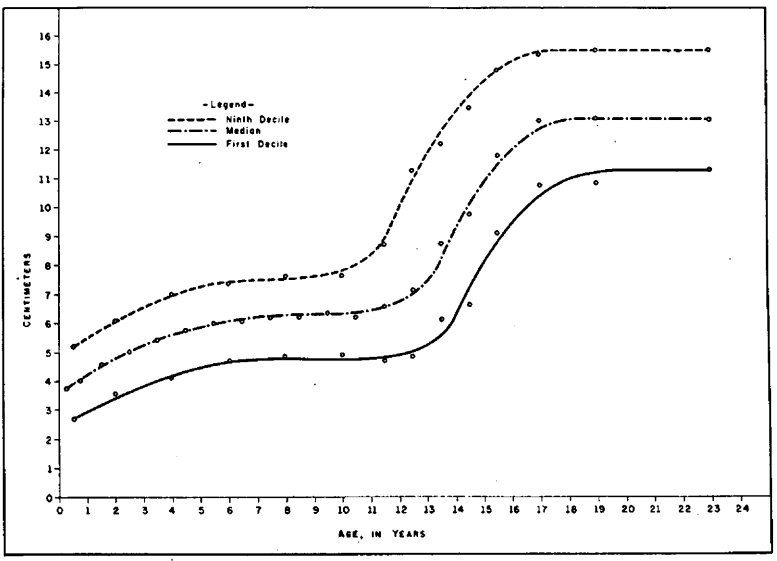

Fig. 5.—Curve for growth of the penis in length from birth to maturity.

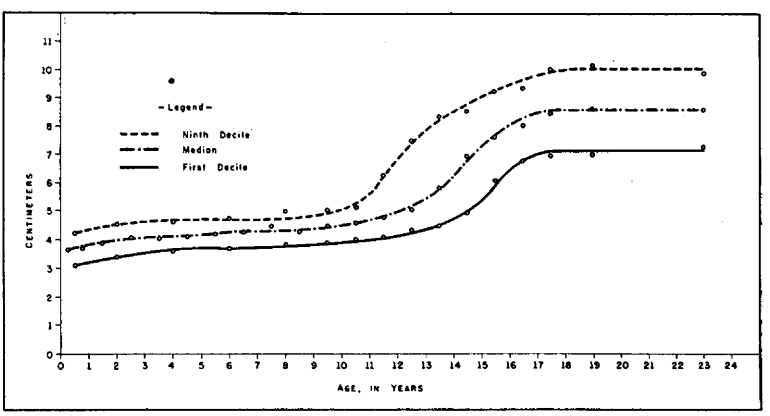

Fig. 6.—Curve for growth of the penis in circumference from birth to maturity.

anterior lobe at the same time shrinks into insignificance, while the middle lobe takes part in the general increase in size.[28] A short time after this a secretion may be massaged out of the prostate. The microscopic constituents [29] of the earliest prostatic secretion are being studied at the time of writing this report.

28. Lowsley, O. S.: (*a*) Personal communication to the author; (*b*) The Prostate Gland, in Oxford Loose Leaf Surgery, New York, Thos. Nelson & Sons, 1935, vol. 3, pt. 746; (*c*) Human Prostate in Youth, M. Rec. **88**:383, 1915; (*d*) Development of Human Prostate, Am. J. Anat. **13**:299, 1912.

29. Röhlich, K.: Ueber die Prostatasekretion, Ztschr. f. mikr.-anat. Forsch. **43**:451, 1938.

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Lowsley,[28] Moore [30] and others [31] have made detailed histologic studies of the prostate in children of all ages and have shown that in newborn infants the prostate has reached a high stage of development and progresses further in the next four to seven days probably as a result of androgenic stimulation from the interstitial cells of the child's own testes, which have developed in response to the chorionic gonadotropins reaching the fetal circulation. In the next four to six weeks the hyperplastic acini involute and are maintained in this state of quiescence until the advent of pubescence, when the testes again produce androgenic hormones and the prostatic acini again become hyperplastic and the lobes develop as previously indicated. The prostate obviously could not be accurately measured in this series, but

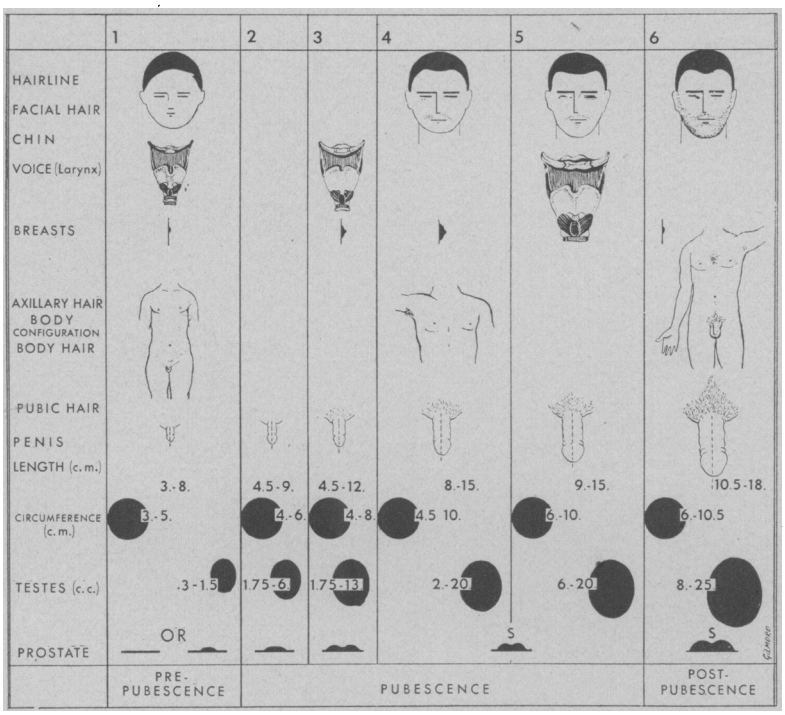

Fig. 7.—Stages of sexual development and maturation.

according to Scammon [1] and other observers [32] its weight curve corresponds to the growth curve of the genitalia.

Sex Hormones.—The hormone content of the blood and urine of children has been studied by numerous investigators,[33] but unfortunately the available technics

30. Moore, R. A.: (*a*) The Histology of the Newborn and Prepuberal Prostate Gland, Anat. Rec. **66**:1, 1936; (*b*) Evolution and Involution of the Prostate Gland, Am. J. Path. **12**:599, 1936.

31. (*a*) Van Duzen, R. E.; Looney, W. W., and Duncan, C. N.: Development of Prostate, J. Urol. **41**:473, 1939. (*b*) Geissendörfer, R.: Prostata, Leipzig, Johann Ambrosius Barth, 1940. (*c*) Ljachowski: Ueber die Veränderungen der Prostata im Kindesalter, Inaug. Dissert., St. Petersburg, 1903; cited by Gundobin.[2b] (*d*) Peter.[4b]

32. Thompson, T., in Holmes, T., and Hulke, J. W.: A System of Surgery, Theoretical and Practical, ed. 3, New York, William Wood & Co., 1883, vol. 3, p. 284. Peter.[4b]

33. Oesting, R. B., and Webster, B.: Sex Hormone Excretion of Children, Endocrinology **22**:307, 1938.

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are not sufficiently accurate to yield conclusive data. Since no assays of hormones were done on our subjects, we shall present Nathanson, Towne and Aub's data.[34]

Gonadotropic (follicle-stimulating) hormone was not found in the urine of the subjects they studied until 13 years of age, just preceding the onset of puberty. However, it probably had been present throughout pubescence but merely could not be determined by the analytic methods used. The androgens and estrogens were assayed by Oesting's colorimetric determination of 17-keto steroids and the Allen-Doisy method respectively. The results obtained by Nathanson, Towne and Aub are graphically illustrated in figure 8. These sex hormones, which are present in about equal amounts in girls and boys until just before the onset of pubescence, probably originate, according to the authors, from the adrenal cortex, but with the advent of pubescence the androgens rapidly increase in the male, paralleling the maturation of the testes. It has been our experience that the amounts of androgens

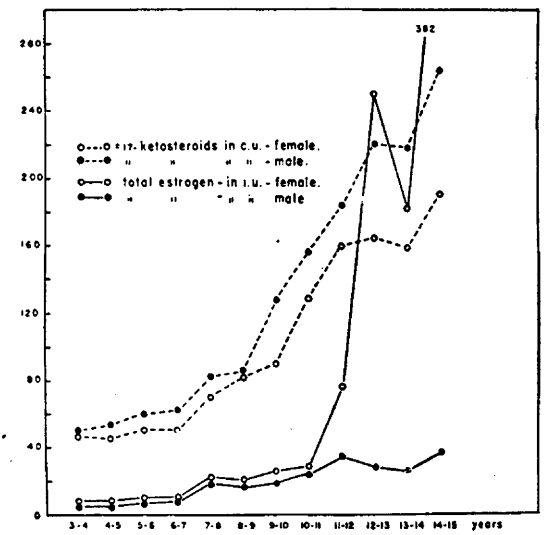

Fig. 8.—Excretion of 17-keto steroids and estrogens in prepubescence and pubescence (from Nathanson, Towne and Aub).[34]

and estrogens excreted are more closely correlated with physiologic development than with chronologic age.

Growth.—Associated with the rapid growth and development of the testes and penis of a pubescent boy there are extragenital evidences of maturity. Growth of children and pubescents has been studied in great detail by many observers; hence no attempt will be made to analyze our data as to correlation of the height and weight with pubescence.[35] It will suffice to state that about 20 per cent of the late prepubescent and early pubescent boys in this series of subjects were from 15 per cent to 50 per cent above median weight for their age. The obesity of all of these subjects was associated with normal genitalia, and many of the boys were taller than other boys of the same age.[36] It has been our observation that prepubertal

34. Nathanson, I. T.; Towne, L. E., and Aub, S. C.: Normal Excretion of Sex Hormones in Childhood, Endocrinology **28**:851, 1941.

35. Dimock, H. S.: A Research in Adolescence: Pubescence and Physical Growth, Child Development **6**:177, 1935. Greulich and others.[4a] Peter.[4b] Shuttleworth.[13c]

36. Bruch, H.: Obesity in Relation to Puberty, J. Pediat. **19**:365, 1941.

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obesity [37] is a normal phenomenon in pyknic [38] or endomorphic [39] constitutional types. It is probably caused by the pronounced increase in caloric intake as a result of the ravenous appetite which so frequently develops in pubescence along with a tendency toward obesity because of the somatotype and at times because of psychogenic factors [40] with reduced exercise. Webster, Harrington and Wright [41] observed a lowered metabolic rate at this age, while others have found that during the rapid phase of development the metabolism is increased.[42] With the advent of puberty most of the boys grow taller and slimmer,[43] although Sheldon [39] has found that they maintain their characteristic biotype.

SECONDARY SEXUAL CHARACTERISTICS

(Fig. 7)

Hair Development.—The degree of development of hair is an important factor in the evaluation of the genital status even though there is a wide variation among individuals, families and races.[44] The pubic region is usually the first site where terminal hair becomes evident.[45] The first step is darkening of the villous hair at the base of the penis; the second is the extension of this growth of hair laterally toward the inguinal region, and the third is the growth upward to cover the mons pubis and adjacent portions of the lower abdominal wall in the distribution pattern of female pubic hair. In the final stage the hair extends up to the umbilicus, forming the typical male escutcheon.[46]

Axillary hair usually begins to develop after the pubic hair has passed its second stage of development, and then it becomes progressively denser. At about the

37. (*a*) Hanssen, P.: Obesity During Growth: Clinical Study, Acta med. Scandinav. **91**:435 1937. (*b*) Kornfeld, W., and Schuller, H.: Ueber Durchschnittswerte und Bewertungsgrundlagen einiger Weichteilmasse bei Kindern verschiedener Altersstufen, Ztschr. f. Kinderh. **49**:277, 1930. (*c*) Ssergeew, V. I.: Dynamick der Körperentwicklung der Jünglinge, Ztschr. f. menschl. Vererb.- u. Konstitutionslehre **19**:522, 1935.

38. Kretschmer, E.: Physique and Character, New York, Harcourt, Brace & Company, 1925.

39. Sheldon, W. H.; Stevens, S. S., and Tucker, W. B.: The Varieties of Human Physique, New York, Harper & Brothers, 1940.

40. Bruch, H., and Touraine, G.: Obesity in Childhood: The Family Frame of Obese Children, Psychosom. Med. **2**:141, 1940.

41. Webster, B.; Harrington, H., and Wright, L. M.: Standard Metabolism of Adolescence, J. Pediat. **19**:347, 1941.

42. (*a*) Nakagawa, I.: Growth and Basal Metabolism of Normal Children, Am. J. Dis. Child. **53**:991 (April) 1937. (*b*) Topper, A., and Mulier, H.: Basal Metabolsim of Normal Children; Puberty Reaction, Am. J. Dis. Child. **43**:327 (Feb.) 1932.

43. (*a*) Rosenstern, J.: Ueber die körperliche Entwicklung in der Pubertät, Ergebn. d. inn. Med. u. Kinderh. **41**:789, 1931; (*b*) Ueber die körperliche Entwicklung in der Pubertät (auf Grund von Individualuntersuchungen), Ztschr. f. Kinderh. **50**:1, 1930. (*c*) Kornfeld, W.: Ueber die Habitusentwicklung in der Pubertätszeit, Wien. klin. Wchnschr. **50**:1610, 1933. (*d*) Neurath, R.: Die Pubertät, Vienna, Julius Springer, 1932. (*e*) Schlesinger, E.: Habitus und Körperkraft bei Kindern und Jugendlichen (Ein Beitrag zum Konstitutionsproblem), Ztschr. f. Kinderh. **49**:159, 1930. (*f*) Todd, T. W.: Physical Analysis in the Adolescent Problem, Am. J. Dis. Child. **43**:533 (March) 1932. (*g*) Nobecourt, P.: Obésité et puberté, Presse méd. **46**:449, 1938.

44. Risak, E.: Ueber die verschiedenen Arten der männlichen Genitalbehaarung, Ztschr. f. d. ges. Anat. (pt. 2) **15**:164, 1930.

45. Crampton.[13d] Greulich and others.[44a]

46. (*a*) Barth, E.: Einführung in die Physiologie, Pathologie und Hygiene der menschlichen Stimme, Leipzig, G. Thieme, 1911. (*b*) Marshall, F. H. A.: Physiology of Reproduction, ed. 2, London, Longmans, Green & Co., 1922, p. 713. (*c*) Scheidt, W.: Somatoskopische und somatometrische Untersuchungen an Knaben des Pubeszenzalters, Ztschr. f. Kinderforsch. **28**:71, 1923. (*d*) Risak.[44]

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same time the villous hair on the upper lip darkens and terminal hair begins to grow just inside the corners of the mouth; it gradually spreads toward the midline, with the hair becoming coarser as the process proceeds. Hair on the chin and on the sides of the face begins to grow shortly after this but usually does not become fully developed as a beard until well on in adolescence. The body and perineal hair develops long before the completion of growth of facial hair but may not reach its full development until much later.[48a, b]

One of the last secondary sex characteristics to develop is the change in hair line over the forehead, as first described by Stein.[47] The uninterrupted bowlike curve noted on immature children of both sexes changes on adolescent boys to the form found on normal men, whose curved hair line is interrupted by two wedge-shaped indentations, one over each lateral frontal region (fig. 7).

The Breast.—Although changes in the breast probably occur in nearly all boys during some stage of pubescence, they are of clinical significance in only a limited number.[48] In these boys they vary in degree from a small, painless subareolar nodule or hyperplasia of the normal mammary gland to pronounced enlargement with pain and even the presence of a colostrum-like secretion. The swelling is due to pericanalicular and periacinous infiltration with connective tissue together with epithelial hyperplasia but no true inflammatory process.

The nodules may be unilateral or bilateral. They begin to grow at varying stages of pubescence and adolescence and take varying periods of time to develop and recede. They are of no special significance unless they persist as a true gynecomastia after the genitalia have fully developed. The hyperplasia in pubescent boys is no different from that which is found in about two thirds of newborn babies.[49] In the latter it is due to the maternal and placental hormones, while in pubescent boys it is due to their own pituitary and sex hormones, the exact mechanism not being known.[50]

The Voice.—The larynx of a newborn infant is relatively large, being about one third the size of that of an adult, and in contour it is more rounded. The organ continues to grow until the third year, when a resting period begins, lasting until the onset of pubescence, during which time there seems to be no sexual distinction. During pubescence there is a rapid growth of the larynx in boys, with an associated change in its form.[51] The laryngeal cavity is enlarged and the ventrodorsal diameter considerably increased. The whole framework becomes stronger. The thyroid cartilage especially increases greatly in its dimensions, giving rise to the laryngeal prominence. The vocal folds are lengthened and thickened, the voice changing in quality and dropping about one octave in pitch.[52] These changes are for the most part effected between 14 and 18 years of age,[53] the first sign being

47. Stein, R. O.: Untersuchungen über die Ursache der Glatze, Wien. klin. Wchnschr. **1**:6, 1924.

48. Brack, E.: Ueber histologische Erscheinungen an der Mamma, speziell an den Mamillen, in der verschiedenen Lebensaltern, Arch. f. Gynäk. **122**:711, 1924. Jung, F. T., and Shafton, A. L.: Mammary Gland in the Normal Adolescent Male, Proc. Soc. Exper. Biol. & Med. **33**:455, 1935; Mastitis, Mazoplasia, Mastalgia and Gynecomastia in Normal Adolescent Males, Illinois M. J. **73**:115, 1938.

49. Lyons, W. R.: Hormonal Basis for "Witches' Milk," Proc. Soc. Exper. Biol. & Med. **37**:207, 1937.

50. Preissecker, E.: Hormonal bedingte Brustdrüsenschwellung in der Präpubertät, Zentralbl. f. Gynäk. **61**:1421, 1937.

51. Footnotes 4 *a*, 4 *b* and 46.

52. Curry, E. T.: Pitch characteristics of the Adolescent Male Voice, Speech Monog. **7**:48, 1940.

53. Fujita, T.: Medizinische Studie über den Stimmwechsel (Mutation) bei Schülern, Fukuoka acta med. **28**:105, 1935.

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a break in the voice about midpubescence, the result according to Froeschels [54] of imbalance of the small cricothyroid and the larger thyrohyoid muscles.

Correlation of Primary and Secondary Sexual Characteristics (fig. 9).—Having observed in normal boys and men from birth to 25 years of age the size of the testes and penis as well as the state of development of the prostate and seminal vesicles and the degree of maturation of the secondary sexual characteristics, we have attempted to correlate these factors.[55] The boys were arbitrarily subdivided into six groups according to their genital status. In the first group were included all the prepubescent boys without any evidence of active genital growth or of

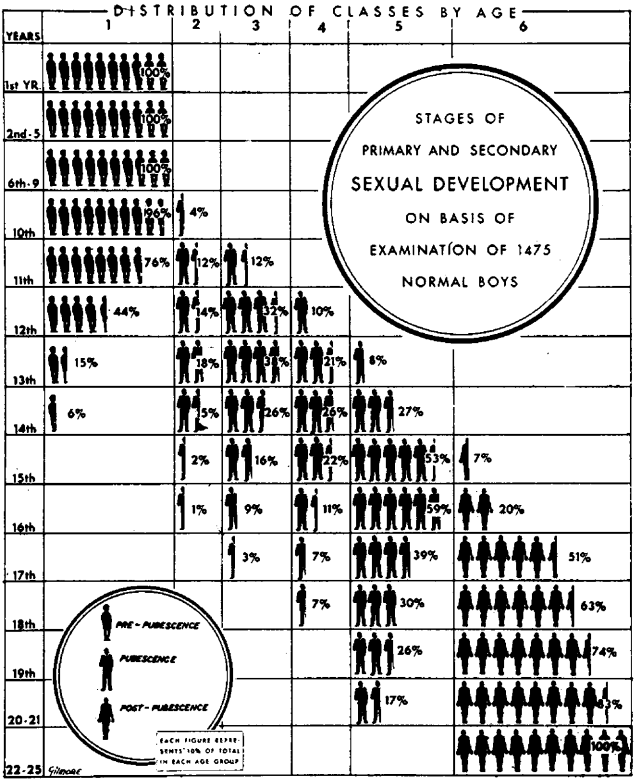

Fig. 9.—Age distribution of the various stages of primary and secondary sexual development.

secondary sexual characteristics. In the sixth group were included all the fully matured subjects, while in the second, third, fourth and fifth groups were included all the boys in the phase of pubescence. The qualifying criterion for the second stage is the beginning of active growth of the testes with some growth of penis but no pubic hair as yet. The third, fourth and fifth groups include respectively the three intervening stages of development of pubic hair with the associated enlargement of genitalia, as illustrated in figure 8.

54. Froeschels, E.: (*a*) Ueber Sprach- und Stimmstörungen der Pubertät, Fortschr. d. Med. **51**:935, 1933; (*b*) personal communications to the authors.

55. Laroche, G., and others: La puberté: Étude clinique et physiopathologique, Paris, Masson & Cie, 1938. Crampton.[13d] Kubitschek.[18]

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With this classification as a basis the subjects were subdivided according to genital status at each age and the frequency distribution plotted in figure 9. This chart illustrates the variations in biologic maturity at each age, an important consideration to bear in mind in judging whether the genital status of a subject is within normal limits, because knowing the average median [56] age of onset of pubescence is of no aid in the management of the individual,[24] from the physical, the endocrinologic or the psychiatric viewpoint.

SUMMARY

A method of measuring the size of the penis and testes is described which was found to be both clinically and statistically reliable and valid. The measurements taken were the length and circumference of the fully stretched flaccid penis and the volume of each testis. The length of the penis was measured on the dorsal surface with an ordinary centimeter ruler and its circumference with a special set of gages. The volume of the testes was determined by comparing them with standard models of known volume.

Fifteen hundred normal boys and men varying in age from 1 day to 25 years were studied as to range of size of the penis and testes, size and shape of the prostate and extent of maturation of the secondary sexual characteristics; these variables were all correlated with chronologic age.

The measurements of the penis and testes are graphically presented, showing the trend of growth. During the first two years, there is only slight growth of the testes and increase in the circumference of the penis, while the length of the penis continues to grow until about 4 or 5 years of age. After this initial slight growth there is no appreciable change throughout prepubescence until the onset of pubescence, when there is a rapid spurt reaching its maximum during the postpubescent period. The variation as to the age at the pubescent spurt and the rapidity of its development is so great that there is a wide range of normal between 10 and 18 years of age. The actual measurements and their percentile distributions are charted.

The secondary sexual characteristics have been correlated with the size of the testes and penis and graphically presented by subdividing biologic maturity into six arbitrary subdivisions. The age distribution of each of these groups was also studied.

The following persons cooperated in this study: Drs. Earl T. Engle, Robert F. Loeb, Donovan J. McCune, Rustin McIntosh, Irving H. Pardee and A. Ashley Weech, of Columbia-Presbyterian Medical Center; Drs. Robert T. Frank and Béla Schick, of Mount Sinai Hospital; Dr. Louis H. Barenberg and Mrs. Alice Turck, of the social service staff of Morrisania City Hospital, and Dr. Robert L. Dickinson and the professional staff of the Schering Corporation.

171 Echo Place, New York.

56. Median, 13.17 years of age; first decile, 11.22 years of age; ninth decile, 14.76 years of age.

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