THE RATE OF GROWTH AND MATURING OF TWINS*

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In the years 1966-1976, 50 pairs of Warsaw twins (27 MZ and 23 DZ) were subjected to longitudinal investigations. The twins were aged 9-11 years at the beginning of the observations, and 19-22 at their conclusion. The observations consisted of comprehensive somatic measurements and of the evaluation of biological maturity. The rate of growth of the twins, defined by the magnitude of yearly increments of body height, proved to be more concordant in MZ than DZ pairs. The appearance of the adolescent spurt occurred in the same year in 81% of MZ and ca. 43% of DZ pairs. A very slight relationship was found between the rate of growth and final body height. The attaining of subsequent stages of sexual maturity in MZ twins was concordant in 88%, and in DZ twins in 30-39%, according to the respective stage. The body height curves were represented be means of three numerical parameters.

INTRODUCTION

In specialist literature we may find a great amount of information on the genetic conditioning of man's level of somatic development. Morphological investigations have a rich tradition and a great amount of knowledge has been collected in this field. Most often, however, the authors based their conclusions on the results of cross-sectional observations of MZ and DZ twins. Hence, their observations are restricted to finding out the within-pair differentiation, as present at the time of the investigation, in individuals with identical and differing genotypes. In order to better elucidate developmental processes, in particular such phenomena as the rate of growth and maturing, longitudinal observations should be organized. There are not too many investigations of this kind. In the literature, we find descriptions of longitudinal observations carried out on single cases of triplets, single pairs of MZ and DZ twins, however, with a limited time of observation. It was a fundamental purpose of the longitudinal investigations we undertook on twins to throw more light on the rate of growth and maturing of twins in the period preceding the maturing, in puberty and in the final phase of growth.

MATERIAL AND METHOD

In the years 1966-1976 we embraced, by longitudinal investigations, a series of Warsaw twins of 50 pairs, including 15 pairs of MZ boys, 12 pairs of MZ girls, 11 pairs of DZ boys and 12 pairs of DZ girls.
At the time of the beginning of observations the twins were 9 to 11 years old, and at the time of the conclusion of the research they were 19 to 22 years old. The observations consisted of comprehensive anthropometric measurements, the assessment of biological maturity, as well as of observations on motorics. The investigations were carried out at yearly intervals in the spring. The zygosity of the twins was checked

by means of morphological examinations, blood group analyses and dermatoglyphics. Complete observations in 49 pairs include a nine-year period of investigations, from age 11 to 19 years.

In the elaboration of the results, variance analysis and correlations, as well as heredity indices (h^2) based on variances and correlations, were applied.

The height curves were analyzed using the method proposed and described by Szczotka (1971). This method enables to apply the parametrization of empirical curves, i.e., their characterization by means of appropriate numbers. This is very valuable, particularly when a series of measurements is involved describing changes of a trait in the course of time.

The idea of the method consists in the representation of the empirical curve of results approximately as a linear combination of a few component functions, the same for all individuals of the group under investigation, marked by $f_1(t), f_2(t), f_3(t)$, ..., and defined for every individual empirical curve of the parameters z_1, z_2, z_3 ... .

These parameters are standardized for the mean zero and dispersion one. They are mutually uncorrelated. In practice we are satisfied with such a number of functions $fk(t)$ which approximate the resultant curves with sufficient precision.

The above method enables to substitute the statistical investigations of the series of resultant curves by examining a few uncorrelated parameters.

In the problem under investigation it was enough to settle for three component functions, that is, also for three parameters.

The parameter z_1, connected with function $f_1(t)$, characterizes the general level of development of body height. The positive values of the parameter show the high situation of the individual curve, and the negative ones its low position on the background of the group.

The parameter z_2, connected with function $f_2(t)$, mainly informs on the rate of growth. Persons with a positive z_2 began with low initial results and improved them rapidly. Persons with negative z_2 have high initial values and a small increment of these values in the process of growth.

The parameter z_3 is in connection with function $f_3(t)$ and characterizes above all the shaping of results in the final stage of development. In persons with high positive values of this parameter, the results rapidly increase towards the end of development, and afterwards a decrease of the increments follows as rapidly. Thus, the process of final growth ends early and on a level below the average one. In persons with a negative value of this parameter, the results towards the end of the development initially increase at a slow rate, and then an acceleration of their growth is noted. As a final result, the individual attains a level higher than the average one.

RESULTS AND DISCUSSION

The rates of growth of MZ cotwins are more similar. This is evidenced by the magnitude of variances for differences in yearly increments of body height. In MZ pairs the variances are several times smaller than in DZ pairs. Particularly high differences in the values of variances between the two groups of individuals could be noted in the period of rapid growth of the twins, i.e., between 12 and 15 years, when the maximal increment of body height called adolescent spurt appears (Table 1). For DZ twins, only in 10 of the 23

Table 1. *Body height increments in twins: Variance and heritability*

	Age:	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19
MZ pairs (N = 26)	S^2	0.6530	0.4182	0.5450	0.4302	0.4563	0.1542	0.0865	0.0473
DZ pairs (N = 23)	S^2	0.9672	3.2256	2.6456	0.8580	0.9911	0.4626	0.1474	0.1163
	h^2	0.325	0.870	0.794	0.500	0.540	0.667	0.413	0.593

pairs, that is, in scarcely 43% of pairs, the adolescent spurt occurred in the same year. In the remaining 57% of pairs, we noted differences in the appearance of maximal increment amounting to one and two years. In MZ pairs, however, a temporal concordance of the phenomenon under discussion was found in 81% of pairs (Table 2). The high similarity within MZ pairs was shown also within the range of the same magnitude of the adolescent spurt (Table 3).

The present results are in agreement with those of previous authors (Stenborg 1938, Zeller 1940, Reynolds und Schoen 1947, Garn 1961, Tanner 1963), based on longitudinal observations of single pairs of MZ and DZ pairs of twins, as well as on single cases of triplets. Different results were, however, obtained by Vandenberg and Falkner (1965) on a sample of 29 MZ and 31 DZ pairs, followed from birth to the age of four years: they found no statistically significant differences in the variances within MZ and DZ pairs.

The rate of growth of a child and the time at which the adolescent spurt appears are closely connected with the rate of maturing, among the external symptoms of which are the secondary sexual characters. In MZ pairs, higher concordance was also found in respect to the development of pubic hair, and also of genitals in boys and of mammary glands in girls. The successive stages of sexual maturity, rated according to Tanner (1963), were reached by 88% of pairs at the same time. In DZ pairs, concordance in this respect was noted in hardly 30-39% of pairs, and it was highest in stages II and V (Table 4). In girls, the age at me-

Table 2. *Time interval in the appearance of the adolescent spurt in cotwins*

Interval (in years)	MZ pairs		DZ pairs	
	N	%	N	%
0	21	80.77	10	43.48
1	4	15.38	10	43.48
2	1	3.85	3	13.04
Total	26	100.00	23	100.00

Table 3. *Magnitude of the adolescent spurt in twins: Variance and heritability*

	S^2	h^2
MZ pairs (N = 26)	0.1429	
		0.825
DZ pairs (N = 23)	0.8180	

Table 4. *Sexual maturity stages: Concordance or time interval in appearance in cotwins*

		Stage II		Stage III		Stage IV		Stage V	
		N	%	N	%	N	%	N	%
DZ pairs (N = 23)	Concordant	8	34.78	7	30.43	7	30.43	9	39.13
	Discordant	15	65.22	16	69.57	16	69.57	14	60.87
	time interval:								
	1 year	12		11		10		11	
	2 years	1		4		6		3	
	3 years	2		1		—		—	
MZ pairs (N = 27)	Concordant	24	88.89	24	88.89	24	88.89	24	88.89
	Discordant	3	11.11	3	11.11	3	11.11	3	11.11
	time interval:								
	1 year	2		2		3		3	
	2 years	1		1		—		—	

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narche was calculated additionally.   This calculation confirmed the greater similarity in maturing of MZ twins (Table 5).

The observations on the hereditary conditioning of growth rate, assessed by the magnitudes of annual body height increments, are entirely confirmed by the results obtained through the complex evaluation of body height curves accomplished by means of mathematical functions. As we mentioned, these curves were characterized by three numerical parameters. For these parameters, correlations within MZ and DZ pairs were calculated. For parameter z_1, defining the general level of the body height development, for parameter z_2, informing on the rate of growth of children, and for parameter z_3, assessing the conclusion of growth, higher correlation values were found in MZ than DZ twin pairs (Table 6). Par-

Table 5. *Age at menarche in cotwins:*
Variance and heritability

	S^2	h^2
MZ pairs (N = 11)	0.0865	
		0.817
DZ pairs (N = 12)	0.4716	

Table 6. *Within-pairs correlation indices*
in the range of numerical parameters

	Z_1	Z_2	Z_3
MZ pairs (N = 26)	0.948	0.902	0.851
DZ pairs (N = 23)	0.843	0.830	0.531
h^2	0.669	0.735	0.682

Table 7. *Correlation between*
numerical parameters and final
body height (N = 98 subjects)

Numerical parameters	Final body height
Z_1	0.932
Z_2	0.349
Z_3	0.057

ticularly great differences for correlation values between the two groups of twins were found in the parameter defining the rate of growth.

We also calculated the correlations between numerical parameters and the body height attained at the age of 19 years, that is, the height which we may consider to be nearly final. It was found that the developmental level of a child between 11 and 19 years is closely correlated with the final body height. It may therefore be assumed that children who were tall in the earlier periods of ontogenesis will also be tall when their development is completed.

Our most interesting result should, however, be considered the finding of small relationships between the rate of growth of children and their final body height. This is pointed out by the low correlation values between parameters z_2 and z_3, respectively defining the rate of growth in the whole period under investigation and the rate of growth in the final stage of development, and the body height of twins at the age of 19 years (Table 7).

This result would imply that the rate of growth and the adult body height are controlled by distinct genetic mechanisms.

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Vandenberg S.G., Falkner F. 1965. Hereditary factors in human growth. Hum. Biol., 37: 357.

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RIASSUNTO

Il Ritmo d'Accrescimento e Maturazione in Gemelli

Nel decennio fra il 1966 e 1976, 50 coppie di gemelli (27 MZ e 23 DZ) della città di Varsavia sono stati oggetto di un'indagine longitudinale. I gemelli avevano 9-11 anni all'inizio dello studio e 19-22 alla fine. Le osservazioni comprendevano estese misurazioni somatiche e una valutazione della maturazione biologica. Il ritmo di accrescimento, definito in base all'ampiezza degli incrementi annuali in altezza, è risultato più concordante fra gemelli MZ rispetto ai DZ. La spinta puberale si è verificata nello stesso anno nell'81 % delle coppie MZ, ma solo nel 43 % di quelle DZ. Il rapporto fra ritmo di crescita e altezza finale è risultato molto lieve. Il raggiungimento dei vari stadi di maturazione sessuale è risultato concordante nell'88 % delle coppie MZ, ma solo nel 30-39 % di quelle DZ.

RÉSUMÉ

Le Rythme de Croissance et de Maturation chez les Jumeaux

Entre 1966 et 1976, 50 couples de jumeaux (27 MZ et 23 DZ) de la ville de Varsovie ont été l'objet d'une étude longitudinale. Les jumeaux avaient 9-11 ans au début de l'étude et 19-22 à la fin. Les observations comprenaient des mensurations somatiques ainsi qu'une évaluation de la maturation biologique. Le rythme de croissance, défini sur la base des augmentations annuelles de la taille, était plus concordant entre jumeaux MZ par rapport aux DZ. La poussée pubertaire eût lieu dans la même année dans 31 % des partenaires MZ par rapport à 43 % chez les DZ. Le rapport entre rythme de croissance et taille finale est très faible. Les différentes étapes de la maturation sexuelle ont été atteintes en même temps dans 88 % des partenaires MZ par rapport à 30-39 % chez les DZ.

ZUSAMMENFASSUNG

Wachstums- und Reifungsrhythmus bei Zwillingen

In der Zeitspanne zwischen 1966 und 1976 wurde in Warschau bei 50 Zwillingspaaren (27 EZ und 23 ZZ), die zu Beginn der Untersuchung 9-11 und am Ende derselben 19-22 Jahre alt waren, eine Längsschnittuntersuchung vorgenommen, die zahlreiche Körpermessungen sowie eine Beurteilung der biologischen Reifung umfaßte. Aufgrund der jährlichen Größenzunahme wurde der Wachstumsrhythmus festgestellt, der bei EZ eine höhere Konkordanz aufwies als bei ZZ. Der Pubertäts-« Sprung » erfolgte bei 81 % der EZ aber nur bei 43 % der ZZ im gleichen Jahr. Das Verhältnis zwischen Wachstumsrhythmus und definitiver Körpergröße erschien geringfügig. Die verschiedenen Stadien der Geschlechtsreife wurden von 88 % der EZ aber nur von 30-39 % der ZZ gleichzeitig erreicht.

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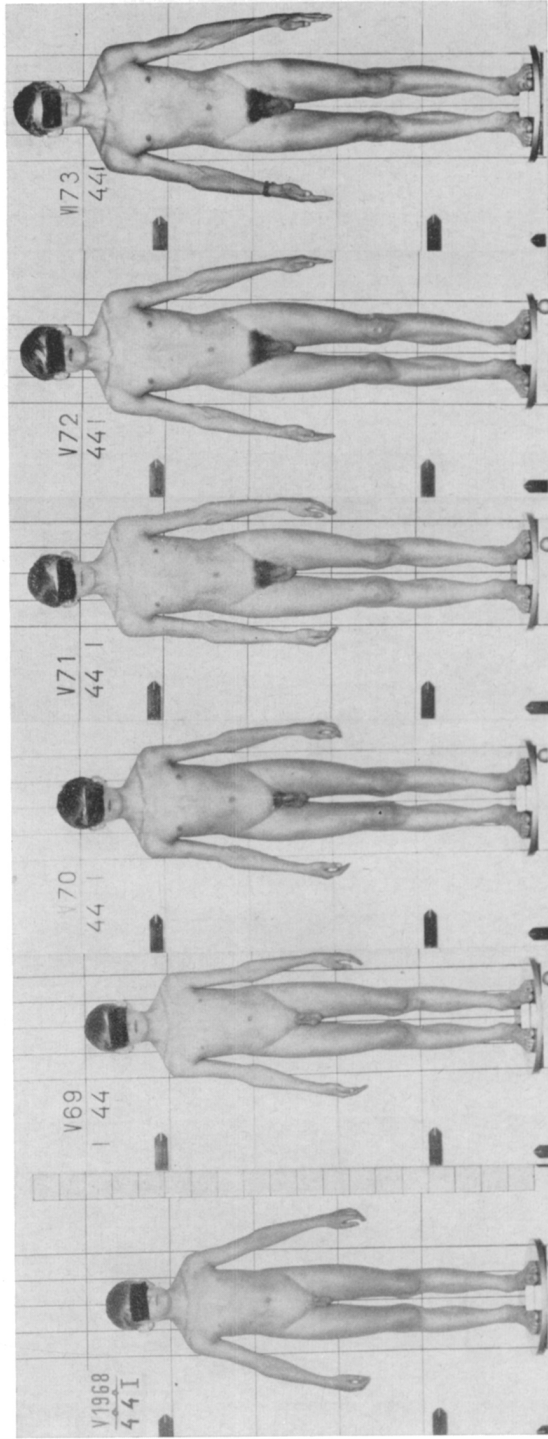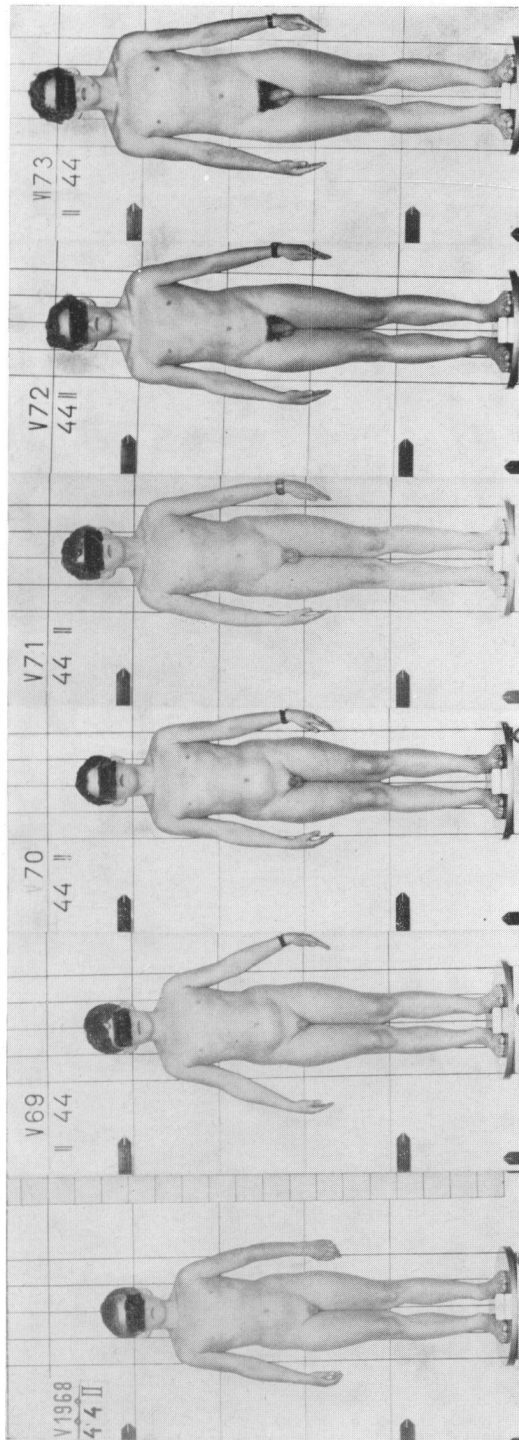PLATE 1. Sexual Maturity in Male MZ Twins.
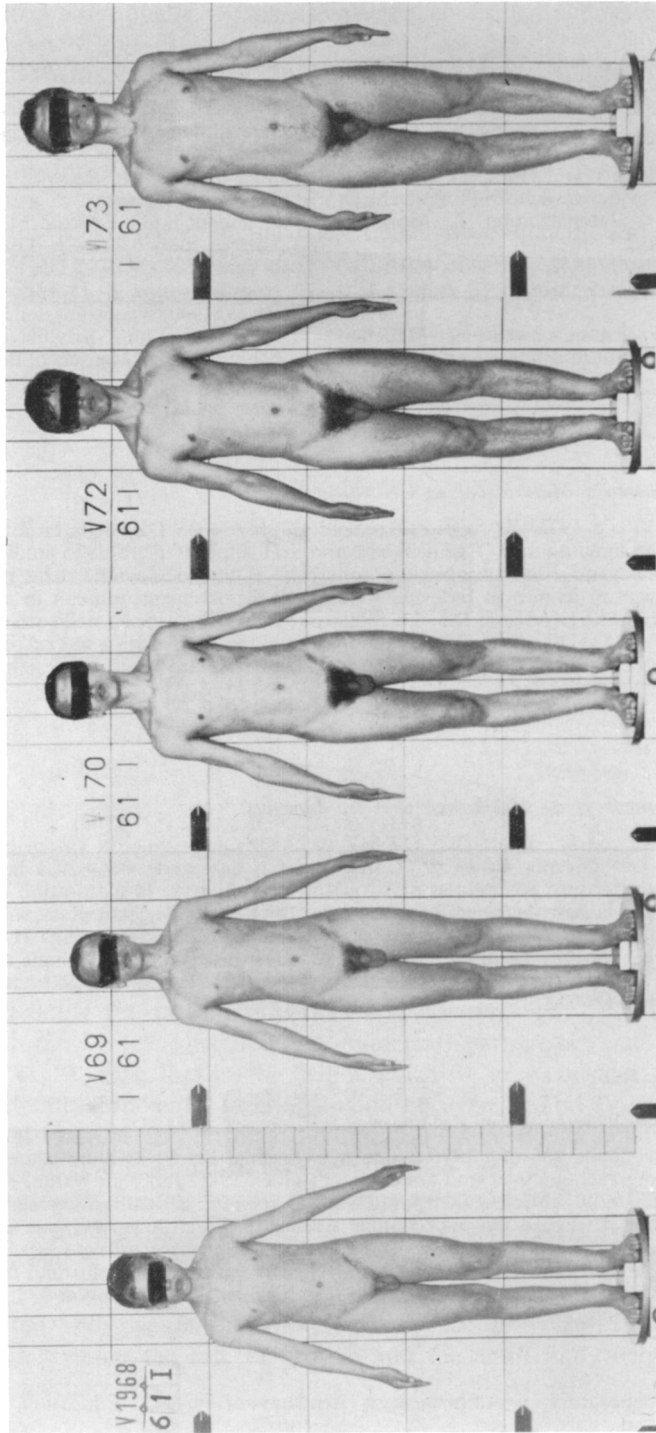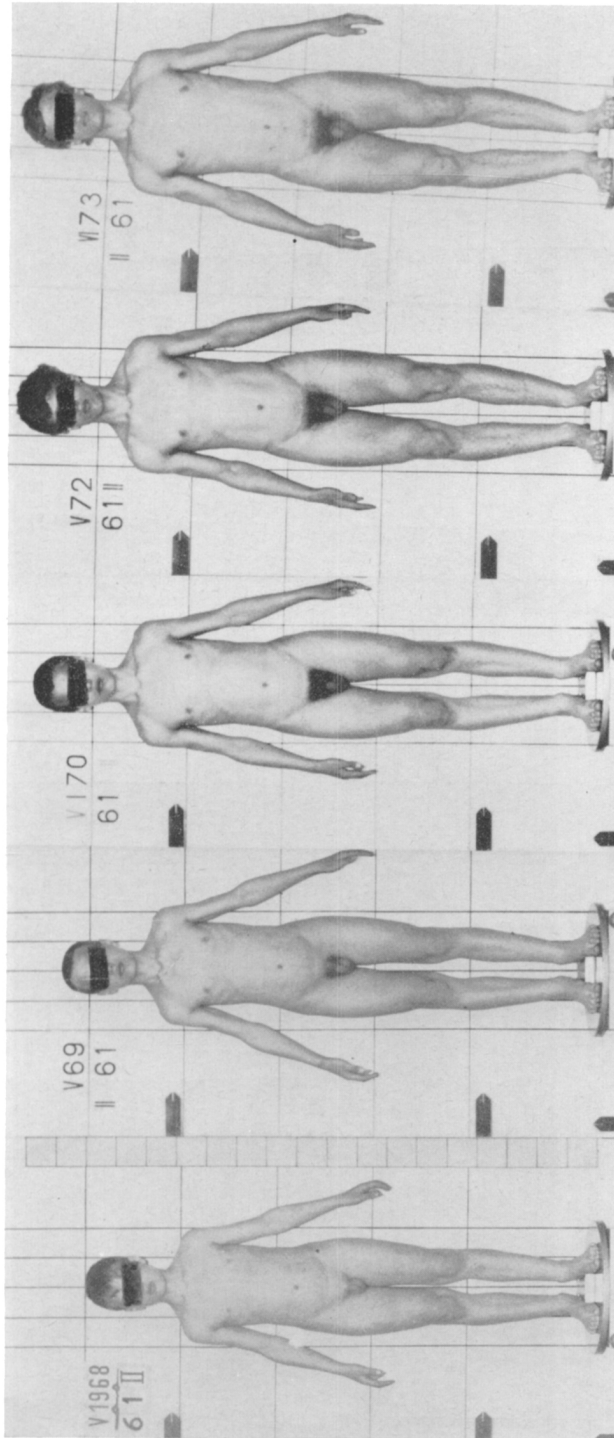
MZ Corwin II

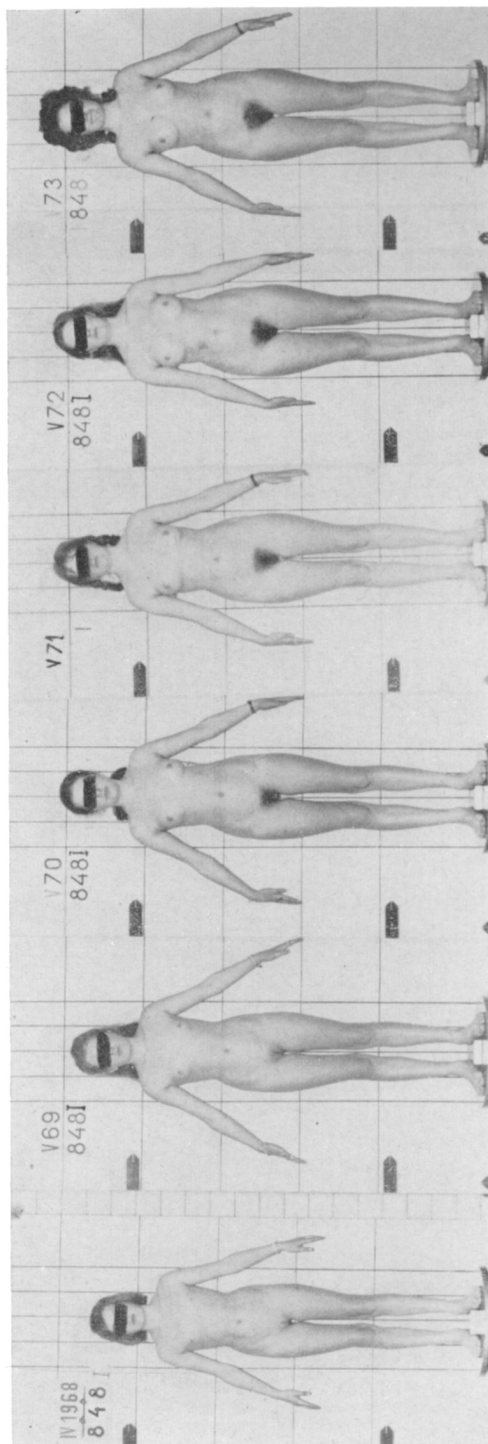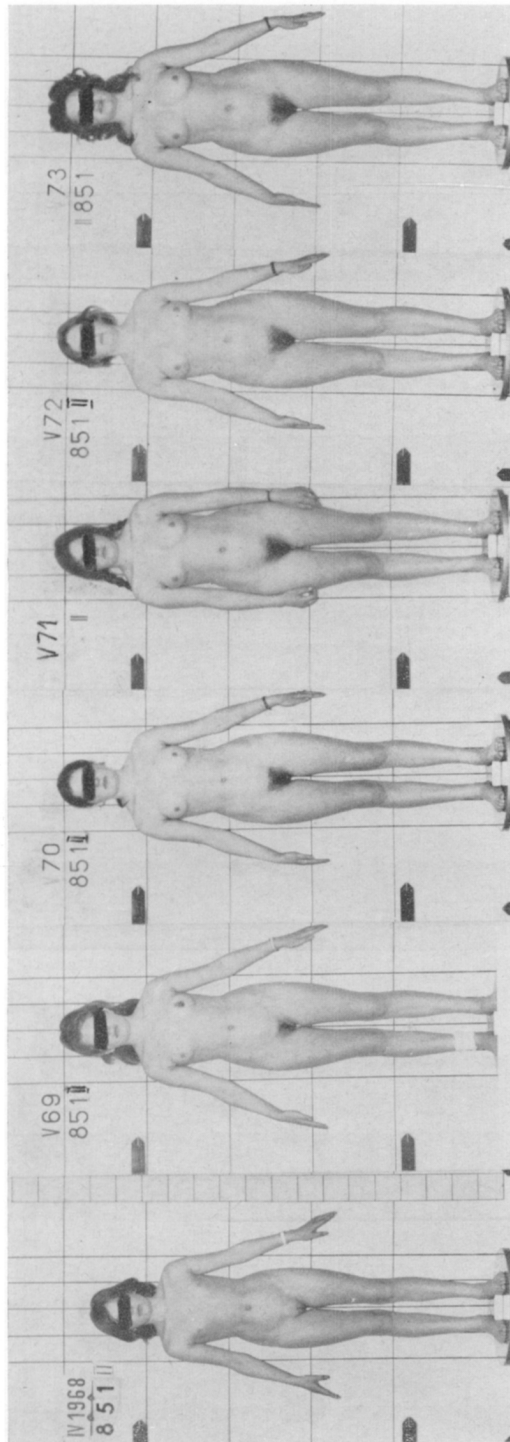PLATE 2. Sexual Maturity in Male DZ Twins.

DZ Cotwin I

DZ Cotwin II
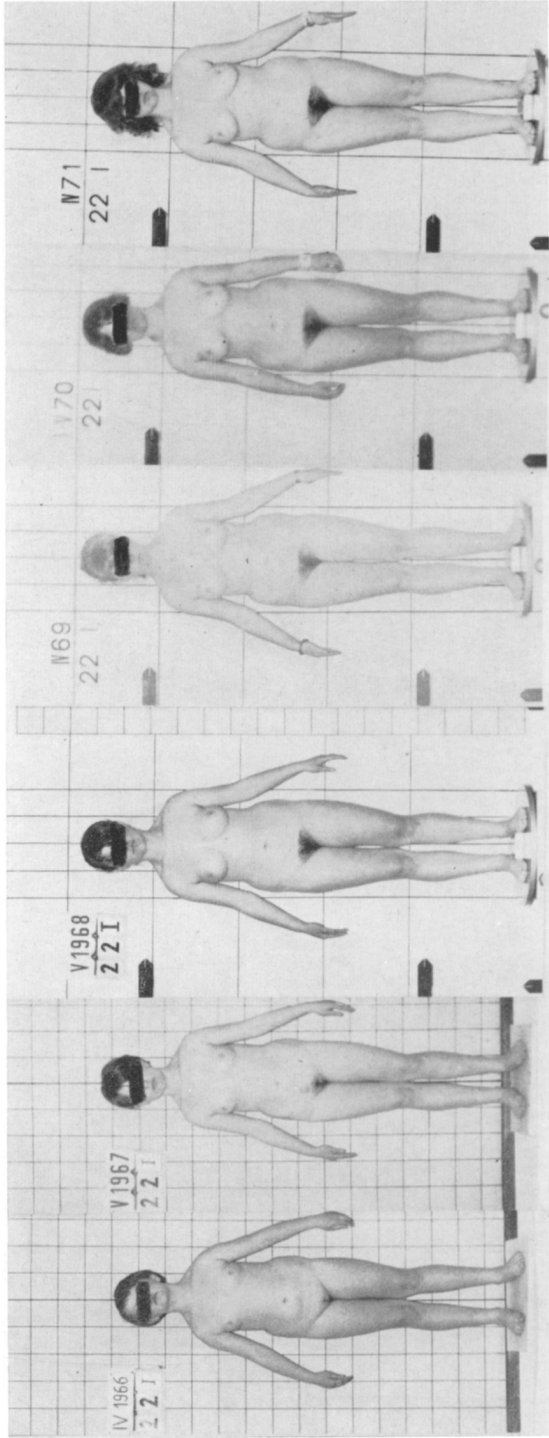
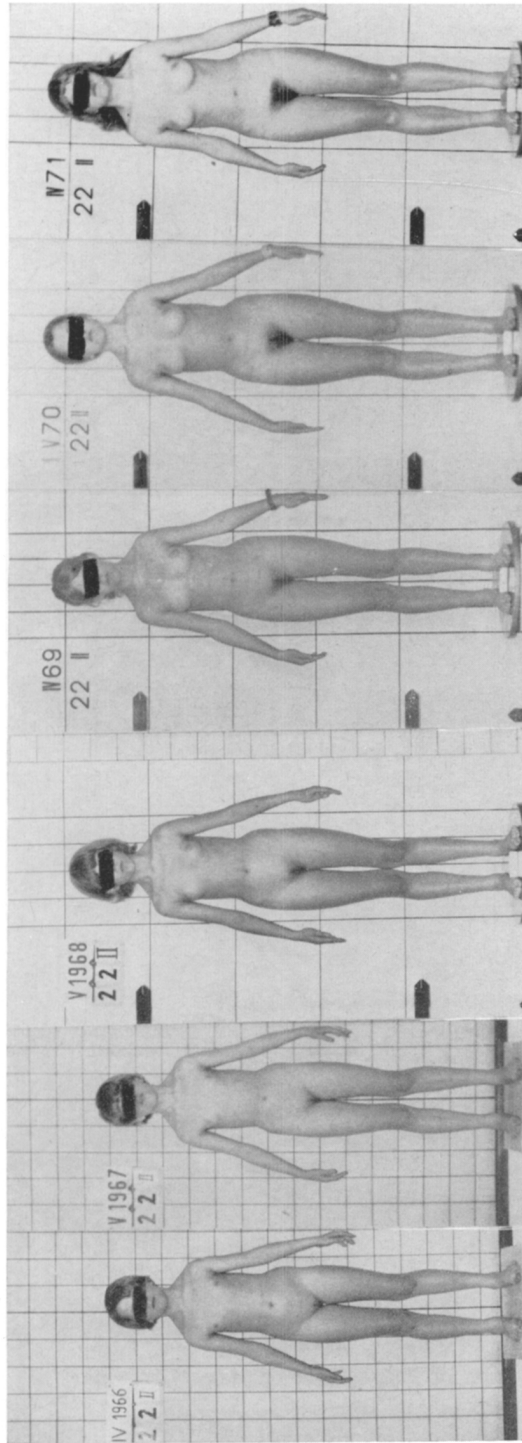PLATE 3. Sexual Maturity in Female MZ Twins.

MZ Cotwin I

MZ Cotwin II

PLATE 4. Sexual Maturity in Female DZ Twins.
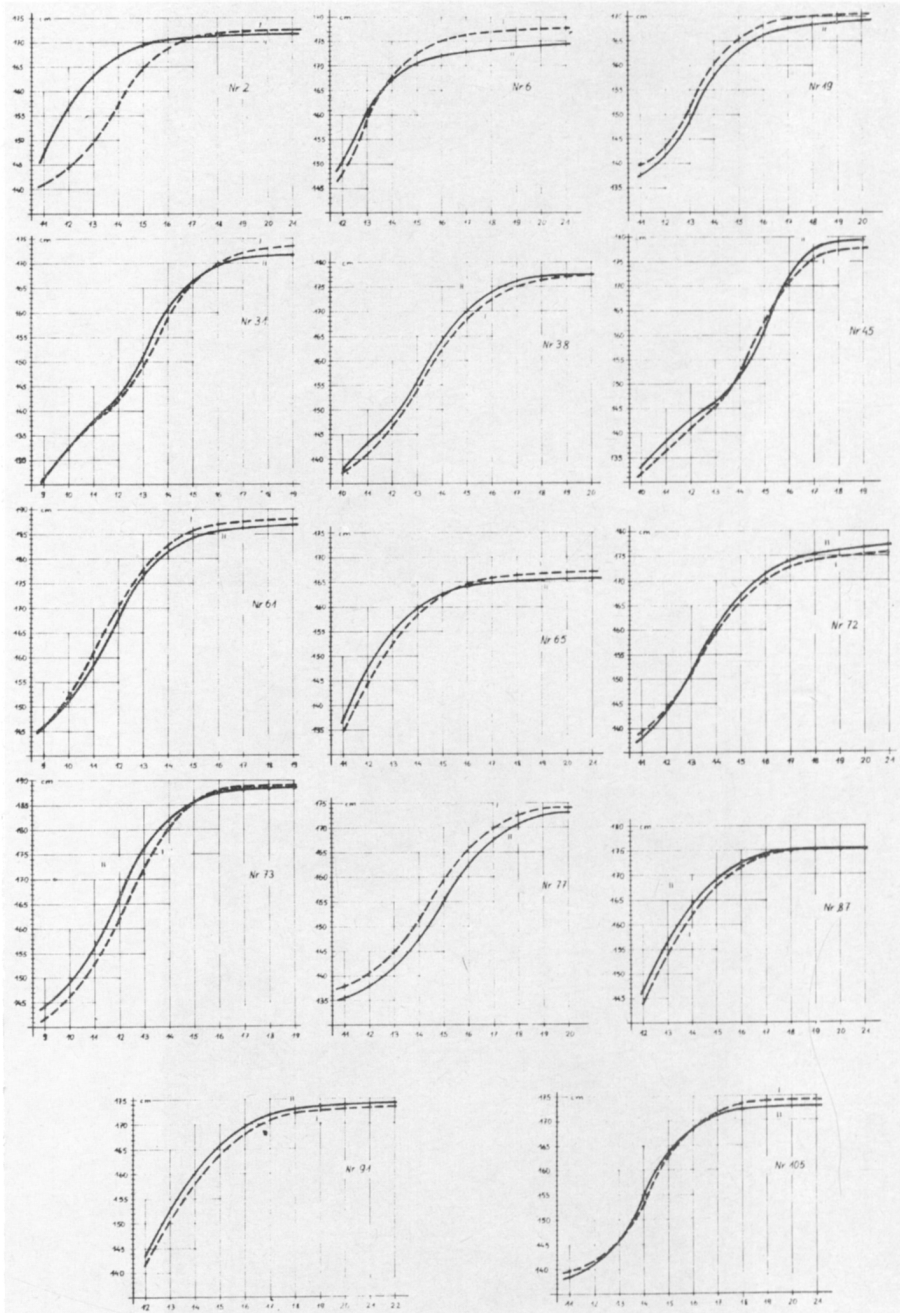

DZ Corwin I

DZ Cotwin II

PLATE 5. Development of Body Height of Male MZ Twins.
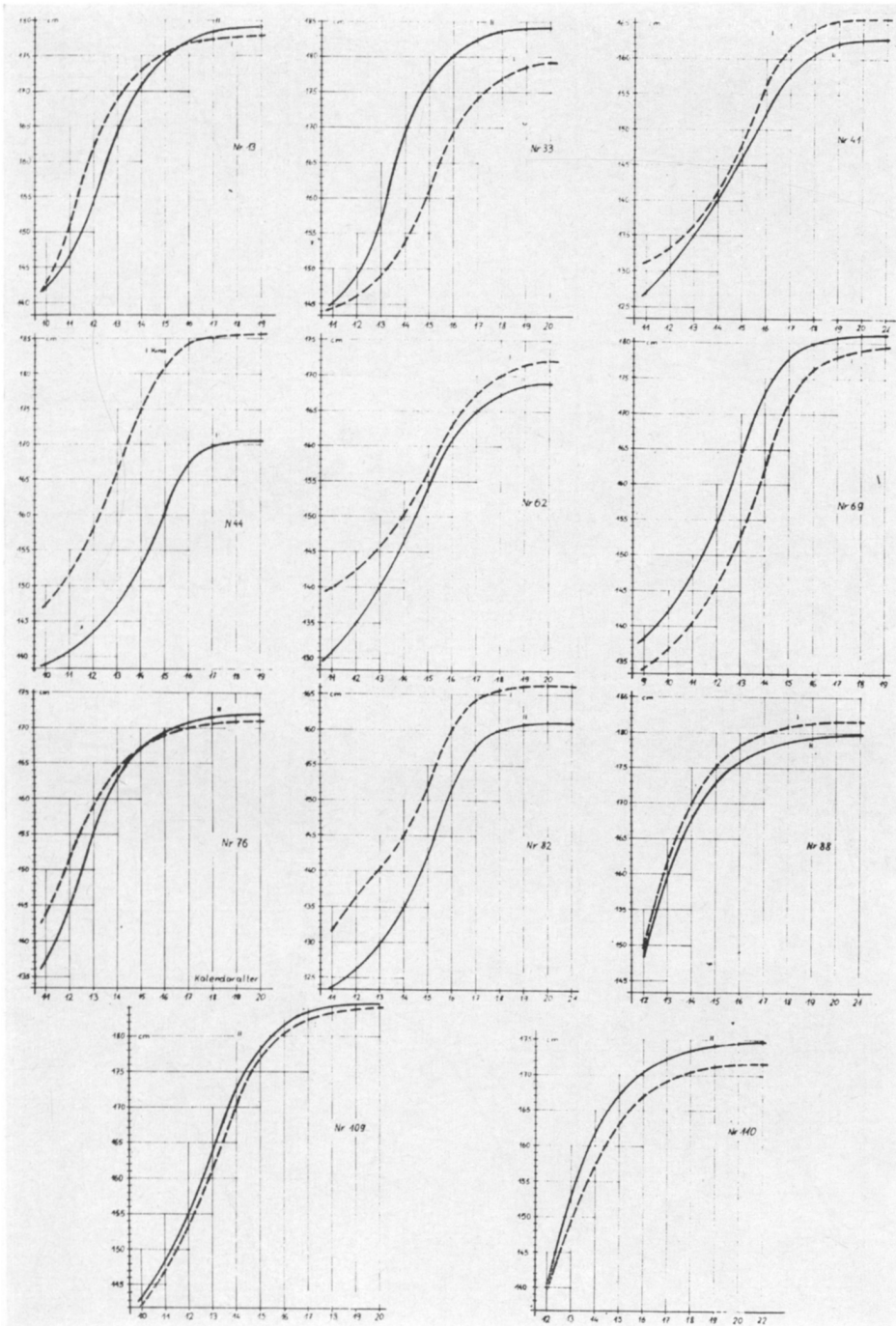
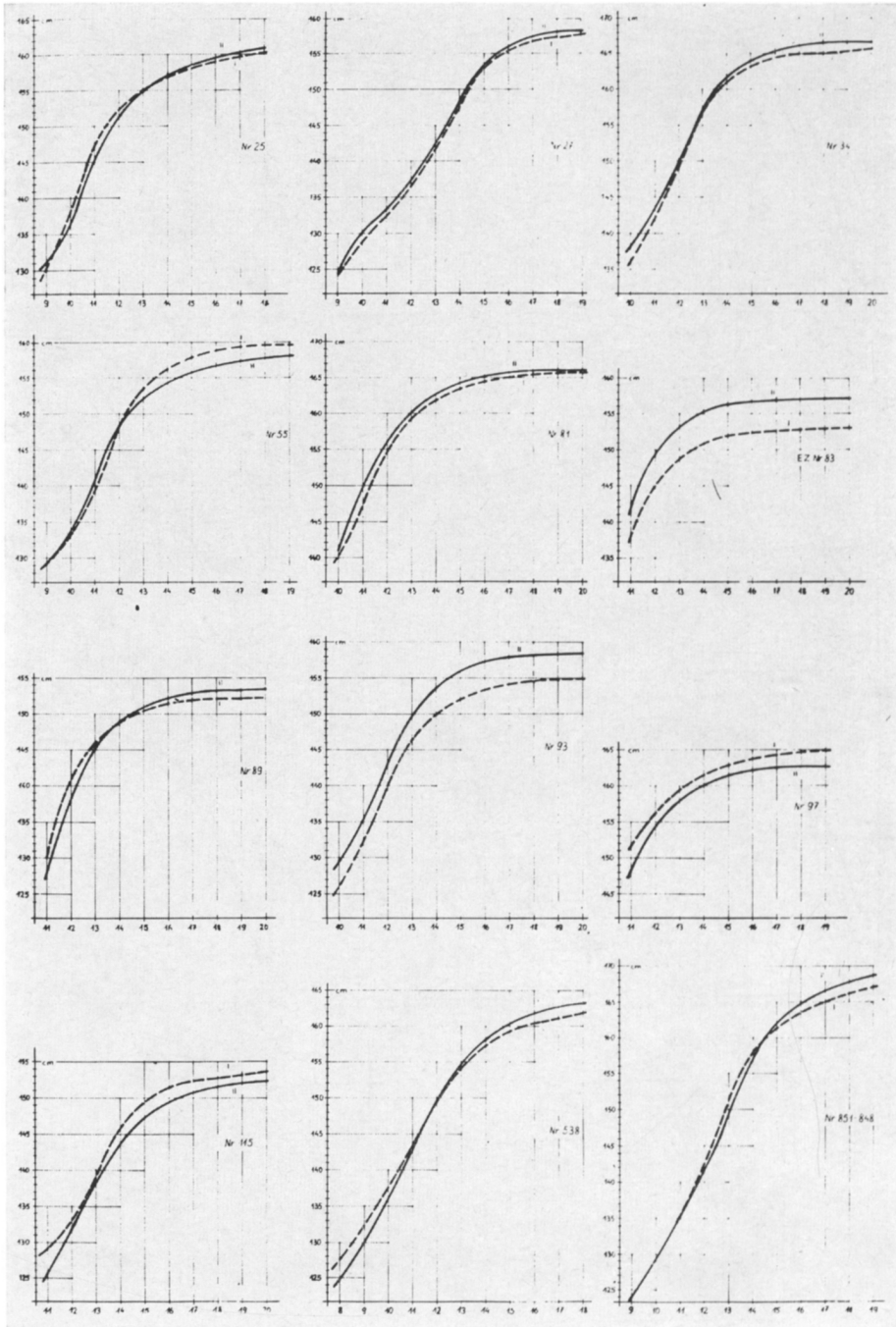PLATE 6. Development of Body Height of Male DZ Twins.

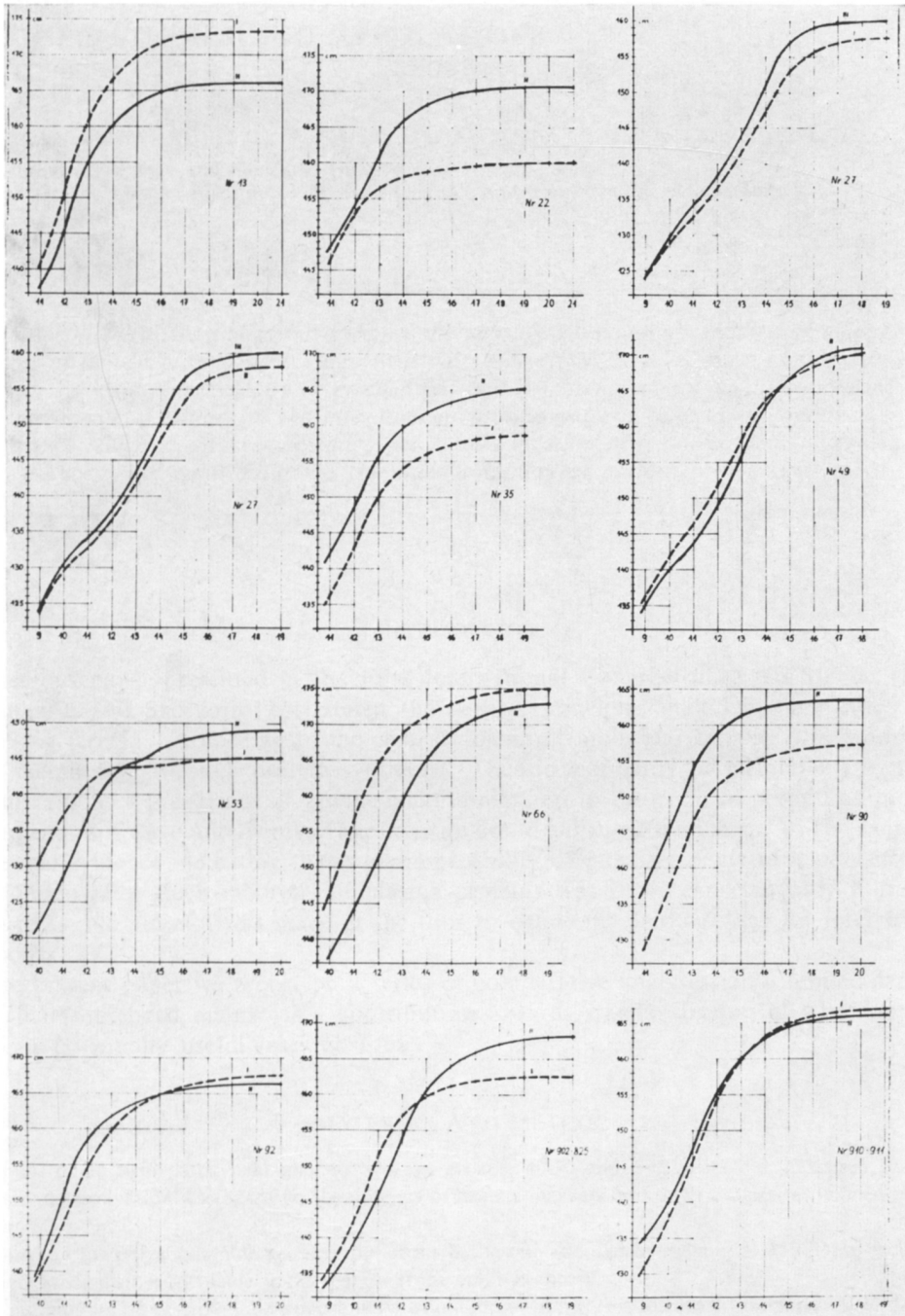PLATE 7. Development of Body Height of Female MZ Twins.

PLATE 8. Development of Body Height of Female DZ Twins.