DETERMINANTS OF PHYSIQUE.

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I. Males.

(i) OBJECT OF THE INQUIRY.

THIS paper gives some first results of an investigation into types of physique and into the alleged relation between physique and temperament. The problem here is to try to discover a method of measuring the tendencies to a particular bodily build that may be present in certain individuals.

Those who have been interested in this problem are psychiatrists and clinicians, who have sought in the first instance some concrete physical criterion to assist them in their diagnoses of mental disorder. The problem, however, has ramifications outside the specific field of practical medicine. Psychologists are interested in it, if only for its bearing on the " body-mind " relation. The question of the distribution of physical types in different racial groups may arise in physical anthropology. Biochemists again are interested in the glandular and metabolic basis of typology ; geneticists may seek to inquire into the genetic basis of constitutional types if they are shown to exist, while to biologists this question may seem intimately bound up with determinants of relative growth. In the sequel we shall try to relate our finding to certain aspects of biology.

Since our concern is primarily with the supposed association between mental and physical types, and since it has been maintained that such types can be most clearly discerned in patients suffering from mental disease, our data consist of measurements of the external dimensions of 64 adult male psychotic patients. Specifically, we shall try to find a few hypothetical components in terms of which to express a number of bodily parts. These components will, however, primarily be means of differentiating between individuals in so far as they account for the variance of the parts studied.

(ii) PAST WORK ON PHYSICAL TYPOLOGY.

In the Hippocratic writings are distinguished, among other types, the habitus phthisicus and the habitus apoplecticus,* and a theory of " humours "

* These, in particular, are mentioned because they are supposed to correspond to the modern schizothymic and cyclothymic temperaments ; *cf.* (5). Some writers trace the humoral pathology back to Egypt.

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is developed. We can hardly claim to have advanced much beyond these classifications; some refinement there has been, perhaps, and a little quantitative precision. In recent years interest in types was revived by the Italian clinical anthropologists, starting with de Giovanni (1). The development of endocrinology gave a further impetus to these studies, unfortunately accompanied by free generalizations and speculations.

Convenient summaries and bibliographies are given by Klüver (2), Burt (3), Miller (4), Wertheimer and Hesketh (5), Paterson (6), and Wells (7). Much discussion has been aroused by the translation of Kretschmer's works (8, 9). There is, however, little new in Kretschmer. The macrosplanchnics, normosplanchnics and microsplanchnics of the Italian school and the digestives, musculars and cerebrals of the French school provided Kretschmer with prototypes for his pyknics, athletics and asthenics. There are numerous other classifications in psychological literature of mental and physical types very broadly corresponding with these distinctions between the fat, broad, short types and the thin, narrow, long type.

Researches made to test Kretschmer's theories have sometimes been confirmatory, at other times negative or conflicting. Most of the work is more or less vitiated by lack of control of independent variables and general absence of, or deficient statistics. Kretschmer himself simply gives the means of the measurements for his groups. He gives no measure of variability or information as to the age, social status, etc., of his patients. Hence we cannot evaluate his data. A recent work on Kretschmer's lines by Willemse (10) does not even give the numbers in his samples, and no measures of variation.

The method adopted in earlier work was either to select persons who appeared slender and asthenic or stocky and pyknic, and then see if more detailed measurements confirmed this division, or to estimate normal (or psychotics) for schizoid or cycloid temperaments and then see if their physique likewise was asthenic and pyknic respectively. It was generally assumed that if two or more types existed, then a frequency distribution should show bimodal or multi-modal form. In nearly all the work the distributions were approximately normal.

The measurements used to discriminate between the subjects were either absolute measurements of parts of the body or morphological indices, usually modifications of Viola's index :

$$= \frac{\text{length of one arm} + \text{length of one leg}}{\text{volume of trunk.}}$$

In a subsequent paper giving an analysis of variance of physical measurements in four groups, we shall give a more detailed criticism of past work.

The only attempt to apply the methods of correlation and factor-analysis to the type problem has been that of Burt (11). In an earlier research (11) Prof. Burt had found, in studying a group of 73 children, a correlation of

·27 between inhibited temperament and asthenic physique, and with 50 students a correlation of ·38.

We may take as our starting-point a recent statement by Prof. Burt (12, p. 643) that " physical types in the popular sense of mutually exclusive and contrasting types cannot be discovered ".

(iii) The Data.

The data consist of 14 physical measurements taken of 64 adult English male patients at Bethlem Royal Hospital—22 schizophrenics, 25 manic-depressives, and a mixed group of 17 paranoiacs, paraphrenics and hysterics.

The measurements and diagnoses of the cases were made by Dr. Emanuel Miller, whom I wish to thank for permitting me to make a mathematical analysis of his material.

The average age of the group was 42·05 years ($\sigma = 12{\cdot}54$ years). The patients were drawn roughly from the same social status.*

The measurements were on—

(1) Head breadth (inter-parietal).
(2) ,, length (occipito-nasion).
(3) Skull diagonal (gnathic-lambdo-mental).
(4) Waist circumference (taken above the level of the umbilicus).
(5) Pelvic ,, (,, at upper level of superior iliac crest).
(6) Thoracic ,, (,, at nipple line).
(7) Thoracic breadth (,, ,, ,,).
(8) Pelvic ,, (,, at upper level of superior iliac crest).
(9) Shoulder ,, (between acromion processes).
(10) Sagittal thorax (taken at the lower end of the sternum horizontally backwards).
(11) Trunk length (taken from sternal notch to the upper symphysis of the pubis).
(12) Arm ,, outstretched (taken from acromion process to external end of ulnar).
(13) Leg ,, (taken from great trochanter to lower end of external malleolus).
(14) Height (total).

(iv) Methods.

The statistical method used was to intercorrelate the measurements for the traits and make a factor analysis of the results.

The methods of factor analysis have been widely used by psychologists in work on mental measurements. Their only application to physical measurements, so far as the writer knows, is by Burt (12).

Various procedures of factorizing data have been suggested by writers

* Occupations: small business or minor professional.

since Spearman devised his two-factor technique (13), namely by Thurstone (14), Hotelling (15), Kelley (16), and Burt (17, 18, 19).

Prof. Burt has shown (17, 19) that these various methods regarded as approximations or alternatives to the same end lead to much the same results. Some of the chief grounds of divergence may be summarized thus :

(*a*) Spearman and Thurstone assume that the factors (or saturation coefficients) are linearly independent only, whereas Kelley, Hotelling and Burt assume that they are also orthogonal or statistically independent.

(*b*) Kelley and Burt prefer to start with a matrix of co-variances, whereas the others start with a matrix of correlations between the variables.

(*c*) Bound up with (*b*) is the question of insertion in the diagonals of the matrix. Thurstone uses the largest correlation in each column ; Hotelling inserts unity ; Kelley uses reliability co-efficients* ; whilst Spearman's formula avoids the difficulty. Burt inserts variances ; since the diagonal figures should be identical with the squares of the saturation co-efficients for the factor dealt with, the first insertions are provisional, derived by smoothing the table, and more precise values may be obtained later, if necessary, by successive approximation.

Thurstone inserts the largest correlations in the diagonals as an estimate of the communalities, which are defined as that part of the total variance of a variate due to traits common to two or more of the variates (14, p. 62).

In the present paper we use the Thurstone centroid method of analysis as described by Thurstone (14).

As an alternative to the centroid method, the " least squares " (Burt) has been applied to the initial matrix of correlations. This procedure gives more precise results for the following reasons : It brings out more clearly the tendency towards hierarchical order present in the matrix at each stage in the analysis. The errors are minimized, and hence the relation between the factors stands out more clearly.

The resulting factor saturations are given in Table II*a* and are plotted in Fig. 2.

The actual procedure was as follows : the first factor saturations derived by the centroid method were used as weights on the matrix of first correlations to determine a new set of weights. The insertions in the diagonals were the squares of the factor saturations for each variate. Repeating the process with the second weights a third set of weights was determined. The differences between the second and third set of weights were negligible.

The third weights were then divided by the square root of the sum of their squares, and then multiplied in turn by the root of the total variance (= the sum of the diagonal insertions) to obtain the factor saturations.

The procedure was repeated on the first residuals to obtain the second

* This is not in consonance with his principle that a matrix of co-variances should be used.

factor saturations. The divergences between the results of the centroid and least squares methods are not serious, but points of interest are certainly brought out.

In another paper we shall compare the use of further methods of analysis on the same data.

The problem of factor analyses is to analyse the variance into its constituent components, the first factor or component accounting for a maximum of the variance.

Geometrically, the variables in the centroid method may be regarded as unit vectors on the surface of a hypersphere of unit radius. The first common factor axis is defined as passing through the centroid of the points defining the vectors. The problem is thus to transform the oblique co-ordinates to which the measurements are originally referred to new independent co-ordinates or axes of reference. The saturations of the tests in the various factors are given by the cosines of the angles between the vectors and the respective axes of reference.

The use of the centroid method may be justified in view of its offering a quick, convenient method of approximating to this result, which is familiar to psychologists. For more precise work the refinements of the "least squares" method of Burt (17, 18, 19) are to be preferred.

It may be asked that since we seek a basis of human types, it would be better to correlate (or co-variate) *persons* instead of *traits*, and then factorize the resulting data (20). Thus in a matrix of measurements in which the columns represent persons and the rows represent traits, either columns or rows may be correlated. When traits are correlated it is assumed that the persons are a random sample normally distributed. If persons are correlated, then the traits must be a random sample normally distributed. The traits must also be numerous, otherwise the degrees of freedom will be so small that a satisfactory level of significance will not be reached. Moreover, the traits must be reducible to the same unit. In general these latter conditions as applied to traits are not obtainable. Consequently, if absolute measurements are correlated between persons, the results seem difficult to interpret (19). Thus we have correlated* 20 persons for 14 physical traits. The results yield correlations of the order ·924–·999. If, however, the columns (i.e., persons) are first standardized for traits, presumably a normally distributed random sample, then the results obtained from correlating rows will, in general, be approximately identical with those obtained for correlating columns. In terms of matrix algebra, the problem in both cases is to reduce a symmetrical matrix to a diagonal or canonical one in which all the elements except those in the principal diagonal are zero. As Prof. Burt says (11), to correlate persons "is sometimes suggestive, occasionally preferable, and in rare instances all but unavoidable". The full proofs are given in (19).

* In material as yet unpublished.

TABLE I.

		1. I-P.	2. O-N.	3. Gn-L-M.	4. W.Circ.	5. P.Circ.	6. T.L.	7. Th.C.	8. S.Th.	9. T.Br.	10. L.L.	11. Ht.	12. Sh.B.	13. P.Br.	14. A.L.
Inter-parietal	1	(547)	375	155	176	332	−112	260	268	295	−128	−018	165	547	119
Occipito-nasion	2	375	(531)	531	267	470	214	190	−094	171	218	077	123	441	030
Gnathic-lambdo-mental	3	155	531	(531)	261	245	106	142	012	249	205	017	035	203	126
Waist circumference	4	176	267	261	(892)	892	148	482	431	389	095	015	084	423	163
Pelvic ,,	5	332	470	245	892	(892)	208	467	443	311	105	037	057	586	−114
Trunk length	6	−112	214	106	148	208	(409)	062	289	209	289	163	265	409	200
Thoracic circumference	7	260	190	142	482	467	062	(588)	441	588	264	069	241	285	151
Sagittal thorax	8	268	−094	012	431	443	289	441	(459)	242	185	065	081	459	071
Breadth of ,,	9	295	171	249	389	311	209	588	242	(588)	221	088	360	142	229
Leg length	10	−128	218	205	095	105	289	264	185	221	(375)	217	317	375	299
Height	11	−018	077	017	015	037	163	069	065	088	217	(217)	145	110	197
Shoulder breadth	12	165	123	035	084	057	265	241	081	360	317	145	(360)	286	301
Pelvic breadth	13	547	441	203	423	586	409	285	459	142	375	110	286	(586)	195
Arm length	14	119	030	126	163	−114	200	151	071	229	299	197	301	195	(301)

n = 64. r = ·245.

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TABLE II.—*Centroid Method (Thurstone). Factors.*

(Saturation coefficients.)

	Variable.	I.	II.
13	Pelvic breadth	·728	−·021
5	,, circumference	·711	−·524
4	Waist ,,	·680	−·371
7	Thoracic ,,	·610	−·164
9	,, breadth	·589	·018
2	Occipito-nasion	·511	−·147
8	Sagittal thorax	·483	−·122
10	Leg length	·438	·415
1	Inter-parietal	·430	−·382
6	Trunk length	·412	·321
12	Shoulder breadth	·407	·361
3	Gnathic-lambdo-mental	·406	−·114
14	Arm length	·327	·420
11	Height	·202	·295

TABLE IIa.—*"Least Squares" Method (Burt). Factors.*

(Saturation coefficients.)

	Variable.	I.	II.
5	Pelvic circumference	·835	−·649
13	,, breadth	·734	·044
4	Waist circumference	·707	−·380
7	Thoracic ,,	·620	−·101
9	,, breadth	·531	·233
8	Sagittal thorax	·512	−·057
2	Occipito-nasion	·492	−·073
1	Inter-parietal	·438	−·133
3	Gnathic-lambdo-mental	·370	·053
10	Leg length	·370	·515
6	Trunk length	·364	·348
12	Shoulder breadth	·343	·526
14	Arm length	·249	·527
11	Height	·148	·323

(v) RESULTS.

The matrix of first correlations of the 14 variables are given in Table I. N = 64. It is noteworthy that the correlations are nearly all positive. Out of 91 coefficients only 5 are negative, and each of these 5 is less than 3 times its probable error.

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In the whole table—

39 r's > 3 times p.e.
19 r's > 2 ,, ,,
20 r's > 1 ,, ,,
13 r's < 1 ,, ,,

A number of the coefficients are thus seen to be small relative to their probable errors.

The saturation coefficients (or factors) as determined by the centroid and least squares methods are given in Tables II and II*a*. The analysis stopped after the second factor, as the second residuals were not significantly large enough to justify proceeding to a third factor. When the centroid method is used with psychological material, it is usually found necessary to rotate the axes in order to give better psychological meaning to the results. In our case no transformation of co-ordinates was thought to be required, since the first pattern, as our subsequent interpretation of Figs. 1 and 2 will show, gives intelligible meaning.

It must be made clear that the factor saturations and their interpretation are dependent upon the particular choice of variables. Everything is relative to the set-up. In a subsequent paper we shall see the effects on a factorial matrix (*a*) of removing certain variables, (*b*) of introducing others. The problem is thus not purely a statistical one. The variables must be selected in the light of a specific hypothesis to be tested. The choice of variables in this paper happens to be a fortunate one.

We seek here information on the following questions :

(*a*) What measurements of the body will permit us to predict most about the size and relative proportions of the body as a whole ?

(*b*) Is there any evidence for the theory of physical types (of Kretschmer and others) ?

(vi) Interpretation of Results.

Predictive Grounds and Causes.

The factors discovered are primarily abstract statistical quantities. They are not concrete entities existing in the body ; they are axes of reference like hypothetical lines of latitude or longitude, not physical forces, but grounds for deductions.

From a practical point of view one is interested in the " causes " that produce a man's physique, i.e., which ones are due to hereditary influences, and which to pre- and post-natal influences, such as disease, malnutrition, etc. For purposes of diagnosis we are interested in symptoms or clues which enable us to predict the total condition. Even physical causes are regarded by modern science as predictive grounds rather than as controlling forces. The question

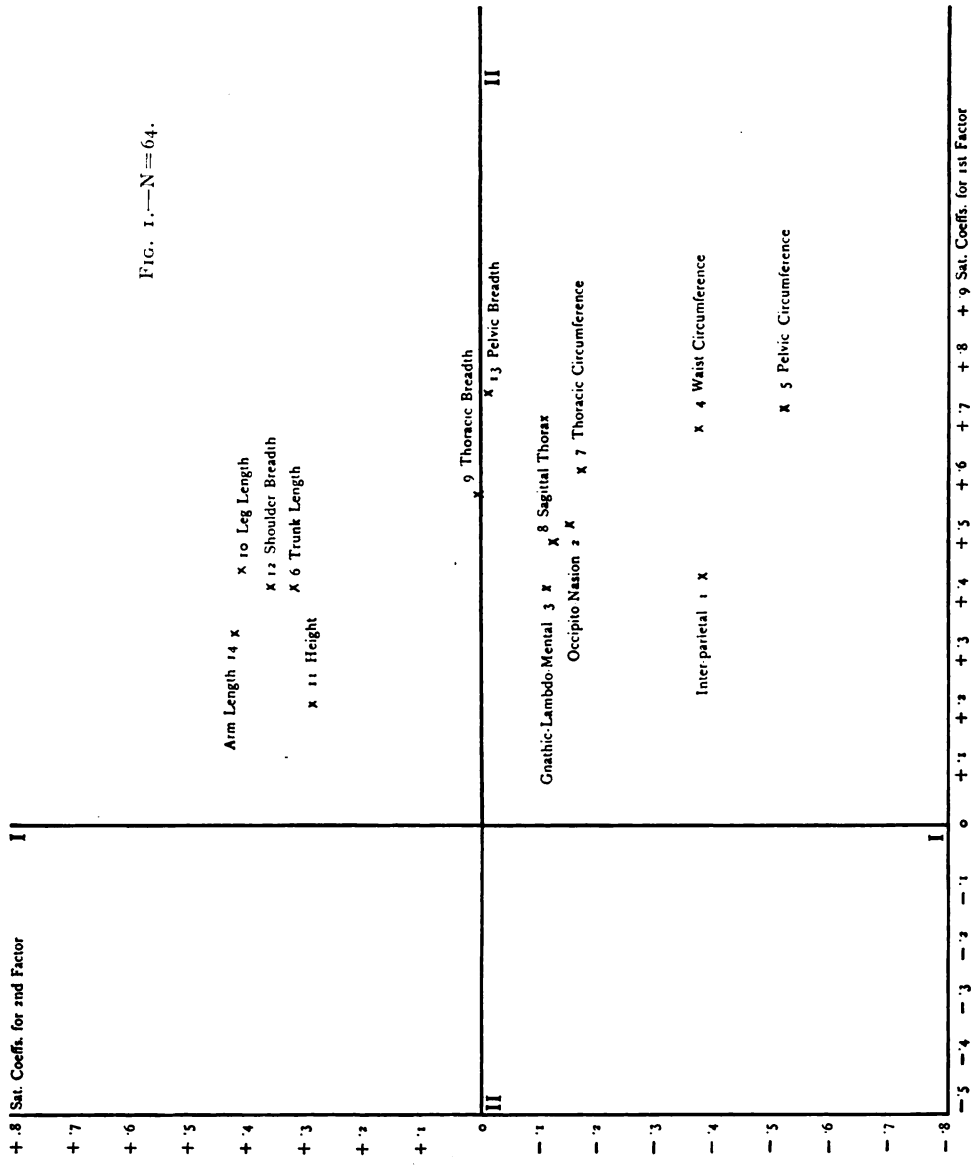

FIG. 1.—N = 64.

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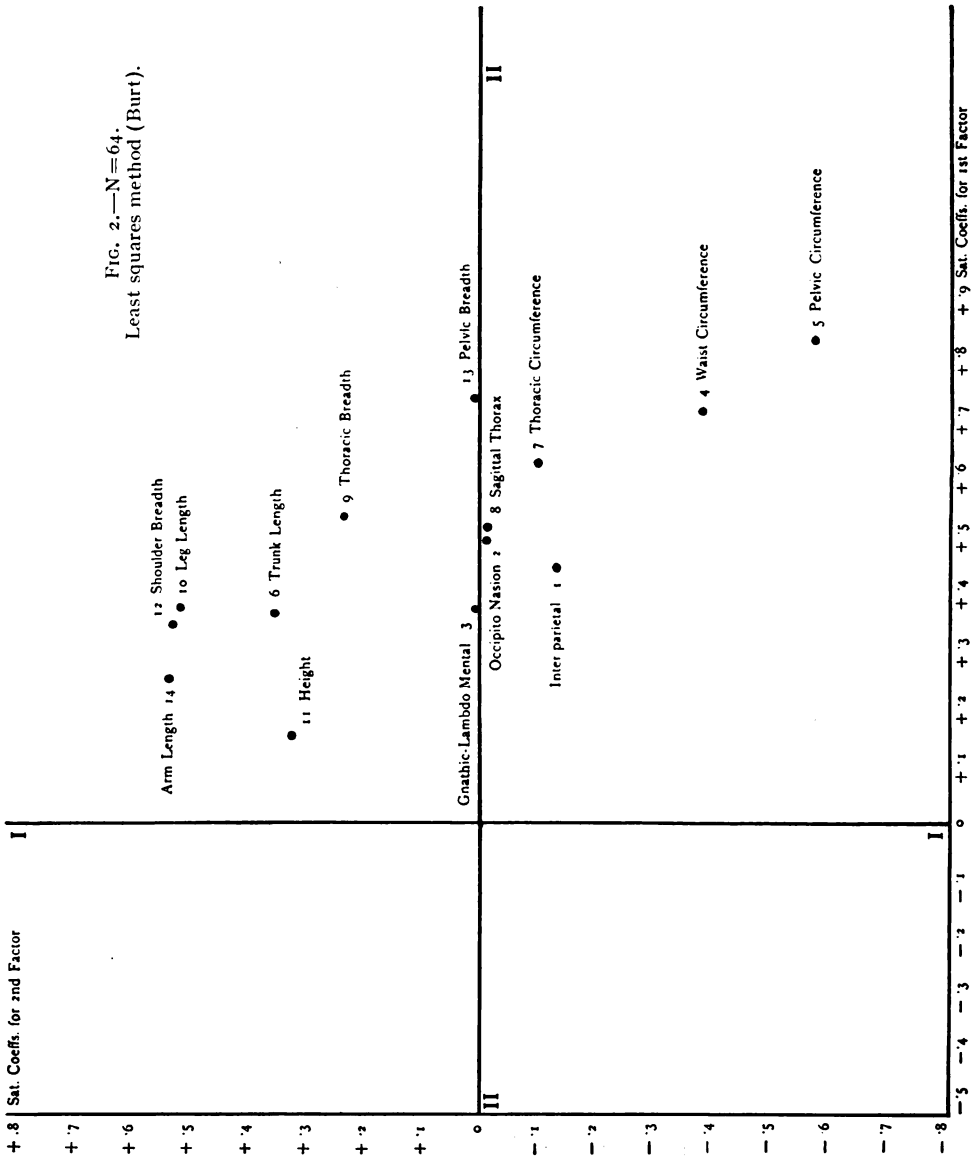
FIG. 2.—N=64.
Least squares method (Burt).



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to be answered is: What is the probability of the occurrence of a certain event? In biological science, particularly, it seems safer to seek empirical clues rather than imaginary causes.

In the past, classifications of physical and mental temperaments in terms of a single endocrine cause has given an over-simplified picture of a highly complex situation, for the "causes" are multitudinous and largely unknown. We therefore avoid assuming concrete causal entities, and speak of quantitative functions leading to the most accurate prediction possible.

In our particular case the task is to measure a person's approximation to a type, and from this to deduce that he will tend to show certain characteristics.

The fourteen physical traits may accordingly be regarded as a series of potential clues, and the saturation coefficients as guides to the weight to be attached to these clues in determining certain generalized characteristics. Thus, if "type" is defined as a tendency towards or away from a certain pattern, each factor may be regarded as referring to a type.

The Effects of Correlating.

The method of measurement adopted rules out the most basic pattern. The measurements have been reduced to the same mean and to the same standard deviation, for we have used correlations, not covariances. The mean and σ of height, for example, must of necessity be much greater than the mean and σ of head-breadth. By reducing the measurements to standard form these differences have been eliminated. In order to get our absolute measurements of height and head-breadth, we could predict them by means of the saturation coefficients; but these predictions (still expressed solely in standard measure) would have to be multiplied by the empirical σ, and the empirical mean would have to be added in order to arrive at the original figures. It is clear, therefore, that by using the correlational method our measurements are expressed in terms of reduced deviations from the fundamental human body pattern.

Factor I.

The saturation coefficients for the first factor are all positive. This factor designates a tendency towards increased size in all directions. It may be called a factor of magnitude. So long as we are considering the effects of the first factor only, it means that if a particular individual has a positive measurement for any of the traits, we may infer that all the other traits will be to that extent longer. If a man's measurement in this factor is positive, he will belong to a big type or be a large man; if his measurement in this factor is negative, he will be a small man or belong to a small type.

Considering, next, the order of magnitude of the traits for the first factor (Table II), it is evident that pelvic circumference comes first and pelvic breadth

next.* These, consequently, would seem to provide the best clues to the tendency towards size. Height and arm length are the worst clues in this respect. If a man is tall it cannot be certainly predicted that he is a large man. If he is taller than the average, he will probably be larger than the average, but the probability is very low.

The trunk measurements, however, are valuable clues to size. It is of interest to note that head length is almost as good a clue as chest depth (sagittal thorax) to the size of the body as a whole.

It would be interesting to correlate this size factor with traits like muscular strength, mental vitality, energy of character, etc. The physician might be interested to know the relations between bodily size and general health, physical vitality and disease.

(*d*) *Factor II.*

Psychologists have been interested in the shape or proportions of the body rather than in its magnitude or total bulk. We may eliminate the size factor or scale of growth as it may be called, and reduce all our individuals to the same general scale of size. The results are shown by the saturations for factor II (Tables II and III).

This factor is positive for a disproportionate increase in the length measurements, i.e., length of leg, trunk, arm and total height. It is also positive for shoulder breadth,† a fact for which we shall soon attempt an explanation. Factor II is negative for circumference of pelvis, waist and thorax, depth of thorax, head-breadth, and slightly for head-length and skull diagonal.

There is thus evident a contrast between length, on the one hand, and circumference on the other. Here, apparently, are some clear indications towards a plump, big-chested or pyknic type, and towards a relatively long, thin or leptosomatic type.

An explanation is required for the place of shoulder breadth among the length traits. At first sight this would seem to be an exception. It is probable, however, that shoulder breadth is determined largely by the length of the clavicle or collar-bone, which is classed anatomically with the long bones, since its mode and dates of ossification are similar to those of the long bones.‡

In determining the absolute measurements of the body as a whole, however, it is evident that factor II contributes far less to the total variance than factor I. Squaring the saturation coefficients in the centroid results, and summing the squares, we find that the first factor contributes 3·7 to the total variance; the second factor contributes only 1·4, i.e., 27% and 10% respectively. Thus

* This order is reversed in the centroid results.

† And to some extent for trunk breadth in the "least squares" results.

‡ It should, however, be noted that mode of growth of the clavicle is not always similar to that of the long bones. Thus, in the achondroplasic dwarf all the long bones are extremely short except the clavicle (21, p. 491).

factor I is more discriminative and gives safer grounds of prediction. The second factor is, however, a better guide to physical types.*

Constitutional Types and Relative Growth.

We may now try to relate our findings to the biology of relative growth Two meanings of " growth " may be distinguished.†

(*a*) The tendency for the bodily parts to increase in size and weight differentially as a result of an organic process.

(*b*) The tendency or impetus to develop into a final shape or "gestalt".

The hypothetical growth-centres in the body, the relative growth-rates of different parts tend roughly to change throughout the developmental period in a general antero-posterior direction. Thus head girth during the entire pre-natal period exceeds chest girth. Arm length in the embryonic stage exceeds leg length ; at birth they are approximately equal, whereas ultimately arm length averages about four-fifths leg length. Human growth is neither steady nor uniform, but continues irregularly, some parts increasing rapidly while others lag behind.

Consequently the determinants of the bodily parts in its different dimensions in the vertical, horizontal and sagittal planes must alter during the growth-period. The two meanings of growth, though apparently distinct, may biologically be related in quite a definite way. That is to say, there may be primary genetic determinants of a final bodily shape which are related to the varying proportions all along the line of growth.

Huxley's work on relative growth, pointed out to me by Prof. Burt, seemed to give a new scientific status to typological studies.

Huxley (22, 23) and Teissier have reached certain conclusions with regard to rates of growth.

They call the growth-rate of an organ isometric if it is identical with that of the organ of reference ; allometric if its growth-rate is greater or less (positively or negatively) than that of the organ of reference.

Simple allometry can be expressed by an equation of the form $y = bx^a$,

where y = the size of an organ,

x = ,, the organ of reference,

a = ratio between the relative growth-rates of x and y,

b = a constant.

The presence of a growth gradient is indicated by a uniform increase or decrease in a.

Prof. Burt (12) gives reasons to believe that equations of growth do not themselves formulate biological laws, but are descriptive only.

* With the least squares method the contributions of the two factors are 3·7 and 2·2 respectively, i.e., 27% and 16%.

† This distinction was made by Prof. Burt in a private communication.

Growth-rates of the body may be studied in three ways, namely :

(1) Linear measurements of dimensional growth.

(2) Areal increments, i.e., of surface area of the body.

(3) Ponderal increments, i.e., of body mass or volume.

Equations of the same type as that of Huxley's have been found to hold good also for the growth of the surface area of parts and length of the body (25, p. 123).

In the present study we have only been concerned with linear measurements, but it would be of interest to relate our results with the determinants of body weight and surface area.

No doubt from the standpoint of genetics, or considered as the multiplication or enlargement of body-cells, the growth-rate at any given moment is the resultant of a large number of different partial growth-rates. Nevertheless from the point of view of the present method of analysis, the growth-rates of the bodily parts may usefully be regarded as predominantly determined by one or two major reactions, or rather by a hierarchy of reactions.

In our case here a special problem arises. Since the sample consists of adult persons, the data, namely physical measurements, are static, not dynamic,* hence one cannot know whether the resulting factors indicate growth factors (meaning (*a*)), or final shape factors (meaning (*b*)). One cannot know certainly whether the factors are due to differences in the constant b or in the exponent α (in Huxley's equation). Investigations on similar lines to ours on growing children at different ages may throw a good deal of light on this problem.

There are, apparently, grounds for believing that growth factors and the determinants of final shape are partly the same, implying an intimate relation between the two notions of growth indicated above. Thus Davenport maintains (26, p. 109), " there are in the germ-cells of each sex a number of different factors determining bodily build. The number varies from zero to two (possibly three) factors for fleshly build in each individual germ-cell ". If this is so, then a so-called pyknic body is not an asthenic one in an arrested state of development. Taller people, in certain races, tend to have narrower heads than shorter people† (27, p. 408). Or compare an ateleotic dwarf (of harmonious proportions) with an achondroplasic one with stunted extremities. These disproportions and differences in resulting physique are, apparently, in most cases present at the outset (21, p. 490). Davenport writes: " I am inclined to conclude that in both ateleosis and achondroplasia there are multiple dominant growth-inhibiting factors " (28, p. 382). Rolleston (21, p. 490), however, quotes one hypothesis to explain achondroplasia as due to amniotic pressure in utero.

An explanation of our results, admittedly speculative, may be attempted in

* There are reasons for believing that certain relatively large bodily changes take place in psychotic adult patients to an advanced age. We shall consider these in another paper.

† We have further evidence of this to be published shortly.

terms of relative growth. The two factors may be regarded as representing two modes of variation in growth processes. The first would be associated with general growth of all the dimensions of the body partaking differentially of length, breadth and depth, though it may seem somewhat artificial to reduce growth to three dimensions in the Euclidian sense. We may infer that this general component leads to a greater multiplication of the cells of every type of which the body is composed.

From this standpoint the first factor saturations could also be regarded as indicating which parts best reveal general development. Pelvic breadth and pelvic circumference would come first in this respect. The fact that width of hips as compared with other parts correlates highly with weight may corroborate this latter statement. Thus Wellmann (29, p. 246), writes: "The most uniformly high relationships for both boys and girls, of eleven physical traits, were between width of hips and weight, ranging from $\cdot 71 \pm \cdot 03$ to $\cdot 93 \pm \cdot 01$." Miles (30, pp. 385–86), working on adults, also finds: "Shoulders (width of) and hips (width of) stand fairly midway between height and weight in variability, and therefore may reasonably be assumed as more representative of the body build, and hence of the normal body-weight than is height alone. . . . They (width of shoulders and hips) may be assumed to contribute a factor to total body-weight that is not wholly included in the height measurements." Actually the correlation between hip width and weight Miles gives as $\cdot 58 \pm \cdot 03$, and that between shoulder width and weight as $\cdot 44 \pm \cdot 03$.

The causative influences of the second factor would seem more specific. Its positive characteristics seem to be determined mainly by the growth of the long bones. We have seen that shoulder breadth, in this group of persons, falls in with the length measurements.*

The physical traits which are negative for this factor are those which depend rather upon the bulk of the softer tissues. Linear and circumferential growth would accordingly be considered as relatively independent modes of development.

It would seem that head breadth is independent of growth in length.† A narrow head would be associated with long limbs, and a broad head with ample circumference of waist and pelvis. To a much less extent this applies to thoracic circumference. Longitudinal growth would tend to produce a relatively flat thorax as compared with the relatively deeper chests of shorter persons.

Contrasting the two factors, we may say that the first defines isometric, and the second allometric growth processes. In other words, factor I may

* It may be worth noting that "among the Pygmies of Africa and Oceania there occurs an infantile type characterized by very short legs, rather long body, narrow shoulders, pot belly, arms of rather more than medium length relative to stature" (Hooton 27, p. 478). On the other hand he writes, "'linear' type is best represented in Nilotic negroes and by other Negroids of the lake region in W. Africa; shoulders narrow, chest flat and rather narrow, etc." (*loc. cit.*, p. 477).

† This is less so in the least squares results.

imply a common rate of somatic development in all bodily regions, whereas factor II, an allometric growth divergence, according to which growth takes place linearly or circumferentially. Theoretically we should be able to determine the growth-rates of these allometric processes in terms of general somatic growth, and thus formulate equations of the $y = bx^n$ type for different parts of the body.

Dates of final ossification of the upper and lower extremities may also be a factor in differentiating the two types of independent growth. Although the long bones are ossified, connective tissue may increase, muscles may go on enlarging, and deposits of fat may be laid down until quite late in life. It would be interesting to compare the dates of final ossification in bones determining length with those in bones that do not determine length. No generalization seems to be possible yet, since observers differ amongst themselves on this question (32, pp. 759–765). It would be interesting, as well, to know whether the dates of ossification of the extremities of long thin individuals are markedly different from those of short broad persons.* Here, also, generalizations seem hardly justified. There may be different predisposing causes in different individuals.

Here we have to consider the hormones that control growth.† In premature synostosis the extremities are diminished much more than the trunk, and arrest sets in early. In the other extreme case of hyperthyroidism, maturation also presumably takes place early. Van Dyke writes (31, p. 82): "So far as the glands of internal secretion are concerned, the pituitary is unquestionably the most important and the most essential regulator of growth. Disturbances of growth may also be clearly present after the removal of the thyroid or the gonads. Also there can be little doubt but that the growth-promoting principle is elaborated in the pars glandularis." The thymus is also said to promote the growth of bones. The anterior lobe of the hypophysis apparently secretes separate hormones for general bodily growth and for genital development and function. Hyperactivity of the genital hormone results in hypergonadism, early puberty (early menstruation in girls), cessation of growth and various disorders of behaviour. Hypogonadism, on the other hand, whether primary or whether due to deficiency of the hypophyseal genital hormone, may delay the epiphyseal closures. Where this is the case, the long bones will continue to grow to eunuchoid proportions, whether the growth hormone in the pituitary is normal or in excess.

There appears to be an intimate relation between biochemical, anatomical and mental changes. Varying physical proportions with concomitant variations in behaviour may be associated with the final dates of ossification as

* B. T. Baldwin reports that "taller and heavier boys and girls matured earlier than smaller children of the same age". Univ. of Iowa, *Studies in Child Welfare*, 1921, quoted by Wellman (29, p. 246).

† Early ossification may be due to an excess or to a deficiency of a particular hormone.

determined by the disturbed balance of the hormones. These variations may be accentuated in mental patients.

We may conclude this provisional discussion by saying that the problems of physical typology have to be reformulated in terms of general and relative growth. The resulting formulations should be related to mental and anatomical variations.

This approach would seem to be more fruitful than an attempt to pass straight from psychology to biochemistry.

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