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TWIN BIRTHS AND TWINS FROM A HEREDITARY POINT OF VIEW

Inaugural dissertation

by

GUNNAR DAHLBERG

LIC. MED., ÖSTG.

By due permission of the Faculty of Medicine of Upsala to be publicly discussed in the Physiological Institute, on March 6th, 1926, at 10 o'clock a. m. for the degree of Doctor of Medicine.

STOCKHOLM 1926
BOKFÖRLAGS-A.-B. TIDENS TRYCKERI.

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PREFACE.

The present work owes its inception to Professor Herman Lundborg, who pointed out to me that, as monozygotic twins are hereditarily alike, an investigation of their diseases gave promise of interesting results. I tender him my respectful thanks for this suggestion, as also for the accommodation provided me in the course of my work by the loan of instruments from The Swedish State Institute of Race Biology, and by placing at my disposal anthropological material and a number of pedigrees belonging to the Institute. I am also indebted to Professor Lundborg because as head of The Swedish State Institute of Race Biology he enabled me to devote some part of my time during my employment in the Institute up to May 1924 to preparatory work on this treatise.

The interest shown my work by Professor Wilhelm Hultkrantz has been very encouraging, and I beg to assure him of my deep gratitude.

Further I beg to acknowledge my great indebtedness to Kungl. Vetenskapsakademien for the Lindahl scholarship granted me for the purpose of this work.

Docent A. Edin has kindly allowed me to make use of his statistical material from Västmanland, and for this I am very thankful.

When first planning my investigation, I very soon found that it would be expedient to employ the twin material for research on the heredity of twin births as well. While collecting data on twins, the investigator can with comparatively ease find starting-points for research on twin births. Further, on studying the literature on the subject, I found that the official statistics on twin births had been comparatively neglected, and might throw light on some of the problems arising. This was the basis of the first part of this work. To Miss Ella Heckscher, who has collected the main part of my genealogical twin material, my sincere thanks are due for her energetical and competent work. I owe a great obligation to the clergy in various parts of the country, who have kindly assisted me with the genealogical information required, and only regret not being able to reach each one personally with my acknowledgements.

On entering more closely into the problem of the hereditary resemblance of twins, I soon reached the conclusion that this resemblance is by no means so self-evident as commonly supposed. Besides, the information I was able to get, naturally must in the main be of anamnetic character, based on statements by the twins or their relations, and thus, cannot have the same value as direct observations. Therefore, I abandoned my above-mentioned original intention of examining the twins from a pathological point of view, confining myself to the short statements found in the last chapter of the second part. Instead, this part was chiefly given over to the study of the occurrence of some "normal" characters in twins, above all some anthropological characteristics, and to an investigation of the general principles ruling the hereditary and environmental divergencies in monozygotic twins.

To Tidens Förlag, who have indirectly helped to make the publication financially possible, I beg to express my warm gratitude.

Finally I thank my friend Mr. Vilgot Hammarling, who has shown my work great interest and sympathy, and in spite of heavy professional work has carried out the translation.

CONTENTS.

PART I.

TWIN BIRTHS FROM A HEREDITARY POINT OF VIEW.

Introduction:

General occurrence of plural births ... page 9
Occurrence of monozygotic and dizygotic twins ... » 12

Twin frequency regarding age and connected factors:

Twin frequency and age of the mother ... » 21
Twin frequency and age of father ... » 28
Twin frequency and number of earlier births ... » 28
Twin births and fertility ... » 33

Twin frequency in demographical categories:

Twin birth and legitimacy ... » 38
Twin frequency in town and country ... » 40
Twin abortions and still-born ... » 43

Twinning and race:

History ... » 52
The conception of race and the race map of Europe ... » 54
Twin frequency as a racial character ... » 57
Triplets and quadruplets ... » 63

Twin theories:

The atavism theory ... » 65
The degeneration theory ... » 68
The intoxication theory ... » 70
Body build and twin frequency ... » 72
On the embryologic mechanism ... » 73

Hereditary factors in populations:

Hereditary factors from a demographical point of view ... » 84
Hereditary factors from a genealogical point of view ... » 91
Heredity of twinning ... » 103
Résumé ... » 116
A twin hypothesis ... » 119
Repetition of twinning ... » 125
Fertility of twins ... » 131
Twin births and eugenics ... » 132

PART II.

TWINS FROM A HEREDITARY POINT OF VIEW.

Similarity of twins:

Resemblance of twins from a theoretical point of view .... page 135
Resemblance of twins from a practical point of view .... » 142
The configuration of the ear in twins .... » 143
Finger-prints of twins .... » 147
The diagnosis of monozygotism .... » 148
The influence on twins of intra-uterine conditions .... » 148
Stature and weight of twins at birth .... » 149
Superfetatio and superfecundatio .... » 154
Mortality of twins in utero, and during the first years of life...... » 156

Hereditary dissimilarity of monozygotic twins:

Genotypical asymmetrical characters .... » 160
Nævus formation in twins .... » 173
Right- and- left-handedness in twins .... » 177
Clasping hands .... » 183
Functional superiority of one leg .... » 185
Résumé of genotypical asymmetries .... » 185
Environment and anthropological characteristics .... » 186

Twins from an anthropological point of view:

History .... » 194
Collecting twin material .... » 194
Measuring method .... » 195
Error in measuring .... » 196
Anthropological differences in absolute measures .... » 203
The differences in pro mille of the measurements.................... » 205
Comparisons between dizygotic twins and brothers .... » 212
Error in measuring, environment and heredity .... » 215
The influence of sex .... » 227
The influence of age .... » 234
Anthropological dissimilarities between first and second born twins » 246
The interrelation of the measurements .... » 250
Eye and hair colour in twins .... » 256
Comparison with the results of other investigators.................... » 259
Twins from a pathological point of view .... » 266

Résumé of results:

Part I .... » 272
Part II .... » 277
Literature .... » 283
Appendix I: Measurements on twins .... » 1—15
Appendix II: Photographs of twins and ear photographs.. » 1—85

PART I.

TWIN BIRTHS FROM A HEREDITARY POINT OF VIEW.

INTRODUCTION.

General occurrence of plural births.

The occurrence of twin births has been the subject of a great many statistical enquiries, and data on the matter are given in the official statistics of most countries. For practical reasons it is not feasible to give a complete survey of the rich statistical collections of figures thus accumulated, besides errors and deficiencies in the methods of collecting the material in many cases have robbed it of practically all value. Therefore, mainly such enquiries and data as have a special bearing on the problems raised, will be treated in this paper. As the literature is scattered in various medical, scientific, and statistical publications, I cannot claim completeness even with this reservation.

Before entering on a closer analysis of the conditions of twin birth frequency, I wish to touch on the subject of plural births in general.

Hellin in 1895 laid down the rule that twin births occur in the ratio of $1 : 88$, triple births in $1 : 88^2$, and quadruple births in $1 : 88^3$ of all births. On the whole this rule has been confirmed by later works. Stöckel 1920 puts the figure at 1 : 80—90. To accord more closely with the empirical figures the denominator might be given a latitude from somewhat below 80 to somewhat above 90. The rule should perhaps be capable of extension to include quintuple and sextuple births as well, though of course the empirical values for occurrences of these rarities cannot be very reliable. Nyhoff 1904 states that quintuple births have been mentioned in the literature in about thirty cases. Five cases of sextuple births are said to be known (Baudoin; quoted Bar 1909). Two cases at least, Vasalli 1888 (quoted Winckel 1904) and Vortisch 1903, may be considered as certain. No certain case of septuple birth is known. Barfurth 1895 and Volkmann 1899, however, have drawn attention to a tombstone over septuplets in Hammel an der Weser. All the seven embryos are represented on the tombstone, and the inscription likewise speaks of septuplets.

As mentioned above Hellin's rule accords fairly well with the figures empirically found. Veit 1855 in his elaboration of Müller's figures, which are founded on a material of 13.360.557 births, gives the following results. Twins occur in 1 : 89, triplets in 1 : 89^2 and quadruplets in 1 : 71.9^3 of the births. The material used is from the birth statistics of Prussia for the years 1826—1849.

In Wappäus' 1859 (quoted Winckel 1904) statistics for Middle Europe the following figures are to be found: out of 19.698.322 births 226.807 are twin births and 1.623 triple births. This is in accordance with the fractions 1 : 89 and 1 : 89^2.

Neefe 1877 from about 50 million births has got these fractions: twins 1 : 82.7, triplets 1 : 80^2, quadruplets 1 : 82^3.

Prinzing 1892 (quoted Prinzing 1906) from 63 million births in Germany during the years 1871—80 has got the following fractions: twins 1 : 85.6, triplets 1 : 84^2, quadruplets 1 : 92^3.

Ruppin 1901 has made a survey for Prussia 1890—99. The yearly average of births during this time was 1.202.570, and among these twins occurred in 1 : 80 and triplets in 1 : 86.6^2.

Guzzoni (quoted Kawenoky 1909) in more than 50 million births finds twins in 1 : 87 and triplets in 1 : 84.3^2.

The difference in the figures thus derived from the official statistics or material otherwise collected, may of course be ascribed to various reasons. Several scientists have sought from different angles to get at the factors affecting twin frequency. A satisfactory, comprehensive account of the results thus arrived at, does not at present exist; the problems, therefore, in many cases have been somewhat one-sidedly treated and their real significance overlooked. The summaries given in obstetrical hand-books in many respects are very unsatisfactory. Thus a short résumé of the present position perhaps is justified.

First we distinguish between monozygotic and dizygotic twin births, and investigate the relative frequency of each group, and, when possible, we keep those two categories apart in all of the following. Then we proceed to treat the influence on the twin frequency of the age of the parents and other factors, more or less connected with this: the number of the mother's preceding births, and of the fertility of the mother. Employing the results thus obtained, we try to explain the differences of the twin frequency within demographic categories of official statistics: married and single, population in town and country. This, on the other hand, leads to an investigation of the twin frequency among still-born and abortions, and to the influence these have on the obtained twin frequency in statistical registration, when more or less accurately carried out. It is then examined to what extent the differences of the twin frequency within the different geographical districts is caused by differing registration, and how far the differences can be connected with the differing racial structure of the populations. Finally I touch upon the occurrence of plural births, especially the triplet frequency.

After this more empirical investigation we pass on to treat the occurrence of twins from a more theoretical point of view. We undertake a critical examination of the twin theories so far prevailing (the atavism theory, the degeneration theory, the intoxication theory, the connection between body build and twin frequency). Then the embryological mechanism for the development of twins is considered and in this connection the experimental examinations of the origin of twins and the occurrence of twins within the animal serie. The theoretical examination of the occurrence of hereditary factors in a population, which then follows, is of a more indirect interest for the following. (The problems raised in this chapter, however, are of principal importance for hereditary investigations in general, and consequently for the exposition of heredity of twin births.) Then is dealt with the importance of heredity for the origin of twin births.

After a short resumé of the preceding as far as it affects twin births, a twin hypothesis is set forth. The repetition of twin births in twin mothers is then considered in the light of certain points raised by this hypothesis. The fertility of twins and twin births from a eugenic point of view is finally briefly dealt with.

OCCURRENCE OF MONOZYGOTIC AND DIZYGOTIC TWINS.

Twins may develop out of one ovum or out of two ova. The embryologic mechanism and associated problems will be dealt with later on.

According to earlier research monozygotic twin births would be comparatively rare. Thus for instance Ahlfeld 1875 among 506 pairs of twins finds only 62 monozygotic, i. e. 12 %. Veit 1888 finds 46 monozygotic among 429 twin births = 11 %. Strassmann 1889 puts the monozygotic twins in his material (320 pairs) at 14.66 %. Lauritzen 1891 in 339 pairs finds 14 % monozygotic. Rumpe 1891 in a material of 123 pairs finds 16.6 % monozygotic.

Spät 1860 (quoted Weinberg 1902 a), however, in a study of cases where the membranes had been more carefully examined, found that the monozygotic were 24.6 % in a total material of 184 twin births. Brem 1891 states in a material of 126 twin births the monozygotic were 22.7 %. Krahn 1891 gave the figure as 19 % monozygotic (among these 2 opposite-sexed pairs) in a material of 127 pairs. Tigges 1896 in a material of 52 pairs found 21 % monozygotic. Quenzel 1898 found 20.4 % monozygotic among 181 pairs of twins.

The enquiries giving a lower percentage, however, were so numerous (those mentioned are only a selection) that it was considered as more or less established that monozygotic twins occurred in a proportion of 12—15 % of the material. In textbooks similar low percentages are still given. In Winckel's Handbuch Strassmann 1904 states that on an average 14—16 % of the twins may be counted as monozygotic. Puech in Bar, Brindeau, Chambrelent 1914, although stating that out of 43 pairs of twins observed by him only 30 were dizygotic, at the same time quotes Strassmann's 14.66 % for the monozygotic. Finally it is mentioned that Prinzing has found the monozygotic in Germany comprise 1:4 of the twins. De Lee 1913 quotes Ahlfeld's figure, 15,55 % for the monozygotic. Bumm 1914 gives the figure as 15 %. Stöckel 1920 puts it at about 14 %. Weber, in Döderlein's Handbuch 1920 estimates the monozygotic twins at 15 %. Williams 1924 states that approximately one out of every five sets of twins belongs to the monozygotic category. Engelhorn 1925 in Halban and Seitz's hand-book states that the monozygotic compose 15 % of the twins.

Weinberg, however, took up the question anew in 1902 (a). On a critical examination the earlier statistical enquiries were proved to suffer from grave inaccuracies. They were based on clinical material, and this never can be accepted as fully representative from a demographic point of view. A more serious error, however, has been committed in dividing the material so that only those twins have been counted as monozygotic, that have been diagnosed as such by an examination of the membranes, while not only those same-sexed pairs, whose membranes have been examined, have been counted as dizygotic, but also in addition to this all the opposite-sexed pairs, whether their membranes have been examined or not. In this way, of course, too low figures for the monozygotic are obtained, as there always is a comparatively large number whose membranes have not been examined, while out of this remainder, however, the opposite-sexed have been picked out as dizygotic and only same-sexed pairs (i. e. comparatively many monozygotic) have been omitted. Under these circumstances of course the dizygotic are overrepresented or the monozygotic under-represented in the final figures, whichever expression may be preferred. The error naturally increases as the number of not examined twins increases. Such a procedure for instance explains Huggenberg's figures, included by Ahlfeld 1875, 158 dizygotic against 2 monozygotic. This circumstance — it seems to me — should also explain why the percentage of monozygotic in the clinical material has tended to rise with the course of time. The development and better organization of the lying-in hospitals of course would reduce the number of not observed or noted twin afterbirths.

Weinberg now made a compilation from clinical material already published, but employing only such material as might be considered reliable (einwandfrei). He then found that among cases where the membranes had been examined the monozygotic amounted to 21.2 % in a material of 839 cases. Further, among the dizygotic in this material the opposite-sexed were 49.2 %.

Basing on the sex proportion among twins Weinberg set forth his so called differential method. He presumes that at dizygotic twin pregnancies the sex of one of the twins is determined independently of the sex of the other one. If now the probability for a boy developing out of a fertilized egg is $0.5 + a$ and thus the probability for a girl is $0.5 - a$, the probability for opposite-sexed pairs among dizygotic pairs must be $0.5 - 2a^2$. The number of boys certainly is a little more than 50 %, but as the deviation from this figure cannot be very great, Weinberg considers that the term containing a in the above formula may be omitted. This being so, the differential method takes this form: Amongst the dizygotic twins the number of same-sexed and opposite-sexed pairs is equal. By doubling the number of opposite-sexed in a certain material we thus get the number of dizygotic twin pairs. When this figure is subtracted from the total, the remainder is the number of monozygotic twins.

Bertillon 1874 and Hensen 1881 have followed the same line of thought. Bertillon in this way calculated the number of monozygotic pairs of twins at 30 % but as this figure did not accord with the empirical figures of that time, he dropped the method. For the same reason Hensen found himself obliged to abandon the differential rule, because it led to "the improbable assumption of 26 % monozygotic among the twins".

Weinberg with his differential method found that the *number of monozygotic twins* varies between 23,4 and 31 % of the twin material, different for different countries. This tallied fairly well with the figures he had got from the literature.

However, Ahlfeld 1902 raised objections against Weinberg's work. He asserts that Weinberg's figures are too high, but does not enter upon a discussion of the differential method, confining himself to a criticism of Weinberg's figures from the literature.

Weinberg 1903 (a), replies with an exhaustive discussion of the alterations in his figures made by Ahlfeld. He finds himself unable to accept Ahlfeld's alterations in more than a few cases, and after these corrections gets the figure 20,9 % instead of 21,2 % for the monozygotic. At this place it might be mentioned that on data from the Official Statistics of Prussia 1826—96, the differential method gives 25.4 % monozygotic, and that most of the works from which Weinberg has drawn his figures are based on material from German clinics. The accordance thus must be said to be good. Weinberg besides has made further collections of data from the literature, and finds his results verified.

More recently published accounts on twin births in clinical material also stand in good accordance with Weinberg's results.

Bruder 1903 among 63 pairs finds 17,5 % monozygotic.

Seegert 1904 gives the percentage of monozygotic in 214 twin births as 24.4.

Strassmann 1904 certainly in his material finds only 14.66 % monozygotic in a material of 375 pairs of twins, but number and sex of those of undecided number of ova are not given, so it is not precluded that all opposite-sexed have been counted as dizygotic. The number of opposite-sexed pairs is not given.

Rubinstein 1905 publishes a material in which every case has been examined regarding membranes. The figure for monozygotic is 35.6 % on 191 cases.

Wenzel, 1905, on 325 cases finds 22.8 % monozygotic.

Prinzing, 1908, emphasizes the objection already advanced by Weinberg against measuring the relation between dizygotic and monozygotic twins by giving the number of examined monozygotic in proportion to the examined dizygotic plus not examined opposite-sexed twins. He has gathered material from some German clinics and also employs some material earlier published. In this he finds 19.6 % certain monozygotic (when including examined and not examined opposite-sexed), and with regard taken to those same-sexed the state of whose membranes is not known, accordingly the figure must be put higher. After dividing this category in the proportion obtaining for the material in monozygotic and dizygotic of the same sex, we get the figure 26.3 % monozygotic. (With the differential method 26.2 %.)

Schapiro, 1912, among 159 twin births finds 22.64 % monozygotic.

Rabinowitsch, 1913, gets 19.7 % monozygotic in 168 pairs of twins.

Hans Meyer, 1914, disputes Weinberg's differential method. Without further substantiating his views, he says, that the premises of the method are improbable and unproved. From the journals of the Charité Meyer has extracted a material from the years 1904—11. On 18,143 single births there occurred 308 twin births, i.e. one to 58.9 single births. Among the twin births are 39 monozygotic, 213 dizygotic, and 56 same-sexed of unknown number of ova. The monozygotic are as 1 : 5 in relation to the dizygotic, if the 56 of the same-sexed with undetermined membranes are left out. If (as Meyer suggests) the unexamined 56 are equally divided between monozygotic and dizygotic, the percentage of monozygotic in the whole of the material would be 21.8. Such a division should be comparatively correct, as the opposite-sexed dizygotic have already been sorted out from those of undertermined number of ova, and consequently in the remainder there must be a comparatively great number of monozygotic twins. By the differential rule the percentage of monozygotic works out at 20.1, which must be said to tally quite well. Meyer, however, does not make this comparison with the differential rule. He shows, on the other hand, that among the certain dizygotic, 57.74 % are opposite-sexed and 42.31 same-sexed. This he considers to be contradictory to Weinberg's method, which reckons with 50 % of opposite-sexed. Meyer, however, does not count the 56 pairs not examined, and these, as has been pointed out, should balance the difference.

Hust, 1916, in 94 pairs has 31.8 % monozygotic.

Wehefritz, 1925, controls Weinberg's differential method with material brought together from literature and finds rather good accordance. This accordance, however, would certainly have been better still, if Wehefritz had employed only later examinations and not counted for instance Meckel's figures (probably unreliable): 137 pairs with 4 monozygotic!

As a whole it may be said, that the results obtained by Weinberg's differential rule from population statistics agree well with the more dependable figures that have been arrived at empirically. That there is some difference should not be a matter for surprise, as the empirical figures are derived from clinical material, which can never be considered as entirely representative from a demographic point of view. It is of course selected with regard to illness, economic conditions, etc., and it must not be taken for granted that this does not affect the frequency of other phenomena as well. The highly differing results obtained from earlier clinical material, as already mentioned, are easily explained by the incompleteness of the data.

Are there now, from a purely theoretical point of view, any objections to be raised against the differential method? The basic assumption, of course, is that the sex of one of two dizygotic twins is decided independently of the sex of the other one, while on the other hand the sex of two monozygotic twins is always decided equally. It may now be taken as fairly well-established that the sex is chiefly decided by the sex chromosomes. If an egg is fertilized by a spermatozoon without an x-chromosome, then a boy will develop, if the spermatozoon has got an x-chromosome, a girl will result. Thus the monozygotic twins always should be of the same sex, and empirically this had been confirmed long before anybody had the least notion of the importance of the sex chromosomes. The mechanism of sex chromosomes also goes to prove that the sex of dizygotic twins is independently decided at the fertilization of the different eggs. In this connection it is of no very great importance that the eggs generally are somewhat more often fertilized by a "male" than by a "female" spermatozoon. Supposing that 150 boys are conceived as against 100 girls, this would signify that among dizygotic twins 9 pairs of two boys would be conceived against 12 pairs of one boy and one girl and 4 pairs of two girls, or together 13 same-sexed and 12 opposite-sexed pairs. Now assume that the figure for opposite-sexed in a certain material is 35 %, by the differential rule, using this proportion of 13 : 12, we get 27.1 % monozygotic. On the assumption that 100 boys are conceived as against 100 girls, the differential rule would give 30 % monozygotic, the difference between the two results being only 2.9 %. There is, however, hardly any reason to assume so large a difference as 150 : 100. The latest researches in this sphere have given considerably lower values. Generally there are born 105 boys to 100 girls. Now in the abortions the boys preponderate still more, so that in the conceptions higher boy figures must be reckoned with. It may be pointed out, in fact, that the spontaneous (not provoked) abortions in this respect should be of chief importance.*

Especially in regard to the early abortions it is, however, difficult to get adequate data. Many do not come under observation. On the other hand, the abortions certainly are overrepresented in the clinical material. Finally, during the first few months the sex must be ascertained by microscopic examination of the sexual glands, otherwise the proportion of boys may easily be put too high. We cannot here enter on a discussion on the elimination of all these errors, but it is evident that the results obtained cannot be regarded as absolutely exact.

Auerbach, 1912, came to the conclusion that the proportion between boys and girls at conception is 116.4 : 100 but himself considers this figure as too low.

Schultz, 1921, in his material gets 108.8 boys to 100 girls.

Tauber, 1923, points out that if the abortions are put at an average of 10 % with a sex proportion of 150 : 100, the primary sex proportion would be 109 : 100, and he is inclined to think that this figure is too high. He tries to confirm this both with material of his own and with material gathered from the literature.

Even if, as mentioned above, these figures give only an approximate value, they should nevertheless prove that in any case the sex proportion probably does not exceed 120:100. Such a proportion only very slightly affects the differential rule.

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* On the assumption that the primary sex proportion does not vary, but keeps constant, *the sex proportion at birth should be an indicator of the frequency of spontaneous abortions.*

If the disposition of the egg to be fertilized by "male" spermatozoa were dependent on its degree of maturity, and if further the eggs of dizygotic twins generally were simultaneously produced, this would be of far greater importance.

Siegel, 1915, 1917 and 1918, has tried to show by statistics that the time of cohabitation relatively to the menstruation has an influence on sex determination. This would mean that the interval of time between ovulation and fertilization, that is to say, the age of the egg were influences in determining the sex.

Wederwang, 1924, has collected material from the literature on the subject, and in summing up the results says that a deviation in the direction indicated by Siegel certainly is observable, but that statistically the hypothesis is not proved.

It has been cited against Siegel's hypothesis that the Jewish ritual forbids cohabitation in his "boy period" (post menstrum). Siegel replies that the Jewish figures are uncertain, and that 10 % at most of the German-Jewish population are orthodox. This, however, seems too easy a way of getting out of the difficulty. According to Siegel's theory, in any case during earlier, more orthodox times, there must have existed quite an extraordinary surplus of girls among the Jews. Further the official statistics to-day on the contrary, universally show an exceptionally large surplus of boys among the Jews, e. g. in Hungary (1906—12) 106.6:100, in Austria (1896—1913) 108.35:100.

It may here be pointed out, also, that in Siegel's material the sex proportion is about 125: 100. In Germany the sex proportion is about 105: 100. This means that Siegel's material is a selection, where a comparatively great number of female births have been sorted out in judging the data. If the material is not representative in regard to the sex of the births for the whole of the inter-menstrum, there is every reason to suspect that it does not give the true sex proportion for parts of this period. Finally, it is by no means proved that the eggs preserve their power of fertilization as long as is demanded by Siegel's hypothesis (about one month). On the contrary, there are reasons for presuming that the eggs degenerate very soon when no fertilization is accomplished, maybe after a few hours (Grosser, 1925). Even if there should take place a change in the disposition of the egg to become male or female (a change in its power of attraction or resistance to the penetration of the different kinds of spermatozoa) under these circumstances there seems however to be no reason to attach too great an importance to this altered predisposition. If such an alteration exists, the number of opposite-sexed (if the eggs are as a rule produced simultaneously) should tend to diminish. This, again, should tend to make the differential method produce too low values for the dizygotic and too high values for the monozygotic. In some cases the eggs certainly are produced at somewhat different periods — in other cases they are surely produced simultaneously. The question as to which of these cases is the more common, will be discussed later.

If, thus, the differential rule should be applicable to the conditions at conception, is this also the case at the time of birth, i.e. do the abortions to any extent influence the proportion between same-sexed and opposite-sexed pairs among the dizygotic? There is no statistical material to furnish a reliable answer to this question. At single births, as above mentioned, abortions of boys are commoner than those of girls. It seems plausible that with dizygotic twins the abortions of boy-boy are the most common, that the opposite-sexed pairs come next and that the girl-girl pregnancies are least affected. From a theoretical point of view there should be no reason to suppose that the same-sexed pairs of dizygotic twins (boy-boy + girl-girl) suffer abortion more or less frequently than the opposite-sexed pairs.

Consequently the conclusion should seem to be that from a theoretical point of view, the differential rule ought to give correct results when used on a sufficiently large material, even if errors cannot be absolutely eliminated. Taking into account the empirical results obtained by means of the rule, these errors, however, do not seem to be of very great importance. None the less, the differential rule has hardly been as well known and appreciated as it deserves. In the obstetrical text-books referred to, it is not even mentioned. In the English-speaking world it is almost unknown. As late as 1915 Margareta W. Cobb discovered the differential rule and applied it to material from Connecticut, evidently without being acquainted with Weinberg's treatise. On the whole Weinberg's excellent work of 1902 has not received the attention it deserves.

It should particularly be emphasized that Weinberg's differential rule is of fundamental importance when it is question of distinguishing between monozygotic and dizygotic, and that the results obtained by this method show, in accordance with the more reliable empirical figures, that *monozygotic twin births* are about 20—30 % of the *total* number of twin births, and further, that *monozygotic twin births* consequently are 0,30—0,40 % of the total births in the population. Similarly, *dizygotic twin births* are 0,70—1 %, or somewhat more, of the births in a population. This is further dealt with in the following chapter.

TWIN FREQUENCY REGARDING AGE AND CONNECTED FACTORS.

Twin frequency and age of the mother.

A priori the number of twins in a material not selected with regard to age, must be expected to be distributed according to the age of the mother, so that a less number fall to the youngest and oldest mothers and a greater number to the ages between these. The twin distribution in other words ought to reflect more or less accurately the common birth distribution in relation to the age of the mother. If the chances of twinning for a certain woman are always constant during her whole life, the twin distribution curve should exactly reproduce the curve of common birth rate distribution. If on the other hand the chances differ with the age of the woman, the curves should differ more or less. This would then be noticeable in that the average ages of the mothers as calculated from the different curves would not coincide. Of course this is a very summary method, and it is better to calculate the twin frequency (per cent) within the different age-groups of mothers.

Several scientists have given data for the age of the mother at twin births, most of them, however, more incidently and without properly realizing the problem.

Goelhert, 1879, gets an average of twin births at an age of the mother of 26—35 years. He does not, however, give any comparative data for single births in his material. Under such conditions his compilation on the age of twin mothers must be almost worthless.

The same may be said of most of the investigations founded on clinical material. No data are given for the average age of mothers at single births as against the age at twin births. Further, even if such data were given, their value would be doubtful, when it is not clear if the mothers in a clinical material at single or twin births, are younger or older than in the population at large. If the displacement is not the same in both groups of mothers, the comparison will be misleading. Taking this into consideration, it is natural that the statements on the matter in the obstetrical literature vary considerably. Thus Rychlewicz, 1889, puts the average age of twin-bearing mothers at 28.16 years. Rumpe, 1891, distinguishes between monozygotic and dizygotic, and finds that dizygotic twin births are most frequent between 26 and 30 years, while the monozygotic are fairly equally distributed. Tigges, 1896, puts the average age of twin-bearing mothers at 27 years. Quenzel, 1898, in clinical material from Halle gets an average age of 26.68 years, in the polyclinical material on the other hand, 30.9 years. Hirt, 1902, has the figure 28.6 years, and Rabinowitsch, 1913, gives the average age as 30.64 years. Hust, 1916, has an average age of 28.5 years for mothers of monozygotic twins and 28.4 for the mothers of dizygotic. Wehefritz, 1925, puts the average age of twin-bearing mothers at 26 years.

As early as 1866, however, Duncan showed that the twin frequency increases and reaches a maximum at 35—39 years. His material is in part questionable because the twin births are taken from clinical material and divided into groups which have been related to single births, taken from the common statistics of Glasgow and Edinburgh. The single births are, if anything, over-represented, and possibly divergencies between the materials may to some extent distort the picture. Duncan's clearer conception of the problem and his results for some reason have not received notice from the obstetricians.

Shortly afterwards age grouping for twin births was introduced in the official statistics of some countries, first in Finland (1878), whose example was followed by Norway, Denmark, France, Hungary and Australia.

I do not know if this departure came as a consequence of Duncan's work. No statement on the matter is given in the several publications. The valuable material thus accumulating has not as yet received much attention.

Ditzel, 1882, quotes Duncan, and gives a table in which the primary material is taken from Danish midwives' journals. He also finds a frequency maximum at 35—39 years. Lauritzen, 1891, working with a statistical material from Copenhagen of 44,294 births, among which 677 twin births, finds that twin births are proportionally most common at 35—39 years (his material is divided into groups of five years). A priori the result must be taken with certain reservations, as the figures in several respects may be a selection.

J. Bertillon, 1898, gives corresponding tables from St. Petersburg, Munich and Nouvelles Galles du Sud, and finds a frequency maximum at 35—40 years.

Weinberg 1902 a, employing population statistics from Finland, 1881—90, and from Saxony, legitimate births 1881—1885, finds an increase of twin birth frequency with increasing age to a maximum at about 40 years. Using his differential rule he distinguishes between monozygotic and dizygotic twins within the different age groups in material from Paris. He finds an increase of dizygotic with the increase of age, while the frequency of the monozygotic does not show any considerable increase.

Prinzing, 1908 a, makes the same calculation on Bertillon's clinical material, and finds a small increase of monozygotic with age and a more pronounced increase of dizygotic.

Weinberg 1909 a, employing population statistics from Denmark, France and Hungary, finds his earlier results confirmed.

Apert, 1923, also distinguishes by means of Weinberg's rule between monozygotic and dizygotic in population statistics from France, Denmark and Hungary; he finds that with the monozygotic age has no particular influence, while it is of greater importance for the frequency of dizygotic and has a maximum at 30—39 years.

Czuber, 1923, in population statistics from Australia finds an increase with age of the frequency of multiple births (not twin births); contrary to the practice of the previously mentioned statisticians he can divide his material into one year groups, and therefore is able to give a more exact curve. He finds an almost straight rise and decline around a maximum at about 38 years.

Wederwang, 1924, giving figures from the official statistics of several countries and applying Weinberg's rule, gets a result which accords fairly well with that of Weinberg. The frequency rises with the age of the mother for dizygotic twins, while on the other hand the frequency of monozygotic does not rise "to any considerable degree".

Thus it is chiefly among statisticians that the influence of age on twin frequency has won consideration, but not even here, as much as the phenomenon should deserve. Obstetricians, for the most part, with a few exceptions, have overlooked this factor. This also may be noticed in the above list — by no means complete — of researches on twin frequency in clinical material, where only the average age of twin mothers is given. Under these conditions it is not surprising that text-books show the same deficiencies. Strassmann, 1904, in von Winckel's Handbuch der Geburtshilfe, states that Duncan has found a maximum of twin births at 25—29 years, a somewhat ambiguous way of putting the matter. Duncan's frequency table, however, is not given. He then quotes an estimate of the average age of twin mothers from Goehlert and Duncan, and finally gives the absolute figures of age distribution from a clinical material of 476 twin births, but does not give the age distribution for the corresponding single births. Puech in Bar, Brindeau et Chambrelent, 1914, says that "the greatest number of twins are produced by women between 25—29 years"; this hardly gives a correct notion of the facts. De Lee, 1913, does not even mention the influence of age. Likewise Bumm 1914. Döderlein, 1920, says that twin fertility is at its height at the age of 25—29 years. None of these in this connection distinguishes between monozygotic

Table 1.

Twin Birth Distribution after the Age of the Mothers in Different Countries.

Countries	Age of the Mothers 15—20	20—25	25—30	30—35	35—40	40—45	45—50	Total ***
Finland 1878—1916								
Total Births** ...	81,491	611,681	846,645	777,624	598,321	314,910	42,838	3,276,568
Twin Births	519	5,386	10,243	12,566	12,166	5,327	386	46,631
% (of total births)	0,64	0,88	1,21	1,62	2,03	1,69	0,89	1,42
Denmark 1896—1910								
Total Births	37,235	235,283	317,618	257,248	175,592	75,404	6,724	1,114,249
Twin Births	282	2,177	3.873	4,095	3,579	1,245	41	15,300
% (of total births)	0,78	0,93	1,22	1,59	2,04	1,65	0,61	1,37
France 1902—06								
Total Births	227,047*	1,095,504	1,243,172	856,168	527,539	210,994	29,025	4,206,979
Twin Births	1,828	7,959	12,464	11,136	8,130	2,650	306	45,351
% (of total births)	0,81	0,73	1,00	1,30	1,54	1,26	1,05	1,08
France 1907—10								
Total Births	175,131	868,208	925,078	658,465	385,721	143,982	13,533	3,218,547
Twin Births	977	6,638	9,917	9,500	7,031	2,127	94	36,653
% (of total births)	0,56	0,76	1,07	1,44	1,82	1,48	0,69	1,14
Hungary 1901—1905								
Total Births	287,894*	1,052,571	954,178	1,179,109		225,931		3,705,373
Twin Births	1,473	8,128	11,376	22,446		3,771		47,254
% (of total births)	0,51	0,77	1,19	1,90		1,67		1,28

and dizygotic. Stöckel, 1920, states that the frequence of dizygotic twin births rises with increased number of births and with rising age and that they are most frequent with mothers at an age of 26—30 years. Williams 1924 states that twin

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* incl. those under 15 years.

** Total births = single births + twin births.

*** incl. births by mothers of unknown age.

pregnancy according to Duncan is noted most frequently in multiparae especially between the twenty-fifth and twenty-ninth years. Engelhorn, 1925 (in Halban and Seitz's handbook) points out that the frequency rises with age, with a maximum of twin pregnancy at 25—29 years.

Thus, and as the influence of age explains a good deal of the peculiarities in the occurrence of twin births some tables derived from official statistics may be justified. (Table 1, 2 and 3).

Population statistics, thus, undoubtedly show that the twin frequency rises with the age of the mother from somewhat be-

Table 2.

The Distribution of Monozygotic and Dizygotic Twin Births after the Age of the Mothers and in per cent of Total Births (Table 1) according to Weinberg's Differential Method.

Countries	Age of the Mothers							Total**
	15—20	20—25	25—30	30—35	35—40	40—45	45—50	
Denmark 1896—1910								
Opposite-sexed Twin Pairs......	67	675	1,374	1,519	1,379	472	10	5,498
% Monozygotic..	0,42	0,36	0,35	0,41	0,47	0,40	0,31	0,38
% Dizygotic......	0,36	0,57	0,87	1,18	1,57	1,25	0,30	0,99
France 1902—06								
Opposite-sexed Twin Pairs.....	539*	2,494	4,298	4,153	3,166	991	122	16,069
% Monozygotic..	0,34	0,27	0,31	0,33	0,34	0,32	0,21	0,32
% Dizygotic......	0,47	0,46	0,69	0,97	1,20	0,94	0,84	0,76
France 1907—10								
Opposite-sexed Twin Pairs......	217	1,964	3,396	3,504	2,774	804	23	12,818
% Monozygotic..	0,31	0,31	0,34	0,38	0,38	0,36	0,35	0,34
% Dizygotic......	0,25	0,45	0,73	1,06	1,44	1,12	0,34	0,80

* incl. those under 15 years.

** incl. births by mothers of unknown age.

low 1 % at 15—20 years to a *maximum* of about 2 % at 35—40 years, then to fall again (Table 1). For Australia the material is divided into one year groups (Table 3). The distribution

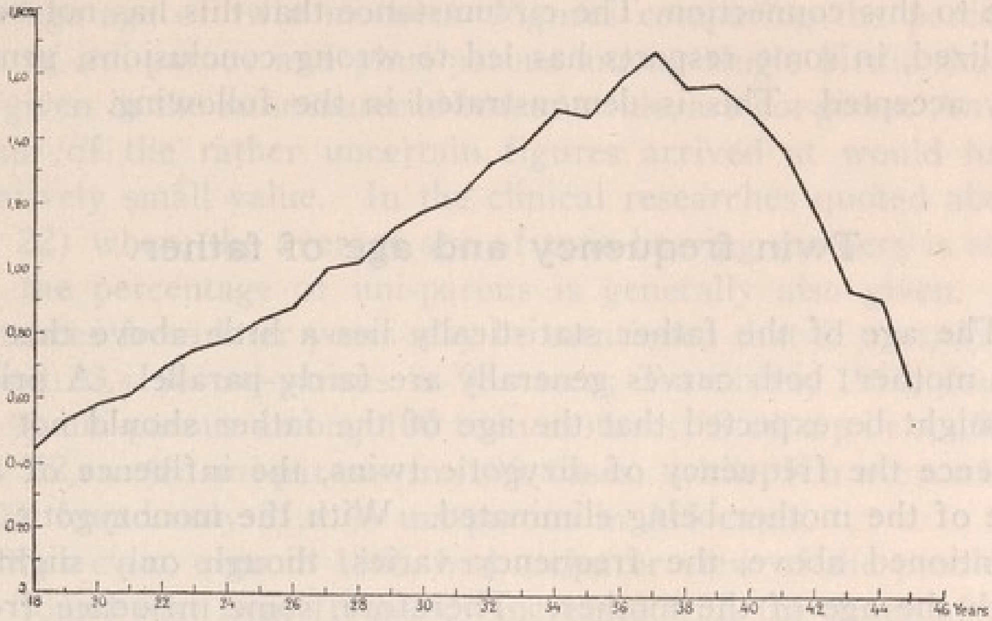

Fig. 1. The twin frequency (per cent) in relation to the age of the mothers (one year groups). The maximum 1.67 %, lies at 37 years. Statistics of Australia 1908—23 (Table 3).

is represented in the curve, Figure 1. The increase is almost straight-lined to a maximum at the end of the thirties (37 years). Then the twin percentage declines rapidly. By means of Weinberg's rule it may, further, be demonstrated that there is a comparatively small increase of the percentage of monozygotic with rising age of the mothers, from about 0,35 % at 15—20 years to about 0,45 % at 35—40 years. It may finally be considered as demonstrated that the increase of dizygotic with the mother's age is very marked, from about 0,50 % at 15—20 years to about 1,50 % at 35—40 years (Table 2). The biological interpretation of these phenomena will be touched on at a later stage.

From the practical obstetric point of view it may be of some interest that the probability of a twin pregnancy is 3—4 times greater with older (35—40 years) than with younger (20—25 years) pregnant women. From a theoretical point of view it should be pointed out that, at a comparison of the twin frequency in different materials, the influence of the mother's age must always be reckoned with. As is shown in the following, a connection with the mother's age for a certain factor must cause an increase, which can be only apparent, and in reality is due to this connection. The circumstance that this has not been realized, in some respects has led to wrong conclusions, generally accepted. This is demonstrated in the following.

Twin frequency and age of father.

The age of the father statistically lies a little above that of the mother; both curves generally are fairly parallel. A priori it might be expected that the age of the father should not influence the frequency of dizygotic twins, the influence of the age of the mother being eliminated. With the monozygotic, as mentioned above, the frequency varies, though only slightly, with the age of the mother. Therefore, some influence from the age of the father might be suspected. But as will be shown later on, this increase probably is only apparent, so there is really no reason to assume an influence from the age of the father.

Czuber, 1923, attempted statistically to determine the possible importance of the age of the father, and reached the definite conclusion that it had no influence.

Twin frequency and number of earlier births.

On an analysis of the frequency of twin births with regard to the order of the births (among first, second, third . . . . born) it will of course be found that the frequency of twin births increases as we reach the higher numbers in the series. This is an inevitable consequence of the increase with the higher age of the mother just demonstrated. Second time pregnant women are of course on an average older than first time ones, third time pregnant women older than second time ones etc. In the distribution after order as well as in the distribution after age obstetricians have generally overlooked the real problem. In the numerous researches published that are founded on clinical material, as a rule only the percentage of uni-parious and pluriparous*) among twin-bearing mothers is given. The results naturally have varied still more than at calculation of the average age of twin mothers. Figures comparing the percentage of uni-parous and pluri-parous among single births should be given in the same material but, as a rule, are not given. An account of the rather uncertain figures arrived at would have relatively small value. In the clinical researches quoted above (p. 22) where the average age of twin-bearing mothers is stated, the percentage of uni-parous is generally also given. As instances from later years may be mentioned that Hust, 1916, found 23,4 % uni-parous in 98 cases; Tauber, 1916, found 30 % uni-parous among 100 twin mothers; Schapiro, 1912, has 52,68 % uni-parous in 186 cases, while Kawenoky, 1909, found only 21,2 % uni-parous in 315 cases.

Duncan, even in 1866, had a clearer view of the problem. He found that twin frequency increases with the order of the birth but it was clear to him that this increase may be the effect of age alone. Therefore he divides his material at once after age and order of birth, and he regards it as proved by his table that not only increasing age but also the later order of the birth, cause an increase in the frequency of twin births.

Ditzel, 1882, also shows with his material that twin frequency increases with later order of birth and he finds a maximum at the sixth birth. Like Duncan he divides his material according to age and order of birth, and gets a result which corresponds to that of Duncan.

Lauritzen, 1891, concludes from his material that the influence of the order of birth is chiefly to be ascribed to age. However, taking Duncan's result into consideration he reserves final judgement.

Bertillon, 1898, concludes that the order of the birth is of greater importance than age, which, however, also has a certain effect.

Weinberg, 1902 a, regards the order of the birth as of no importance for the frequency of the monozygotic but of obvious influence on that of the dizygotic.

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* Uni-parous and pluri-parous here used as denoting the number of births (not children) per mother.

Prinzing, 1906, leaves the question, which is of greater importance, undecided. Employing Bertillon's and his own material in a later work 1908 (a) he finds that the monozygotic show an increase corresponding to the number of preceding births (P. thinks that derangements at the embedment of the egg would easier take place in older mothers and thus also abnormal division). He finds, further, that the percentage of opposite-sexed among the twins does not depend on the order of the birth.

Weinberg, 1909 a, finds he cannot decide if the increased frequency is caused by age or number of preceding births, because there is no material available arranged both after age and order of the birth.

Czuber, 1923, also leaves it an open question if age or order is the more important factor.

Wederwang, 1924, like Prinzing employing Bertillon's material, concludes that there is reason to suppose a stronger influence by age, and that the order of the birth works further increase. However, he regards Bertillon's material as too small to permit any definite conclusions.

To sum up the position in the literature it might be said that twin frequency increases with increasing age and number of preceding births, to a small degree for monozygotic, to a more marked degree for dizygotic, for both to a maximum towards the end of the thirties. If one or both of these factors are chiefly active cannot be decided with certainty from researches as yet carried out. The statistical material brought together is rather small and, further divided into five years periods. The increase with the number of preceding births which is to be noticed within each group, may of course in these cases very well be an effect of the displacement in age within the group at the transition from a lower to a higher birth number. Duncan's table may be quoted as an example:

Showing the Comparative Frequency of Twins in Different Sets of Pregnancies of Wives of the Same Age.

Mother's Age	25 to 29			30 to 34			35 to 39		
	No of Children	No of Twins	One in	No of Children	No of Twins	One in	No of. Children	No of Twins	One in
regnancies 2d, 3d & 4th........	3,235	20	162	1,628	19	86	568	9	63
regnancies 5th, 6th & 7th	766	6	128	1,568	27	58	993	17	58
regnancies 8th, 9th & 10th......	28	1	28	283	7	40	616	19	32

In the official statistics of several countries (Hungary, Australia) the twin births have been grouped after birth number. There is, however, no table of twin frequency, grouped both after number and age.

In the obstetric literature, as mentioned, the problem has been overlooked. It should here be pointed out that in the text-books above mentioned very incomplete information is given. Strassmann in Winckel's Handbuch 1904, states that among 12 cases of his own there were one uni-parous and 11 pluri-parous! Further he quotes a statement from Duncan that 22,73 % are uni-parous, 40,91 % 2—5-parous and 36,36 % 6-parous or more. Duncan's table is not given. Finally he states that among the mothers of monozygotic twins 33,67 % are primiparous and among mothers of dizygotic twins 22,78 % (it is not stated how large the material is). Puech in Bar, Brindeau et Chambrelent, 1914, points out that pluri-parousness is one of the factors which influence twin frequency, but mentions that this has been shown by Prinzing to be due to the influence of age. Weber, in Döderlein's Handbuch 1920, mentions that triplets are more common with mothers who have had several children, but twins are passed over. Williams, 1924, states, as already mentioned, that twins are most common with pluri-parous. Engelhorn, 1925, says that for dizygotic, not for monozygotic, twin frequency increases with the number of preceding births.

However, in the official statistics of Australia, tables are now given which lend themselves to the solving of this problem. A regrouping of twin and single births during 1908—23 according to the age of the mothers gives the following table, where the increase of twin frequency above mentioned, may be observed. Now there are further tables from later years of first-born legitimate single births distributed after age and of first-born legitimate twin births likewise distributed after age. On relating these figures to each other the adjoining table results (Table 3).

The increase among first-born to be noticed here cannot be ascribed to any other influence but that of age. If the number of preceding births has a similar influence there should be an even more marked increase in the series where this number also rises from one group to the other. This, however, is not the case. Graphically, the two series are illustrated in fig. 2. The very small divergences doubtless may be considered as accidental. In only one group (34 years) did the difference

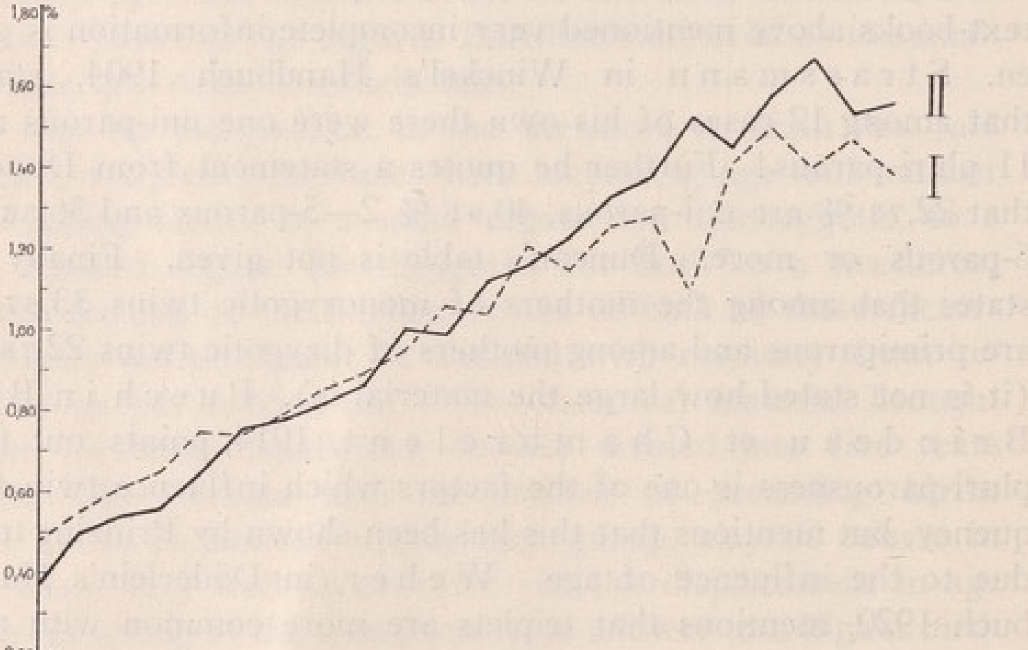

Fig. 2. The twin frequency (per cent) in relation to the age of the mothers (one year groups) among legitimate first births (the dotted line = I) and legitimate second and later births together with illegitimate births (the full-drawn line = II). Statistics of Australia 1908—23.

Table 3.

The Twin Frequency after the Age of the Mother among First-born and Later-born and among Total Births in Australia 1908—23.

	Age of the Mother																					
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Births (number of mothers)	28,536	46,416	61,921	82,794	98,436	112,832	118,696	121,429	123,979	120,335	120,702	112,725	109,662	92,682	94,528	84,790	77,992	70,700	65,357	56,797	53,568	44,509
Twin births	125	246	358	503	684	841	925	1,016	1,094	1,203	1,227	1,259	1,295	1,135	1,254	1,167	1,164	1,038	1,039	948	834	698
I. %	0,44	0,53	0,58	0,61	0,69	0,75	0,78	0,84	0,88	1,00	1,02	1,12	1,18	1,22	1,33	1,38	1,49	1,47	1,59	1,67	1,56	1,57
Legitimate first-births (number of mothers)	17,222	27,726	33,974	43,514	48,217	49,839	45,579	41,908	38,107	33,741	28,414	23,223	20,042	14,679	12,827	9,907	8,205	6,844	5,535	4,229	3,640	2,707
Legitimate first-born twin births	83	153	207	282	360	370	361	361	344	325	302	244	244	171	163	128	91	98	84	60	58	38
II. %	0,48	0,55	0,61	0,65	0,75	0,74	0,79	0,86	0,90	0,96	1,07	1,05	1,22	1,16	1,27	1,29	1,11	1,43	1,52	1,42	1,59	1,40
Legitimate second- and later-births + illegitimate births (number of mothers)	11,314	18,690	27,947	39,280	50,219	62,993	73,117	79,521	85,872	86,594	92,288	89,502	89,620	78,003	81,701	74,883	69,787	63,856	59,822	52,568	49,928	41,802
Legitimate second- and later-twin births + illegitimate twin births	42	93	151	221	324	471	564	655	750	878	925	1,015	1,051	964	1,091	1,039	1,073	940	955	888	776	660
III. %	0,37	0,50	0,54	0,56	0,65	0,75	0,78	0,82	0,87	1,01	1,00	1,13	1,17	1,24	1,34	1,39	1,54	1,47	1,60	1,69	1,55	1,58
Difference between the percentage II and III	— 0,11	— 0,05	— 0,07	— 0,09	— 0,10	+ 0,01	— 0,01	— 0,04	— 0,03	+ 0,05	— 0,07	+ 0,08	— 0,05	+ 0,08	+ 0,07	+ 0,10	+ 0,43	+ 0,04	+ 0,08	+ 0,27	— 0,04	+ 0,18
Standard error of the difference	± 0,077	± 0,067	± 0,060	± 0,053	± 0,052	± 0,050	± 0,052	± 0,055	± 0,057	± 0,062	± 0,069	± 0,075	± 0,084	± 0,097	± 0,107	± 0,122	± 0,125	± 0,152	± 0,173	± 0,192	± 0,216	± 0,235

exceed 3 times the standard error*. A different tendency that might indicate an influence of the number of births is not noticeable. A division into monozygotic and dizygotic cannot be made, but if one of these groups were influenced to any considerable extent this certainly would be noticeable even in this table.

The results thus obtained by me, from a twin-statistical point of view, is of a certain importance. We have before demonstrated that the influence of age must always be eliminated at a comparison of the twin frequency in different materials. If it were also necessary to pay regard to the number of the mother's preceding births, the statistic problems in many cases would be practically impossible to clear out.

The fact that the number of preceding births does not affect the twin frequency, indicates further that twin mothers have not increased fertility. In the following we intend to deal more closely with this problem and to show the part played here too, by the age of the mother as regards the provoking of increased figures for the number of births in twin mothers.

Twin births and fertility.

Under birth rate is understood the number of births per thousand inhabitants; statistical fertility, on the other hand, is generally taken to mean the number of births per thousand married women of 15—45 or 50 years of age (the upper limit may be somewhat differently drawn). Biologically the fertility of a woman ought to mean primarily her disposition to conceive. Now, this potential capacity cannot be directly measured. The real (efficient) fertility might perhaps most appropriately be defined as the number of children per married woman relatively to the time she has been married. This real fertility naturally is not a true reflection of the potential one. A good many social and other factors

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* Here as well as in the following, the standard error of percentages is calculated according to the formula $\sqrt{\frac{p\,(100-p)}{n}}$, where p = the percentage, and n = the total number of observations upon which the percentage is founded.

here play their part, and their influence in most cases cannot be gauged. The statistical fertility differs from the real fertility, to a not calculable amount, and of course this applies also to a comparison with the potential fertility.

Many efforts have been made to relate twin frequency to fertility. The obstetricians who have handled the problem, however, have conscientiously abstained from giving a clear definition of what they mean by "fertility", and they seem to pass in their arguments somewhat nonchalantly from one to the other of the definitions mentioned above.

Duncan, 1866, thinks it probable though not proved that twin-bearing mothers have larger families than others.

Kleinwächter, 1871, also associates the occurrence of twins with fertility (quoted Winckel 1904 — original work not accessible to me).

Puech, 1874, investigating twin births in different parts of France, notes that twins are more common in northern France and rarer in the south. This he supposes to be due to the difference in fertility between these parts. In northern France fertility is higher than in the south. He also shows that periods of maxima and minima of fertility (birth rate!) coincide with high and low rates of twin frequency.

Neefe, 1877, also shows that birth rate and twin birth rate run together. Curiously enough he has shown that twin births in his material are more common among catholics than among protestants.

Hellin, 1895, is of opinion that the ovaries of mothers bearing dizygotic twins are likely to be richer in follicles. These mothers therefore ought to be more fertile. Presumably he means potentially fertile. He seeks to establish this view by showing through figures from France that periods of higher fertility (in this case, of course, birth rate) have increased twin frequency.

Weinberg, 1902 a, finds the births by mothers bearing dizygotic twins not to be more frequent than those by mothers of monozygotic twins, but he will have found a higher fertility among the mothers of twin-bearing mothers. These, he states, show an average of 7,3 births.

Prinzing, 1907, does not think that twin frequency is conditioned by birth rate alone. He points out that the birth rate in the official statistics of the European countries, does not run parallel to the twin rate. Further he shows that the birth rate of Prussia has declined from 1871 to 1900, while the figure for twins during the same period has risen.

Bonnevie, 1919, cannot find any certain increase of the number of births per marriage in the Ringbue family on a comparison of the "twin-bearing branches" with the others.

Wehefritz, 1925, considers that Duncan, Puech and others have proved that twin births are due to fertility. Wehefritz seeks to uphold this statement further by means of a curve showing the number of children in twin families and in families with single births, taken from Bonnevie. The curve really indicates that the number of children in the different kinds of families are very evenly distributed.

Text-books as a rule mention that twin frequency is connected with fertility. Strassmann in Winckel's Handbuch, 1904, says that Puech has proved the plural births to depend exclusively on the fertility of a country, that is to say, the more fertile a country is, the more common are twin births. Weber, in Döderlein's Handbuch 1920, accepts Hellin's opinion, which, he says, is confirmed by experience (he does not state, however, the facts behind this assertion). Women with twins have more numerous follicles and increased tendency to conceive. In Bar, Brindeau et Chambrelent, 1914, Puech gives the strong development of the ovaries as one of the reasons of twin births without further entering upon the question. Stöckel, 1920, supposes that twin births are caused by a hereditary excessive fertility. Williams, 1924, says that heredity of twin births exists only in the form of "abnormally actively functioning ovaries". Engelhorn, 1925, thinks that twin births undoubtedly are connected with the fertility of women and quotes Hellin and a supporting case from Berger, according to which a mother had 30 pregnancies with 36 children.

The potential fertility cannot be directly measured by statistical means. What can be done, is to investigate if the real fertility shows any increase, and if so, whether this can be interpreted as a sign of increased potential fertility. Is there then, any such increase to be found?

It should be emphasized that if first the average number of children of twin-bearing mothers is determined, and then compared with that of single-bearing mothers without regard to the length of the fertile period, the result must be that the twin-bearing mothers show the larger number. They are generally older, and thus have had a longer fertile period. A small difference in the number of children therefore does not prove anything. Only if the increase in the average number of children of twin-bearing mothers is very marked, there would possibly be a reason to assume increased fertility.

Duncan, 1866, gives the following table of the number of children by single birth and the number of children of twin-bearing mothers before the twin birth.

Showing the Average Size of Families after Different Durations of Marriage in Mothers generally and in Mothers bearing Twins*.

No. of Years Married	under 5	5—9	10—14	15—19	20—24	25—29
Average Size of Families...	1,699	3,940	6,063	7,967	9,868	13,075
Average Size of Twin Families	2,523	4,936	7,397	9,793	9,533	

The figures in Duncan's table being a little higher for twin-bearing mothers, does not prove anything, as the material is divided into groups of five years, and so small an increase may be explained by a displacement within the groups of twin-bearing mothers towards the higher age limit.

Weinberg, 1902 (a), as above mentioned also has dealt with this problem. His material is derived from Würtemberg (end of 19th century). In mothers bearing monozygotic twins the average number of births is 7, in mothers bearing dizygotic twins, 6,7. Weinberg had expected a larger number of births

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* The mothers in this table are those only who continue fertile up till the different durations of marriage.

in the dizygotic. The difference is too small to mean much, and rather points in the other direction. No figure is given for single births or for the average length of the fertile period of the twin-bearing mothers. As already mentioned these might be expected to have had a longer fertile period than single-bearing mothers, and their average number of births under these conditions is not of such an order as necessarily to indicate increased real fertility. The less so as Weinberg has shown that the length of time between births is *not* shorter for mothers of twins than for others. In this regard it is of no very great importance that he has found a greater number of births in mothers of twin-bearing mothers; the figures show a very moderate increase, 7.3 births for grandmothers of dizygotic twins, 6.5 for grandmothers of monozygotic. As these figures probably date as far back as the middle of the 19th century, when fertility generally was higher, they should not cause surprise. Childless marriages are not counted at all — a circumstance that in itself must help to raise the average number of children. Comparative figures for single-bearing mothers are not given.

Neither can the figures found by Bonnevie, 1919, be said to prove a higher fertility in mothers of twins and their relatives. In the "twin-bearing branches" of the Ringbue family Bonnevie finds an average number of births per marriage of 6,72 ± 0,25. In the whole family this figure is 6,38 ±0,14. The difference is 0,34 ± 0,28. Even this small difference cannot be considered as statistically established.

Prinzing's enquiry, just quoted, seems to have definitely proved that there exists no real connection between twin frequency and birth rate. Nor was this to be expected. A rise of the birth rate may be caused by an increased number of births by more aged mothers. If so the twin rate likewise rises. If on the other hand the rise is caused by an increased number of births among the young mothers the twin frequency will fall. Prinzing also points this out.

The same applies to the statistical rate of fertility. This is obvious, and figures would here be superfluous.

The result of investigations so far made may be summed up thus: An increase of the real fertility in twin-bearing mothers is not statistically proved, and results of investigations rather speak against the existence of such an increase. Theoretically we cannot exclude the possibility of the potential fertility being somewhat heightened, even if there is no such increase, but at present there are no statistical grounds for such an assertion. The increase of the number of births (fertility) that has been regarded as established in twin mothers, is, as I have pointed out, certainly explained by the influence of age.

Finally it may be pointed out that if twin mothers have increased fertility, this must cause an increase of the percentage of twin births with the number of births among the mothers in a population, independent of the influence of age. Such an increase, however, does not exist, as I have above been able to demonstrate. With regard to this, our above conclusions gain in certainty. The statement generally set forth, that twin mothers have increased fertility, has no foundation. On the contrary, it may statistically be regarded as proved that they have no increased real fertility.

TWIN FREQUENCY IN DEMOGRAPHICAL CATEGORIES.

Twin birth and legitimacy.

In the official statistics of most countries data are given for the frequency of twin births among legitimate and illegitimate births. Is there any reason to expect any difference in frequency between legitimate and illegitimate twin births? Mothers at illegitimate births are, of course, on an average decidedly younger than at legitimate births. Consequently the twin frequency among illegitimate ought to be lower than among the legitimate. Also, such a difference is regularly to be found. The question, then, arises: Is it to be explained by the influence of age alone?

Weinberg, 1902 (a), is of opinion that the difference partly is accounted for by age. He goes on to quote some figures from different countries showing that monozygotic twins are to be found in about the same number among legitimate and illegitimate births. On the other hand dizygotic twins are considerably more numerous among the legitimate. Besides age he does not state any definite factor which he considers to be of importance in this connection.

Prinzing, 1906, also quotes figures from official statistics showing that twin births are rarer among the illegitimate. He does not make any attempt to prove that the difference corresponds to the influence of age, though he considers this to be the case.

Czuber, 1923, divides his material into 5-years groups and gets the same age curve for legitimate and illegitimate, though the rise of the curve is slightly more rapid for the illegitimate.

A collection of my own gave the following result (Table 4).

Table 4.

Births and Twin Births distributed after the Age of the Mothers and Legitimacy in Denmark 1911—1920.

	Age of the Mother							Total *
	18	19	20—24	25—29	30—34	35—39	40—44	
Legitimate births (number of mothers)	3,607	8,503	121,132	193,546	157,920	103,111	41,237	648,187
Legitimate twin births	26	68	1,363	2,762	2,927	2,381	674	10,281
%	0,72	0,80	1,13	1,43	1,85	2,31	1,63	1,59
Illegitimate births (number of mothers)	5,840	8,231	36,715	15,365	7,152	4,087	1,446	83,933
Illegitimate twin births	37	61	429	231	137	106	32	1,060
%	0,63	0,74	1,17	1,50	1,92	2,59	2,21	1,26
Difference (between twin births %) ...	— 0,09	— 0,06	+ 0,04	+ 0,07	+ 0,07	+ 0,28	+ 0,58	— 0,33
Standard error of the difference	± 0,17	± 0,14	± 0,06	± 0,10	± 0,16	± 0,25	± 0,14	± 0,04

* incl. births by mothers of unknown age.

The twin frequency is 0,33 % lower in illegitimate births. On a division into age groups the difference is very slight, in spite of a rather rough division. Singularly enough, here as well as in Czuber's material the curve for the illegitimate lies a little above that for the legitimate in the higher age groups. It might be conceived that twin pregnancies are harder to conceal than single pregnancies and therefore more regularly are brought to notice and registered. However, the difference is very small and does in no group exceed 3 times the standard error. There is hardly any reason to suppose a real difference in the frequency of twin births among legitimate and illegitimate births on a basis of these figures. Further, it may be pointed out that the illegitimate for the most part can be assumed to be first born. The figures found then are consistent with our previously demonstrated fact that the number of previous births does not influence the twin frequency.

Twin frequency in town and country.

Already Neefe, 1877, has noticed that twin births are more common in the country than in the towns. In the official statistics of several countries also, the material is divided after this point of view. Weinberg, 1902 (a), shows on the statistics of Prussia, 1890—99, that after the differential rule the monozygotic are as common in the towns as in the country, but the dizygotic more common in the country. He associates this with the greater fertility of the rural population. His figures are as follows:

	Twin births from one ovum per 10,000 births	Twin births from two ova per 10,000 births
In the towns	32,5	87,7
In the country	33,1	99.0

Here, too, the difference may well be caused by a different age distribution. The circumstance that the frequency of only the dizygotic varies, but hardly that of the monozygotic, points in that direction. A table from France with grouping after age takes the following form (Table 5).

Table 5.

The Twin Frequency after the Age of the Mother in the Towns and in the Rural Districts of France 1907—10.

	Age of the Mother							Total*
	15—19	20—24	25—29	30—34	35—39	40—44	45—49	
Live-births and still-births:								
Births in towns ...	90,075	404,018	398,340	264,341	144,344	50,452	4,192	1,376,052
Twin births »	480	2,947	3,957	3,499	2,420	717	26	14,242
» » % ...	0,53	0,73	0,99	1,32	1,68	1,42	0,62	1,03
Births in the country	85,056	464,190	526,768	394,124	241,377	93,530	9,341	1,842,495
Twin births »	497	3,691	5,960	6,001	4,611	1,410	68	22,411
» » % ...	0,58	0,80	1,13	1,52	1,91	1,51	0,73	1,22
Births with at least one still-born:								
Births in towns ...	4,672	19,057	19,273	14,325	9,591	4,088	459	74,009
Twin births »	123	627	718	546	387	147	5	2,588
» » % . .	2,63	3,29	3,73	3,81	4,04	3,60	1,09	3,50
Births in the country	2,796	13,993	16,938	15,134	11,572	5,862	748	69,738
Twin births »	141	728	974	913	702	259	13	3,776
» » % . .	5,04	5,20	5,75	6,03	6,07	4,42	1,74	5,41
Live-births with only live born:								
Births in towns ...	85,403	384,961	379,067	250,016	134,753	46,364	3,733	1,302,043
Twin births »	357	2,320	3,239	2,953	2,033	570	21	11,654
» » %	0,42	0,60	0,85	1,18	1,51	1,23	0,56	0,90
Births in the country	82,260	450,197	509,830	378,990	229,805	87,668	8,593	1,772,757
Twin births »	356	2,963	4,986	5,088	3,909	1,151	55	18,635
» » % ...	0,43	0,66	0,98	1,34	1,70	1,31	0,64	1,05
Difference between town and country among live-births and still-births ...	+ 0,05	+ 0,07	+ 0,14	+ 0,20	+ 0,23	+ 0,09	+ 0,11	+ 0,19
Standard error of the difference ...	± 0,033	± 0,014	± 0,020	± 0,026	± 0,042	± 0,066	± 0,096	± 0,012
Difference between town and country among live-births	+ 0,01	+ 0,06	+ 0,13	+ 0,16	+ 0,19	+ 0,08	+ 0,08	+ 0,15
Standard error of the difference	± 0,030	+ 0,014	± 0,017	± 0,026	± 0,042	± 0,063	± 0,150	± 0,011

* incl. births by mothers of unknown age.

The difference in twin frequency between town and country is 0,19 %. On a grouping after age the difference in most of the age groups turns out to be less, but there remains a distinct difference with consistently higher values for the country. The most likely explanation of this disparity would be some difference in the mode of registration. If the still-born (single births and twin births with the death of one or both children) are subtracted from the material, the rest are births with only live born. If this is done the difference between the figures for country and town is diminished. The difference for the still-born, thus, becomes larger. The still-born twins are a comparatively large part of the still-born in the country, viz. 5,41 %, while they are only 3,50 % in the towns. As will be shown below (p. 50) the percentage of twins increases, the more if the early abortions — apart from the very first months — are taken into account. There is, therefore, reason to suspect that the registration in the country is more accurate and that this has something to do with the difference, though of course this does not preclude that there is, also, a real difference in the number of still-born. For the live-born (déclarés vivants), this explanation is also possible. The case would be this:

In the towns the live-born are registered with less accuracy, and a good many who have died only just after birth, and thus a comparatively large number of twins, are registered as still-born. Consequently the percentage of live-born twins will be lower in the towns. As regards still-born a good many prematurely born in the towns escape registration, especially those from the earlier months of gestation. This would mean a comparatively low percentage of still-born in the figures for twins.

At present it cannot be decided if this is a sufficient or correct explanation. It is, of course, possible that there exists a real increase of twin frequency among the rural population irrespective of irregularities in the registration. Increased intermarriage in the country might possibly, as suggested by Bonnevie 1919, cause an increase of the twin births if the disposition to bear twins, as Bonnevie assumes, is a hereditary recessive character.

Both as regards legitimate and illegitimate births, and as regards births in town and country, I have been able to demonstrate that the differences of the twin percentages are partly due to the influence of age. On the other hand, there are reasons to assume that the differences are also due to a different frequency of still-births and abortions, or to a registration, differing in accuracy, or to both these factors. In the following, we therefore intend to deal more closely with the part played by abortions and still-born as regards the twin frequency.

TWIN ABORTIONS AND STILL-BORN.

The line between abortion and premature birth cannot be very sharply drawn. Nor is the line between still-born and live-born for practical purposes quite definite; and the rules that are more or less imperfectly applied in different countries, are not the same. Abortions are not registered. As still-born are counted those who are at least six months (180 days) old (Sweden, Belgium, France, Saxony, Switzerland). In some countries the limit is drawn at 28 weeks (196 days) (Norway, Denmark). Others have a seven months limit (210 days) (Hungary), and some have no formal regulations at all (Finland, Holland, Austria, Italy). In some countries, finally, the time limit is combined with a limit drawn after a certain minimum length of the embryo (Prussia 180 days and 32 cm., Wurtemberg 196 days and 37 cm.). In England twins are not specially registered. (Quoted Wederwang 1924).

The proportion between live-born and still-born may possibly be affected by the varying regulations on the time within which notice must be given. The number of still-born may be expected to increase the longer the giving of this notice can be delayed because then some children, dead shortly after birth, can be reported as still-born. In some countries (Finland) there are no regulations. In most countries (France, Belgium, Switzerland, Italy, Germany, Denmark, Hungary) only a short time (2—7 days) is allowed. In Sweden and Norway the time allowed is 42 days and one month respectively, but as the registration of the birth is coupled with the christening, notice is usually given much earlier.

As now not only the time limit for registration is differently fixed in different countries, but as also the frequency of abortion and the number of still-born varies, it is of great interest to know if their occurrence follows the laws established for twin births, and further if they are of such an order that their exclusion or inclusion would affect the twin frequency to any considerable extent.

The still-born as a rule are included in the figures used above. They are of special interest, however, as an indicator of the distribution of the abortions. A priori it should be expected that the abortions would be distributed more or less identically with the still-born. It is, by the way, well known that the still-born are very common at twin births. In Sweden the still-born twin births (pairs with one or both dead) during 1891—1910 were 7,70 % of the still-born births (still-born single births + twin births with one or both dead).

If thus the still-born are excluded, this should occasion a decrease in the figure for twin frequency, because a comparatively large number of still-born twins are not counted.

What is further the frequency of still-born, if monozygotic and dizygotic are differentiated? Already Weinberg, 1902 (a), has tried to solve this question, though he does not consider the clinical material at his disposition as quite reliable for the purpose. According to this material still-born are more common among monozygotic (14,2 %) than among dizygotic (8,2 %). Employing the differential rule on statistical material (Sweden, Saxony, Austria, Prussia) he finds in Sweden, for instance, that among the monozygotic twins 13,8 are still-born and among the dizygotic 7,6 %.

Prinzing, 1906, quotes the results obtained by Weinberg from clinical material, but regards the figures as too small to draw definite conclusions from.

The next question, is: What is the distribution after age of the mothers of still-born twins compared to total still births? If their distribution over the different ages is the same as that of the live-born, they will not affect the form of the twin curve. If they are particularly numerous in more aged mothers, they will cause a steeper rise of the curve. If, finally, still-born twins are particularly common in the youngest and oldest age groups, they must cause a levelling of the curve. Of course, the figures for still-born twins in this connection must be related to still-born births.

Finally, how are the still-born twin births distributed in relation to total still births, grouped after age and divided in monozygotic and dizygotic? The statistics of France provide material for a collation along these lines. Applying the differential rule I get the following table (Table 6).

Table 6.

The Twin Frequency distributed after the Age of the Mother among Live-births and Still-births in France 1907—10. The Frequency of Monozygotic and Dizygotic is calculated after Weinberg's Differential Rule.

	Age of the Mother						Total*	
	15—19	20—24	25—29	30—34	35—39	40—44		
Births (number of mothers)	175,131	868,208	925,078	658,465	385,721	143,982	3,218,547	Group I
Twin births	977	6,638	9,917	9,500	7,031	2,127	36,653	
%	0,56	0,76	1,07	1,44	1,82	1,48	1,14	
Opposite-sexed twin pairs	217	1,964	3,396	3,504	2,774	804	12,818	
Dizygotic in % of the births	0,25	0,45	0,73	1,06	1,44	1,12	0,80	
Monozygotic in % of the births	0,31	0,31	0,34	0,38	0,38	0,36	0,34	
Still-births (single births + twin births with both dead)	7,354	32,323	35,237	28,566	20,443	9,690	140,022	Group II
Still-born twin pairs with both dead	150	628	718	566	369	146	2,639	
%	2,04	1,94	2,04	1,98	1,81	1,51	1,88	
Opposite-sexed twin pairs	31	144	180	167	108	37	685	
Dizygotic in % of the births	0,84	0,89	1,02	1,17	1,06	0,76	0,98	
Monozygotic in % of the births	1,20	1,05	1,02	0,81	0,75	0,75	0,90	

* incl. births by mothers of unknown age.

	Age of the Mother						Total*	
	15—19	20—24	25—29	30—34	35—39	40—44		
Still-births (single births + twin births with one or both dead)..	7,468	33,050	36,211	29,459	21,163	9,950	143,747	Group III
Still-born twin pairs with one or both dead...	264	1,355	1,692	1,459	1,089	406	6,364	
%................	3,54	4,10	4,67	4,95	5,15	4,08	4,43	
Opposite-sexed twin pairs	51	349	501	459	370	133	1,893	
Dizygotic in % of the births	1,36	2,11	2,77	3,12	3,50	2,67	2,63	
Monozygotic in % of the births	2,18	1,99	1,90	1,83	1,65	1,41	1,80	
Live-births with at least one alive	167,777	835,885	889,841	629,899	365,278	134,292	3,078,525	Group IV
Twin pairs with both live-born	713	5,283	8,225	8,041	5,941	1,721	30,289	
%................	0,42	0,63	0,92	1,28	1,63	1,28	0,98	
Opposite-sexed twin pairs	166	1,615	2,895	3,045	2,404	681	10,925	
Dizygotic in % of the births	0,20	0,39	0,65	0,97	1,32	1,01	0,71	
Monozygotic in % of the births	0,22	0,24	0,27	0,31	0,31	0,27	0,27	

An inspection of this table shows that among the still-born (Group III) the percentage of twin births (one or both of the twins dead, in per cent of births with at least one dead) rises with rising age, though slowly — that is to say, not so rapidly as the percentage among live born. An inclusion of the still-born, therefore, would slightly level the curve.

Among the still-born (Group III) the twin births are 4,43 %, among the live-born 0,98 % (Group IV), so an inclusion of the still-born would cause an increase of the twin birth percentage to 1,14 % (Group I).

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* incl. births by mothers of unknown age.

On a differentiation between monozygotic and dizygotic it will be found that the monozygotic show a comparatively larger increase among the still-born than do the dizygotic. The monozygotic are 0,27 % of the births among the live born and 1,80 % of the births among the still-born; they are thus 6—7 times multiplied. The dizygotic are 0,71 % of the births among the live-born and 2,63 % of the births among the still-born; they are thus only 3—4 times multiplied.

Finally, regarding the age frequency of monozygotic, we find a slightly increased percentage of twin births with rising age among the live born, and on the other hand a comparatively sharp drop with rising age in the percentage of monozygotic among the still-born. An inclusion of the still-born, therefore, would lessen the increase of monozygotic with rising age. As for the dizygotic there is to be found a distinct increase with age among the still-born, though not quite so large as the increase among the live-born. An inclusion of the dizygotic, thus, would to a certain extent, though rather slightly, lessen the increase of dizygotic.

Assumed that the still-born were a far larger group than here found, the result of an inclusion of this finally might be to defeat the increase with age of the monozygotic in the total material — but a marked increase with age of the dizygotic would always remain.

On the whole, then, the effect of including the still-born would be this: The twin frequency would increase, and the monozygotic would increase more than the dizygotic. The increase with age would lessen slightly for the dizygotic, more markedly for the monozygotic.

Wederwang, 1924, also has given this problem his attention. He employs other methods of calculation and arrives at a wholly different result. He finds that the increase of the opposite-sexed (dizygotic) twins with the age of the mother and the order of the birth, does not depend on an increased chance of simultaneous fertilization of two eggs with higher age of the mother or the higher number of her previous pregnancies, but that it is caused by the higher death rate of the monozygotic twins, who more frequently are aborted.

This, of course, is a mistake. The frequency of the monozygotic may be increased or decreased in different ages, this does not in the least influence the frequency of the dizygotic twins relatively to the single (or total) births. Wederwang's later conclusions that he thinks himself entitled to reject the hypothesis of Weinberg and Prinzing about the dizygotic twins increasing in frequency with the mother's age and the order of the birth therefore seem quite unwarranted.

Wederwang does not reckon the still-born twins in proportion to the still-born births, but states the still-born twins in per cent of the number of twins born — that is the rate of still-born among twins. This rate decreases with the advancing age of the mother, to rise again in the highest age groups. Further, it rises most for same-sexed boys, then for same-sexed girls and least for opposite-sexed twins; finally these traits are most pronounced if only those cases are counted where both the twins have died. This was to be expected and is due to the circumstance that monozygotic still-born decrease in relation to total births with rising age of the mother, while dizygotic still-born increase, although not to the same degree as with the live-born dizygotic.

Wederwang calculates the relation of the death rate of the same-sexed to that of the opposite-sexed (in per cent) with rising age, and finds that this rate is low at an earlier age but rises as age advances. Thus he finds that "the chance of both twins dying increases for the same-sexed with the advancing age of the mother, if this chance is calculated in relation to that of both twins dying among the opposite-sexed." From this quite correct result Wederwang now draws his above stated conclusions. During his per cent calculations he evidently forgets to keep in mind the significance of the different percentages. His result accords in principle with a distribution of the still-born which does not at all influence the age curve for twin births, neither for the monozygotic nor the dizygotic.*

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* To explain W.'s calculations let me refer to the following diagram (schematically drawn after the statistics of France) Fig. 1 is an ideal curve for monozygotic in per cent of births with the still-born added, without the curve changing its form. Fig. 2 illustrates the corresponding condition regarding dizygotic twin births. If now the still-born are counted in per cent of the corresponding twin

Wederwang has employed the same material that has been used by me, viz. the official statistics of France 1907—13 (somewhat longer period). If we consider only those cases of still-born twin births, where both twins have died (Table 6 group II), my results are not in the least affected. There is, as the table shows, a decrease with rising age for the monozygotic. Further, there is an increase with age for the dizygotic, not so strong as among the live-born but quite decided. To get, by adding two such age curves with increasing twin percentage for rising age, one curve where this increase is missing, is of course practically impossible. Such a result could only be got if the circumstances with regard to the dizygotic were reversed so that there was a decrease with age. This decrease must be assumed to be at least as strong as the increase in the whole material of still-born and live-born, and furthermore it would be necessary to assume that the abortions at twin births are almost as numerous as the registered twin births — two very unlikely assumptions. Wederwang's assertion is not only unproved but extremely improbable.

As already mentioned, the distribution of the still-born is in itself of less interest, because it is more or less completely included in the twin material. But it offers greater interest as an indicator of the distribution of the abortions. The still-

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births, the curves in Fig. 3 result. If these percentages are calculated in per cent of each other the curve takes the shape shown in Fig. 4, indicating that the chance of both twins dying increases with rising age for the monozygotic, if this chance is calculated in relation to the chance of both dying among the dizygotic. For all that, the still-born do not in the least change the twin curves.

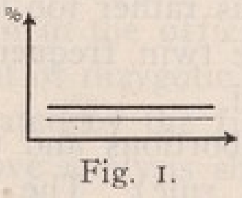

Fig. 1.

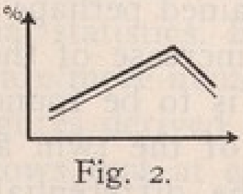

Fig. 2.

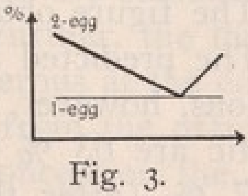

Fig. 3.

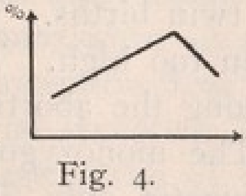

Fig. 4.

Fig. 1: Percentages of monozygotic twin births with rising age of the mothers. Live births — the thin line; live births and still births — the thick line. Fig. 2: Corresponding curves for dizygotic. Fig. 3: Dizygotic still births in per cent of total dizygotic births (the thick line). Monozygotic still births in per cent of total monozygotic births (the thin line). Fig. 4: Per cent still births among monozygotic in per cent of the percentage of still births among dizygotic.

born are for a great part the prematurely born, who have died in the 7:th—10:th month. There is of course no reason to assume any particular limit at the end of the sixth month. Those who have died in the earlier months most probably would show the same proportions as the pregnancies that are aborted in later months. In this case the abortions would slightly increase the twin frequency, especially for the monozygotic, and somewhat level the age curve for the dizygotic and above all for the monozygotic.

Twin abortions may be expected to be comparatively numerous (more than 1—1,5 %) among the abortions, and the monozygotic to be increased more than the dizygotic; finally the age curve for the monozygotic would drop sharply and for the dizygotic show a slight rise with age. This applies to twin abortions in relation to single abortions.

The only statistics on this matter that I have been able to find, are given by Prinzing, 1908 (b). He has obtained clinical material from Budapest. The material is not large, 2,560 single abortions and 62 twin abortions. Prinzing finds that the abortions of twins increase from month to month. In the second month there are 0,4 % twin abortions among the single abortions, in the third month 0,6 %, in the fourth month 1,3 %, in the fifth 2,1 % and in the sixth 2,9 %. As a whole the twin abortions are 2,5 % of the single abortions, but it must be remembered that the largest errors exist in the material from the first months. Twin and single births from these months probably come into this to a less extent than in later months. It is to be thought that the inaccurate figures for the first months tend to reduce the total percentage of twin births. The figure obtained perhaps is rather too low than too high. The predicted increase of the twin frequency among the abortions, however, is to be found.

The monozygotic are 63 % of the twin abortions and the dizygotic only 37 % (after the differential rule). The increase, as expected, affects the monozygotic most.

No age grouping has been made, possibly because the material was too small. As, however, the first two predictions have come true, there is some probability that the influence of age will also prove to be what was expected.

The result in that case would be that an inclusion of the abortions would still more tend to level the percentage curve for the monozygotic, distributed after age. It seems probable that the increase with age for the monozygotic would *disappear* altogether. The curve for the dizygotic at conception, on the other hand, would always show an increase with age, though not quite so marked as among the registered births.

Schultz, 1921, has found that the abortions (0—6 months) are 7/114 of those born during and from the 7:th month. By employing these figures and the percentage (2,5 %, obtained by Prinzing) of twin births among the abortions, I have calculated, on the basis of figures for births from the Official Statistics of Sweden 1891—1910, the increase of twin frequency occasioned by abortions and still-born, if they are included. Among live born, twins occur in 1,30 % (twin births with both alive, counted in per cent of births with at least one child alive). Among live born and still-born (twin births counted in per cent of the total number of births), twins occur in 1,46 % (thus an increase of 0,16 %). The calculated percentage of twin births at conception is 1,52 (thus an increase of 0,8 % and as regards live born an increase of 0,22 %). These figures of course are not exact, and they are further affected by age conditions among the mothers in the total material, but they give a notion of the magnitudes to be reckoned with. Even though Prinzing's and Schultz's figures may be to a certain extent corrected by later investigators, it is still possible to sum up the influence of the still-born and the abortions in this way:

At the time of conception twins are somewhat more frequent than in the official statistics. Further, the monozygotic in per cent of dizygotic are more numerous at the conception than indicated by the figures derived from the official statistics. My above analysis shows that at conception the age curve of the monozygotic rises very slightly, probably not at all, with age, but that at conception the dizygotic show an increase towards a maximum at 35—40 years, though a little less marked than in the demographic material. If abortions and still-births are excluded this causes a slight increase of the age curve for monozygotic and a steeper rise of the age curve for dizygotic. The mortality during the first year is treated in another place.

TWINNING AND RACE.

History.

It has been long known that the twin frequency shows quite large variations from one country to another. Most authors have silently quoted the different figures without attempting an explanation. Generally it seems to have been taken that the differences depend on chance or the manner of collecting the data.

Already Puech, 1874, however, points out that in France the twin figures are higher in the northern parts of the country and lower in the south. He discusses the possibilities of this being a result of the racial differences between the populations in these parts, but comes to the conclusion that the immediate cause is that of fertility. Fertility in its turn is affected by several factors among which there is also that of racial difference.

Weinberg, 1902 a, finds that as regards monozygotic twins the influence of race, if it exists, must be very slight. In the dizygotic he considers a distinct influence of race to be perceivable. The Teutonic peoples and Hungary, Croatia, Slavonia have more numerous twin births than the Latin peoples. In the Slav provinces of Austria the twin frequency is not increased.

Prinzing, 1906, emphasizes that the influence of age and order of the birth does not suffice to explain the difference between twin frequency in different places. After an age curve from Finland and Hungary he calculates the twin figures for the provinces of Austria—Hungary, and finds that the really observed twin frequency does not correspond to the calculated. The difference, he says, must depend on racial peculiarities.

Prinzing, 1907, finds that the twin frequency is lowest among Latins, medium among the Slavs and highest among

Finns and Teutons. He also finds that twins are more common in the northern (more Teutonic) parts of Germany, France and Italy. He shows with figures from different districts of Baden that the difference does not solely depend on the distribution of the mothers after order of the birth. Figures for the age of marriage in the Austrian Crown-lands, in Switzerland and Italy point in the same direction. It only remains to assume a racial difference. Like Weinberg he finds that it is chiefly the number of dizygotic that varies.

Apert, 1923, points out that Tchuriloff's finding of increased twin frequency with higher stature, does not apply to New Zealand and U. S. A., for instance, the stature there being high but the twin frequency low. The connection with stature which has, however, been proved by Tchuriloff, may nevertheless in Apert's opinion be explained by the racial influence.

In obstetrical text-books generally the racial influence is not mentioned. Only Puech in Bar, Brindeau, Chambrelent, 1914, mentions race as one of the factors bearing on the twin frequency and states that dizygotic twins are most common in the Aryan race.

As a whole the present position might be described thus: The differing twin frequency of different countries and parts of countries may at least partly be explained by a differing age distribution of the mothers. As Prinzing has shown, however, this does not explain all the dissimilarities and the remaining ones may possibly be due to racial differences, but may on the other hand be the result of irregularities in the methods of registration. No direct comparison of age curves from different countries has been made, and the errors arising from the registration methods have not been considered at all. The parallelism between stature and twin frequency, found by Tchuriloff, speaks in favour of an influence of race. The higher values for twin frequency, found by Prinzing in the northern, more Teutonic parts of France, Germany and Italy points in the same direction. The question, however, is far from settled and previous researches do not allow any definite conclusions.

The conception of race and the race map of Europe.

The conception of race has been defined in different ways; and evidently it is difficult to draw the exact outlines of such an idea and it is also inevitable that its appearance must change with the times.

Martin, 1914, defines race or variety in this way: "The individuals belonging to one variety must have a sum of characters in common and be distinguishable from other groups just by this particular combination of characters (character complex).

Martin fails to include in his definition that the characters must he hereditary, and in the sequel also is somewhat vague.

Fischer, 1923, accepts Grosse's definition: "With race in anthropology is understood a considerable group of people that have in common a hereditarily conditioned, congenital, corporeal and mental habit and by this are distinguished from other similar groups."

Generally also most scientists reckon with hereditability of the racial characters.

If the composition of a racially mixed people is examined, and all individuals possessing characters at variance with those of the principal race are eliminated as not pure stock, a somewhat peculiar condition arises. Take Sweden (e. g. Retzius and Fürst: Antropologia Suecica 1900). First all the brown-eyed are eliminated, and we get a rest of light-eyed. From this all the short-headed are eliminated. From the remainder, again, all the short-sized are eliminated, from the now remaining all the dark-haired etc. The more characters that are included, the greater the number of individuals to be eliminated. Counting a sufficient number of characters, will anything be left? If, on the other hand, only a few characters are included, there will remain a comparatively large proportion of pure race. According to Antropologia Suecica the pure race in Sweden counting the four characters mentioned amounted to 10,4 %.

To enter this problem a little further, make the assumption that pure negroes and people of pure Nordic race of equal number live together in one country. Assume, further, that in all marriages an equal number of children is born, with the same intervals, that is to say, that the fertility is in every respect equal. The development, now, may proceed after three different lines. The races may live side by side without mixing with each other, negroes and whites may completely mix, and finally some negroes and some whites may mix while the others keep to themselves.

Now we know that if a group of heterozygotic and homozygotic breed promiscuously without any selection, the composition of the mixed race remains constant (Baur 1919), if the characters are inherited after Mendel's laws.

What, then, would be the result under these suppositions, of a racial investigation in the different cases. In the first case — no mixing — of course no individuals would have to be eliminated (provided no transgrediating racial characters are dealt with). In the second case — complete mixing — practically no part of pure race would be left, if a sufficient number of racial characters were counted. If the characters are few, or only a few are counted at the investigation, a greater or smaller number of individuals satisfying the demands on racial purity will "mendel forth". If finally, the mixing is incomplete, a portion of the pure race will be left, but this part will diminish only very slightly if the number of characters is increased.

Thus, if we want to know the racial composition of a people, information is wanted chiefly on two points. First, how great a percentage of these characters is derived from a certain race, secondly, how many are the individuals of pure race. To get an answer to the first question, only a few characters are needed. If two characters are inherited in the same way, they should give the same percentage, if no selection has occurred while the crossing has continued (cp. p. 85). To get an answer to the question on the number of individuals of pure race, so many characters must be included that the proportion does not considerably diminish in the eliminations for the last characters.

But if selection should occur for one or more characters, the conditions will be changed. It is then necessary to include more characters in order to clear up the composition of the mixed part of the population. If the selection is intensive and lasting, out of the mixed part may issue a more or less clear type with a certain combination of characters that is not to be found in the original race. In this case from the biological point of view a new race has come into existence. Historically, it is still a mixed race. It is of importance to distinguish between race from a biological point of view and race from a historical point of view. It is, for instance, possible that the Jews, though historically a mixed race, on a closer examination might prove to have a more or less pure and preponderating combination of characters, that is, contain a race in the biological sense.

It should further be pointed out that the conditions are very much complicated by the transgrediating* racial characters. Most quantitative characters may be assumed to be of this kind. Coupling between characters also helps to complicate the position. It is not proved that all racial characters are heritable after Mendel's laws, though so far this may on the whole be an admissible assumption. The result finally must vary on account of the differing numbers of the original races, that go to make up the people and on account of differences caused by external factors (environment).

Now, proceeding to the racial conditions of Europe, it is obvious that the investigations so far made have not been thorough enough to show how far pure race constituents enter into the picture. Nor is it possible to discern if a selection has occurred for one character or another. Our knowledge of the racial conditions of Europe is very defective from other points of view as well (uniformity of examination methods, size of material etc.). The race maps that have been produced, therefore, give an incomplete and uncertain picture, and in several respects are founded on rather bold constructions. Under these conditions no absolutely regular correspondence can be expected between the twin frequency and the racial frontiers as they have been drawn. At present an investigation in too great detail would hardly be worth while, and I shall give only a very general survey of the distribution of the twin frequency.

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* By transgrediating racial characters we mean characters that two races partly have in common; the range of variation for the characters includes a certain joint area.

Twin frequency as a racial character.

Not only the race maps of Europe, however, are deficient. As mentioned above the statistical data for twin frequency are also rather inadequate.

As previously pointed out, it is probable that the higher twin frequency of northern Europe may be explained by a higher average age of the mothers. It is possible, though, that this inequality is balanced by a differing curve for ageing and fertility. A south European mother of 35 years perhaps corresponds to a northern one of 40 years. A difference between the curves also may be due to dissimilarities in registration between the materials. It is therefore first of all necessary directly to compare and examine the age curves of different countries. Unfortunately such curves can be obtained only from France, Norway, Denmark, Hungary, Finland and Australia. See Table 1, p. 25. Now, on a comparison between Finland and Denmark, the figures are found to be in close accordance (see also fig. 3). In both countries the percentage of Nordic race is comparatively high and other racial constituents do not seem to carry with them any noticeable difference in twin frequency. On the other hand, the figures from France

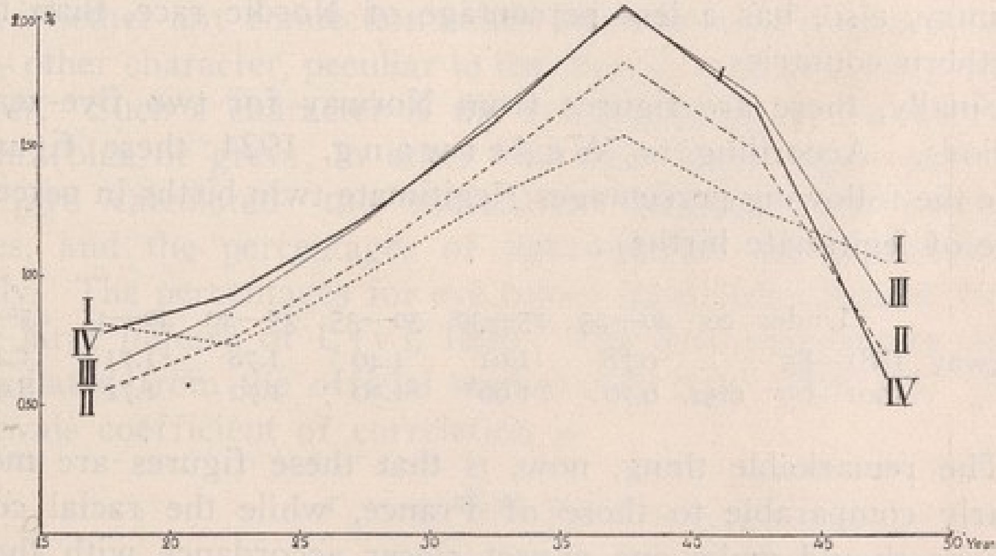

Fig. 3. The twin frequency (per cent) in relation to age of the mothers (five years groups) in France 1901—05 = I; France 1907—10 = II; Denmark = III, and Finland = IV.

will be found to be considerably lower. For the period 1907—10 they are higher than for the years 1903—06. The increase in the total figures amounts to 0,06 %. This is due to more strict regulations for the later period, the prematurely born and still-born for instance being more conscientiously included in the registration. It may be recalled that the inclusion of still-born in Sweden will cause an increase of 0,16 %. The increase in France is well within this limit — some still-births must have been included already in the earlier period. The increase being so marked, seems rather to indicate that the application of the new regulations has been very strict. Consequently, when the curve for the later period falls so far below that of Denmark and Finland (see fig. 3), this cannot very well be due to incomplete registration. Evidently, the difference is real, and may be due to the racial difference between France and Denmark and Finland, countries populated with more Nordic race.

As to Hungary a comparison is difficult on account of the rough grouping in different ages. No conclusions can therefore be drawn from the figures from this country.

The figures for Australia (see Table 3.) are almost level with those of France, but as the racial conditions of this country are very insufficiently investigated, it is not possible to found any definite conclusions on them. It seems probable that this country, also, has a less percentage of Nordic race, than the northern countries.

Finally, there are figures from Norway for two five-years periods. According to Wederwang, 1924, these figures give the following percentages (legitimate twin births in percentage of legitimate births):

		Under 20	20—25	25—30	30—35	35—40	40—45	45—50
Norway	1881—85		0.78	1.01	1.40	1.78	1.71	1.24
„	1901—05	0.54	0.76	1.06	1.50	1.72	1.72	8.9

The remarkable thing, now, is that these figures are most nearly comparable to those of France, while the racial conditions should make one expect closer accordance with those of Denmark and Finland. If these figures can be relied upon, they would indicate that the difference found between France (or Australia) on the one hand, and Denmark and Finland on the other, is not due to racial difference, but to other factors. However, the figures show a striking peculiarity in not giving a distinct maximum at 35—40 years; for the group 40—45 they are almost as high in the period 1881—85, and quite as high in the period 1901—05. It is, of course, possible that there is a displacement of the maximum towards a higher age; if so, the displacement must be quite considerable. The divergence in regard to both the height of the curve and the development of the maximum, may, however, be regarded as signs of a lacking reliability of the figures. Which is the case, naturally cannot be decided. We have simply to take the figures as to a certain degree speaking against the assumption of twin frequency being a racial characteristic, while keeping in mind that circumstances may be advanced for regarding the figures as not quite reliable.

Summing up the results, a comparison between France, and Denmark and Finland, seems to favour the view that the Nordic race has higher twin frequency than other European races, while the figures from other countries do not give any distinct evidence one way or the other, the figures from Norway speaking against this higher twin frequency of the Nordic race. This is as far as we can get with the help of age curves.

In order to strengthen the conclusions, it could be investigated whether any connection exists between twin frequency and any other character, peculiar to the Nordic race as against other races. Such a character is the eye colouring, in Nordic race light (blue or grey), in other European races pigmented iris. I have calculated the correlation between twin percentages, and the percentages of light-eyed in the provinces of Italy. The percentages for eye colour have been obtained from the large inquiry of Livi, 1896. The twin percentages were calculated from the official statistics of Italy 1901—05. The Bravais coefficient of correlation is

$$r = +\,0{,}56 \pm 0{,}12.$$

Thus there is an established positive correlation; in a province with a higher percentage of light-eyed, the twin percentage generally is higher.

The same calculation was made for France, employing the percentages of Topinard, 1889, for eye colour in the different departments. The twin percentages have been calculated from the official statistics of France 1907—10.

The Bravais coefficient of correlation is

$$r = +0{,}35 \pm 0{,}09.$$

Here also, there is an established positive correlation between eye colour and twin frequency.

Finally, the same calculation was made for Germany, employing the figures of Wirchow, 1883, for eye colour, and figures for twin frequency for 1912 and 1913 from the official statistics of Germany.

The Bravais coefficient of correlation is

$$r = +0{,}06 \pm 0{,}15.$$

Here there is no established correlation. Now, it seemed possible that this might be due to the racial conditions of Germany having changed from the time of Wirchow's investigation 1883 to 1913, racial regional limits not remaining the same as in 1883. The industrial development must have involved great changes with reactions also on the racial distribution. This influence must have been stronger for the later years, and also should be stronger for Germany than for Italy and France, which have not been industrialized to the same extent. From this point of view, it seemed possible to me that employing earlier figures for twin frequency, a correlation might be brought out. The earliest figures for Germany that I have been able to find are from 1901—02. The Bravais coefficient of correlation between the twin percentages for these years and Wirchow's eye colour percentage is

$$r = +0{,}35 \pm 0{,}13.$$

For this time, consequently, the correlation may be regarded as almost established.

From other countries there are no figures allowing corresponding calculations.

The results from France, Italy and Germany show that there is an undoubted connection between light eye colouring and twin frequency. The dark-eyed race elements in these countries have a lower twin frequency. This might be due to the light-eyed having comparatively greater real fertility at higher age of the mothers. In itself it does not seem very probable that a correlation so regular and distinct should emerge in such a roundabout fashion. Further, there has been brought out a difference between France, and Denmark and Finland, fairly independent of the influence of age, but in accordance with a direct connection between eye colour and twin frequency. Any other factor explaining this connection, it is at present difficult to find. Then, it only remains to assume that twin frequency, like eye colour, is a racial characteristic. Thus, between the light-eyed race elements of Denmark, Finland, Italy, France, and Germany, and the dark-eyed race elements present in the three last-mentioned countries, there is a marked difference in twin frequency also. The Nordic race seems to have a higher twin frequency than the dark-eyed race elements, which at present in these countries are regarded as chiefly Mediterranean and Alpine.

Taking into account the correlation above demonstrated, there is further reason to regard the figures from Norway as less reliable. The contradiction between the figures from Norway, and those quoted from other countries, probably must be explained by the Norwegian figures being for some reason or other less correct.

The connection here in question has regard to the twin percentage, that is, the sum of monozygotic and dizygotic. Counting monozygotic and dizygotic separately, with the help of Weinberg's differential method, we find that the figures for Denmark (see table 2, p. 26) lie considerably above those from France (and that the figures from Hungary seem to be almost level with those from France). For other countries figures are lacking. Thus the racial difference seems to apply to monozygotic as well as dizygotic, and not be confined to one kind only.

The coefficient of correlation for monozygotic will be found to be:

France $r = +0{,}05 \pm 0{,}07$ for monozygotic,
Italy $r = +0{,}57 \pm 0{,}11$ » dizygotic,
» $r = +0{,}43 \pm 0{,}14$ » monozygotic.

For Italy there is thus an established correlation, about equally large for monozygotic and dizygotic. For France, there is no established correlation for monozygotic, and the correlation found for twin births thus applies only to dizygotic. For Germany, there are no data for a calculation of the monozygotic in 1901—02. For 1912—13 there was no correlation for monozygotic, which, of course, has nothing to say.

Summing up, we should say that through my above calculations a connection has been shown between twin frequency and eye colour, chiefly, it seems, concerned with dizygotic, but probably applying to monozygotic as well. It seems strange that no correlation has been found for monozygotic in France, but this is of no great importance, when, nevertheless, a difference has been shown in the age curve of monozygotic for France, compared to Denmark and Finland. The Nordic race, therefore, must be taken to have a stronger twinning tendency regarding both monozygotic and dizygotic, in comparison with Alpine and Mediterranean race. When more extensive and more reliable statistical and anthropological data are available for different countries, it will be possible to go more deeply into the problem. Finally, it should be pointed out that nothing is definitely known about the twin percentage at conception, and about the change brought about by the earliest abortions. The conclusions apply to registered births, that is, twin pregnancies carried beyond the 6th month.

There is, however, hardly any reason to assume that differing registrations cause the connection we have found. But it is perhaps possible to assume that, at conception, the twin frequency is the same, and that the racial structure causes a differing capacity of bringing forth the twin pregnancy to term. Our incomplete knowledge of the abortion frequency in the earliest months, does not permit a decision on this point. We can only state that, in some way or other, the twin frequency is racially conditioned.

TRIPLETS AND QUADRUPLETS.

Triplets and quadruplets, of course, do not come within the scope of this work, but the question of their occurrence may be touched on in passing. Their general frequency is indicated by Hellin's law (p. 9) according to which triplets occur in $1/n^2$ and quadruplets in $1/n^3$, n varying between about 80 and about 90. It is known that the number of ova varies in plural births. Triplets may be developed out of one, two or three eggs. The casuistic data for number of ova found in the literature, of course have no statistical value.

Saniter, 1901, makes a digest from literature and finds in all 8 cases of monozygotic triplets. In the triplet material at his own disposal from the university clinic in Berlin, there are 9 trizygotic, 14 dizygotic, and 2 monozygotic.

Hust, 1916, in his twin material has two cases of triplets with in one case one egg and in the other three eggs.

Strassmann, 1889, in his clinical material finds 1 monozygotic, 5 dizygotic, and 4 trizygotic.

These figures (in all 4 monozygotic, 19 dizygotic, 14 trizygotic) are too small to give any precise percentages, but they indicate with a certain plausibility that dizygotic and trizygotic triplets are more common than monozygotic.

Table 7.

Triplet Births in Finland 1878—1916, grouped after the Age of the Mother and related to Births and Twin Births.

	Age of the Mother						
	15—20	20—25	25—30	30—35	35—40	40—45	45—50
Births (number of mothers)	81,495	611,730	846,731	777,796	598,620	314,994	42,844
Twin births	519	5,386	10,243	12,566	12,166	5,327	386
Triplet births......	4	49	86	172	299	84	6
Triplet births in thousandth % of births	4,9	8,0	10,2	22,1	49,9	26,7	14,0
Triplet births in % of twin births...	0,77	0,91	0,84	1,37	2,46	1,58	1.55

No investigation as to the distribution of triple births after the age of the mother relatively to single births seems to have been made. I have been able to compile the table p. 63 from the official statistics of Finland (Table 7).

It will be seen from the table that the triplet births increase strongly with the mother's age, when counted in per cent of the total number of births (single births + twin births + triplet births) from 0,005 % at 15—20 years to 0,05 % at 35—40 years. The triplet births, however, also increase in relation to the twin births. If triplet births are counted in per cent of twin births, the percentage increases from 0,47 % at 15—20 years to 2,46 % at 35—40 years. In both cases, the maximum lies at 35—40 years. It is not possible to calculate the number of ova from the number of same-sexed and opposite-sexed, as there are no figures showing the sex distribution. Even with such figures one cannot exactly calculate the number of ova without making certain assumptions.

Weinberg, 1902 (a), has made the following calculation: In Prussia 1826—96, there were 7,733 triplet births, 3,612 same-sexed, and 4,121 opposite-sexed. If among these there were a = monozygotic, $2b$ = dizygotic, and $4c$ = trizygotic, the following equation results:

$$a + b + c = 3{,}612 = \text{same-sexed}$$
$$b + 3c = 4{,}121 = \text{opposite-sexed.}$$

If $2b = 4c$, i. e. the number of dizygotic and trizygotic is equal, a not unreasonable supposition, the monozygotic will be found to be about 1/7 of the triplets.

In the literature some casuistic statements about the number of ova in quadruple births are to be found. As examples of the different possibilities the following may be mentioned:

Brattström, 1914, gives a case of quadruplets from four ova.

Steffek and Leopold (quoted Winckel 1904) give a case of trizygotic quadruplets.

Saniter, 1901, has a case of dizygotic quadruplets (three embryos from one ovum).

Panizza (qouted Winckel 1904), and Lindig, 1912, each has one case of monozygotic quadruplets.

Regarding quintuplets Winckel, 1904, and Döderlein, 1920, state that every possible combination of eggs will occur.

TWIN THEORIES.

What is the cause of twinning, and what is really the difference between monozygotic and dizygotic twins? The different state of the membranes in the afterbirth has long been known. It is said to have been observed for the first time by Levret, 1761 (quoted Apert 1923). The explanations given on the origin of twins during earlier times were purely speculative, and now only have an interest as curiosities.

The atavism theory.

Only when some light had been thrown on the physiology of fertilization, could the problem be more successfully attacked. It was then made clear that some twins were produced from two different ova. This at once suggested a resemblance to the multiparity of the animals, and this plural production of ova therefore was regarded as an atavism. Already Hellin, 1895, holds this view. Further, it was attempted to show that twin pregnancy is often associated with other atavistic phenomena, above all doubling of genitals (uterus bicornis etc.) but also with supernumerary nipples etc. Casuistically a number of such occurrences have been described.

Dunning, 1889, gives a compilation from the literature of 246 cases with doubling of genitals and pregnancy, among which are 17 plural pregnancies.

Patellani, 1896, gives a number of twin pregnancies with doubling of genitals. He ascribes both the monozygotic and the dizygotic to "transitory relapses", into conditions that are the rule in other animals.

Weinberg, 1902 a, talks of the well founded conception of plural births from several ova as an atavistic phenomenon.

Tropet, 1906, has collected from the literature 186 cases of doubled uterus and pregnancy, among these 23 cases af twinning. Besides he has 16 cases of his own of doubled genitals with pregnancy and 91 with single pregnancy.

Kawenoky, 1909, and Neuhäuser, 1913, also regarded twinning as an atavism. The "connection" between deformities in the genitals, for instance polymasty, Neuhäuser considers as a testimony of this.

Bauer, 1917, points out that twinning and plural pregnancy are a kind of atavism with corporeal (degenerative) disposition as qualification.

Beckman, 1921, also stresses the connection with double formations. From literature B. picks out (together with those collected by Tropet) 76 cases of double uterus with twin pregnancy.

Zimmermann, 1924, has found only 47 such cases in the literature. In his clinical material there are in 10,600 births 17 cases of double uterus and pregnancy but none with twin pregnancy.

Wehefritz, 1925, says that twin pregnancies ought to be interpreted as an atavistic phenomenon.

In text-books, also, as in other treatises the atavism theory is accepted.

In Winckel's Handbuch, 1904, Strassmann quotes his previous treatise, saying that twinning is to be regarded as an atavism and adding that there is hardly any doubt that pregnancy with several ova is not an atavism.

Prinzing, 1906, mentions that generally the hereditary disposition to twinning is regarded as an atavism.

Döderlein, 1920, points out that the occurrence of dizygotic plural births shows the transition to uniparity in man not to be complete, and that these pregnancies might easily be explained as a kind of atavism.

Bar, Brindeau, Chambrelent, 1914, do not mention the atavism theory or the connection with malformations of the genitals.

Engelhorn, 1925, points out that the fact that polymasty and doubled uterus are connected with twin pregnancy speaks in favour of the atavism theory. According to Engelhorn the heredity of twin births further supports this theory.

Now, is there any such connection? First, regarding the supposed connection with polymasty, this can be unhesitatingly denied.

Leichstenstern, 1878, has taken from the literature 70 cases of polymasty with pregnancy among which only three twin pregnancies. Leichstenstern himself regards this as evidence that no connection exists. This does not prevent Strassmann, 1904, from quoting these figures as proof of a connection. However, both polymasty and double formations are too rare phenomena to occur at all regularly together with the much more common twin births. (According to Zimmermann's above figures doubling of the uterus occurs in about 1—2 pro mille of all mothers.) Still a certain connection is conceivable. If so, twinning should be comparatively frequent (more than 1—1,5 %) in the pregnancies with polymasty and doubled uterus. The figures collected from the literature might give this notion some show of plausibility. The increase found by Leichstenstern, three pregnancies on 70 with polymasty, may well be accidental and in any case tell against any very strong connection. More marked is the increase found for instance by Tropet at doubling of the uterus, 39 twin pregnancies among 163 cases.

Here, however, the very limited value of these collections of cases must be borne in mind. A case of doubled uterus or polymasty combined with twin pregnancy, of course far easier finds its way into the literature than such an abnormity combined with single pregnancy. The atavism theory itself lends interest to the twin cases. It is thus quite natural that the twin pregnancies become overrepresented. The total number of 76 cases of twin pregnancy with doubled uterus that could be collected by Beckman, 1921, under these circumstances is not exactly impressive; in any case the figures from the literature cannot be regarded as decisive. Taking into consideration the tendency to over-representation of twin pregnancies, Leichstenstern's figures for polymasty must be said to speak against the existence of any real increase. With regard to doubling of the uterus some figures given by Strassmann, 1904, are of especial interest. In 476 twin pregnancies he found 1 uterus bicornis septus, 3 uterus bicornis and one uterus arcuatus. Lauritzen, 1891, in 415 twin births once found doubling of the uterus. These figures hardly indicate any connection.

To sum up, it may be said that not even a slight connection between twinning and polymasty or doubling of the uterus has been statistically established, and that the figures rather go to disprove the existence of such a connection.

The atavism theory thus, I find, has lost its chief support. Besides, in the present state of our knowledge of heredity the general conception of atavism hardly can be kept up. To call a phenomenon an atavism, does not, au fond, explain anything. The point is: Is the character in question hereditary, and if so, has the tendency to twinning arisen through mutation or kept continually in some strain of genus homo from an earlier stage of development. It is hardly possible to get proof of the continuous survival of a tendency which is not always manifest. Employing the term atavism for the mutations in which a character has been "lost" is inappropriate, when we do not know if the so called loss of a character really corresponds to a loss of anything in the heredity-bearing substance. Under such conditions the term atavism had better be dropped altogether.

The degeneration theory.

To explain twinning as a sign of degeneration is to fall back on a conception almost as vague as that of atavism. The term degeneration is used and has been used in varying senses — of a falling off of the intellectual level in a people, of an increased spread of hereditary diseases etc.

Grabe, 1922, puts twinning in connection with mental disease (looked upon by him as a phenomenon of degeneracy). He finds that twin births have occurred in 16,6 % of the families of 283 nurses. He finds twin births in 30 % of the families of 685 insane. He does not state the number of single births in the family. Such statistics of course are of no value whatever. There is no knowing whether the families of the insane have not been more closely questioned; it is even probable that the information about their families is more complete, because in this case Grabe has been obliged to question the relatives themselves and thus probably has got fuller information than in the case of the nurses. A connection between mental disease and twinning, therefore, cannot be said to have been demonstrated by Grabe's inquiry.

Larger, 1901, regards epilepsy, hysteria, insanity, alcoholism, syphilis, tuberculosis, sterility etc. as signs of degeneracy. Casuistically he seeks to establish a connection between these phenomena and twinning. These selected genealogical tables, of course, do not prove anything. On the pedigrees of historic families (Cæsar, the Carolingians, the Bourbons, etc.) he attempts to show that twinning occurs as a sign of the beginning of degeneracy. The argument is original rather than convincing.

Puech in Bar, Brindeau, Chambrelent, 1914, also mentions that twinning is regarded as a sign of degeneracy and in this respect distinguishes between dizygotic and monozygotic twinning, which latter he looks upon as a real monstrosity. Other writers express similar opinions (Weinberg, 1902, Prinzing, 1909).

Kalmus, 1923, (his own *précis*) has tried to prove a connection between twinning and nervous disease. Out of 2,839 patients (suffering from psychopathy, 50 %, psychosis, 7 %, epilepsy, 6,29 %, insanity, 3,3 %, tabes, 1,7 %) 10,3 % have twins in their families. The number of single births is not given. As already said it is obvious that these statistics cannot prove anything. He finds that among the patients themselves, one in 90 is a twin, and though this, in fact, answers to the twin frequency at birth, it is nevertheless an increase, Kalmus says, because half the twins die during childhood. Now, the frequency of twin births really is about 1 : 90 of the births, but consequently the frequency of twins is double this figure, about 1 : 45 of the born. When Kalmus then finds one twin among 90 patients, this answers to the mortality he has himself assumed.

Engelhorn, 1925 (Halban and Seitz, Handbuch) says that it has been pointed out from psychiatric quarters that twin pregnancy is more common among the families of insane and quotes Kalmus and Grabe.

Theoretically there should be no reason to expect a connection between properties of the ovary that cause twinning, and properties of the nervous system that occasion mental disease or social inferiority. Nor do the statistical results, as I have demonstrated, point to the existence of such a connection.

The intoxication theory.

A number of writers will have traced a connection between twinning and some intoxications, above all syphilis. While the atavism theory has been widely accepted in Germany, the intoxication theory has won belief chiefly in France. There, further such intoxications have been regarded as causing degeneracy, and in this way attempts have been made to couple the intoxication and the degeneration theories. While in the atavism theory the stress has been laid on dizygotic twinning, in the intoxication theory attention has rather centred on the monozygotic, though in neither case has a sharp line between the two been drawn.

Already Ed. Fournier, 1898 (quoted Popoff, 1908), will have observed a connection between twinning and syphilis. He is convinced that syphilis causes twinning — ”how and through what process he does not know”. His opinion has been accepted by many later writers.

Pointin, 1908, with Fournier considers that twinning is caused by syphilis. Out of his 27 twin pregnancies syphilis is present in 5 cases.

Popoff, 1908, shares the same view. In 38 cases she has 8 certain cases of syphilis. Among the others there occur abortions, premature births, hydramnion and hydrocephalus, abnormities that she regards as due to syphilis. Therefore she contends that though the mechanism is still unknown, syphilis in most cases is the cause of twinning.

Massoni, 1912, states that in 13 cases of twin pregnancy, Wassermann is positive only in one case.

Gallo, 1923, gives a digest from the material of the Naples clinic, and finds that syphilis is a little more common among twin mothers. He does not, however, consider that the increase is large enough to establish beyond doubt a connection between twinning and syphilis, but he expresses his opinion with a certain caution.

Apert, 1923, quotes besides Popoff an investigation by Merklen on 17 twin pregnancies, of which 9 were luetic. Apert is of opinion that syphilis is of importance especially in regard to monozygotic twinning, though not in all cases. Tuberculosis, alcoholism, overwork and destitution may be of some influence.

Puech in Bar, Brindeau, Chambrelent, 1909, states that twinning is particularly common in connection with such phenomena of degeneracy as tuberculosis, neurosis, alcoholism, and above all syphilis. He does not give any direct facts in support of this assertion.

Of the figures quoted above only those of Gallo have any statistical value. The other investigations are more casuistic in character. Besides it is hardly permissible as Popoff does to base a diagnosis of syphilis on an abortion. Gallo has made his diagnoses with the Wassermann test. His material comprises 690 twin-bearing mothers, and of these 21,4 % have syphilis. Among the single-bearing mothers in the same clinic 14 % have syphilis. The higher percentage for twin-bearing mothers is explained, it seems to me, by their higher average age, as twin births are comparatively numerous in older mothers. These have been "exposed" during a longer time, and can be expected to have been infected with syphilis to a greater extent. Under these conditions there is hardly any reason to leave the question open (as Gallo is inclined to do). So much more so since with such a connection, one might expect a low twin frequency in countries with a low syphilis frequency and vice versa. This is not in accordance with the known facts. In the rural districts of France the syphilis frequency certainly is comparatively low, while the twin frequency is unusually high, 1,22 %

(p. 41). In the French towns, on the contrary, the twin frequency is low, 1,03 %, while the syphilis frequency probably is higher. A comparison between the countries points in the same direction. France has 0,34 % monozygotic and 0,80 % dizygotic, while Denmark has 0,38 % monozygotic and 0,99 % dizygotic, and Sweden has 0,37 % monozygotic and 1,09 % dizygotic twins. There should be reason to presume that the syphilis frequency is higher in France than in Denmark and Sweden, while the reverse is the case with twinning. Taking these points into account I think we can consider as certain that no connection exists between syphilis and twin pregnancy.

Regarding the connection with tuberculosis, alcoholism, overwork, etc., the evidence is still more slender, not to say nonexistent. It is made up of direct assertions (Apert and Puech) and casuistic data, e. g. Keim, 1899, (quoted Seriber, 1906), Larger, 1901.

Similar views will be met with when later on the subject of experimentally produced double individuals is touched on. Already it may be pointed out that so far no double individuals have been produced by applying bacterial toxins. Even if these toxins should have the effect assumed, therefore, it is not proved that they can reach a sufficient concentration in the human body. In any case it may be asserted as I have above pointed out that the intoxication theory statistically is unproved and as regards syphilis is demonstrated as false.

Body build and twin frequency.

Under this heading reference might be made to two enquiries where it has been attempted to relate the twin frequency in certain respects to the body build.

Tchuriloff's (quoted Apert 1923) enquiry has already been mentioned (p. 53). He attempts to demonstrate a connection between stature and twin frequency — the higher the stature in a certain region, the more numerous are the twins — and he really is able to work out a parallel. As Apert has pointed out, this probably is explained by the influence of race. The taller women of the Nordic race have a greater number of twins.

Clerico, 1904, on some 50 twin pregnancies shows that the twin frequency is greater in women with a wide pelvis (large external bi-cristal diameter) than in those with a narrow pelvis. In the group with narrow pelvis twins occur in 0,51 %, among those with medium pelvis in 1,64 %, and among those with wide pelvis in 3,91 %. The material, of course, is small, but the indication is consistent for the groups and quite strong. This also was to be expected. Naturally those with narrow pelvis are chiefly the young mothers — not yet fully developed. Among those with wide pelvis are most of the older mothers, in whom the thickness of the soft parts has given a larger measure for the pelvis. He does not, it seems, give age figures for the different groups (the work has not been accessible to me in the original), but I think it may be assumed that the influence of age sufficiently explains the result. (Possibly also racial characters may play their part.)

ON THE EMBRYOLOGIC MECHANISM.

Before passing to the question of the hereditability of twinning, we shall have to touch shortly on the genesis of twins. It may be considered as established that twins with two chorions are derived from two ova that have been fertilized each by a separate spermatozoon.

Further, by the occurrence of the corresponding corpus luteum, it is established that the ova may be produced each from its own ovary (Kretz 1899, Peters 1900 and others). There have also been found two corpora lutea in the same ovary at twin pregnancies (Dubois and Daiyan 1876, Hoefft 1843, quoted Winckel 1904).

Finally follicles with more than one egg are found in adults. Bumm, quoted Zondek 1923 a, found in a twin-bearing mother, dead from bleeding, 2 (sometimes 3) eggs in almost every follicle. Strassmann, 1904, mentions a similar case, Rabl, 1899, in a 25 years old multipara found almost ripe follicles of several eggs. Arnold, 1912, also found follicles with 2 or more eggs — nothing is said about the occurrence of partus. Häggström, 1921, in a 22-years nulliparous mother has found athretical follicles with several eggs. He has not found ripe follicles with more than one egg and thinks that athretical follicles with several eggs are caused by a degenerative parthenogenetic process.

As far as I know there is no case known of dizygotic pregnancy with *one* corpus luteum found at the postmortem. This is hardly a matter for surprise, as the opportunities of observing the corpus luteum at twin pregnancies have been so rare.

Already since Wolff, Mechel and Geoffrey St. Hilaire it has been known that twins might originate in another way, namely from one egg (quoted Strassmann 1904). Since then a considerable amount of observations of monozygotic twins has accumulated. They always have a common chorion. They may have separate amnions, but also in rare cases may have a common amnion. They may for a shorter or longer stretch have a common umbilical cord, and finally they may be conjoined. One therefore has distinguished between diamniote, monamniote, unifunicular twins etc.

Now, twins with one chorion might be imagined to have arisen from two different eggs through fusion. There are great difficulties for such a view, however. There ought to be found transitional forms between monozygotic and dizygotic as regards their membranes; the chances that two independent eggs would meet in the uterus cavity at so early a stage are extremely small, and so on. Also this view is now generally abandoned. It is taken as established that twins with a common chorion originate from one egg.

The possibility is left that this egg may have two nuclei, and that a mono- or binucleated egg might be fertilized by one or two sperms.

The later discussion of these questions was opened by Broman, 1902. He put forth the hypothesis that giant sperms and double-tailed sperms gave rise to monozygotic twins, possibly at the fertilization of an egg with double quantity of chromosomeous substance. On the other hand, he considers that double-headed sperms move too slowly, and need not be taken into account. Monster formations and teratoms he would ascribe to a-typical sperms. These different kinds of sperms he considers as normally occurring, and he points to the possibility that exhaustion, alcohol, infections etc. might be of importance for their production.

Hoeffer, 1909, is of opinion that the double-headed sperms give rise to the monozygotic twins.

Kæstner, 1912, goes still further and maintains that fertilization of a binucleated egg or of one egg and an abnormally large polar body, will entail double formations.

Sobotta, 1914, strongly contests the line of thought lying behind these hypotheses. He points out that, presuming the co-operation of several sperm nuclei at the fertilization (of binucleated eggs), one should expect the occurrence of different sex. Further that binucleated eggs in animals give rise only to giant formations, and finally that the hypothesis of Broman about the number of sperm tails as the deciding factor, would lead to the absurd supposition of normally 12-tailed sperms in some species of armadillo. In the armadillo all the young in one litter originate from one egg — and their number may rise to twelve. Sobotta contends that the monozygotic twins are to be viewed as an analogy to this polyembryony in the armadillo, where such twins arise from one egg and one sperm with one nucleus each.

Sobotta, 1918, emphasizes his conception of monozygotic twins as an analogy to the poly-embryony of the armadillo.

Another group of hypotheses has been founded on experimentally produced double formations. By different interferences it has been possible to produce double formations from normal eggs of lower animals. Among the factors that have proved to act in this way are mechanical influences (shock, pressure, abnormal gravitational influence etc.), temperature disturbances, changes of the osmotic pressure, etc.

The egg has been placed in abnormal surroundings, and double formations and other abnormal processes have resulted, and it has then been concluded that at twin formations in man the egg was subjected to similar abnormal influences.

Mall, 1908, has maintained that embryonic malformations and also twins generally are caused by faulty implantation in the mucosa, and consequently deranged circulation in the egg. In support of this view he cites some cases of twin eggs with degenerative changes that on description rather seem to be postmortem phenomena. One of the cases, as a matter of fact, is dizygotic and from a syphilitic woman.

Werber, 1915, citing his experiments with acetone and butyric acid on ova of Fundulus, modifies this hypothesis, and ascribes malformations to a heaping up of pathological products of metabolism and consequent intoxication. Twins have been formed only in a few cases, and Werber lays chief stress on other malformations.

Patterson, 1913, found that the egg of Dasypus passes through a prolonged "period of quiescence", about three weeks, after fertilization. Newman, 1921, regards this temporary retardation of development as essential for poly-embryony. When the development begins again, the egg is disorganized — has lost its polarity, and now develops from two or more poles at once.

Newman attempts to strengthen his hypothesis by experiments on Patiria larvae. In cultures of these, double formations often appear normally. From eggs that develop without having been fertilized, double formations are particularly common. Also in cultures of larvae, where space has been especially limited (overcrowded). Finally where the fertilization has taken place through sperms of a foreign species. In all these cases he claims to have established evidence of retardation of development. (One might suspect that the increase of double formations is only apparent, owing to increased mortality for eggs with single formations. This possibility has not occurred to Newman, and he does not give any figures for dead eggs, so it is not possible to come to any conclusion.)

Applying his theory to man, Newman, 1923, uses a compilation by Arey on tubal pregnancy. Among some sixty cases of twin pregnancy in the tuba, more than two thirds are monozygotic. This percentual increase of the monozygotic according to Newman is explained by the nutritive conditions being unfavourable in the tuba, causing delayed development, etc. For monozygotic twins in the uterus Newman supposes a similar retardation as the immediate cause ("understimulating of the egg, due to some defect in the development-initiating mechanism of the sperm; belated placentation, due to a failure of the corpus luteum to stimulate the uterine mucosa"). But he also admits that there is nothing to preclude the supposition that this retardation may be conditioned by a hereditary factor, though this possibility seems to him "on the whole somewhat fantastic".

At about the same time as Newman, Stockard, 1921, put forth a similar hypothesis. With experiments on eggs from Fundulus and trout, through low temperature, lessened supply of oxygen, the action of $MgCl_2$ and ether etc., he has been able to produce a slightly enhanced number of double formations. His figures, however, are very small. Also he finds a retardation of development in all these cases, and further that double formations are caused by influences at the very earliest stages. Later only simple monsters are caused.

In his argument he particularly stresses the lack of oxygen as a cause of this retardation. In Dasypus he considers lack of oxygen during the time before the attachment of the egg to the mucosa, to be deciding. To man, also, he applies this view, citing a case of dizygotic triplets where the egg that contained two embryos, was less advantageously attached to the mucosa, than the other one.

The proofs of the Newman-Stockard hypothesis are not very strong. Ysander, 1924, points out that "in the majority of cases of double monsters in the human subject, it has not been possible to demonstrate any abnormality of the ovum as judged by the placental attachment". He further points to the fact that the period of quiescence in Dasypus sets in immediately before the gastrulation, and that Stockard in his experiments has found for the most part only minor abnormities during this period, while double monsters are produced more easily at an earlier stage; finally Ysander stresses that the regularity with which multiparity occurs in Dasypus, cannot be fitted outright into the schematic theory of Stockard

It may be added also that Arey's collection of cases of tubal pregnancy is not quite convincing. Obviously, if there is a disposition for an egg to be checked and implanted in the tuba, this, in many cases, will much sooner take place with one egg than simultaneously with two, and consequently sooner with monozygotic twins than with dizygotic. Finally, regarding the experiments that are the chief foundation of the hypothesis, the interpretation of Newman and Stockard does not accord with certain experiments performed by Loeb.

Loeb, 1909, experiments with eggs of Echinoderms and finds that if these are placed in a non-alkaline solution, in which there are no K, Na, or Ca ions present, development is retarded and double formations and twins produced. But these double formations occur only if the egg remains in the solution till the first cleavage has taken place. If before this the egg is moved to a normal medium, no double formation will occur, even though its development has been retarded. Further, if a small quantity of KCN is added to the solution, the cleavage of the egg is wholly impeded. If the egg is then moved to normal medium, no double formation will occur, though the cleavage has been delayed longer than in the absence of alkalis. Thus, a retardation of development, alone, cannot have the effect that Newman-Stockard ascribe to it. (It must be remembered that Stockard considered the reduced oxidization to be the deciding factor, because he thought the retardation of development was due to this.) Loeb is of opinion that the production of twins on lack of Ca is caused by the non-development of a pseudo-membrane that normally binds the first cells together.

Regarding the Newman-Stockard hypothesis, it may finally be mentioned that such a period of quiescence of the egg occurs in roedeer (Cervus Capreolus). According to Bischoff, 1854, the rutting season and fertilization fall in the end of July and beginning of August. In a few days the fertilized egg passes into the uterus and here passes a rest period of about 4½ months. After this the development to a fetus is very rapid. Bischoff has examined quite a large number of pregnant roedeer, but never seems to have found signs of polyembryony. Sakurai, 1906, has found that the growth of the egg is not wholly impeded but is so slow that the development of 4—5 months in roedeer corresponds to the first 4—5 days in swine and sheep.

These hypotheses on the origin of monozygotic twins, as already mentioned, have to a large extent been founded on analogies with the conditions in animals, especially Dasypus. Therefore it should be of interest to review the conditions in animals in general. Multiparity caused by the simultaneous liberation of several eggs is of very common occurrence and it is obvious that this is a hereditary character. The average number of young varies from one species to another. The larger animals generally have a smaller number of young (Clauss-Grobben 1917), and there are several species on the border line between pluriparity and uniparity. Sheep have two young almost as often as one. Assuming a connection between pluriparity and polymasty, Graham Bell, 1923 (quoted Newman 1923), above all by selecting ewes with supernumerary nipples for breeding tried to develop a race of constantly twin-bearing sheep. He was able to develop a race with six nipples (normally two nipples) but pluriparity did not follow this character. This result was to be expected as is explained in connection with the atavism theory (p. 67). Castle, 1924, has worked at Bell's material and thinks that there is no reason to presume heredity of pluriparity in sheep. However, Wriedt, 1924, has brought together the literature on this subject and considers heredity firmly proved as regards sheep. In cattle twins are stated to occur in 1 : 80, in horses in 1 : 400, maybe oftener.

Several embryos from one egg are especially common in Dasypus. The occurrence of polyembryony in different species of this genus has been investigated by Patterson and Newman. The number of young is almost constant for each species, varying from 4 (Dasypus novemcinctus) to 12 (Dasypus hybridus). Obviously bearing several young from one egg is a hereditary character in these animals. The same is the case with some species of parasite hymenoptera, e. g. Lithomastix, Ageniaspis, where the fertilized egg divides into something like a thousand small cells, each one developing into one individual (Goldschmidt 1920).

It has not been investigated in detail to what extent polyembryony occurs among other animals. Double formations are known in all classes of animals (worms, amphibians, reptiles, fishes, birds and mammals etc.). In mammals of course double formations are very rare as is also the case in man. This, naturally, does not preclude that monozygotic embryos (twins etc.) might be comparatively common, not only in man but also in animals. There has been very scanty investigation on this point. The work may proceed after three different lines — in the first place direct embryologic research. Such investigation is rather laborious and thus generally tends to get a more casuistic character. Casuistic reports of this kind are occasionally to be found in the literature. Corner, 1922, has given, for instance, an embryologically examined case of monozygotic twins in swine. Earlier no such case had been found (though two suspected cases) during 30 years delivery to the institution from a pig butchery. Secondly, the number of embryos may be compared with the number of corpora lutea in the ovaries. If it is found that the number of embryos is greater than the number of corpora lutea, the result, however, is not unequivocal. It is conceivable that one follicle has held two ova. Such cases are known from dogs (Smyth 1908, Waldeyer 1870), cats (Rabl 1899), rabbits (Honore 1901) and others. It is further possible that two follicles have been lying so close to each other that their corpora lutea have coalesced — the resulting corpus luteum then, of course, should be rather larger than normal. Another result — always the same number or greater number of corpora lutea than embryos — naturally is not strictly evidence either, as it cannot be known how many eggs have remained unfertilized. Some investigators, however, have entered this field. In cattle for instance, Lillie, 1916, in 69 cases always found two corpora lutea at double pregnancy (in one case no corpus luteum in one ovary, but the other ovary never came to be examined), and to a certain degree this speaks against a common occurrence of monozygotism in cattle. Frænkel, 1903, in order to establish the functions of corpus luteum, burnt it out in rabbits, and gives the number of corpora lutea and of embryos. In his material several cases are to be found where the number of embryos is greater than the number of corpora lutea.

The third method is to calculate whether the sex proportion in the different litters conforms to the assumption of pure polyembryony. In cases of polyembryony the number of litters of a more same-sexed type should be greater than expected, and those of more opposite-sexed type less numerous. However, a very large material is necessary, if the monozygotic are uncommon. Further, the number of monozygotic cannot be exactly calculated from these figures, if the possible occurrence of monozygotic triplets, quadruplets etc., is taken into account. The investigators that have been engaged in this direction, however, have not been able to establish a divergence pointing to a frequent occurrence of monozygotism.

In dogs and swine Wentworth, 1914, found good agreement with the theoretical figures, in sheep possibly a small divergence. Duncker, 1915, also found good correspondence of these figures in swine. Parkes, 1923, who has worked out with biometrical methods the sex proportions on figures from the National Duroc-Jersey Pig Record, Vol. LXVII, arrived at a very strange result. He found that the opposite-sexed litters were more common than the chiefly same-sexed ones. He makes no attempt to explain this result. However the divergence probably is the outcome of a registration error. It may be that at sending in the figures the real ones have been forgotten and new ones fabricated so as to look probable, consequently not too much same-sexed. This explanation is the more probable as Duncker and Wentworth have found good agreement in swine.

On the whole the position, then, is this: Both polyembryony (several embryos developing from one egg) and polyovulation (the liberation of several eggs at the same time) are more or less common in animals. In most, polyovulation is the rule, and in these cases must be considered as a hereditary character. Polyembryony too is to be found in certain animals (Dasypus) as a definite hereditary character. Some animals, among these man, have become uniparous, but even among the uniparous, polyembryony and polyovulation are more or less frequently to be found, and hereditability of these characters may well be assumed, even where the occurrence is more exceptional. The occurrence of polyembryony in mammals (except in Dasypus and man) in other respects has been very little investigated. Nor is it known how often polyovulation caused by several eggs from one follicle occurs, certainly it occurs both in man and in some animals.

From a general biological point of view, there also is occasion to assume heredity. But how does this conform to the theories just touched upon, regarding the origin of twins? First, as regards the morphological hypotheses of binucleated eggs and sperms etc., there are strong reasons against them, as Sobotta has pointed out. If, with Sobotta, we want to assume analogy in the embryologic mechanism between the polyembryony of the armadillo and monozygotic twinning in man, to a certain degree it must be justifiable in consequence to assume heredity in man also. Even if there should exist morphological differences in eggs or sperms giving rise to monozygotic twins, compared with those giving rise to single births, in principle there is, however, nothing that precludes the assumption of heredity for these differences and thus for twinning. An egg or sperm with a disposition to double formation, must differ in its structure from a normal egg. There is nothing surprising in this difference being discernible in the morphological build. The situation, of course, is different, if the sperms (or eggs) responsible for the formation of twins, should prove to be of very common occurrence. Broman considers this to be the case, but his investigation does not include a sufficient number of persons to place the matter beyond doubt. He has examined 11 men. The number of double-tailed sperms varies between 1 pro mille and 20—40 pro mille. There does not seem to be any evidence, as far as man is concerned, for Broman's supposition that alcohol, morphia, and similar poisons would give rise to these sperms. On alcoholizing mammals, no increase of double formations seems to have been noticed in the embryos (Pearl, Stockard, quoted Gyllensvärd 1923).

Deluca and Widakowick, 1918, have attempted to show that two-headed sperms are more common in luetics than in healthy men; this would explain the greater frequency of twinning in luetics. As has been shown above, it is no longer possible to maintain a connection between lues and twinning, and Deluca's results, therefore, rather go to disprove the supposition that the two-headed sperms are of any importance for the formation of twins. Deluca and Widakowick find that in healthy men we can reckon with about 6 pro mille double-tailed sperms, in syphilitics, on the contrary, with an average of about 13 pro mille (in the works of Deluca and Widakowick it says 13,13 per cent, which probably is a misprint), and in men with hereditary lues with 32 pro mille.

As a whole it might be said that the morphological hypotheses are very improbable, and that in any case they do not exclude the assumption of heredity for the tendency to monozygotic twinning.

The position is similar vis-à-vis the group of what might be called physiological hypotheses that have been founded on the experimental twin research. The supposition of retarded development, reduced oxidization, or lowered rate of metabolism, as the immediate cause of twinning, does not preclude hereditability of these physiologic characters. The abnormal development of an egg with tendency to double formation, of course may very well be coupled with changes in metabolism, etc. There is absolutely no evidence to support the belief that the external circumstances (changes of the osmotic pressure, lack of oxygen, etc.) that in lower animals give rise to double formations, should do the same in man. By similar measures it has been possible to cause parthenogenetic development in lower animals, and it would then be justifiable to assume the possibility of parthenogenetic development in man, a phenomenon that has never been scientifically established. The physiological hypotheses, especially so far as they try to explain twinning by abnormalities in the conditions of the fertilized egg in the uterus, therefore, are not very probable.

Strangely enough, we meet in this sphere with the same tendencies as earlier in the atavism theory — to see a connection between morphological abnormalities and twin formation — and in the intoxication theory — to associate twin formation with poisons and external injuries. In so far as these hypotheses are concerned with twinning, they must, on the whole, be said to fail; on the other hand, the question whether abnormalities, poisons and injuries to the egg or sperm play any part in the occurrence of other malformations does not come within the scope of this work.

HEREDITARY FACTORS IN POPULATIONS.

Hereditary factors from a demographical point of view.

If a character is heritable after simple Mendelian laws, its distribution in the population will offer certain characteristic traits. As, however, the problems bearing on this matter have not been paid very great attention, I intend very briefly to touch on them here, before entering upon the question of heredability of twinning. The following is of a certain theoretical interest, and certainly has a practical importance for methodics at hereditary researches. Therefore, it has also a certain importance for the investigation into heredity of twin births, which is more fully pointed out p. 103, though this importance is of a rather indirect nature. This chapter, however, is not indispensable for the understanding of the sequel.

If a hereditary character is constantly to be found in a certain percentage of a population, naturally, the disposition corresponding to the manifest character, also must be found in a proportion fixedly related to that of the manifest character. From the frequency of the disposition, it is possible to calculate how often, at chance marriages, the character will be manifest, and vice versa.

Assume that in a certain population there are constantly a number of homozygotes $DD = a\ \%$ and of heterozygotes $Dd = b\ \%$. The number of homozygotes of the type dd then is $(100 - a - b)\ \%$.

The different kinds of crossing between these types have the following probabilities, giving as a result, if the number of children per marriage is put at c, and the number of marriages at N.

Probability of crossing:

		Column I DD children	Column II Dd children	Column III dd children
No. 1. $DD \times DD = \frac{a^2}{100^2}$	giving per marriage	c	—	—
No. 2. $Dd \times Dd = \frac{b^2}{100^2}$	»	$\frac{1}{4}c$	$\frac{1}{2}c$	$\frac{1}{4}c$
No. 3. $dd \times dd = \frac{(100-a-b)^2}{100^2}$	»	—	—	c
No. 4. $DD \times Dd = \frac{2ab}{100^2}$	»	$\frac{1}{2}c$	$\frac{1}{2}c$	—
No. 5. $DD \times dd = \frac{2a(100-a-b)}{100^2}$	»	—	c	—
No. 6. $dd \times Dd = \frac{2b(100-a-b)}{100^2}$	»	—	$\frac{1}{2}c$	$\frac{1}{2}c$

The number of individuals in the second generation is Nc. Among these the following number are of the type DD:

$$\frac{a^2 Nc}{100^2} + \frac{b^2\,N(\frac{1}{4}c)}{100^2} + \frac{2abN(\frac{1}{2}c)}{100^2}$$

But the percentage of DD keeps constant (e. g. Baur 1919), that is equal to the percentage of DD in the previous generation $= a$ %.

$$\therefore \frac{a^2\,Nc}{100^2} + \frac{b^2\,Nc}{100^2 \cdot 4} + \frac{abNc}{100^2} = \frac{aNc}{100}$$

$$\therefore b = -2a\,(\pm)\,20\sqrt{a}. \quad \text{Formula I.}$$

$$\text{or: } a = \frac{100-b}{2}\,(\pm)\,5\sqrt{100-2b}$$

If it is a question of a recessive character, a in the above equation is known, and if a question of a dominant character, $a + b$ is known; in both cases, thus, the number of homozygotes and heterozygotes in the population can be calculated. Bauer, 1923, on the basis of a statement by Lenz, 1923, states that if a monohybride, recessive character exists in $\frac{1}{n}$ in a population, the corresponding genotypical predisposition exists in $\frac{1}{\sqrt{n}}$. individuals. From this starting-point Bauer deduces some mathematical expressions for sex-coupled heredity. The starting-point of course is false, as appears from our above analysis.

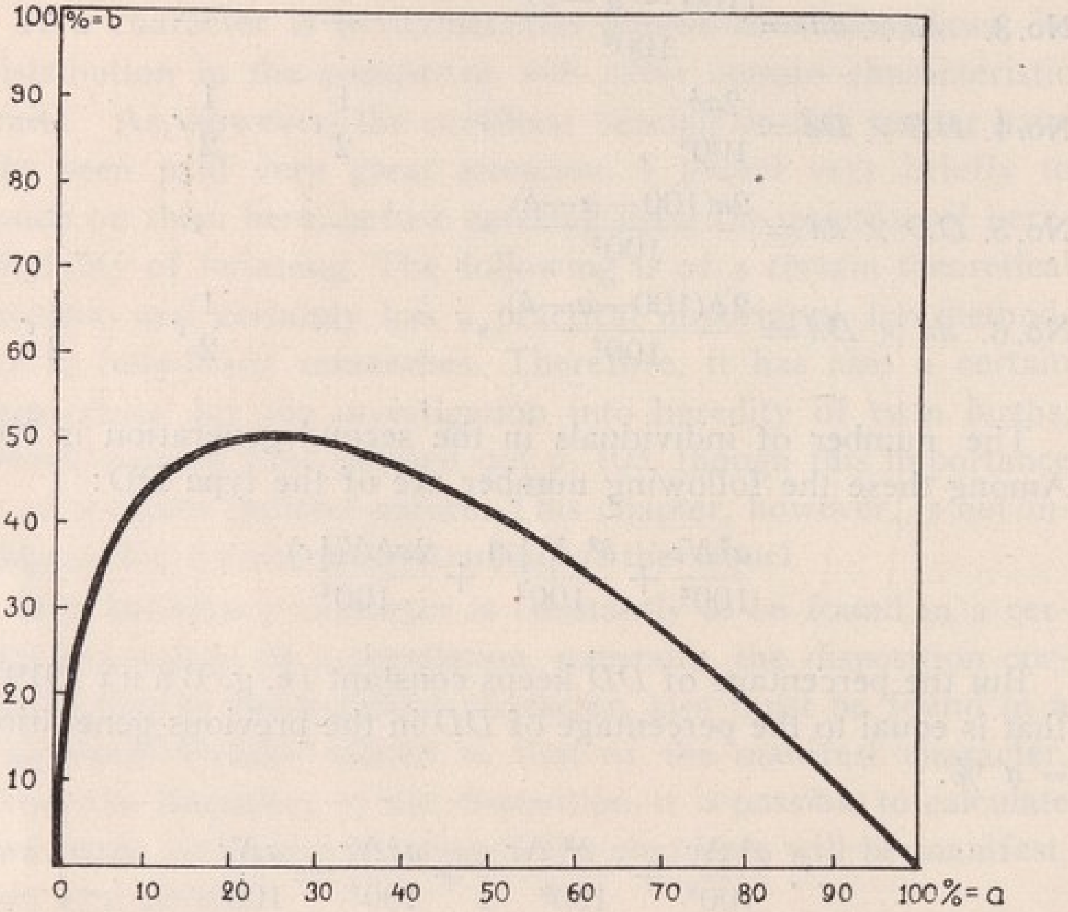

Fig. 4. The frequency (per cent) of heterozygotes *(Dd)* in a population with rising per cent homozygotes *(DD)* according to formula I. The percentage $DD = a$ % rises from 0 to 100 %. The maximum of heterozygotes 50 % lies at 25 % homozygotes *DD* in the population.

Our equation gives the different possibilities for the composition of the population in regard to a monohybride character. The corresponding curve appears in fig. 4. From the equation follows, that if the number of homozygotes for a recessive character increases from zero, the number of heterozygotes rises sharply to a maximum of 50 % when the homozygotes reach 25 %. We have, then, the simple Mendelian proportions in the population, homozygotes with the character, ¼, heterozygotes, ½, and homozygotes without the character ¼. If the number of recessive homozygotes is further increased, the number of heterozygotes decreases, but less sharply on this side of the maximum.

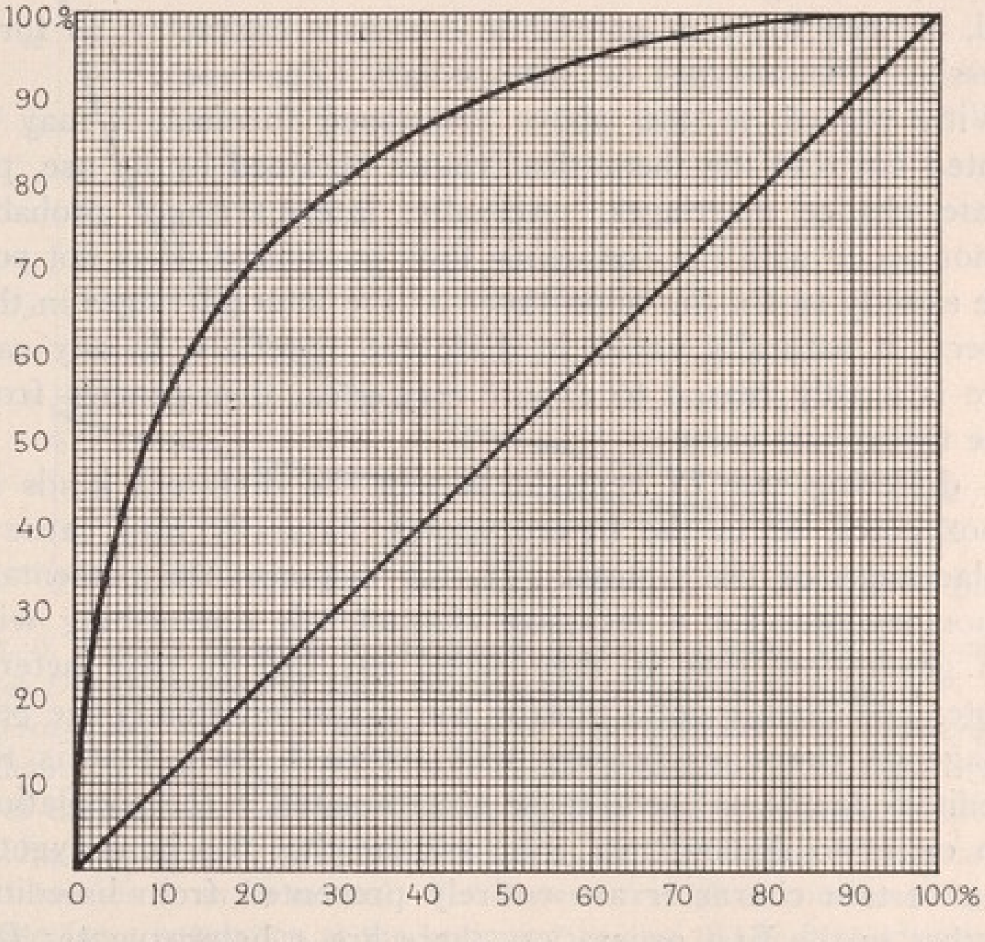

Fig. 5. Showing the different possibilities for the composition of a population according to formula I. The lower right half gives the percentages of homozygotes with the character (*DD*). The part between the black lines gives the corresponding percentages of heterozygotes *Dd* and the remaining part gives the percentages of homozygotes without the character *(dd)*. The percentages corresponding to a certain known percentage are read after the vertical lines. E. g. if homozygotes *DD* are 9 %, the heterozygotes *Dd* are 42 %, and homozygotes *dd* 49 %.

Fig. 5 shows different possibilities for the composition of the population. Assumed, for instance, that brown eyes are dominant over blue eyes and inherited as a monohybride * character, the lower right half of the schema corresponds to the different percentages of light-eyed, and the upper left half corresponds to the percentages of brown-eyed, the part between the black lines giving the percentages of brown-eyed heterozygotes, the rest of this half the percentages of brown-eyed homozygotes. From the schema, then, the percentage of heterozygotes at any known percentage of manifest character bearers, can be directly read, as well for a monohybride dominant character, as for a recessive (Pisum-type) or intermediary (Zea-type).

With regard to the above mentioned formula, it may be pointed out that the theoretical values obtained by its use, postulate chance marriages. Actually, intermarriages probably do not occur with the frequency thus postulated. It is not possible exactly to fix the importance of the intermarriages in this respect; it naturally varies in different materials. In any case there is hardly reason to expect very great divergencies from these theoretical values.

A differing rate of reproduction in the different kinds of homozygotes, or in the heterozygotes, naturally may cause a displacement of the figures. If, for instance, the percentage of homozygotes for a recessive character is diminishing with each generation, that is, they breed less rapidly than heterozygotes and homozygotes lacking the character, finally the percentage of character bearers will approach zero, that is the hereditary factor will tend to be exterminated in the population.

In order to demonstrate this, assume that the homozygotes for a certain character are entirely prevented from breeding, and that in the first generation, there are x heterozygotes *Dd*, and y homozygotes *dd*, without the character. After n generations the proportions of yn and xn will be:

$$\frac{yn}{xn} = \frac{2y + nx}{2x} \qquad \text{Formula II.}^{**}$$

From this equation, figures can be got for the displacement of the percentual proportion of x and y between free homozygotes and latent character bearers. Fig. 6 shows graphic-

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* This assumed only as an instance. It is not my intention to state that the conditions are so uncomplicated.

** Proved by calculation from n to $n + 1$.

ally the displacements calculated from $x = 25 = Dd$ and $y = 50 = dd$, and from $x = 18 = Dd$ and $y = 81 = dd$. As will be seen, the lower curve is identical with that part of the upper curve, lying to the right of the value for $n = 8$!

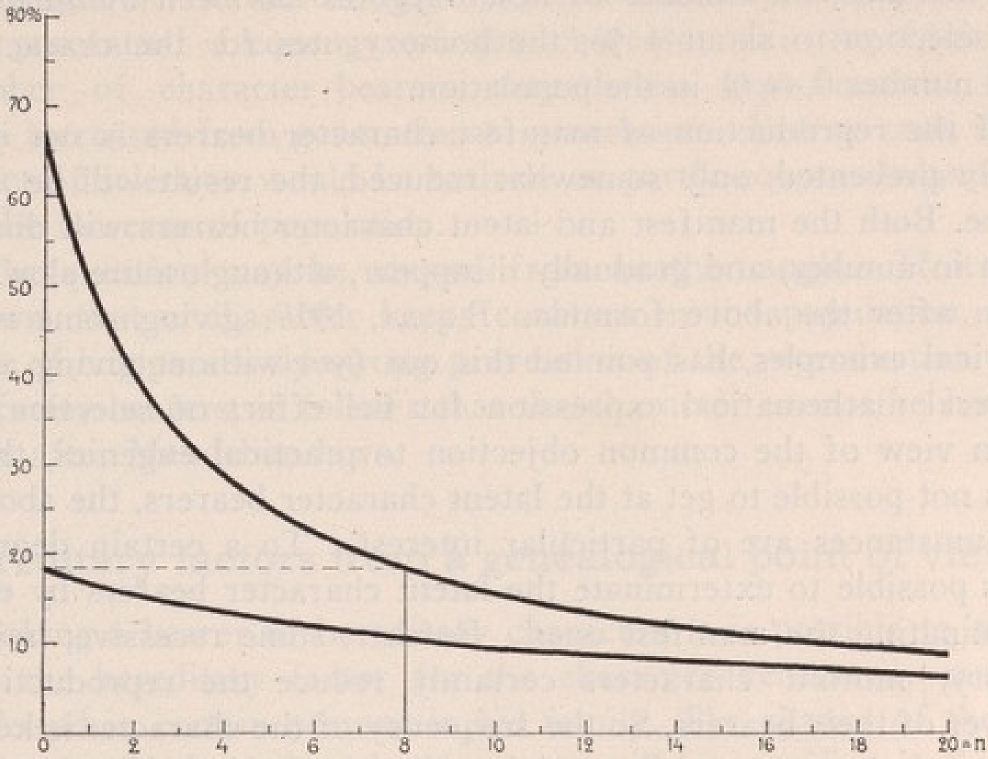

Fig. 6. Curves showing the decrease of heterozygotes *Dd* if homozygotes *DD* are prevented from reproduction according to formula II. The heterozygotes are given in per cent of heterozygotes and homozygotes without the character *(Dd + dd)* in the population. The upper curve gives the decrease for 66,7 % heterozygotes (the population at the beginning having 25 % *dd*, 50 % *Dd*, and 25 % *DD)* during 20 generations (*n* increases from 0 to 100). The lower curve gives corresponding increase for a population at the beginning having 18,1 % heterozygotes in per cent of heterozygotes and homozygotes without the character (e. g. in the population 81 % *dd*, 18 % *Dd*, and 1 % *DD)*.

From the equation appears that for $n = \infty$, in relation to x, y will be infinitely great. The curve asymptotically approaches the x-axis. An entire prevention of reproduction in the homozygotes for a recessive character, at first causes a sharp decrease of the heterozygotes as well. The more numerous the homozygotes *DD* in the poulation, the more quickly the displacement goes on. In the sequel, the decrease of the heterozygotes will proceed more and more slowly, and they will never be entirely exterminated. In reality, even at intensive and extended selection, a small percentage of heterozygotes with the character always will have to be reckoned with. In this situation, however, only very isolated homozygotes will mendle forth. If, for instance, the number of heterozygotes has been diminished by selection to about 4 %, the homozygotes for the character will number 0,04 % in the population.

If the reproduction of manifest character bearers is not entirely prevented, only somewhat reduced, the result will be the same. Both the manifest and latent character bearers will diminish in number, and gradually disappear, although more slowly, than after the above formula. Baur, 1919, giving some numerical examples, has pointed this out (yet without giving any general mathematical expression for the effect of selection).

In view of the common objection to practical eugenics, that it is not possible to get at the latent character bearers, the above circumstances are of particular interest. To a certain degree it is possible to exterminate the latent character bearers by exterminating the manifest ones. Further, some recessive, hereditary, morbid characters certainly reduce the reproduction power of their bearers. So the frequency of the character is kept down close to zero. One might talk of a self-purification of the race, with regard to harmful tendencies. Obviously, this applies to dominant characters as well; here, as a rule, we have to reckon with a sorting out of character bearers, that is to say, both homozygotes and heterozygotes, so that the above formula for this case has no practical interest.

Finally, it may be pointed out that the above laws should similarly apply also to more complicated inheritance after Mendelian laws.

However, the influence of selection may conceivably be counter-balanced by the character arising again, through mutations on a sufficiently large scale. There are no reliable data for the frequency of mutations in man. Baur, 1923, states that in organisms so far examined, Drosophila and Antirrhium, the frequency is at least 1 %. Baur, 1924, puts the mutation frequency in Antirrhium at about 5 %. These figures have regard to the total number of mutations of different kinds. One particular kind of mutation, therefore, ought to be infinitely more scarce, and we have reason to expect an even balance between selection and mutation, only if the selection is very inconsiderable. If there is no selection, the mutations will naturally tend to raise the frequency of the character. A situation that might be of interest, would arise, if the selection diminished the percentual frequency of the character, but the absolute number of character bearers, nevertheless, kept constant, or even increased from generation to generation. In that case, the effect of selection would be entirely or partly counter-balanced by the increase of population.

The question may be viewed from another angle. If it is known that a character keeps constant in the population, in spite of comparatively strong prevention of the reproduction of character bearers, it follows that the character cannot be heritable after Mendelian laws.

Hereditary factors from a genealogical point of view.

Taking a bearer of hereditary character, it is possible to say that the hereditary factor for the character necessarily must be found in certain persons in his family. The chance of their having married, so that the character will be manifest in their children, therefore, is greater than in a marriage taken on chance in the population. Consequently, among the ancestors of the character bearer, there must be a larger number of character bearers, than among the population at large. The degree of this increase depends on the character being dominantly or recessively hereditary, its being determined by one or more factors, etc.

At investigations on the heredity of characters in man, generally it has been attempted to build up descending pedigrees, analyse these and look for a correspondence with Mendelian figures. This has proved to be an excellent and practicable way. However, in certain cases another kind of genealogical table is preferable. Starting from one character bearer, information is then collected about his parents and their fraternities, then about their parents (the grandparents of the original character bearer) and their fraternities, etc. We may call this an ascending pedigree of families; se fig. 7.

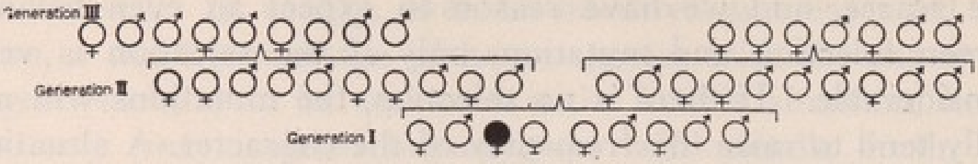

Fig. 7. Ascending pedigree. Starting from a certain character bearer (the black symbol) we examine his brothers and sisters (Generation I). Then the parental fraternities are examined (Generation II). Then the fraternities of their parents also are examined (Generation III), and so on.

Assume, as above, that in the population there are a % of homozygotes DD, for a recessive character D, b % of heterozygotes Dd, and thus $(100 - a - b)$ % of homozygotes dd. Assume, further, that c children are born per marriage, and that the number of marriages is N. I refer to the schema p. 85.

Desiring to find out the probable hereditary position of the parents of certain character bearers DD (column I) taken by chance, it is possible to state that they must be either of the type DD or Dd (belonging to line 1, 2 or 4).

Further, it will be found that among the 2 N parents those of the type DD, number:

$$2\,N\frac{a^2}{100^2}+\frac{2ab\,N}{100^2}\cdot\frac{1}{2};$$

and of the type Dd:

$$2\,N\frac{b^2}{100^2}\cdot\frac{1}{4}+\frac{2ab\,N}{100^2}\cdot\frac{1}{2}.$$

The probability of the parents of the character bearer being of the type DD (that is the number of DD parents on the whole number of parents) then is $\frac{2a}{2a+b}$ and their being of the type Dd (that is the number of Dd parents on the whole number of parents) $\frac{b}{2a+b}$.

The probability of both parents being of the type DD is:

$$DD\times DD=\left(\frac{2a}{2a+b}\right)^2;$$

of both parents being of the type Dd:

$$Dd \times Dd = \left(\frac{b}{2a+b}\right)^2;$$

and of one being of the type Dd, the other of the type DD:

$$DD \times Dd = 2\,\frac{2ab}{(2a+b)^2}.$$

These formulas have a certain interest with regard to Weinberg's proband method.

In N marriages among the parents of the character bearers, with c children per marriage, the number of character bearers will be:

$$\left[\frac{2a}{2a+b}\right]^2 Nc + \left[\frac{b}{2a+b}\right]^2 N\frac{c}{4} + 2\,\frac{2ab}{(2a+b)^2}\,N\frac{c}{2};$$

the number of character bearers (homozygotes) in relation to the number of children Nc:

$$\left[\frac{4a+b}{4a+2b}\right]^2.$$

By inserting the value for b expressed in a (formula I, p. 00) the following term is arrived at:

$$\frac{\text{Number of } DD}{\text{Total number of children}} = \frac{1}{4}\left[\frac{1}{10}\sqrt{a}+1\right]^2; \text{ Formula III a.}$$

This term gives the relation between *character bearers DD, taken by chance,* and the total number of children in their fraternities; this ratio should be obtainable with Weinberg's proband method also. (See Hæcker 1923.)

It will be seen from the term that if character bearers in the population are scarce, that is, a approaches to zero, the ratio approaches to ¼. In other words, in that case, probably it is chiefly a question of marriages between heterozygotes, from which this ratio should be expected. Marriages $Dd \times DD$ give the ratio ½, and marriages $DD \times DD$ give the ratio 1; and if such marriages are to be found among the parents of the character bearers, the ratio must be higher than ¼. From the schema, fig. 5, it also appears that if a is very small, the number of latent character bearers in the population will be comparatively great. If *a* approaches to 100 %, the above term approaches to 1, in other words, if the number of character bearers is great, naturally most marriages are of the type *DD* × *DD*, and all the children have the character manifest. This is shown graphically in fig. 8. The ratio grows from ¼, with *a* rising from 0, at first quickly, then more slowly to ½ when the number of character bearers is 17,14 % of the population, and to ¾ when *a* is 53,58 % of the population; when $a = 100$, the ratio is 1.

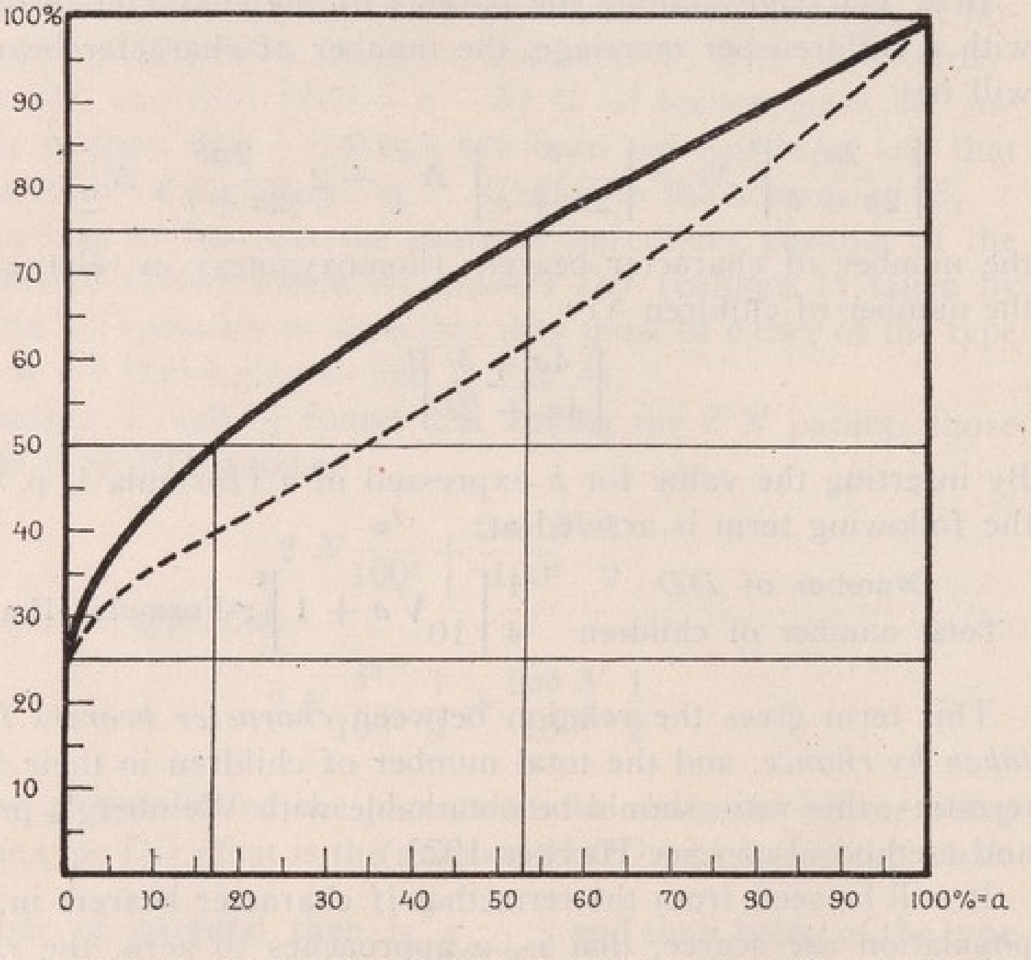

Fig. 8. Curves showing the percentages of manifest character bearers (homozygotes *DD*) among the fraternities of character bearers. The full drawn line gives the percentages for fraternities of character bearers taken on chance from a population. When the percentages of character bearers in the population *(= a)* rise from 0 to 100 %, the percentages of the fraternities rise from 25 to 100 %. The dotted line gives corresponding percentages for all fraternities with character bearers in a population.

When employing this formula it is of course necessary to be sure that the qualifications on which the formula is based, really exist. The character bearers should be taken by chance, as we have already emphasized. This implies that all the character bearers independent of the sort of family (homozygotes or heterozygotes) to which they belong, should have the same chance to be taken into the material, and further, that a family should be counted twice, if two character bearers of the same family happen to be included in the primary material. These qualifications generally exist for instance in an investigation of conscripts or of material from some hospital clientèle.

There is another method, however. We can exhaustively examine a population fixedly limited as regards time and place. Thus all the families with character bearers are included. A family with several character bearers then has not more chance to be included than a family with one character bearer. If we use the same symbols as before, we find that the following number of marriages in a population give character bearers (schema p. 85, line N :o 1, 4 and 2):

$$\left.\begin{array}{rlll} DD \times DD = \frac{a^2}{100^2} N & \text{with } \frac{a^2}{100^2} Nc & \text{children and} & \frac{a^2}{100^2} Nc \\ DD \times Dd = \frac{2ab}{100^2} N & \text{»} \quad \frac{2ab\, Nc}{100^2} & \text{»} \quad \text{»} & \frac{2ab\, Nc}{100^2 \cdot 2} \\ Dd \times Dd = \frac{b^2}{100^2} N & \text{»} \quad \frac{b^2\, Nc}{100^2} & \text{»} \quad \text{»} & \frac{b^2\, Nc}{100^2 \cdot 4} \end{array}\right\} \text{character bearers}$$

The total number of character bearers therefore is:

$$\frac{a^2 Nc}{100^2} + \frac{2ab\, Nc}{100^2 \cdot 2} + \frac{b^2 Nc}{100^2 \cdot 4},$$

and the total number of children is:

$$\frac{a^2 Nc}{100^2} + \frac{2ab\, Nc}{100^2} + \frac{b^2\, Nc}{100^2}.$$

The relation between the character bearers and the total number of children in these fraternities thus is:

$$\frac{\text{Number of } DD}{\text{Total number of children}} = \frac{\left(a + \frac{b}{2}\right)^2}{(a + b)^2}.$$

By inserting the value for b expressed in a (Formula I, p. 85), the following term is arrived at:

$$\frac{\text{Number of } DD}{\text{Total number of children}} = \left[\frac{10}{20 - \sqrt{a}}\right]^2. \quad \text{Formula III b.}$$

This term gives the relation between the character bearers DD and the total number of children in *all fraternities with character bearers in a population.* This ratio should be obtainable with Weinberg's "Geschwister" method. (See Hæcker 1923.)

It appears from the term that if the character bearers are rare, that is, if a approaches to 0, the ratio approaches to ¼ = 25 %. If a approaches to 100, the ratio approaches to 1. The percentage of character bearers in the fraternities increases from 25 — 100 % when a increases from 0—100 %. The corresponding curve is shown in fig. 8, the dotted line. The curve lies lower for this term than for Formula III a. The increase obtained in the fraternity is less pronounced if a whole population is examined without redoubling of certain families than if character bearers taken by chance are examined, and one family is counted as many times as character bearers of this family happen to be taken as basis for the research. It should finally be pointed out that Weinberg's proband method must be used to correct the result. In marriages between heterozygotes, one fourth of the children get the character. In reality this will mean that some families get several character bearers among their children while other families have no character bearers among their children. The latter families therefore will not be counted in the material. Families of heterozygotes will be included in the material in too small a degree in both the methods here employed. On a summing up of the material, too high a percentage of character bearers therefore is obtained. Weinberg's proband method corrects this source of errror, and by employing this method we should obtain the percentage theoretically demanded by my formulas.

To return to the ascending pedigree of families starting from a heterozygote of the type *Dd* (schema p. 85, column II), in analogy to the above the probability for his parents being of the type *DD*, will be found to be:

$$DD = \frac{a}{2a+b};$$

for the type *Dd:*

$$Dd = \frac{100\,b}{(2a+b)(200-2a-b)};$$

and for the type *dd*

$$dd = \frac{100-a-b}{200-2a-b}.$$

In the same way, starting from the type *dd* (schema p. 85, column II) the probability for the parents being of the type *Dd,* works out at:

$$Dd = \frac{b}{200-2a-b};$$

and of the type *dd:*

$$dd = \frac{2(100-a-b)}{200-2a-b}.$$

We now put $\frac{100-a-b}{200-2a-b} = r$, and $\frac{a}{2a+b} = s$.

Employing these terms we find that

starting from	DD	Dd	dd
the probability for the parents being of the type DD =	$2s$	s	—
» » » Dd =	$1-2s$	$1-r-s$	$1-2r$
» » » dd =	—	r	$2r$

Starting from character bearers, and building up an ascending family pedigree, thus, it will be found that their *parents* (in fig. 7, generation II) are of the type

$$DD = 2s \text{ and } Dd = 1-2s;$$

Their parents in their turn (generation III, fig. 7), have the type

$$DD = 2s \cdot 2s + (1-2s)s = 2s^2 + s\,;$$

and the type

$$\begin{aligned} Dd &= 2s(1-2s) + (1-2s)(1-r-s) = \\ &= -2s^2 - s + 2rs + 1 - r\,; \end{aligned}$$

and the type

$$dd = (1-2s)\,r = r - 2rs\,.$$

In the same manner the combinations can be calculated for their parents, etc.

However, we stop at this, confining ourselves to calculating the combinations for the parents' fraternities (generation II), from the terms found for the grandparents (generation III).

The crossing $DD \times DD$ in generation III, gives the following number of character bearers in the parents' generation, among $2c$ children:

$$DD \times DD = (2s^2 + s)^2 2c\,.$$

The crossing $DD \times Dd$ gives the following number of children of the type DD:

$$DD \times Dd = 2(2s^2 + s)(-2s^2 - s + 2rs + 1 - r)\frac{2c}{2}\,.$$

The crossing $Dd \times Dd$ gives the following number of children of the type DD:

$$Dd \times Dd = (-2s^2 - s + 2rs + 1 - r)^2 \frac{2c}{4}\,.$$

The total number of character bearers in this fraternity, in relation to the total number of children is:

$$\frac{2c\left[(2s^2 + s) + \frac{1}{2}(-2s^2 - s + 2rs + 1 - r)\right]^2}{2c}$$

By exchanging s and r for the corresponding terms of a and b, we get:

$$\frac{1}{4}\left[\frac{100\,(4a+b)^2 - 4a\,(2a+b)^2}{(2a+b)^2 \cdot (200-2a-b)}\right]^2,$$

and by inserting $b = -2a + 20\sqrt{a}$ (formula I, p. 85) we arrive at:

$$\frac{\text{Number of } DD}{\text{Total number of children in parents' fraternities}} = \frac{1}{16}\left[\frac{3}{10}\sqrt{a} + 1\right]^2.$$

Formula IV.

From this formula it appears that if *a* approaches to 0 (in reality, of course, *a* never can be 0, as, when drawing up a pedigree table we are starting from character bearers, and then such must be found in the population) the number of character bearers in the parents' fraternities approaches 1/16. Further, for a = 100, the same figure is 1. All the children in that case are character bearers. Graphically this is shown in fig. 9. The

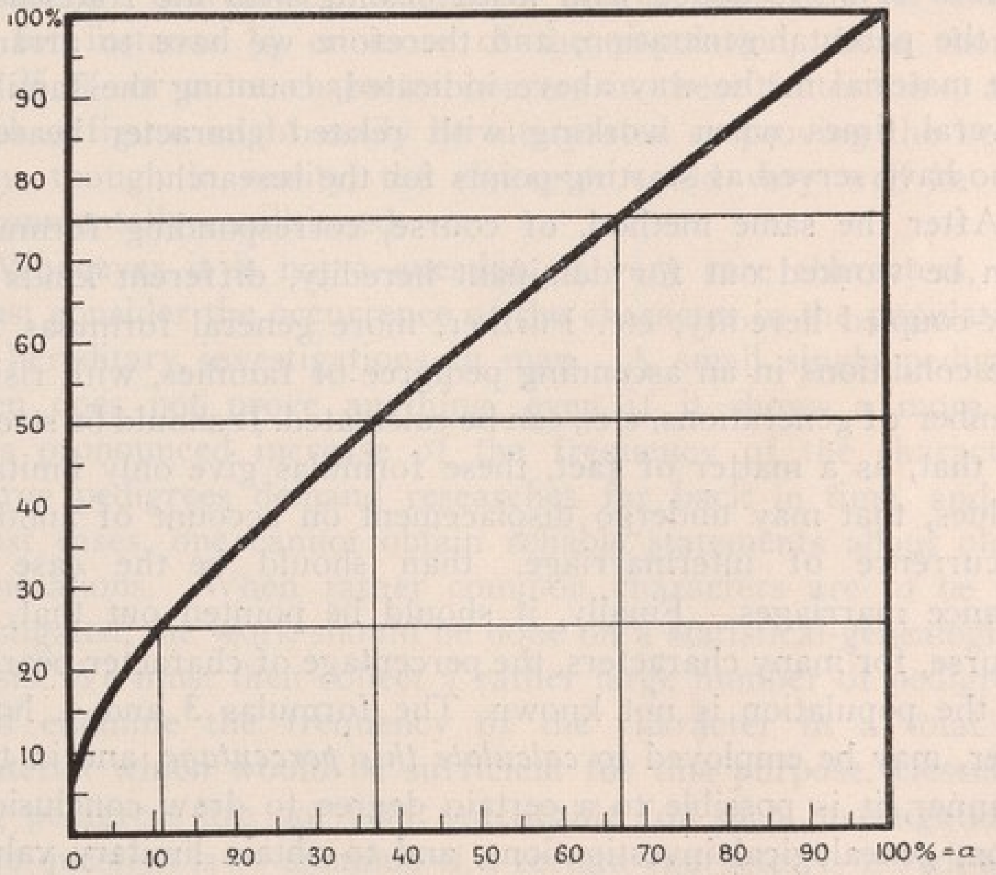

Fig. 9. Curve showing the percentages of manifest character bearers (homozygotes *DD)* among the fraternities of parents of character bearers taken on chance from a population. When the percentages of character bearers in the population *(= a)* rise from 0 to 100 %, the percentages of the fraternities rise from 6,25 to 100 %.

ratio in the parents' generation grows from 1/16 to 1, as *a* rises from 0 to 100, at first sharply, then more slowly.

It must be emphasized that by deducing this formula, we have issued from manifest character bearers taken by chance and all of them given equal weight. This implies that if several manifest character bearers belonging to the same family (or pedigree) appear in the primary material, their families in the pedigree should be counted as many times as this repetition occurs. Even if we issue from a whole population, from all manifest character bearers, the calculation must be made in this way. In this case many families with heterozygotes in the parental generation are lost. We are able to correct this loss by help of Weinberg's proband method when dealing with fraternities in the first generation. The same source of error is now to be reckoned with when dealing with the fraternities in the parental generation, and therefore we have to arrange the material in the way above indicated, counting the families several times when working with related character bearers, who have served as starting-points for the research.

After the same method, of course, corresponding formulas can be worked out for dominant heredity, different kinds of sex-coupled heredity, etc. Further, more general formulas for the conditions in an ascending pedigree of families, with rising number of generations, etc., can be calculated. It should be stressed that, as a matter of fact, these formulas give only limitary values, that may undergo displacement on account of another occurrence of intermarriage, than should be the case at chance marriages. Finally, it should be pointed out that, of course, for many characters, the percentage of character bearers in the population is not known. The formulas 3 and 4, however, may be employed to *calculate this percentage,* and in this manner, it is possible to a certain degree to draw conclusions from genealogical investigations, and to obtain limitary values for the composition of the population. It is evident that the formulas under these circumstances must be used with caution, and that it is necessary to control that the pedigree tables used, can be considered as corresponding to the population in question.

With regard to the employment of the above formulas in hereditary investigations, the following may be pointed out.

When there is question of a character which is rare in a population, the chance of the character incidentally meeting in several persons of the same pedigree is not very great. If we now can find a pedigree with an increase of the frequency of the character among the members of the pedigree, which by a closer analysis proves to accord more or less with the mechanism of Mendelian heredity, this generally should be considered as almost proving the heredity. If, on the contrary, the character is rather common in the population, it may now easily occur that we incidentally get a small pedigree with a number of character bearers that apparently correspond to the Mendelian laws. If further the fraternities of the characters bearers are examined, and if the character exists in for instance ¼ or more of the population, there should be 25 % or more character bearers in these fraternities, and such a figure might easily be interpreted as proving the heredity, though in reality, the character could very well be environmentally conditioned.

Whenever it is not a question of very rare characters, we must consider the occurrence of the character in the population in hereditary investigations in man. A small single pedigree then does not prove anything, even if it shows a more or less pronounced increase of the frequency of the character. Large pedigrees demand researches far back in time, and in most cases, one cannot obtain reliable statements about older generations. When rather common characters are to be investigated, the work should be done on a statistical-genealogical basis. We must then collect a rather large number of pedigrees and examine the frequency of the character in a total of material which would be sufficient for this purpose. Descending pedigrees are not very practicable for such investigations. The question is to examine if a certain character is hereditary, by issueing from certain individuals in a population, either manifest character bearers taken by chance or all the manifest character bearers in the population. Further, we must also generally confine ourselves in the following to living persons, who can be examined. In this case it should be appropriate to use ascending pedigrees of the type which I have suggested, and to examine only the *character bearers* and their fraternities and possibly also their parents and their fraternities.*

Then in ordre to settle whether the obtained proportion of character bearers really is an increase, we must know the figure for the character in the population. If we find an increase corresponding to the increase theoretically demanded, it may be considered as proved that it is question of a monohybride character. If the increase is less than was expected, it may be a question of characters depending on several Mendelian factors (as is already mentioned, I intend to deal more closely with these problems in a later work). If no increase is to be found, or if the increase is much larger than is theoretically expected, there is reason to presume that the character is environmentally conditioned.

The above formulas therefore might be of a certain practical value in hereditary investigations. With regard to the above mentioned points, many problems can be raised. I have now confined myself to simple recessive characters in ascending pedigrees, and I hope to be able to make a more detailed examination of similar problems in a later work. The chief object of this treatise has been to emphasize the importance of statistical-genealogical investigations and the insufficiency of single pedigrees in an examination of the heredity of not too rare characters. Further, I have principially wanted to show the part played by the composition of the population in hereditary investigations. As we pass on from an examination of rare characters, which are of interest more as curiosities, we are forced to leave the descending pedigree. Up till now, such pedigrees perhaps has been used most on account

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* Naturally we can examine the descendants of the character bearers. I intend to deal with this problem in a later work. Here I will only mention that among descendants of homozygotes the ratio of character bearers is:

$$\frac{20\sqrt{a} - a}{200 - a}.$$

of their similarity to the examination of the off-spring by the method of experimental hereditary research. At an examination of more common characters in human material other methods must be employed, and among these, one of the principal means is statistical-genealogical researches in which proper regard is taken to the composition of the population.

For reasons below pointed out, the above formulas are not directly applicable to an examination of the heredity of twin births. The basic principles that we have established by our mathematical calculations are of importance in this connection. Single pedigrees built on an accidentally found accumulation of cases cannot be accepted as proof. Casuistic pedigrees must be considered rather worthless. Reliable results can only be arrived at by help of large pedigrees or by the employment of statistical-genealogical material. These points of view may be regarded as self-evident, but the repeated publication of small pedigrees proves this not to be the case. Also from this point of view, the above exposition is justifiable, especially as the formulas we have obtained can be of a considerable practical use.

HEREDITY OF TWINNING.

The above theoretical considerations are of a certain interest, with regard to twinning. The fact is that the mortality of twins (both monozygotic and dizygotic) is greater than that of single born, that comparatively few twins grow up and have issue (see p. 160). Further, the real fertility of the surviving twins (both of monozygotic and dizygotic), is hardly greater than the common fertility (see p. 131). Consequently, the twins are subject to strong percentual reduction in each generation, before reaching reproductive age. First, as regards monozygotic twins, if monozygotic twinning is hereditary, it might plausibly be assumed that monozygotic twins are homozygotes for the tendency to twinning, that is, the egg, from which the two individuals originate, also has the tendency in homozygotic form. The twins, as was just said, are subject to strong reduction in each generation, and according to what was said above, p. 90, perhaps it should be expected that the character would become extinct in the population. However, of course, the homozygotes in each generation give rise to two individuals. With normal mortality and fertility, the number of character bearers would be doubled for each generation. All the same, the percentage of monozygotic twins keeps fairly constant, at about 0,30—0,40 %. This may mean that the mortality is great enough, first, to reduce the monozygotic twins to half their number, and, furthermore, to correspond to the common mortality for the remainder in the year groups before and during reproductive age. Whether this really is the case, can hardly be decided, as sufficient statistical data are not available.

With regard to dizygotic twins, a similar argument applies, but there is not the same reason, to assume that the dizygotic are homozygotes.

As will be shown below, p. 127, there are reasons to assume that twinning is not inherited after Mendelian laws, but after another mechanism. Our formulas presuppose heredity after simple Mendelian laws, and further, that the number of homozygotes in the population is known (and that a homozygote is one person, not two, as in the case of monozygotic twins). Therefore, it is not possible directly to apply the formulas worked out above, in order to calculate the increase of twin percentage that should be expected in the pedigree table of twins.

Even if the heredity should not follow Mendelian laws, in principle, an increase should be expected in an ascending pedigree table founded on a pair of twins. The disposition quite certainly must be found in some of the ancestors, and these therefore, have increased probability for marriage with twinning. In the total number of children in the pedigree table, therefore, we must expect a higher twin percentage.

With regard to what is known in other respects, about the occurrence and origin of twins, in principle there should be no reasons against the assumption of heredity. On the contrary, from a general, biological point of view, with regard to the conditions in the animal series, there rather is occasion to assume heredity. The connection between twin frequency and racial characteristics, to a certain extent, points in the same direction. No connection having been found between twin frequency and any definite external factor, also strengthens the case for heredity.

Below, for the sake of brevity, the bearing of monozygotic twins will be called diembryony, and the bearing of dizygotic twins, dizygotism.

Twinning has since long ago been considered hereditary or due to a hereditary predisposition, etc. The view was somewhat confused, partly, no doubt, on account of the general confusion of views regarding heredity at the time. The evidence available was purely casuistic. The occurrence of several cases of twinning in one or more generations of a family, does not by itself prove that twinning is hereditary. These selected cases have a value mostly as curiosities, even though they give a general impression that heredity is playing a certain part. Besides, as a rule no distinction has been made between monozygotic and dizygotic, and the simultaneous single births are very incompletely recorded, or sometimes not at all. Generally also, the data have been furnished by the mothers, and not controlled, therefore cannot be taken as absolutely reliable. There is, of course, a common tendency in some persons to exaggerate existing abnormalities in order to attract interest, the most marked instance of this being the Silesian wife who kept the fetuses from her six successive abortions, then to proclaim them as sextuplets, born at the same time, Freund see Nyhoff 1904. Having regard to these considerations it would be of small interest here to give such cases. In Winckel's Handbuch, 1904, Strassmann surveys the earlier case reports in this field.

In the later literature also, scattered family tables over twin births are to be found. Thus, in a work by Jordan, 1914, on left-handedness, some twins have been included in his pedigree tables, considered by the author to testify to heredity of recessive type. Whether diembryony occurs in his material, cannot be decided. The same is the case with a pedigree given by Davenport, 1912.

These and similar cases certainly may be more reliable than the earlier casuistics, but in small pedigrees the possibility can not be excluded, that, with a phenomenon of so common occurrence as twinning, the accumulation of cases is purely accidental. In the preceding chapter we have more explicitly demonstrated this.

Besides, there are, however, more comprehensive inquiries, either in the form of genealogical investigations or statistical examinations.

Goehlert, 1879, has made a genealogical collocation on European royal families. Speyr, 1894, has made use of and somewhat enlarged Goehlert's material. They are both of opinion that there generally exists a hereditary predisposition for twinning. Weinberg, however, has pointed out that Goehlert has included some cases of twinning, that are to be found neither in the sources referred to by him or elsewhere. Naegeli-Åkerblom, 1902, submits Goehlert's work to severe criticism in this respect, and finds it generally unreliable.

Jullien, 1897, in 434 twin-bearing mothers in 4 cases finds twins on the paternal side and in 10 cases on the maternal side.

Lauritzen, 1891, in 62 twin-bearing mothers finds twins in the family in 18 cases—10 times on the paternal, and 8 times on the maternal side.

Evidently, investigations of this type cannot give a decisive result. What we want to know is, whether the number of cases met with in a family, really represents an increase. For this purpose it is necessary to know the number of single births in the whole family, and further, it is necessary always to go equally far back.

A statement that a certain number of twin-bearing mothers have twins in their families, is too vague and depends on the degree of conscientiousness exerted in inquiring, etc. First of all, we must have comparative figures for the number of twins in the families of single-bearing mothers, and besides, such figures are of value only if all cases have been equally closely examined — and if the data go back equally far in all the families.

Weinberg, 1902 a, has paid attention to these sources of error. First he makes a comparison of data for fathers of twins. On material from Würtemberg he finds that 101 fathers of twins are descended from families with 901 children, among whom 6 pairs of twins (1:150), and their sons have in all 1,199 children with 8 twin births (1:150). This result did not encourage him to go on, and he is of opinion that, so far, there is no reason to assume heredity on the male side.

On the female side he gets these figures and draws his conclusions, in the following manner: —

Cases of more than one child at a birth in Stuttgart and 4 villages.

		Twins of the same sex			Twins of different sex		
		Material examined	Total number of births	With more than one child at a birth	Material examined	Total number of births	With more than one child at a birth
Of the mother	of the twin-mothers	579	3,970	61	254	1,848	45
» » sister ...		575	2,579	55	201	1,022	24
» » daughter		833	3,430	44	323	1,464	27
Total among the relations of the twin mothers		1,987	9,979	160	778	4,334	96

"A subtraction gives the following numbers for births from one ovum: 1987—778 = 1209 cases in 5645 births and 64 pairs of twins.

Among the relatives of dizygotic twin mothers, twin births are found in a ratio of 1 : 44. The corresponding ratio for twins from one ovum is 1 : 88. This difference is very significative. The number of births from one ovum corresponds very nearly with the percentage for the whole population, the frequency of twins in Stuttgart being in a ratio of 1 : 92.

So far, therefore, the inheritance of the capacity of giving birth to twins can be shown only in the case of two-egg twins."

Rosenfeld, 1903, publishes a statistical genealogical investigation on the German nobility and his results are in favour of heredity. He cannot, however, distinguish between monozygotic and dizygotic twins and his material is rather small.

In a later work, 1909 (b), Weinberg to some extent has enlarged the material on the female side, and again comes to the conclusion that heredity of recessive type is to be assumed on the female side for dizygotic but not for monozygotic twinning.

On the male side he finds the following figures: the mothers of fathers of twins have 5,196 births, among these 57 twin births, or 1,097 per cent.

H. Meyer, 1914, has compiled material from royal families and from schools in Berlin; he concludes that there must be some sort of inheritance, but finds he cannot get at the real mechanism of this heredity, and cannot distinguish between monozygotic and dizygotic in his material.

Meyer, like Rosenfeld, in his genealogical material does not give the number of single births, but deals in terms like "predisposition" of the parents by the occurrence of twin births in their families. It is, of course, difficult to draw definite conclusions from these compilations.

Jones, 1918, genealogically follows five different lines in the U. S. A. for statistical purposes. Regarding twins he finds the following figures within the different lines (A, B, C, D, E).

Line A	4,184	births	11	twin pairs
" B	4,116	"	32	"
" C	4,147	"	11	"
" D	3,421	"	25	"
" E	4,744	"	8	"

These figures he considers as giving evidence of heredity — two of the lines have twin births thrice as often as the other three. It may be mentioned that 32 out of the 87 cases were opposite-sexed.

Bonnevie, 1919, on a genealogical examination of a Norwegian peasant family finds 7.7 per cent twin births in some of its branches. The dizygotic are about 80 per cent of these, (after the differential method), and therefore she holds that the heredity of dizygotic twinning must first of all be investigated. She also points out that Weinberg has ruled out the idea of heredity for monozygotic twinning and like Weinberg, she is inclined to exclude this possibility. She is of opinion that heredity is bound only to the mother of the twins and to her family, not to that of the father. There are cases where the father is a twin, or has twins in his family, but if the mother's family is known, there is always heredity on her side too.

Davenport, 1920, thinks to have established inheritance both for dizygotic and monozygotic, and both on the maternal and the paternal side. He takes 30 mothers with "certain or highly probable" diembryony, and among their brothers and sisters he finds 13 per cent (10 pairs) of twins in 77 births. On the paternal side he finds 13 per cent twins (5 pairs) out of 38 births. He does not state how many of these pairs of twins are opposite-sexed.

Davenport further examines the twin frequency among parents of twins both monozygotic and dizygotic. As in the above cases of the monozygotic, he counts only those parents that have had more than one pair of twins. "Of 355 labors occurring to the mothers of repeating mothers 16 (4,5 per cent) were twin labors. Of 289 labors occurring to mothers of twin-repeating fathers 12 (4,2 per cent) were twin labors." Also he finds an increase of the twin births among the children of these parents' brothers and sisters; the increase is between 4 and 7,5 times the average proportion of twin births in the whole population. "These statistics, then, indicate that there is no important difference in the hereditary influence to twin production on the part of the father and the mother of offspring which include two or more sets of twins."

This conclusion, now, is drawn not only in regard to diembryony but also dizygotism (since both kinds are included in his above material). With regard to dizygotism Davenport now sets forth a theory that liberation of two eggs is comparatively common. Twin pregnancies, however, occur comparatively rarely, owing to a common hereditary occurrence of lethal factors in the sperms. In a marriage with a man who lacks these lethal factors, on the other hand, twin pregnancies are fairly common. This, according to Davenport, would explain the increase of twin births on the fathers side.

A number of casuistic genealogical tables also are intended to demonstrate heredity on the male side (e. g. Strassmann, 1904, Wilson, 1908, Peiper, 1923) but these are not very comprehensive and therefore of small interest.

Wehefritz, 1925, tests the heredity of twinning on some pedigrees published by him, and on Bonnevie's material. He assumes that twin pregnancy is due to a recessive unit character in the mother. This character can manifest itself only in women. By putting the number of twin-bearing mothers in relation to the number of mothers without twin births in a fraternity, he finds, employing Weinberg's proband method, the proportion 1 : 3,8, which he regards as indicating heredity in accordance with his assumptions. His own material gives 24 : 109, and together with that of Bonnevie 40 : 153.

Theoretically, Wehefritz had expected 1 : 3, and the divergence he takes to be due to the character not always manifesting itself. His conclusions have regard only to dizygotic pregnancy. In his own material, he is sure of having chiefly dizygotic twins. If the material should not be selected, and is not composed of some especially "interesting" pedigrees, Wehefritz' results must be regarded as evidence of heredity. In any case the material is too small for special importance being attached to the particular figures. If one family had been omitted from pedigree No. 1, the proportion would have been 1 : 7,8, in his own material, and in the total material 1 : 5, instead of 1 : 3,8.

In text-books of obstetrics the results are summed up in various ways. Strassmann in Winckel's Handbuch, 1904, as above mentioned, quotes a number of case reports and says it is a matter of common knowledge that the disposition to twinning is hereditary. He makes no distinction between monozygotic and dizygotic or between the maternal and paternal side. Puech in Bar, Brindeau, Chambrelent, 1914, assumes heredity on the paternal as well as on the maternal side, but he does not enter upon a detailed discussion of the problem, and makes no distinction in this respect between monozygotic and dizygotic. Weber in Döderlein's Handbuch, 1920, says the assumption of heredity of plural births is founded on wide experience, and states that most authors assume heredity only on the maternal side. However, he quotes a genealogical table from Strassmann, 1904, that seems to show heredity on the paternal side. Engelhorn, 1925, is of opinion that at twin pregnancies the hereditary disposition plays the greatest part and quotes Bonnevie's investigation and some casuistic cases.

In text-books on heredity the presentation of the subject likewise is rather confused. Shallmayer, 1918, says the absence of external causes speaks in favour of heredity of the disposition to twin or plural births, without further entering upon the problem. Hofsten, 1919, maintains that the tendency to twinning is inherited after Mendelian laws. Lenz, 1923, discusses the question in more detail. He assumes heredity for dizygotic on the maternal side, depending on a recessive disposition, and quotes Weinberg's figures. But he considers it possible, too, that external circumstances, possibly alcohol, play a certain part. He further quotes Davenport's figures, giving as his opinion that simultaneous maturing of two eggs is not essential. He proposes a modification of Davenport's theory: normally two eggs are liberated, but the fertilization of one causes the secretion of substances that prevent the fertilization of the other one. A hereditary failing to develop these fertilization-preventing substances would account for the paternal heredity. Siemens, 1923, mentions that Weinberg has not been able to establish heredity for monozygotic twinning. Dizygotic twinning, on the other hand, seems to be hereditarily conditioned, and several authors seem to think that only the mother has heredity to twin formation. He quotes Davenport's figures as tending to show heredity of the father, too, at dizygotic twinning.

To sum up, the present position seems to be this:

At dizygotic twinning it is a priori difficult to imagine the father of the twins as bearer of a hereditary character, conditioning the occurrence of dizygotic pregnancy. The hypotheses propounded by Davenport (on lethal factors), and by Lenz (on fertilization-preventing substances), of course, are permissible only when it has been reasonably well empirically established that a hereditary disposition of the father has an influence. In the brothers and sisters of fathers of twins (consequently chiefly dizygotic), Weinberg found among 2,100 single births, 14 twin births, that is about 1 : 150.

In Würtemberg from where the material was taken the common twin frequency is 1 : 92 of the births. The lower frequency in the material, drawn by Weinberg from the family registers, possibly is a consequence of some twin births being omitted. Still-born and those dead immediately after birth, possibly have not been entered in the registers, and the twins thus have been underrepresented. The figure probably should be put at the common frequency, and it is quite possible that the real figure is still higher. However, it does not seem very probable that by omitting these births, the figure can have been lowered from 1 : 15 to 1 : 150 — in other words, that 90 per cent of the twin births have been omitted. Davenport has found precisely 1 : 15 among the relatives of the fathers of monozygotic and dizygotic twins. This discrepancy may possibly be explained by Davenport having got his data from the fathers themselves, these having conscientiously included all the twin births, while forgetting some single births.

In Weinberg's work 1909 a, the figures are higher than in that of 1902, and on the whole correspond to the general frequency. The registration in this case may have been more careful. Perhaps the material is from a later period. This cannot be definitely stated, but the contradictory results invite caution, and the problem of the influence of the father cannot be considered as settled. A new investigation of the matter is needed.

As to the heredity of dizygotism on the maternal side, Weinberg's and Davenport's figures of course point in the same direction (Weinberg 1:44 in the relatives of twin-bearing mothers). The genealogical results of Jones and Bonnevie also are of this nature. The increase found in the families treated by them, is very marked, and in the case of Bonnevie, undoubtedly is to be ascribed to the dizygotic. This probably is true of Jones' figures, too. Regarding the influence of the father in dizygotism, these investigations give no decisive evidence. In any case the hereditability of dizygotism in the families of twin-bearing mothers, may be considered as established.

In regard to diembryony, once again the figures of Weinberg and Davenport are incompatible. In order to get his figures Weinberg has had to make a number of assumptions: that mothers of opposite-sexed dizygotic twins have the same number of relatives, with the same average number of children, and with the same twin frequency among these children as in the mothers of same-sexed twins. To this is added the introduction of the differential method, and the assumption that among the children of the relatives of mothers of monozygotic twins, dizygotic twins occur in the same proportion as among the population at large. These undoubtedly are legitimate assumptions, but in reality, of course, chance displacements will occur. Weinberg's figures therefore cannot be taken as quite exact.* Now, Weinberg found 1:88 twin births among the relatives of mothers bearing monozy-

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* Similar critical considerations were set forth in an earlier paper (Dahlberg, 1923). I then treated in some detail the assumption that dizygotic twins ought to be found in the same percentage in the families of monozygotic twins, as in the population at large. As an instance of the importance of a displacement in this respect, I calculated the increase, first, on the assumption that the twin pairs in a family were monozygotic in 100 %, then, on the assumption of 60 % being monozygotic. Weinberg, 1925, has taken this as a suggestion on my part that the monozygotic in this case should be estimated at 60 %, and, further, finds my criticism of no importance, because his method is cut out for a large material, and cannot be employed on ''a village or a family with some 20 twin births". If the number of monozygotic twin births in Weinberg's material of monozygotic twin families, 1902, is calculated, as I pointed out in my previous paper, it will be found to consist of 21 monozygotic twin pairs. A chance displacement of these figures, consequently, may very well be imagined, as the material is not larger; further, if there is an increase of monozygotic twins in these families, but not of dizygotic, and some twins should not have happened to be registered, the result may be about the same twin percentage, as in the population, but the twins of these families to a comparatively large proportion will be monozygotic. Thus, it is not precluded that there is an increase of monozygotic twins in the families of monozygotic, but of course I never meant to suggest that this increase would be precisely 60 %. My statement that Weinberg's figures do not prove heredity of monozygotic twinning, but neither prove the opposite, therefore, still holds good. As I have myself experienced, it is very difficult to get a sufficiently large and reliable material of twin families. On the other hand, of course it is not permissible to draw more definite conclusions than justified by the material.

gotic twins, and this he does not regard as an increase. If the above suspicion is right, that some twin births have been omitted in the registration, there may, all the same, be a very strong increase. If Weinberg's corresponding figure for twin frequency among the relatives of fathers of twins (1 : 150), is chosen for comparison, 1 : 88 means almost a doubling.

Davenport has found 13 per cent twins among the relatives of mothers, bearing monozygotic twins, and the same increase on the fathers side. The whole material, 15 pairs in 115 births, is not large, but it supports the view that diembryony is hereditary both on the male and on the female side. Here, too, Davenport's frequency is higher than Weinberg's. Davenport's figures thus consistently lying above Weinberg's, to a certain degree strengthens the belief that Weinberg has omitted some twin births, and Davenport some single births.

On the whole it might be said that heredity is established for dizygotism on the maternal side. It cannot be decided if heredity is present on the paternal side, but it hardly seems probable.

There are strong reasons to assume heredity of diembryony, probably both on the maternal and the paternal side, but this is not yet quite clear. With regard to the monozygotic twins, as may here be pointed out, Bonnevie has overlooked the fact that the increase in her material affects not only the dizygotic *but also the monozygotic.* About 20 per cent of the 7,7 per cent twin births are monozygotic. This speaks strongly in favour of diembryony — if on the maternal and paternal side alike, cannot be decided.

With a view to giving some contribution to the solving of these problems, I sought to obtain a number of ascending pedigree tables for twins. Starting from monozygotic and dizygotic twins, I collected information about parents and their fraternities, and about grandparents and their fraternities with statements about the occurrence of twins in these fraternities. However, the result was unsatisfactory, partly because the material was incomplete, partly because it could not be made comprehensive enough.

Nevertheless, I shall give a short account of the results. In the total material, which comprises 6,885 births, among which

85 twin births, the twin percentage was 1,23 ± 0,14 %. It is, thus, lower than in the population at large; the official statistics of Sweden, 1891—1910, give 1,46 %. The difference is explained by the still-born and those dead immediately after birth not being fully included in the statistics, because in the parish registers, from which the figures are derived, these births are not always entered. Only those who have lived for some time after birth, are entered. This omission affects the twin births more than the single births, and monozygotic twin births more than dizygotic as brought out, p. 47. The figures are as follows: Table 8.

Table 8.

The Occurrence of Twin Births in the Families of Monozygotic and Dizygotic Twins.

Births among the mothers and grandmothers of dizygotic twin mothers	2,389	Births among the mothers and grandmothers of monozygotic twin mothers	1,104
Twin births among these	36	Twin births among these	10
Twin births in % ± standard error	1,51 ± 0,25	Births among the mothers and grandmothers of monozygotic twin fathers	1,027
Births among the mothers and grandmothers of dizygotic twin fathers	2,365	Twin births among these	11
Twin births among these	28	Births among the parents of the mothers and grandmothers of monozygotic twins	2,131
Twin births in % ± standard error	1,18 ± 0,22	Twin births among these	21
		Twin births in % ± standard error	0,99 ± 0,21

Total births	6,885
Twin births	85
Twin births in % ± standard error	1,23 ± 0,14

On a comparison between the paternal and the maternal side in the pedigree tables of dizygotic twins, it will be found that on the paternal side (2365 births) the twin percentage is 1,18 ± 0,22, and on the maternal side (2389 births) 1,51 ± 0,25. The percentage is a little higher on the maternal side, but of course the difference, 0,33 ± 0,33 %, is not statistically established. The material is too small. In the pedigree tables of monozygotic twins, among 2,131 births the twin percentage is 0,99 ± 0,21. Here also the material is too small. When the mean error is so large, the higher figures for the dizygotic, both on the paternal and the maternal side, may well be due to chance. Under these conditions no definite conclusions can be drawn from the material collected. With the means at my disposal it has not been possible to enlarge the material to sufficient extent.

Thus, it can only be said that the figures found, do not contradict the conclusions derived from earlier researches, i. e. that diovulation is hereditary on the maternal side, but that there are at present no figures to show heredity on the paternal side — a priori not very probable — and finally that diembryony probably is hereditary, and, if so, possibly both on the maternal and on the paternal side.

RÉSUMÉ.

The main points of the above regarding twin and multiple births, may be summed up shortly thus:

1. Multiple births on the whole may be taken to follow Hellin's law, according to which twins occur in $1/n$, triplets in $1/n^2$, quadruplets in $1/n^3$, quintuplets in $1/n^4$ of the single births, n varying between a little under 80 and somewhat above 90.

2. The number of monozygotic twin pairs in a material, according to Weinberg's differential method is calculated by doubling the number of opposite-sexed twin pairs, and subtracting this number from the total number of twin births. The remainder is the number of monozygotic twin pairs.

Empirically this method has proved to give satisfactory results, and from a theoretical point of view, no serious objections can be raised against it, even though some errors may not be quite excluded. According to this method the monozygotic twins are about 20 to 30 per cent of the twins, a result which is in accordance with the empirical figures.

3. If the twin births are calculated in percentage of the total births for different age groups of mothers, it will be

seen that the twin frequency rises steeply with rising age, from about 0,5 per cent to not quite 2 per cent. The maximum lies at 35—40 years. After that age the twin frequency again decreases. On an analysis of this age curve after the differential method, this rise with age proves to be almost wholly due to an increase of the dizygotic twin births. The monozygotic twin births are very nearly the same number with rising age of the mother. Only a very slight increase is observable.

4. Twin births are more common with higher number of the birth. (That is to say, they are comparatively rare in first births, more common in for instance the 6th births). This has been shown to be due to the rising age of the mothers. An influence from the number of previous births independently of age, cannot be shown.

5. An increased real fertility of the twin mothers has not been proved. The existing figures on the contrary disprove such an increase. A higher potential fertility (tendency to conception), of course is not excluded, but as yet there are no reasons for such an assumption.

6. That twin births are more rare among illegitimate births, is due to the mothers being on an average very much younger than the legitimate mothers.

7. That twin births are generally more common in the country than in the towns, may possibly be explained by the registration being more careful in the country. A different distribution of the births after age in some degree also tends to give the country a higher total percentage of twins. However, a small real difference may also exist.

8. Still-born twins are more common among monozygotic than among dizygotic. A grouping after age shows that the monozygotic still-born in percentage of total still-born, decrease in frequency with rising age. The dizygotic still-born in percentage of total still-born increase distinctly with rising age though not quite so much as among the live born. The abortions probably follow the same laws, that is to say, they are more common among the monozygotic, decreasing with rising age, and are less common in the dizygotic, slightly increasing (in per cent) with rising age. At present, however, no material is available to establish the influence of age on the abortions.

If the abortions and the still-born (twin and single births), are omitted, this can approximately be calculated to cause a decrease of the twin frequency with 0,20—0,25 per cent, besides causing a sharper rise of the age curve for monozygotic as well as dizygotic twins. At conception, rising age probably does not influence the frequency of monozygotic, but causes a distinct increase in the number of dizygotic twins.

9. The difference in twin frequency between different countries, is partly due to a different age distribution of the mothers, partly to differences in registration. These factors however are not sufficient to explain all the differences. The regional correspondence of racial characters and twin frequency in Europe, indicate a sort of connection. Probably the Nordic race has greater average disposition to twinning, than Alpine and Mediterranean race.

10. A connection between twin births and doubling of the genitals or with polymasty, has not been established, and may be regarded as out of the question. The available figures rather go to prove the reverse. The theoretical line of thought behind this hypothesis, that is to say that twin births are to be regarded as an atavism (the *atavism* theory), in view of modern conceptions is quite untenable.

11. A connection between mental disease and twinning, has not been shown, and there is no reason to assume one *(degeneration* theory).

12. A connection between syphilis and twin pregnancy, does not exist, nor are there any figures to show a connection with alcoholic poisoning, tuberculosis etc. The *"intoxication* theory" statistically is absolutely unproved — with regard to syphilis it may be regarded as demonstrably false.

13. Monozygotic twins originate from one egg fertilized by one sperm. It is improbable that the egg would contain two nuclei, or the sperm have two tails. There is at present no positive reason to assume such morphological irregularities in the eggs or the sperms of twins.

14. Experimentally it has been possible, by the influence of temperature, osmotic pressure, the absence in the water of certain metallic ions etc., to produce double formations in a greater number than normally occur, from eggs of lower animals.

There is no reason to suppose that a similar abnormal environment of the human egg during the time immediately after fertilization, gives rise to monozygotic twins. It cannot be regarded as permissible to draw analogies from the above mentioned experiments on lower animals, directly to man. The evidence so far advanced in support of this view, has not stood a closer scrutiny.

15. Heredity of the disposition to bear dizygotic twins, has been shown to exist in the mothers. Hereditary dispositions of the father of dizygotic twins, are probably of no importance. For monozygotic twins, also, heredity probably exists, and the disposition probably can be present both in the father and in the mother.

We thus can state that the twin frequency is due to the occurrence of hereditary characters in some of the individuals in a population. The racial structure affects the twin frequency. Further, the twin frequency varies under the influence of the mother's age. Dissimilarities in the twin frequency, when they are not caused by a differing registration of the still-born, can be explained by the effect of these factors. The more completely the still-born are registered, the higher is the twin frequency. On the contrary the increase with age of the twin frequency is reduced under the influence of the still-births, and if all abortions and still-born are included, the increase with age probably disappears for monozygotic, while there remains a distinct increase for dizygotic. At investigations into twin frequency, it is therefore necessary to consider the effect of heredity, of the mother's age, the racial structure of the material, and of the accuracy of the registration.

A TWIN HYPOTHESIS.

An attempt to work the facts so far established, (cf. preceding chapter) about the occurrence of twins, into a uniform theory must to a certain degree have a hypothetical character. Several points are still uncertain, and a more comprehensive hypothesis, of course, forces a decision on these points. As science proceeds, our views in this respect, as in others, are sure to be modified. For the present, the hypothesis I am here advancing, however, may justify itself and be of some service — for my own part, I have found it very serviceable in the work of comparing and sifting the results of earlier investigators.

That an egg gives rise to monozygotic twins, may be due to a hereditary disposition of the egg to double formation. It may also be due to such a disposition of the sperm. Whether these eggs or sperms differ in appearence from normal eggs or sperms (binucleated eggs, etc.) we do not know, but there is at present hardly any reason to think so. It is obvious that in consequence of this disposition, the development of the fetus, or rather the double fetus, will be different from the ordinary. Possibly the development differs even physiologically (e. g. a stage of retarded metabolism) but at present we have no reason to suppose this to be so.

Dizygotic pregnancy also is due to a hereditary disposition. It is, then, conceivable that these dispositions are either entirely independent, or that there is a connection between them. The results of Bonnevie favour the last-mentioned alternative. The two dispositions are to be found in the same family, heightened to about the same degree; this, of course, may also be accidental.

If such a connection exists, the simplest explanation of the matter would be that sometimes the disposition (the tendency to double formation) manifests itself before the reducing division, and sometimes afterwards. If it has not manifested itself before the reducing division, afterwards it can hardly do so till after fertilization. An egg is predestined — has a predisposition — after a certain time to undergo a reducing division. At the same time, we now have a disposition to a final segmentation after a certain time, coinciding with the previous space of time. There is, one might say, a race between the tendency to reducing division and the tendency to double formation.

The twinning tendency is of the same nature both in man and in woman, both in eggs and in sperms. In woman, the tendency sometimes causes dizygotic, sometimes monozygotic pregnancy. The sperms can only cause monozygotic pregnancy. Only in the case of monozygotic twin pregnancy can heredity on the male side be demonstrated. As to the nature of the tendency in other respects, we do not know more here than we do about other hereditary characters. On the other hand, from this point of view there is nothing incredible in the assumption of such a tendency. Many other hereditary characters — e. g. a certain stature, a particular shape of the nose — in a way are only tendencies to a certain number of divisions.

Returning to the tendency to double formation in the egg cells, the mechanism that has here been suggested, explains the occasional occurrence of two-egg follicles. The binucleated eggs that have been found, Stöckel, 1899, Rabl, 1899, would be eggs that have not had time to complete their fission. Examinations of ovaries from twin-bearing mothers, with regard to this hypothesis, are af great interest — but, so far, very few such examinations have been made.

But if the tendency to double formation is predestined to manifest itself at a certain time, and if reducing division and then fertilization take place a considerable time before this, the tendency to double formation can assert itself only in the course of the later embryonic development. In that case, the result would be not two independent twins, but two more or less conjoined, the more conjoined, the later the tendency has come into play. This would accord with Schwalbe's opinion that the more independent the individual parts of a double formation, the earlier the terminal point has been reached, the latest point at which the tendency must manifest itself. This race between the tendency to reducing division and the tendency to double formation and gastrulation, thus explains all the transitional stages that are to be found between more or less conjoined twins, independent monozygotic with one amnion, and monozygotic with two amnions.*

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* Ahlfeld, 1894, states that monozygotic twins have a common amnion in 1:60. Weinberg, 1902 a, on figures from Würtemberg, finds monozygotic double monsters in 1:207 monozygotic twin births. On the whole, thus, monozygotic twins occur in about 0.30 per cent of the births. Monamniote monozygotic twins in about 0.005 per cent of the births, and double monsters in 0.0015 per cent of the births. Naturally the figures are very approximate.

How does this hypothetical view accord with the conditions in the animal series? The matter may, perhaps, be expressed in this way: in some animals the tendency to multiple formation during the progress of development has been definitely located to a period after the reducing division, as e. g. in Dasypus. In the pluriparous generally, the manifestation of the tendency has been located to a period so far in advance of the reducing division that the follicles are formed independently with one egg each. The organization, however, is not fully stabilized. It happens that a last rest of division tendency "sticks", and we find follicles with several eggs, or double formations in these animals too, just like in man. In exceptional cases in Dasypus, on the other hand, the doubling tendency becomes located to a period earlier than the reducing division, causing the occurrence of follicles with several eggs. (Rosner, 1901, quoted Patterson, 1913, Cuenot, 1903, quoted Apert, 1923.) This much in passing — a detailed discussion of the problems concerning the condition in the animal series, would still be premature.

As previously stated, it is established, however, that dizygotic twin pregnancy may arise also from eggs from two different follicles, even from one egg from each of the ovaries. Naturally, the ovulation mechanism sometimes may become disordered, so that two follicles burst simultaneously. It is to be expected that such disturbances are more easily caused in older, than in younger mothers. When the ovary begins liberating eggs, and also when it is ceasing, and comparatively few eggs are left, the chance of accidental simultaneous maturing of two eggs perhaps is not so great. Consequently, a considerable increase with age is to be expected for the dizygotic, but not for the monozygotic twins, and it might be intelligible that dizygotic twin pregnancy is comparatively rare with mothers belonging to the oldest and youngest year groups. But it is more surprising that the maximum for frequency of dizygotic pregnancy is so high — near the age of 40. This should indicate that the older a woman is, the more easily — the more frequently — do the eggs of the ovaries mature. When the maximum is reached at about the age of 40, the egg liberation rapidly ceases. Taking this into account, there might be reason to suspect that, in reality, the potential fertility increases with age, reaching a maximum at 40 years.

Accordingly it would be possible to distinguish between dizygotic, not hereditary, with two corpora lutea, and hereditary dizygotic and monozygotic from one follicle and with one corpus luteum.

Strassmann, 1904, points out that in the majority of cases, the dizygotic have conjoined placentas and consequently must have been imbedded close to each other. In Strassmann's opinion this may possibly be so, because the eggs in this case originate from the same follicle and stick together through granulosa cells when entering the uterus.

On the basis of my theory, I shall very briefly survey the conditions regarding triplets, quadruplets etc. I refer to the figure 10, p. 124. According to Lex Hellin, one egg would divide into two in $1/n$ cases. In $1/n$ cases the other egg divides into two, and in $1/n$ one of these eggs in its turn divides into two (in the figure the division is carried out only to one side). Quadruplets will then occur in $1/n^3$, n being 80—90. The reducing division, however, may take place before any of these divisions, after one division, or after two, etc. This explains all these different combinations of number of eggs with number of embryos that have been demonstrated.

Now, especially with regard to triplets, they must be monozygotic, dizygotic or trizygotic. But besides (at a more advanced age of the mother) it might happen that at conception of a twin pair, monozygotic or dizygotic, accidentally an extra egg would be liberated. The number of dizygotic and trizygotic triplets, consequently, in each case should be larger than the number of monozygotic triplets (as has also been shown p. 63), and, further, both the other kinds of triplets increase with age, while the number of monozygotic would remain almost constant (not yet demonstrated). The total increase with age of the triplet percentage ought to be stronger than that of twins and have a maximum at 35—40 years, just as the twin percentage (which has been proved).

The case is similar with regard to quadruplets and quintuplets. It is at present difficult to decide how many hereditary factors must be assumed for these categories.

As already said, the view here outlined does not pretend to be more than a working hypothesis. It explains some striking peculiarities in the occurrence of twins, and, at least for the moment, satisfies the demand for a consistent view. As far as can now be seen, no hitherto established fact seems to be definitely incompatible with my hypothesis; on the other hand it has been necessary, on certain points to make assumptions for which there is at present no definite proof. The hypothesis, for the present, is in need of verification especially regarding:

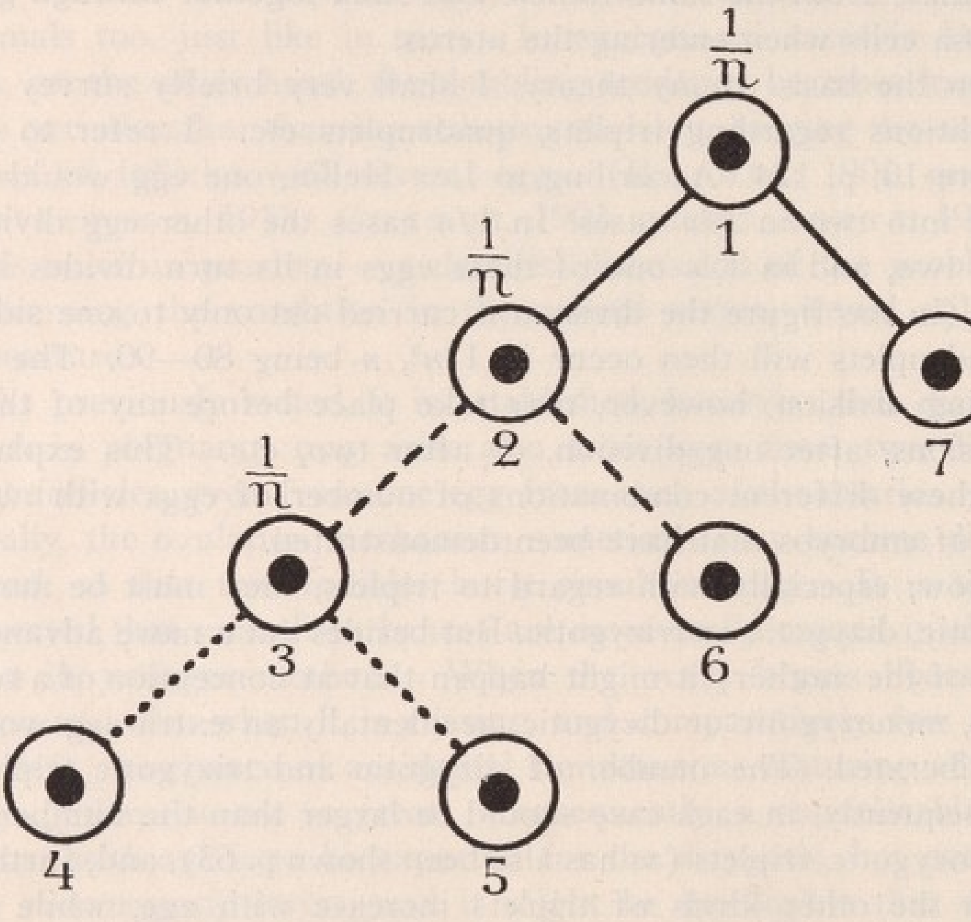

Fig. 10. Showing the development of quadruplets. In $1/n$ cases, the egg No. 1 divides into two (2 and 7). In $1/n$ cases one of these (No. 2 in the figure) divides into two (3 and 6), and in $1/n$ cases, one of these eggs (No. 3) divides into two (4 and 5). Thus quadruplets develop in $1/n \times 1/n \times 1/n = 1/n^3$ cases. The fertilization can take place before the division in No. 1, in No. 7 and 2 (before their divisions), in No. 7, 6 and 3 (before their divisions), and in No. 7, 6, 5 and 4. Thus quadruplets are developed out of one, two, three, or four eggs.

1) the occurrence of dizygotic follicles in the ovaries of twin-bearing mothers; 2) the number of corpora lutea in twin pregnancies; 3) the connection between monozygotic and dizygotic twinning in twin-bearing families. With regard to the last mentioned point, my original intention was to show that an increased number of dizygotic twins is common in the families of monozygotic twin-bearing mothers and vice versa. The collection of genealogical material, however, proved to be too time-absorbing and costly, and the material I had been able to obtain was quite insufficient for this purpose. This being the case, I made an attempt to investigate the conditions as regards repetition of twinning in order to find out if such a connection might not be established in that way. This turned out to be a more practicable path. The results obtained will be shown in the following chapter.

REPETITION OF TWINNING.

Weinberg, 1902 a, has collected statistical material for the problem, how often twinning is repeated by mothers who have once borne twins. In his material, from Stuttgart, there are 1,156 same-sexed twin births, with 6,604 other births, among which 143 multiple births; and 545 opposite-sexed twin births with 3,019 other births, among which 101 multiple births. With the help of the differential method Weinberg calculates from this that mothers of monozygotic twins have another twin birth in 1 : 85 births. Mothers of dizygotic twins repeat in 1 : 30.

These figures, Weinberg thinks, show that the tendency to repeat the twin birth, exists only in the case of dizygotic twinning, and that this tendency generally is not very strong.

In his work 1909 Weinberg, on the basis of a somewhat larger material, arrives at the same conclusions.

If the tendency to dizygotic twinning is hereditary, it is of course only to be expected that mothers who have once borne twins, show a higher number of twin births. The increase found, strengthens our conclusions about hereditability of dizygotism.

According to my hypothesis the mothers of monozygotic twins, should not show an equally large increase. If the father is bearer of the tendency, of course the increase should be inconsiderable. If the tendency is to be found in the mother, according to my hypothesis the increase should be equal to the increase found in dizygotic twin mothers. The total increase, however, must be somewhat lower than in the case of dizygotism. Weinberg, as a matter of fact, finds none or a hardly noticeable increase. Possibly incomplete registration plays a certain part (vide p. 112).

Davenport, 1920, in families with more than one pair of twins finds that among 160 repeated twin births, there were 54 opposite-sexed. After the differential method, the monozygotic are 33 per cent of these twin births, a fairly normal proportion, indicating that the tendency to repetition exists both for diembryony and for dizygotism.

In any case, Weinberg's result is quite remarkable. The tendency to repeated twin birth, as pointed out by Weinberg, cannot be very strong. As regards the tendency to repeated dizygotic twin pregnancy, there are different possibilities.

Above, the possibility was mentioned that the ovulation mechanism might be accidentally deranged, so that two eggs would be liberated simultaneously. Probable causes would be for instance an inflammatory irritation, an afflux of blood to the ovary, etc. Now it is conceivable that the tendency to diovulation is just a hereditary disposition to such disturbances. The mother produces two eggs only under the influence of certain external factors. When these have ceased to act, only one egg is produced. Further, the twin-disposed mothers only very rarely come under the influence of such environments. Under these conditions, however, the increase of twin births in their families, should not be so regularly recurring, as has been found for instance by Weinberg, 1902 a. The environmental conditions, varying from generation to generation, rather would serve to hide the disposition, as this can manifest itself only under special environmental constellations. No particular external factor by which the twin frequency is conditioned, has been found. Apart from the influence of age and race, the twin frequency is fairly constant in varying climatic and social conditions (e. g. legitimate and illegitimate births). These considerations, of course, do not absolutely preclude this view, but certainly make it rather improbable.

There is the possibility that in mothers of dizygotic twins, normally two eggs are liberated, while only in rare cases more than one is fertilized. That in the majority of cases, the sperms should reach only one egg, does not, however, seem very probable. Nor is it probable that both the eggs should be fertilized, but in most cases only one be developed. All the same, a certain influence might be ascribed to these factors, independently of the view held in other respects.

Even if it is thought that double pregnancy is due to a special hereditary tendency in combination with environmental factors, for all that, a connection may exist between monozygotism and dizygotism, of a kind that was hypothetically suggested in the previous chapter.

Another explanation of the fact that all eggs are not produced in pairs in twin-bearing mothers, is possible. The first segmentation of the egg is asymmetric. One cell is bearer of the germ plasm, the other one goes to the soma. In the egg of Ascaris, the asymmetry is discernible under the microscope even at the first segmentation of the fertilized egg. In man, too, there must be a similar asymmetry in the segmentations leading to the formation of the individual. Mendel's law, so far as it is concerned with the chromosome theory, is based on the assumption that, as regards hereditary tendencies, the segmentation within the germ plasm is symmetrical. Only at the reducing division the tendencies are separated — they are then distributed to the two cells in the way known. Regarding monohybride characters it will be easily understood that in a heterozygote only half of the eggs get the character in question. If only a few of the eggs get the character, polymery is supposed to be present. Other irregularities have been explained by crossing over phenomena etc. No such mechanism is conceivable, as an explanation of the fact that eggs in pairs occur only comparatively rarely in the mothers of dizygotic twins, as the tendency manifests itself before the reducing division. However it is possible that asymmetric segmentations occur even within the germ plasm proper, and that the tendency to double formation remains only in certain parts of the germ plasm, then to manifest itself sometimes before, and sometimes after the reducing division (sometimes, perhaps, it does not manifest itself before gastrulation and can assert itself only in part of the germinal cells of the new individual).

In certain cases a similar mechanism might be suspected as causing divergencies from the simple Mendelian figures with regard to other characters also.

The tendency to monozygotic twinning manifests itself only after the reducing division; the fact that it asserts itself so very rarely in a twin-bearing mother, might be explained by assuming polymery.

With regard to the different alternatives here suggested, at present it seems impossible to come to a final decision. The great theoretical interest of these alternatives, may, however, justify a contribution towards establishing the fundamental facts.

The material is derived partly — and principally — from my genealogical twin material, partly from some family tables from Norrland, placed at my disposal by the State Institute of Race Biology, Uppsala. Finally Docent A. Edin has allowed me for this purpose to make use of his genealogical-statistical material from parishes of Västmanland, for which I am very thankful. I have been able to obtain material only from families where the first twins have been dizygotic. The diagnosis has been founded on the twins being opposite-sexed or their having on personal examination by me been diagnosed as dizygotic because of dissimilarity.

Among 323 mothers, who had borne dizygotic twins, there occurred 432 births after the twin births, among these 25 twin births. The percentage of twin births, thus, is 5,79 ± 1,12. The corresponding percentage in the population at large may be put at 1 %.

The former figure applies to mothers with a tendency to dizygotism. Therefore, it should be expected that among their later twin births, about half would be opposite-sexed. Only 6, however, of the further 25 twin births, are opposite-sexed, while 19 pairs are same-sexed. The relatively large number of same-sexed, indicates an increase of monozygotic twin births as well. Calculated after the differential method, there would be 13 monozygotic and 12 dizygotic pairs, that is 52 % monozygotic. On the whole material the percentage of monozygotic twin births, would be 3,01. Monozygotic twin births in Sweden 1891—1910 are 0,37 %. The mothers here in question, however, are nearing the end of their fertile period, thus comparatively old. There are no Swedish figures for the frequency of monozygotic twin births at different ages. Judging from the figures from Denmark, Table 2, however, the percentage of monozygotic births might be put at not higher than 0,45. The increase, thus, is very pronounced — more than 6 times the percentage of monozygotic. On the other hand, the material is small. If the mean error for the increase is calculated, with regard to the mean error of the differential method, and to the mean error in relation to the whole mass, the difference and its mean error, will be found to be:

$$2{,}56 \pm 0{,}97\,\%\,;\ 2m = \pm\ 1{,}94\,\%\,;\ 3m = 2{,}91\,\%.$$

Thus, although the material is not larger, the difference is fairly well established, amounting to nearly 3 times the mean error. The marked increase of monozygotic twin births by mothers of dizygotic twins, therefore, cannot very well be regarded as due to chance, but must be ascribed to *a real, increased tendency in dizygotic mothers to bear monozygotic twins.* The hypothesis above propounded, p. 119, that a connection exists between monozygotic and dizygotic twinning, these being the manifestation of the same tendency to double formation in the mothers, sometimes resulting in dizygotism, sometimes in monozygotism, is strongly borne out by these facts. Statistically it has been shown that dizygotism is hereditary, for monozygotism this has not been as incontestably proved. On the contrary, some authors have found reason to state that monozygotism is not hereditary. If a connection between monozygotism and dizygotism exists, as I have tried to make out, and the tendency to bear dizygotic twins is hereditary, the tendency to bear monozygotic twins must be so too. Finally, it must be pointed out that according to my hypothesis, only part of the dizygotic births are hereditarily conditioned, while some are due to chance liberation of two eggs at once. The increase of twin births here brought out, from about 1 % to 5,62 % difference (4,62 ± 1,11; 3m = ± 3,33) should apply only to the hereditarily conditioned twin births. According to my hypothesis, therefore, the monozygotic should increase more than the dizygotic. This, also, is the case. The monozygotic are 52,00 ± 10,00 % of the repeated twin births. In the population (figures from Denmark) they amount to at most 25 % in the higher age groups. The difference amounts to twice the mean error, and thus is not statistically established, but however, there is strong probability for this being a real and not a chance displacement. It may be remembered, however, that in my material, as has before been pointed out, the still-born and those dead just after birth to a rather large extent are not included. The figure for repetition of twinning, therefore, is too low, and the omission affect the monozygotic more than the dizygotic (see p. 115). The increase of the figures found in monozygotic thus certainly is too low, and our above conclusions consequently gain in certainty.

We can issue from the fact that in our material, the twin percentage corresponds to about 1 % in the population, (compare Table 8) while in Sweden the twin percentage 1891—1910 is 1,46 %. About ⅓ or more of the twin births thus are omitted. With regard to this, the figure for repetition of twinning after one twin birth instead of 5,62 % may be put at about 10 % (perhaps rather too high a figure), which also can be said to express the real probability for a woman with tendency to twin birth bearing twins in a given pregnancy. It is quite evident that if in mothers with dizygotism, all births up to and including the first twin birth, are excluded, the percentage of twin births among later births expresses the real probability of twin births by these mothers. Naturally our above figure, however, is far from exact. Assume that such married women regularly bear two children. In that case it can be calculated that 1 % of them will bear twin pairs, and that 18 % will have one twin pair and one single born. Assuming five children per marriage, 41 % will have at least one twin pair. It is clear from these figures, as pointed out above, that only in a small proportion of the mothers having the tendency, this will manifest itself.

Further, the twin births are about 1,5 % of the births. The tendency to repetition for each individual birth in mothers with tendency to twinning is about 10 % or somewhat lower. Consequently among mothers in the population there must be about 15 % or somewhat more, who have tendency to twinning.

FERTILITY OF TWINS.

It has long been known that, in cattle, one of the twins sometimes is sterile. Investigations by Lillie and by Keller and Tandler have shown that this is the case in opposite-sexed pairs, and that by an interchange of hormones through anastomosis, the female twin is influenced in male direction and becomes intersexual. (Quoted Newman, 1917.)

No similar mechanism is known in man. On examination of the placentas of dizygotic twins, no anastomosis has been found (Schatz, 1884—86—87, Lauritzen, 1891, and others). Cases of morphological intersexuality in dizygotic twins, are extremely rare in the literature.

Goehlert, 1879, however, claimed to have established that twins often are sterile but his material is small, and his data not very reliable. Weinberg, 1902 a, takes the question under renewed consideration. In his material from Stuttgart there were 110 female twins, who had been married for at least 20 years. These had in all had 464 births, that is about 4 births each, which must be considered fairly normal fertility (11 had no children). The opposite-sexed twins were 33, with, in all, 158 births, that is 4,8 births per mother. The female twins of opposite-sexed pairs, thus were not less fertile than those of same-sexed pairs.

It is of especial interest to note that among the 464 births of these twins, there were only 10 twin births, that is, 2,2 per cent. This is not a very large increase, but all the same indicates heredity of twinning.

TWIN BIRTHS AND EUGENICS.

Grotjahn, 1912, has suggested that child-bearing by mothers who have once borne twins, should be prevented, twins being of inferior quality.

Weinberg, 1915, points out that the risk of another twin pregnancy is so small, that the suggestion hardly is justified.

Doubtless, Weinberg is right. Twins have not proved to be worse equipped than other people. The mortality during the early years, of course, is large (see p. 156), but on examination of grown-up twins, I have not found them noticeable worse off, physically or mentally, than others, and proof to the contrary I think hardly exists. It has been said that twins never are characterized by exceptional talent. During a discussion in the medical press (British Med. I. 1912, Twinship and Fame), certainly, only a couple of English lawyers could be advanced as instances of famous twins. But even if this deplorably should be so, Grotjahn's suggestion hardly would be justifiable.

In earlier ages measures against twinning have been taken for quite other reasons. The old Teutons, as well as some Negro tribes (Togo and Dahomé), and South American Indians thought a twin birth proved adultery, and the children, sometimes the mother too, were killed (Tauber, 1916). Possibly, the varying frequency of twin births in different races has been influenced by similar measures in early times.

PART II.

TWINS FROM A HEREDITARY POINT OF VIEW.

SIMILARITY OF TWINS.

Resemblance of twins from a theoretical point of view.

The state of a man in a given moment, is the result of his hereditary nature (genotype), and the environments in which he has developed. Both may vary. If the environment differs too much from "normal" conditions, the result is death. Nor can an individual develop sucessfully, if the composition of his hereditary structure is too abnormal. Within these bounds set by death, environment as well as hereditary structure may vary. The hereditary structure determines the modes of reaction, the line of development. The environment must be of a certain nature, if this development is to take place, but on the other hand, it may modify the course of development both as to rate and direction. This course, determined by heredity, environment and time, which every individual has to run through, is on all sides bounded by death. Within these bounds, of course, the individuals differ, so that the chance of meeting two individuals that are exactly alike, is practically nil. Naturally, to all the branches of science that have man for their object it is of extreme importance to get a clear conception of the rôle of these different factors: time, environment, and heredity.

The differences between two individuals may be due to the influence of time, that is, their age. This factor, of course, may be eliminated by selecting individuals of the same age. The real difficulty is to discern the part played by environment and by heredity.

If environments are exactly alike, how great are the variations that may be caused by heredity, and if the hereditary structure is alike, how great are the variations that may be caused by environment? Further, what is, on the whole, the influence of heredity and environment? These are, of course, difficult questions, and so much the more so, as the answer cannot be the same for different characters.

If a character in an individual can only be modified to a very slight degree under the influence of environment, we say that it is hereditarily conditioned. Individuals with the hereditary factors conditioning the character in question, always have the character manifest, however environments may vary. *In a limited sense, then, hereditary characters* are those of very small variational latitude under the influence of environment.

If, on the other hand, a character manifests itself only under a certain environmental constellation, we say that it is *environmentally conditioned.* An attack of typhus implies a certain composition of the hereditary structure, that is in evidence in most people, but that is non-existent in for instance dogs; however, the character cannot manifest itself, but under the influence of particular and not common environmental factors (typhus germs).

Between these characters, hereditary in a limited sense, and phenomena caused by environment, there are a great number of transitions. Many characters are developed only on the basis of certain hereditary factors in combination with certain environments. In this connection we use the terms *predisposition, constitutional tendency,* etc.

The differences between two individuals not related to each other, are due to (besides differences in age) differences between their hereditary structure as well as differences in their environment. Certain of the differences are known to be hereditary in the limited sense. It has been established that they regularly occur in the families, under varying external conditions. Counting with a single set of 24 chromosomes in man, each bearer of one factor that is inherited independently of the other factors, the chance of getting two like combinations is one in $2 \cdot 2^{24}$ = one in 32 million cases.

The factors certainly are many more (even if partly coupled), and the chances of meeting two hereditarily like individuals, therefore, are exceedingly small. Besides, there are the environmentally conditioned differences. It is of course well known that very rarely two individuals who are not related to each other, are so much alike that it is not possible to tell one from the other.

With regard to brothers and sisters there is a greater chance of meeting individuals more closely resembling each other. The hereditary variability, in this case, is not quite so large. Environments, too, generally are more similar. There is the difference in age to be reckoned with, but even if this is eliminated the chances are very small of meeting very closely similar individuals. A higher or lesser degree of resemblance, a certain family likeness, of course is common, but resemblance so as to mistake one for the other, is extremely rare. I have seen one such case however, two brothers. An anthropological measuring gave the following results. A photograph could not be obtained as they refused to be photographed.

	Age	
	18 years	19 years
Stature	1,731	1,723
Sternal height	1,419	1,419
Height of symphysis	896	893
Height of acromion	1,404	1,427
Height of tip of middle finger	633	637
Biacromial diameter	358	360
Bicristal diameter	288	291
Length of head	178	188
Breadth of head	147	149
Frontal minimum diameter	102	103
Face breadth	131	133
Bigonial diameter	108	104
Face length	130	128

The differences between the measurements accord with those of monozygotic twins, obtained by me. If the differences are calculated in pro mille of the corresponding measurements and then summed up, the total is 190 pro mille, corresponding to the average figure for the monozygotic, 211 pro mille.

Dizygotic twins, as always being of the same age, and thus perhaps growing up under more similar conditions, should, all the same, show the same hereditary variability as other brothers or sisters. The phenotypical variation should be somewhat less than in other members of the same family, even apart from the influence of age, but extremely rarely should they be liable to be mistaken for each other.

Monozygotic twins generally are stated to have the same hereditary mass, because they originate from one egg. In text-books this is cited as an established fact, e. g. Baur, Fischer, Lenz, 1923, Baur, 1919, Gates, 1923, v. Hofsten, 1919.

Discussing the embryological mechanism for the development of monochorial twins, we pointed out that there are embryological and general biological reasons to believe that such twins originate from one egg, fertilized by one sperm, one or the other being bearer of the tendency to double formation. It could not be absolutely excluded, however improbable, that the irregular character of these sperms or eggs would be morphologically manifested by the presence of double nuclei (or double tails in the sperms). Of course, neither normal fertilization or fertilization followed by double formation, has been directly observed in its earliest stages in man.

However, it is known that monochorial twins always are same-sexed. In the literature isolated cases of opposite-sexed monozygotic twins are cited, e. g. Krahn, 1891, but there is every reason to suspect that in these cases the evidence of the membranes has been wrongly interpreted. I have not been able to find any case of opposite-sexed monozygotic twins, where the after-birth has been preserved for closer control.* It is further

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* Lenz has pointed out that, theoretically, it is conceivable that two eggs are inbedded so close to one another that they melt together and form a monochorial twin pair. If this happens, it should naturally be extremely seldom.

Siemens, 1925, points out that he has found a few cases of extremely similar twin pairs, said to have had two chorions (2 cases) or two placentas (3 cases), and further, he has found very different twins, said to be monochorial (1 case). From this, Siemens concludes that monoevident that opposite-sexed twins never resemble each other so closely, as to be mistaken for each other, while some same-sexed twins are almost impossible to tell apart. In some cases, further it has been established that such twins were monochorial. That twins developed from two eggs, cannot be extremely similar (except in very exceptional cases), has previously been pointed out. Among twins, the like ones seem not to be very rare. That dizygotic twins differ from each other, is due to (besides differing environment) their having differing hereditary mass. The monochorial twins have had as differing environment; if they are more alike, this can only be due to greater similarity of their hereditary mass. If, now, a double nucleus has arisen by the number of chromosomes being halved (as in a reducing division), the resulting twins would be more different than the dizygotic. A fertilization with two sperms is excluded, because they are never opposite-sexed. The double nucleus, if it exists, therefore must have been caused by usual mitosis, by longitudinal halving of the chromosomes. Thus the monochorial twins should either be alike in the hereditary mass,

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zygotic twins are able to produce two chorions, and, on the other hand, that dizygotic can melt together and become monochorial. The diagnosis of the number of eggs is more reliable when founded on the degree of resemblance than on examinations of the membranes of the eggs. If the number of monozygotic is calculated from the sex distribution among twins, he finds that they are about 30 %, while statements built upon examinations of the membranes give only 15 %. The divergence is explained by the fact that the examination of the membranes of the eggs does not give an exact expression for the number of eggs.

Siemens himself, however, emphasizes that experienced examinators, too, can be mistaken; the most probable explanation seems to me to be that such mistakes have been made in the cases mentioned by Siemens. An estimation of the degree of resemblance is, further, to a certain extent subjective, and certainly cannot pretend to constitute an infallible diagnosis in every individual case. Finally, if for instance dizygotic developed into monochorial, one could expect, as I have pointed out above, to meet with a case, where opposite-sexed twins turned out to be monochorial and where the membranes had been preserved for an histologic examination. In spite of the enormous number of twin births observed in the clinical hospitals during the course of years, I have not, however, been able to find one such case in the literature. It is also very improbable that monozygotic should develop two chorions, a case that has never been embryologically observed. The non-accordance, supposed by Siemens, between figures from clinical material and the calculated number of monozygotic, does not exist, as I have pointed out before (p. 21).

or not more alike than the dizygotic. The existence of identical twins, decidedly favours the first-mentioned possibility. It is then to be expected that the number of such twins should answer to the number of monochorial. No attempt has so far been made to demonstrate this.

In order to get addresses of twins, I made enquiries of the parish registrars (pastorsämbetena) in some Swedish dioceses, asking also for information about the degree of resemblance. The following figures show the results from two dioceses. For 1,115 twin pairs information about resemblance was given and of these 365 were identical. After the differential method the number of monozygotic among these 1,115 twin pairs, would be 363 (the opposite-sexed pairs 376). Naturally in some cases the parish registrar may have been wrongly informed, so that dissimilar twins (in some cases opposite-sexed) have been stated to be alike and vice versa, but this is quite surprisingly uncommon. On examination of twin pairs, as a rule I have been able to verify the diagnoses given by the registrars.

It must, therefore, be regarded as established that the *number of identical twins corresponds to the number of monozygotic.*

The objection might be raised that the estimate of "identity" is more or less arbitrary. Even in the case of dizygotic twins, a number of pairs of closer resemblance might be sorted out, and this would not necessarily constitute a difference in principle between the two groups. The number of identical twins coinciding with the number of monozygotic, however, is a strong reason to assume that it cannot be a question of only such an arbitrary limit.

Further it must be remembered that regarding appearences we have an extraordinarily sharp sense for details. We notice with surprising accuracy even the small changes in appearence caused by the play of features. If we cannot tell two twins from each other, this must imply an extensive conformity in facial configuration. On the other hand, for an estimate of resemblance we do not pay the same attention to differences in the shape of the head, stature, length of extremities, etc. As will be shown later on (p. 211), this more subjective resemblance is accompanied by a close resemblance in anthropological measurements. The identical twins have been found to have an average resemblance in measurements far greater than in those put down as dizygotic. See further p. 205.

Thus it may be regarded as established that monochorial twins originate from one egg, fertilized by one sperm. Whether the nucleus of the egg or sperm has undergone a mitosis before fertilization, or whether the first mitosis takes place only after fertilization, from the point of view of heredity is of no consequence. Small differences, occasioned by environment, however, are to be expected. External conditions, as a rule are pretty much the same for both the twins, but cannot, of course, ever be exactly alike. Is there, now, from this point of view, absolutely no possibility that hereditary differences in more exceptional cases might occur?

On the assumption that monozygotic twins originate from an uni-nucleated egg, fertilized by one sperm, Siemens, 1924, discusses this problem. He points out the possibility of uneven distribution of the hereditary factors, and of the hereditary structure of one of the twins being injured (idiokines), and concludes that this certainly is conceivable, but that practically the chances are so small as to be negligible. Idiokinetic injuries seem to be very rare in man. With regard to the other possibility, uneven distribution of the hereditary factors between the cells from which the two individuals originate, there is no reason to assume a more uneven distribution, than between the cells from which one individual is developed. It is of course known that disturbances in the segmentation, sometimes occur in animals. Exceptionally, such a disturbance might entail differences between monozygotic twins, but this has not, as Siemens emphasizes, been observed. The differences between monozygotic twins, therefore, should be environmentally conditioned. This conclusion also is drawn by most scientists who have treated these problems.

However, it seems to me that one cause of hereditary differences has been overlooked, namely certain asymmetric characters*. We do not know how the symmetry plane runs with regard to an asymmetric character, e. g. heterochromia iridis, at

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* Baur, 1924, and later Leven, 1924, also point out that one-sided dispositions might entail differences between the twins (see p. 175).

the growth of monozygotic twins. From a theoretical point of view it is not precluded that such characters may occasion differences between the twins. However, these characters probably are comparatively rare, and this source of error consequently should not very much affect the above conclusion that the differences are environmentally conditioned. It is, on the other hand, necessary always to keep this possibility in mind. The problem will be discussed later on.

Resemblance of twins from a practical point of view.

In the individual case, monozygotism can always be diagnosed with perfect certainty by examination of the afterbirth. With regard to grown-up twins, as a rule it is not possible to get reliable information about this. Theoretically, however, dizygotic twins should be expected to present comparatively great dissimilarities, monozygotic twins, on the other hand, small dissimilarities. On examining twins, one certainly has the impression that there are, as to degree of resemblance, two distinct categories. In certain cases, the twins can hardly be told from each other. A scar, a birth mark, etc., may sometimes serve to distinguish even these; in other cases it is impossible if one has not had opportunity to observe them for a long time. In these cases one is always told that they are often confused by teachers, school-fellows, and neighbours. It is quite common for the father sometimes to do the same, while as a rule the mother is better able to distinguish them. During the years of growth, the mothers usually more than the fathers have devoted themselves to the children, and are better trained in noticing the small differences in question.

Opposite-sexed twins, on the other hand, are always more unlike, and with regard to some same-sexed also, the differences as a rule are very striking. It has already been pointed out that from a theoretical point of view there is an exceedingly small chance of dizygotic twins getting the same or nearly the same hereditary mass. In other words, there should be twin pairs who in resemblance more or less approach the monozygotic and stand between these two classes. In examining 190 pairs of same-sexed twins I have only in a few cases been doubtful about the diagnosis of monozygotism or dizygotism. The twin material examined, thus, in accordance with the theoretical considerations, proves to be made up by first very dissimilar pairs, then of extremely similar pairs, and finally of very isolated pairs standing between these distinct classes. These latter, however, are of so rare occurrence as to practically negligible. If the material is divided with regard to resemblance, in two classes, the "like" class almost exclusively should be made up of monozygotic, and the "unlike" class almost wholly by dizygotic twins. In this connection, however, it should be mentioned, first of all, that this does not apply to very small children. The dissimilarities have not hade time to differentiate, nor are we perhaps so trained in grasping the differences in appearence in children (just as is the case with regard to people of a foreign race). Secondly, the resemblance so far referred to, chiefly has regard to facial configuration, and in judging this there always enters a subjective element. The ability of different investigators to distinguish between appearances, also varies. Therefore it is desirable always to make sure and to state whether the household, teachers, etc. have difficulties in distinguishing between the twins, and also to give photographs. I have endeavoured to get photographs of all the monozygotic twins. In some cases, this has been impossible, which is certainly very much to be regretted. In some of my photographs the resemblance does not appear as distinctly as could be wished, this being due to different mien, light, attitude, etc. It must be remembered that photographs are not always "like" the original. Besides the resemblance in general appearence, evidenced by personal observation, and by the statements of the twins and their families about their liability to be confused, and finally photographs, there are some further points on which information may be of importance for the diagnosis of monozygotism or dizygotism.

The configuration of the ear in twins.

It is well known that the configuration of the outer ear varies to a considerable degree. It has even been suggested that photographs of the ear might be used for identifying purposes (Imhofer, 1906) a suggestion that has not, however, won approbation, possibly because there is no simple and convenient system in existence for registering such photographs. However it should not be impossible to evolve such a system and a photograph of this kind certainly would be of value, if included in the descriptions of criminals, etc. Some details, and one or more measurements, often are contained in the description, but naturally this can never replace a photograph with all its details. Further, if such a photograph is to be of any use, it must be established that the chances of two people having closely similar ears are very small. That the lineaments of the ear are highly variable, as just said, is well known. Imhofer tried to come to a definite conception of its variability by selecting four typical characteristics of a certain ear, and then seeing if the same combination of characteristics was to be found in a material of 500 photographs. The combination was not repeated. If only three characteristics were included, seven ears were found to have the combination wanted. Imhofer did not make any inquiries as to the degree of resemblance between right and left ear of the same person.

During my examinations of twins, I soon found that in the twins very closely resembling each other, the configuration of the ears also was very similar. Small differences were to be found, just as between right and left ear of the same individual. Thus, there was no identity in all details, but far greater resemblance than in dizygotic twins. In order better to be able to demonstrate these conditions, I have photographed the ears of one hundred persons in natural scale. In the same way the ears of some monozygotic and dizygotic twins examined in Uppsala and neighbourhood, have been photographed. The photographs have been taken in the following manner: The person photographed, rests his face against the edge of a wooden frame, so that the ear falls in the middle of and in the same plane as the frame. The camera is fixed so that an object in the plane of the frame, is pictured in natural scale on the plate. A centimetre scale is placed beside the ear, so that even small displacements in the scale of enlargement, can be observed. A piece of metal wire, fastened with mastic, marks the plane through the lower rim of the orbit and the auditory canal, its point marking the centre of the auditory canal, usually hidden be the tragus.

The photographs have been sorted in pairs after their degree of resemblance, and the most like pairs are reproduced in Appendix II. At the same time ear photographs from dissimilar (dizygotic) and identical (monochorial) twins are reproduced. It appears from the pictures that the resemblance in configuration of the ears, is far greater in two identical twins, than in dissimilar (dizygotic) twins or in any two individuals selected in the way above mentioned. As a comparison are also given the right and left ears of individuals with particularly marked difference between their ears. Their difference thus ought to be somewhat larger than in monozygotic in general — show the maximum of these differences. At first, my intention was to make measurements on the photographic material collected. This, however, proved too laborious, and I had to give it up.

Volta, 1924, has made measurements on the ears of 19 twin pairs (4 measurements on each ear) and estimated their degree of resemblance as to shape and configuration etc. On the basis of these observations he finds himself able to distinguish between twin pairs with rather similar ears, and pairs with more differing ears, corresponding to monozygotic and dizygotic twin pairs.

Even if there is a possibility that two non-twins might have similar ear configuration, this should be very rare. In other words, the variations in the shape of the ear, are very great. This cannot very well be due to varying environment after birth. Already at birth the configuration on the whole should be complete, the later development hardly can alter it to any considerable degree. The variability of course might be ascribed to differing intra-uterine conditions, to mechanical factors, nutrition, etc. However, the intra-uterine conditions in several respects must be quite as varying for monozygotic as for dizygotic twins and for single births. If thus, intra-uterine environment plays any considerable part, there should be no reason to expect a greater resemblance in the monozygotic than in the dizygotic. On the whole, it might be said that a great variability can be due to environmental conditions post-partum. In that case we ought to find *small* variability *both* in dizygotic and monozygotic twins. If post-partum environment does not play any part, the variability may be due to intra-uterine conditions, and then we should expect *great* variability *both* in dizygotic and in monozygotic twins. Finally, the variability may be occasioned by hereditary factors, in which case we should find *small* variability *only* in the monozygotic twins.

With regard to facial configuration (and anthropological measurements), we have been able to make out that probably there is great variability in not related individuals and in dizygotic twins, and on the other hand great resemblance in monozygotic twins. This indicates that the variability chiefly is hereditarily conditioned (and that the monozygotic have like hereditary structure).

The same seems to apply to the configuration of the ears. There is great variability in man generally. As there is a priori small probability for the post-partum environment being able to change the configuration of the ear, and we have found great resemblance in the monozygotic, the variability must be hereditarily conditioned, and consequently we can expect great variability in the dizygotic. In other words, *identical twins should have like ear configuration, twins more unlike, should have unlike configuration.* This, I think, I have also been able to demonstrate, as may be inferred from the photographs of twins and of ears, given in Appendix II. At the time when the first photographs of twins were taken, I did not realize the importance of the configuration of the ears, and therefore neglected to have the ear made visible in the photograph. The great reduction in size unfortunately prevents observation of the finest details, but those details that can be made out, give a certain guide. The material of dizygotic twins of course is small and serves more as a sample, though it is not selected from this point of view.

The conclusion is that an inspection of the configuration of the ears, always should preceed the diagnosis. Particularly with regard to children, in whom the configuration of the face is not yet differentiated, such an inspection is of importance. In one case of two four years old children (No. 154, Appendix I) I found so great resemblance in appearance that I was doubtful about the diagnosis, monozygotic or dizygotic. An inspection of the ears, however, made me decide in favour of dizygotism. When, later on, I asked their mother about the after-birth, she answered that there had been two after-births when the twins were born.

Finger-prints of twins.

It has been established that the finger-prints — the papillary patterns — never are the same in two people. Further it has been shown that the papillary pattern is complete at birth, and that afterwards it does not change under the influence of post-partum environment. On these facts the modern dactyloscopy is founded, and in practice they have proved to hold good on very extensive trials.

The variability with regard to the papillary patterns, consequently cannot be due to post-natal conditions. It may be due to intra-uterine environment or variations in hereditary factors or to both.

In so far as it is due to variations of the hereditary mass, we should expect to find resemblance in monozygotic twins, with conditions conforming to what has already been established with regard to facial and ear configuration.

Wilder, in several treatises, 1904, 1908 and 1916, has elaborated the subject in regard to twins. In twins of like appearence, he has found quite a high degree of resemblance. The type of the pattern as a rule is the same, though the number of papillary lines varies. Reversal of the patterns, mirrorlike, is not uncommon. In some cases patterns of a different type are to be found in one or more fingers. Later investigators, e. g. Poll, 1914, Bonnevie, 1923, and 1924, Ganther and Rominger, 1923, have come to the same conclusions. The prints are not exactly identical, but are more similar in monozygotic twins, than in dizygotic, and in other brothers and sisters. See further p. 168.

This is in accordance with what I have been able to observe during my investigations. To a certain degree, thus, an inspection of the finger-prints can help in the diagnosis of monozygotism or dizygotism.

The diagnosis of monozygotism.

As above brought out, the following demands should be satisfied, for a diagnosis of monozygotism for a grown-up pair of twins:

1. That in appearence the twins give an impression of very great resemblance or "identity".
2. That during childhood neighbours, school-fellows, etc., have had difficulties in distinguishing them, and sometimes confused them.
3. That the configuration of the ears does not show great dissimilarity (as between left and right ear of each twin).
4. That the finger-prints show a certain similarity (as between left and right side in each twin).
5. That the anthropological measurements do not show too considerable differences. In this inquiry these measurements have not been taken into account for the diagnoses as the object was to find how far they show similarity. See: Twins from an anthropological point of view.

At publication if possible, photographs should be given (full-face and profile, with ear visible). If information can be obtained about the nature of the after-birth (one or two chorions), this of course is of great interest.

THE INFLUENCE ON TWINS OF INTRA-UTERINE CONDITIONS.

It is obvious that varying intra-uterine conditions play a certain part and occasion some degree of variety in the offspring. Nutritional conditions, mechanical factors, the quantity of amnion fluid, and endochrine influences from the mother, are among the factors to be reckoned with. At single births these factors vary from case to case. They also vary at dizygotic births, though the endochrine influence from the mother, perhaps is more similar for the two twins. On the other hand, nutritional and other conditions, as the size of the placenta, pressure, etc., may vary very much. Finally, at monozygotic twin births, the conditions must be at least as variable in regard to these circumstances.

On the whole then, in several respects the intra-uterine conditions may be said to vary to a considerable degree both at single pregnancy and at dizygotic or monozygotic twin pregnancy. In these different kinds of pregnancy the variations of course, are not exactly the same in different respects, but variations in the intra-uterine conditions there certainly are.

Stature and weight of twins at birth.

With regard to these circumstances, stature and weight are of especial interest. The varying intra-uterine nutritional conditions can be expected to cause a somewhat differing general development, and above all differences in size. Consequently, a considerable variability in weight can be expected, both at single births and at dizygotic twin births.

At single births, time, environment and heredity vary. The great variability in weight that has been established, is due to — besides intra-uterine environment — the variations in age and in hereditary mass.

In dizygotic twins, the age may vary — the two twins are not necessarily of exactly the same age. It is a long-standing matter of dispute, to what extent superfetatio (i. e. fertilization of an egg belonging to a later ovulation period) does occur. The dispute cannot yet be regarded as settled, but the results might be summed up thus: if superfetatio occurs at twin births, in any case this is not a very common phenomenon (see p. 154), and the difference in age between the two twins, therefore as a rule should be less than one month. (According to the hypothesis I have propounded, p. 119, the time between the fertilizations in the case of hereditarily dizygotic, should be short or none at all; in the case of other dizygotic it may be longer). Some influence may be ascribed to the difference in age. Obviously environment and heredity give rise to differences between dizygotic twins.

Monozygotic twins are of exactly the same age. Their hereditary structure, also, (apart from asymmetrical characters, above referred to) should be alike. The variability must be ascribed to variations of the intra-uterine conditions. With regard to the influence of age, however, it must be remembered that if one of the twins is still-born, naturally it cannot be taken for granted that the influence of age is equal. It is perhaps possible with more or less certainty to tell how long ago death took place, but naturally this must always to some degree be doubtful. Therefore, for our purpose it is necessary that both twins should have been alive at birth.

Schatz, 1887, has made compilations from material from Rostock and Marburg, regarding weight and stature of twins. He has the following mean differences in stature:

	Born in 8th,	9th,	10th month	
Monozygotic	1,3	2,1	2,8 cm.	,, ,,
Dizygotic with separate placentas	1,4	1,8	2,7 cm.	mean difference
Dizygotic with fused placentas	1,8	1,8	2,8 cm.	,, ,,

He comes to the conclusion that dizygotic differ as much when the placentas are fused, as when they are separate, and further that the differences are about equal in monozygotic and dizygotic. Schatz found the following figures for the mean weight differences:

	Born in 8th	9th	10th month.
Dizygotic with separate placentas	193	330	255 gm.
Dizygotic with fused placentas	251	246	571 ,,
Monozygotic	336	291	600 ,,

This is in accordance with the figures regarding stature. The weight differences are about equal for monozygotic and dizygotic. However, it must be mentioned that the number of cases on which the mean difference is calculated, is rather small (especially as regards those born in the 10th month) and further that cases where one or both twins were dead, have been included.

Lauritzen, 1891, has had a larger material available. He finds the following averages for fully developed twins:

	Average weight	Average stature
136 dizygotic with separate placentas	2,901 gm.	48,9 cm.
79 dizygotic with fused placentas ...	2,839 „	48,1 „
28 monozygotic	2,736 „	47,7 „

For the differences he gets the following figures:
The largest twins having a length of

	40.5—45	45.5—50	above 50 cm.
Dizygotic with separate placentas	1,4	1,3	1,9 cm. mean difference
Dizygotic with fused placentas	2,0	1,8	2,5 „ „ „
Monozygotic	2,3	1,6	2,1 „ „ „
Dizygotic with separate placentas	249	258	345 gm. „ „
Dizygotic with fused placentas	287	253	458 „ „ „
Monozygotic	278	299	391 „ „ „

The results on the whole are in accordance with those of Schatz. The twins are of less weight and less stature at birth, than single born children. In these respects their development is belated, for monozygotic and dizygotic alike. Lauritzen also includes still-born in his material.

Weinberg, 1902 (a), has used Lauritzen's and Schatz's figures together with figures taken from other authors. His result is, that when the taller twin is 45,5 to 50 cm. the mean difference of weight is, in

315 dizygotic twins, 297 gm.
60 monozygotic twins, 357 gm.

He does not consider the divergence between the mean differences for monozygotic and dizygotic (60 gr.), as statistically established.

The same is the case with the difference in stature. When the taller twin is

	45·5—45	45·5—50	above 50 cm.
The mean difference for the dizygotic is	(161 cases) 1,4	(319 c.) 1,7	(112 c.) 3,0
For the monozygotic	(37 „) 2,0	(62 c.) 2,2	(13 c.) 2,9

All these compilations point in the same direction that on an average the differences between monozygotic twins are as great as between dizygotic, in regard to those born during the last months of gestation. For the earlier months, there is not sufficient material for a definite conclusion, but the few cases given by the above-mentioned authors, seem to indicate that the case is the same with those born during these months.

All of them, however, include still-born, and it is not entirely precluded that this may have influenced the results. The differences should be particularly large for the still-born, and these are especially numerous among the monozygotic. Therefore I thought a new compilation justified, with the still-born sorted out and only live-born twin pairs included.

Table 9 is founded on the primary material published by Silberstein, 1907, Rabinowitsch, 1913, Hust, 1916, Tauber, 1916.

The result accords with that of the earlier authors. The differences in weight and stature are about equal in monozygotic and dizygotic twins. Sorting out the still-born, consequently does not affect the figures to any considerable extent.

When a new individual develops, all the cells originate from the fertilized egg cell. The genealogy of the cells thus proceeds on three different lines, namely, the cells going to the formation of the soma, the *soma-plasm,* those going to the *germ-plasm,* and finally those going to form the tissue in the afterbirth, the *trophoblast.* The different lines diverge at different times or run together for a varying space of time — that they do diverge is, of course, a fact, and not a hypothesis.

Table 9.

Weight and Length of Monozygotic and Dizygotic Twins at Birth.

Born in the	10th month					9th month				
	Number of pairs	Average weight gm	Mean of the difference gm	Average length cm.	Mean of the difference cm.	Number of pairs	Average weight gm	Mean of the difference gm	Average length cm.	Mean of the difference cm.
Monozygotic.	21	2,490	403	47,4	2,2	16	2,310	388	46.1	1,8
Dizygotic …	75	2,630	346	48	1,6	73	2,440	352	46,9	1,8
Born in the	8th month					7th month				
	Number of pairs	Average weight gm	Mean of the difference gm	Average length cm.	Mean of the difference cm.	Number of pairs	Average weight gm	Mean of the difference gm	Average length cm.	Mean the of difference cm.
Monozygotic.	16	2,320	264	43,4	1,5	6	1,820	362	45,1	2,2
Dizygotic …	39	2,200	214	45,2	1,7	20	1,820	267	42,9	2,0
Born in the	10th and 9th months					8th and 7th months				
	Number of pairs	Average weight gm	Mean of the difference gm	Average length cm.	Mean of the difference cm.	Number of pairs	Average weight gm	Mean of the difference gm	Average length cm.	Mean of the difference cm.
Monozygotic.	37	2,410	396	46,9	2,0	22	2,180	290	43,8	1,7
Dizygotic …	148	2,540	348	47,5	1,7	59	2,070	232	44,4	1,8

The trophoblast develops into a protective nutritive organ for the soma and the germ-plasm (just as the soma, on a later stage, is in a way a protective and nutritive organ to the germ-plasm).

Temporary conditions in the uterine mucosa, and mechanical and other factors influencing the development of the vessels of the placenta, are responsible for the trophoblast completing its task more or less perfectly in different parts at twin pregnancy. One of the twins may be better nourished than the other, in monozygotic as well as in dizygotic twin pairs. Besides, in the case of dizygotic twins, one may have a "better" heredity than the other, is able to get more out of his trophoblast, and perhaps also is able to develop a better trophoblast. In the monozygotic, there is another factor that may increase the differences, namely asymmetries of the vessels. By thorough investigations Schatz 1884, 1886, 1887, and 1911, has been able to demonstrate the existence of a "third circulation", by which blood from one of the twins enters into the capillary system of the placenta, then to run off by veins passing to the other twin. This asymmetrical distribution of the blood is partly balanced, by direct venous and arterial anastomoses, but surely very often not completely. Some investigators, Küstner, 1883, Lauritzen, 1891, have offered criticisms of Schatz, pointing out that he has ascribed rather too great importance to these asymmetries (especially for the formation of the hydramnion), but beyond doubt, in many cases they must have a certain effect, nor has this been denied. On the other hand, there is hardly reason to think that asymmetrical characters in monozygotic twins, should be the cause of differences in weight and stature between the fetus. See: Twins from an anthropological point of view.

The results with regard to weight and stature therefore mean that in the dizygotic, heredity and intra-uterine conditions occasion as great variability for these characters, as environment *alone* in the monozygotic.

Superfetatio and superfecundatio.

These results have a certain interest with regard to superfecundatio, that is fertilization of two eggs from the same ovulation period (intermenstrum) by sperms from two different cohabitations, and superfetatio, that is fertilization of two eggs from two different ovulation periods, and consequently ovulated a month or more between.

The possibility of superfecundatio can be regarded as nearly proved by Nürnberger's (1912, 1914) case. A white woman gave birth to twins, one being a fairly typical mulatto, the other one without signs of Negro admixture. The father was stated to be a mulatto. The chances of a mulatto getting purely white offspring with a white woman, certainly is extremely small. At least a very special, and very rare gen combination of hereditary factors should be required. Even if the case is not absolutely decisive, it makes the existence of superfecundatio very probable, so much the more so, as the possibility theoretically cannot be precluded, and as experiments have proved the occurrence of superfecundatio in animals.

In order to prove superfetatio, a great number of cases have been cited, of twins with so marked developmental differences that the only possible explanation should be the assumption of an age difference between the fetuses. We shall not here enter upon these case reports. Only, it must be stressed, as has often been done, that the difference in development in these cases may be due to heredity and environment, and not necessarily to difference in age.

In the above material of only live born, there were, for instance weight differences between monozygotic twins, in the four most striking cases amounting to 1,300 gm., 1,050 gm., 1,040 gm., and 900 gm., and in stature 4 cm., 4 cm., 8 cm. and 3 cm.

Piering, 1889, further has given one case of great interest from this point of view. In monozygotic triplets he found these weights: 700 gm., 2,220 gm., and 2,170 gm. All were liveborn; the smallest one died on the second day after birth. The maximum weight difference amounted to 1,520 gm.

Pfeilsticker, 1905, has a case of live-born monozygotic twins (monamniote), weighing, No. 1. 2,250 gm., No. 2. 1,730 gm., and measuring 47 cm. and 44 cm. respectively, thus differing 520 gm. and 3 cm.

Hunziker-Kramer, 1909, gives a case of monozygotic twins, both live-born, weighing 1,400 and 2,000 gm., and measuring 40 and 42 cm. respectively. Difference, 800 gm., and 2 cm.

Several similar cases are to be found in the literature, showing that the intra-uterine conditions alone, may occasion divergencies in weight and stature, far exceeding what could a priori be expected. Cases of different-sized fetuses from the later months of gestation, therefore hardly prove superfetatio. After about three months, there is no anatomical possibility of superfetatio (Bumm 1914). The difference in development caused by this age difference during the later months of gestation, is almost on a level with the difference that in extreme cases may be occasioned by environment. Keifer, 1914, (Bar, Brindeau, Chambrelent), for instance, puts the growth in weight during the last three months at 2,000 gm., and in stature at 14 cm. The cases from the later months of gestation, thus, to a large extent loose their power of evidence. In cases from the earlier months it is difficult to decide, whether the development difference occasioned by environment, may not have been further increased by the death of the fetuses at different times. Two corpora lutea in different stages of development, cannot either be considered as evidence, as it cannot be precluded that both eggs originate from one follicle, the lesser corpus luteum belonging to an earlier menstruation and an egg that was never fertilized.

It is all but impossible to prove the existence of superfetatio — whether any of the cases found in the literature, with regard to these different possibilities of interpretation, can be regarded as evidence, is very doubtful. Normally, of course, ovulation ceases when one egg has been fertilized; it is however, easily imagined that this mechanism cannot, or has not time to function, with regard to eggs belonging to the same period of ovulation. It is, of course, possible that the mechanism occasionally will fail, even with eggs from different ovulations, and this may lead to a twin pregnancy. It seems, however, more probable that in most cases the eggs belong to the same period of ovulation, and that superfetatio, if it exists, in any case is very exceptional.

Mortality of twins in utero, and during the first years of life.

The still-births among twins also are of interest for estimating the influence of intra-uterine environment. That a twin is still-born may be due either to intra-uterine causes, or to heredity. If it is found that monozygotic twins go together — both die or both live — more frequently than dizygotic, this should to a certain extent be due to their having similar dispositions, thus more often meeting the same fate, though, as was shown above, intra-uterine conditions, with regard to nutrition and growth, are rather more varying (occasion greater differences), in monozygotic, than in dizygotic twins.

Weinberg, 1902, gives figures from Sweden, 1871—1890, from a material of 14,523 twin births.

If the first of a dizygotic twin pair is alive, the other one dies in 6,2 per cent; if the first dies, the other one dies too in 24,3 per cent.

If the first of a monozygotic twin pair is alive, the other one dies in 9 per cent; if the first dies, the other one dies in 49,1 per cent.

These figures indicate that the monozygotic twins more often go together — both die. On material from France, the matter may be expressed in another way. If the probability of one twin dying is $\frac{1}{a}$, the probability of one twin living is $1 - \frac{1}{a}$. The probability of both dying is $\frac{1}{a^2}$, of both living $\left(1 - \frac{1}{a}\right)^2$, and of either of them dying $2 \cdot \frac{1}{a} \cdot \left(1 - \frac{1}{a}\right)$. The probability of one twin dying is $\frac{1}{a}$, calculated by dividing the number of still-born by the number of *twins* born. From the figure thus resulting, the different categories are calculated. The theoretical figures are based on the assumption that the death of one twin occurs independently of the other one, and the divergence of the empirical figures, consequently is a measure of the dependence of the twins of each other — their tendency to go together. A compilation from the official statistics of France, 1907—1910, gives Table 10.

As previously shown the chance of a monozygotic twin dying, is considerably greater (about double), than of a dizygotic twin dying.

Regarding both monozygotic and dizygotic twins, the chance of their both dying or both living, is greater than theoretically calculated. They go together in life and death, more than should be expected. The death of one only, on the other hand, occurs more rarely, than theoretically should be expected. The difference between the empirical figures and the theoretical, is decidedly larger for the monozygotic. They go together in life (the difference between empirical and theoretical figures

Table 10.

Theoretical and Empirical Figures showing the Disposition of Twins to keep together with regard to Mortality.

Monozygotic	
Number of dead twins	5,116
» » twins born	21,034
Dead in % of twins born = $\frac{100}{a}$	24,3 %
Living in % of » » = $100 - \frac{100}{a}$	76,7 %
% pairs with both dead = 1,269 pairs	11,5 %
% calculated according to $\left(\frac{100}{a}\right)^2$	5,9 %
% pairs with both alive = 8,439 pairs	76,6 %
% calculated according to $\left(100 - \frac{100}{a}\right)^2$	57,5 %
% pairs with one dead = 1,309 pairs	11,9 %
% calculated according to $2 \cdot \frac{100}{a} \cdot \left(100 - \frac{100}{a}\right)$	36,8 %
Dizygotic	
Number of dead twins	6,526
» » twins born	51,272
Dead in % of twins born = $\frac{100}{a}$	12,7 %
Living in % of twins born = $100 - \frac{100}{a}$	87,3 %
% pairs with both dead = 1,370 pairs	5,3 %
% calculated according to $\left(\frac{100}{a}\right)^2$	1,6 %
% pairs with both alive = 21,850 pairs	85,3 %
% calculated according to $\left(100 - \frac{100}{a}\right)^2$	76,2 %
% pairs with one dead = 2,416 pairs	9,5 %
% calculated according to $2 \cdot \frac{100}{a} \cdot \left(100 - \frac{100}{a}\right)$	22,2 %

+ 19,1 % for monozygotic, + 9,1 % for dizygotic) and in death (difference between empirical and theoretical figures + 5,6 % for monozygotic, + 3,7 % for dizygotic), more than do the dizygotic. At the same time, comparatively more rarely than should be expected, only one dies or one lives. (The difference between empirical and theoretical figures is — 24,9 % for monozygotic, — 12,7 % for dizygotic).

This result, then, indicates that, in some cases, one only of two monozygotic twins dies, because the intra-uterine conditions are less favourable to him, than to the other twin. The environmental differences, at least as regards nutrition, should be rather more pronounced for monozygotic, than for dizygotic, as has been showed. Rather less often, only one should die in dizygotic twin pregnancies. But, besides, in some cases one twin dies in dizygotic pregnancies, on account of hereditary factors that make him less resistant. Therefore, the figure rises for this group of the dizygotic. In some cases, the intra-uterine conditions kill both the twins. The figure for the monozygotic is added to, by those cases where, on account of unfavourable hereditary factors both die.

Certainly, some of the dizygotic die from the same cause, but in many cases only one of the twins. Heredity, therefore, entails that the monozygotic, more frequently than dizygotic, live or die both together, and more rarely behave differently. Another factor possibly working in the same direction, is constituted by the anastomoses (see p. 154) in the monozygotic. By carrying products of decomposition from a dead to a living fetus, they may cause the death of this one also. It is impossible exactly to determine the relative importance of these two factors (similar hereditary factors and the influence of the dead twin on the living one) as the cause of the similarity of the monozygotic in life and death. In dizygotic, too, there might, however, take place a certain exchange of substances from the dead to the living twin, though the non-existence of the anastomoses of the vessels makes this exchange less rapid. This, however, to a certain extent points to the assumption that the more marked resemblance of the monozygotic would be due to chiefly hereditary factors — but we cannot draw any absolutely certain conclusion.

Westergaard, 1891, has investigated the mortality of twins during their first year of life, and found that, if one of the twins dies, there is great probability of the other one dying, too. If one lives, the probability of the other one dying is not by far so great, but all the same greater than at single births. The material has been provided by an English insurance company. After five years, somewhat more than ½ of the male twins are alive, against 5/6 of the male single born, and ⅔ of the female twins, against ⅞ of the female single born. The mortality is greatest during the two first years of life. Out of 279 pairs, after five years 73 have both died, in 64 pairs one twin has died, and only 142 pairs, that is about half the number, are still both alive. In later years the mortality of twins seems rather to be somewhat less than normal.

HEREDITARY DISSIMILARITY OF MONOZYGOTIC TWINS.

Genotypical asymmetrical characters.

Earlier investigators in heredity, for the most part have been concerned with characters symmetrically distributed in the soma. However, some characters most probably are asymmetrically distributed, but these have not been sufficiently noticed, and it is at present difficult to give an explanation of the mechanism underlying these asymmetries. Nor shall this be attempted here. I only want to point out a few circumstances of special importance for the question of resemblance between monozygotic twins.

Przibram, 1908, has cross-bred angora cats that have one blue eye and one yellow, with symmetrically blue-eyed, and with symmetrically yellow-eyed. In both cases he got both symmetrically blue-eyed and symmetrically yellow-eyed. On crossing symmetrically blue-eyed, with a right blue- and left yellow-eyed, in two cases he got *reversal of the asymmetric,* that is, left blue- and right yellow-eyed. This is extremely important. It might be imagined that the distribution of the hereditary factors in the body is the same in all respects, and that environmental factors call forth or surpress the pigmenting of one of the eyes, but a priori such a view seems rather improbable. Both in man, and in several animals, the colouring of the eyes has proved to depend on strictly hereditary characters. Further, Przibram has been able to follow this asymmetric character, with or without reversal, through three generations and this decidedly points to heredity. It is interesting to note that Darwin states that white cats with blue eyes usually are deaf, and seems to regard this as a hereditary "correlation". Przibram says that so far as he has been able to test the matter, these "asymmetrical" cats seem to be deaf on the same side as the blue eye. In cats, the iris pigment is not developed at birth and Przibram, in his material counts only these cases that have reached an age, to make it possible to discern the colour of the eyes.

The asymmetric character, further may be due either to an asymmetric segmentation in the soma, the right side getting a factor (gen) that is lacking in the left side, or to the factor itself being of such a nature that it can manifest itself only in one side of the body. The position of the gen in relation to other gens, may play a certain part; the quantity of the factor may differ in the different sides of the body, or there may be an asymmetry in the protoplasma. However this may be, from our point of view it is sufficient to have established that the disposition is distributed in the soma in such a way, as to occasion the manifestation of different characters within its different parts, independently of the influence of environment. We do not know how, or where, the limit runs in the soma — of course it cannot be taken for granted that it follows the median line of the body. In the schematical figure 11, for simplicity's sake I have drawn the limit along the median line, but to our argument, of course, this is of no consequence. As Przibram's experiment has shown, sometimes reversal of the asymmetry from right to left, will take place (no. 1 and 2 in the figure). There is the other possibility, that the limit runs not in the length direction of the body, but transversally (no. 3 and 4 in the figure). This would explain why Przibram, on crossing asymmetrically blue-yellow-eyed with symmetrically yellow-eyed (heterozygotes?) and blue-eyed, in both cases got symmetrically blue-eyed, and symmetrically yellow-eyed offspring. His material is not large enough, to enable us to form an opinion as to the frequency of these reversals. (It would be of very great interest to examine the colouring of the eyes in the offspring of cats with symmetric eye-colouring that is a result of crossing asymmetric cats with symmetric. Przibram does not give any information on this subject). On the whole, however, there should be reason to assume the existence of asymmetric characters that are hereditarily determined, depending on hereditary factors, and having a tendency to asymmetric manifestation, independently of the influence of environment. When, below, genotypical asymmetries are mentioned, it is such hereditarily determined differences that are in question, *not* differences due to environment.

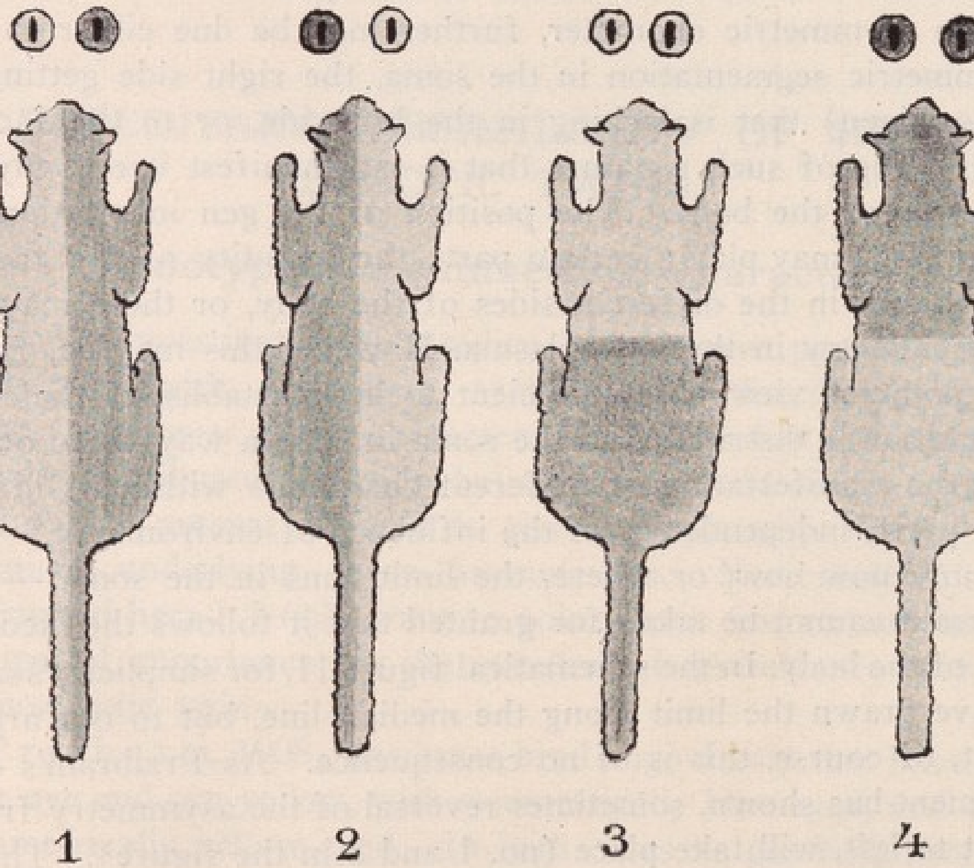

Fig. 11. Showing the distribution of a genotypical asymmetry in the soma (of cats). 1 and 2: the character (the shaded part) runs in the longitudinal direction of the body with reversal from right to left. 3 and 4: the character runs in transversal direction with reversal. Above is shown heterochromia iridis with corresponding possibilities.

Results essentially in accordance with those of Przibram, have been obtained by Bond, 1920, on cross-breeding four-toed hens with five-toed. He got 172 four-toed, and 192 five-toed hens, and 38 four-toed on the left and five-toed on the right side. After crossing these asymmetric hens, in two cases reversal of the asymmetry resulted, that is, the extra toe was placed on the right foot.*

Already in 1912 Bond gave a similar case of heterochromia iridis in man. I refer to the following schema fig. 12. The mother is blue-eyed, the father's eyes are asymmetrically pigmented. One daughter has the same asymmetry, one son has the asymmetry reversed.

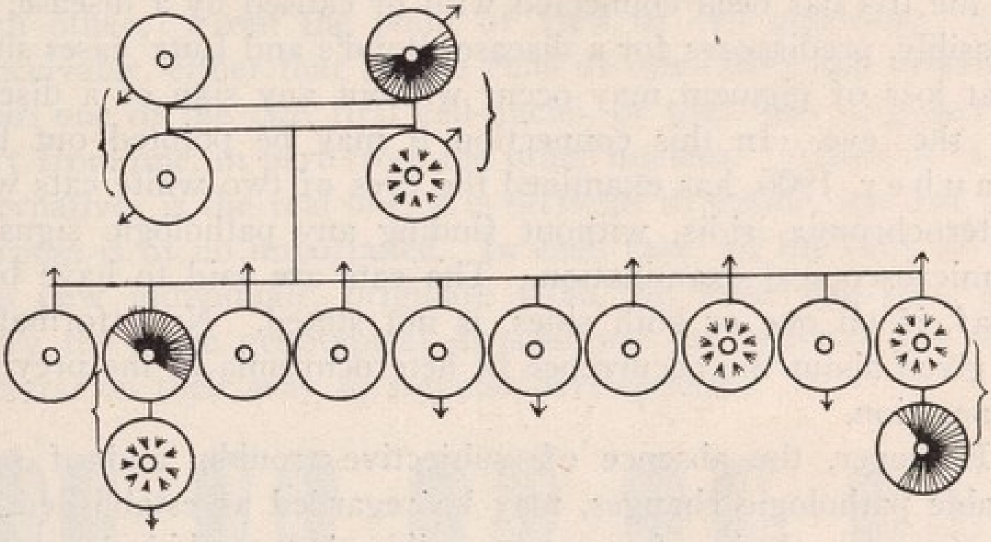

Fig. 12. Pedigree showing heterochromia iridis. The father and one daughter are alike, one son has reversed asymmetry. (Bond 1912).

Now it has been found that in heterochromia iridis, the lighter eye often is the seat of diseases (e. g. glaucoma, iridocyclite, etc.), and it has been maintained that the disease has been causing a decolouration of the iris. For certain cases this may be correct. Lutz, 1908, citing some case reports on heterochromia, gives 17 cases of his own, in some of which decolouration is stated to have taken place after birth (in these cases however, the difference in colour, according to Lutz, has been less marked). In other of his cases, the difference is stated to have been

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* Some years ago I saw an Alsatian wolf-dog with one ear erect and one drooping. Its father had drooping ears, its mother erect.

in existence from birth, and further he has six cases of distinct heterochromia *without* complications. Bond, also, in most of his cases has found no signs of disease. During anthropological examinations of Swedish conscripts on behalf of "the State Institute of Race-Biology", I have had an opportunity to see a number of cases (about 20) of heterochromia, and in none of these cases the individual in question has had any subjective trouble from his eyes. With regard to the casuistic on this subject, it must be remembered that, according to the very nature of the matter, healthy cases have small chance of getting into clinical reports on heterochromia. The case reports, therefore, only prove the existence of cases where loss of pigment in the iris has been connected with or caused by a disease, or, possibly, predisposes for a disease. Bond's and Lutz' cases show that loss of pigment may occur without any sign of a disease of the eye. In this connection it may be pointed out that Lauber, 1906, has examined the eyes of two white cats with heterochromia iridis, without finding any pathologic signs at a microscopical examination. The cats are said to have been deaf, if on one or both sides, is not stated. No information is given about the occurrence of heterochromia in the previous generation.

However, the absence of subjective trouble, and of noticeable pathologic changes, may be regarded as established for some cases. It is, of course, possible that morbid changes in utero may have injured the power of forming pigment — which however does not begin to function till the time of birth — but it hardly seems probable that the eye can be injured in this way without the consequence of abnormal developments in other respects also. Nor is there any evidence to show that intrauterine disturbances are the cause. As both Bond (in man) and Przibram (in cats), have been able to follow the abnormality through several generations (Bonds in two generations and Przibram in three, in several pedigrees) the hereditary character of this peculiarity should be fairly well established as regards their cases.

These instances might suffice to show the existence of genotypical asymmetries, and that reversal of the asymmetry at its inheritance is probable. Also, it may be regarded as probable that the limit for these characters can be displaced in the soma, towards one or the other side. The problems, of course, are related to such phenomena as pie-baldness, partial albinism, etc., where there is also reason to suspect asymmetry in the segmentation of the soma. Perhaps, also, they are related to asymmetries in the segmentation of the germ-plasm that were above (p. 127) suggested, with regard to twinning.

When twins are developed out of one egg, the process might be imagined to be that the first segmentation gives rise to two equal parts, each developing into one individual. With regard taken to what is known about polyembryony in Armadillos, it seems probable that, first, a more homogeneous cell mass is formed, in which by degrees two parts are delimited against each other. From the point of view of cell genealogy, it is conceivable, either that all the cells of one individual originate from one of the two first cell-nuclei, or that they originate in part from one, in part from the other nucleus. Which of these alternatives is the real one, it is difficult to decide, and for our purpose is of no importance. In each case, all the cells of the two new individuals, originate from the same egg cell, and carry the same genotypical dispositions for symmetrical characters, on their way to somatic development.

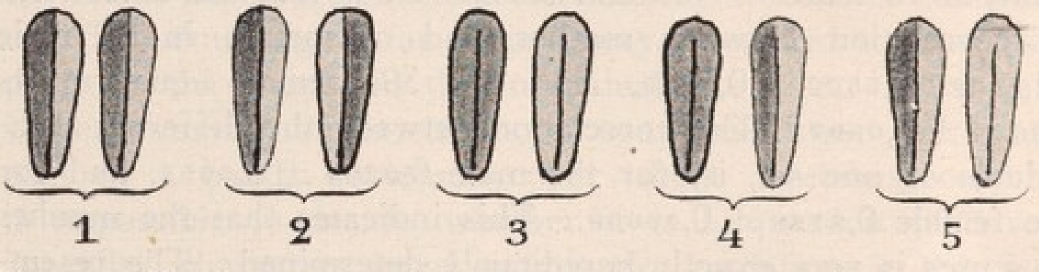

Fig. 13. Showing genotypical asymmetries causing dissimilarities in monozygotic twins. 1. The character (the shaded part) is present in both twins on the same side. 2. The character is present in both twins on opposite sides. 3. One twin has the character on both sides. 4. One twin has the character on both sides, the other on one side. 5. The character is present only on one side in one twin.

As to the genotypical asymmetries, we do not know how the limit runs in the soma. With regard to the rules propounded above, the following alternatives should come into question as to differences in monozygotic twins (see fig. 13): 1. The character is to be found in both twins on the same side. 2. The asymmetry is reversed, so that the character is found on opposite sides. 3. The limit for the asymmetry coincides with the limit between the twins, and one twin only has the character, which, therefore, is lacking in the other twin. 4. Finally, the limit may conceivably run in a way to give the character to one twin, and to one side of the other one, while lacking on one side of twin No. 2. 5. A reversal may take place, so that only one side of one of the twins, has the character. Also, of course, gradual displacements of the limit, between these somewhat schematical types, will have to be reckoned with. In the following, I will try to demonstrate these rules by some cases.

Already in the Armadillo, phenomena are to be met with that are of great interest from this point of view. Dasypus novemcinctus, the nine-banded Armadillo, has an armour of five shields, clothed with plates of horn. The body is covered by nine bands, clothed with such plates — scutes — varying in number from 50 to 70 per band. Newman, 1916, has conscientiously studied these cutaneous coverings, and has reached extremely important results.

The number of scutes in the banded region has a variability of 516 to 625 (108 scutes), and an average deviation from the mean of 15 scutes. Newman further finds that the coefficient of correlation between mother and offspring, in 56 male sets is 0,5522 ± 0,0625, and in 59 female quadruplets 0,5638 ± 0,0597. The correlation between the different individuals of one set, is, for the male 0,9294 ± 0,0057, and for the female 0,9129 ± 0,00059. This indicates that the number of scutes is very exactly hereditarily determined. The resemblance to the mother is quite large, but the offspring should as often resemble the father, which is in accordance with the correlation found. That the resemblance between the different individuals of a set, is so close to 1.—, is convincing proof that the characters are hereditarily determined. There is a small variation, and this may possibly be due to intra-uterine conditions (possibly also to genotypical asymmetries) — the variability in the sets, however, seems hardly to exceed ten scutes.

There are, however, isolated cases of doubling of scutes, and doubling of a large or small part of the bands (see fig. 14), in almost every case, asymmetrically in relation to the median line, and often on only one half of the body. Doubling of the bands occurs in about 3 per cent of the individuals examined. Doubling of scutes, is more common. Newman finds a close genetic relation between these anomalies. Sometimes, band doubling is inherited as doubling of the scutes, and vice versa; if the mother has the doubling tendency, doubling is always to be found in the offspring. Newman regards it as beyond doubt that it is a question of hereditary characters. He has published a very large material of such doublings.

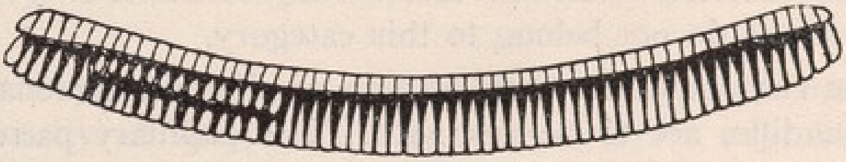

Fig. 14. Schematically showing doubling in a band from the armour of an armadillo. (Newman 1917).

There are cases where all the individuals of a set, or three, two or only one, show doubling. Further, there are numerous cases of one individual showing the doubling on the right side, another on the left. So far, the results are in accordance with the above laws. However, the conditions are rather complicated. The doubling is far from always localized to the same parts of the bands, in the individuals of a set. Further, it is very varying in extension — sometimes over the greater part of a band, sometimes over short stretches only. It is impossible to decide, whether it is a question of several "parallel" characters, or of quantitative gradations in the distribution of the characters, etc. Also, it is difficult to say, whether the doubling of scutes and bands, is due to separate characters. Possibly surrounding conditions are of importance for the manifestation of the characters. For further details of the different forms occurring, I must refer to Newmans works.

Newman, 1917, says the results obtained, argue strongly for an unequal distribution (or somatic segregation) of factors during cleavage. "Thus, we appear to have the possibility of a segregative mechanism which, in so far as an individual or set of monozygotic twins is concerned, might give results that would resemble the segregation of unit characters in the maturation division of the germ cells." Later on Newman adds: "In conclusion I should, therefore, like to emphasize the fact that somatic divisions may be as important agents in segregating unit characters, as germinal divisions involved in the formation of gametes (maturation or reduction divisions) are believed to be."

It seems to me that Newman is hasty to generalize his results. There is, of course, no reason to assume somatic segregation in polyembryony for other characters, than those asymmetrically distributed in an individual. Most hereditary characters, it seems do not belong to this category.

In the cutaneous covering of man, similar phenomena, as in the Armadillo, are to be met with. The papillary patterns in man, in a way, may be said to correspond to the arrangement of scutes in the Armadillo. Here also, however, the conditions are very involved. Hereditary characters, of course, play their part. Even if post-natal conditions do not influence the papillary patterns, therefore, it is quite possible that the intrauterine conditions may do so. Already on a classification of the patterns, it will be found difficult to draw any sharp limits between the different categories. Galton increased the number of his categories from 4 and 5 to 53, and assumed continuity between the types, Elderton assumes 5 types, and attempts to bring out heredity after Mendelian laws, without attaining quite unequivocal results (Gates, 1923). Bonnevie, 1923 (a, b), 1924, examines the number of papillary lines in the different patterns, and finds reason to believe that this depends on 5 polymeric factors. The question is far from solved. Probably the conditions are so complicated, because we have to reckon with asymmetric characters.

One case, given by Wilder, 1916, is of especial interest from this point of view. The father has calcar loop on both feet, the mother calcar loop and a divergence. Two of the children have loop on one foot, divergence on the other; in one case, loop on the *right* foot, in the other, on the *left* foot. Calcar loop is very rare — except in this family the pattern has been found only four times in 1,000 individuals examined.

But not only occur asymmetries, and reversal of the asymmetries from one half of the body to the other. One type of pattern may be found on one finger on one side, and on another finger on the other.

The limiting plane for the asymmetries and their reversals, obviously run in different ways. Finally, it is not improbable that a certain pattern, for instance on the little finger, may appear different if transferred to, and developed on, for instance, the thumb. In the varying play of the papillary lines, naturally, it is extremely difficult to tell what depends on symmetric hereditary characters, genotypical asymmetries and environment.

In monozygotic twins, a certain similarity, though not complete identity of the papillary patterns is to be expected. To a certain extent, perhaps, intra-uterine conditions may cause dissimilarities. Above all, however, the asymmetry mechanism should be of importance. Very often also, reversal of the patterns, "mirror imaging", is to be found in twins. Sometimes a pattern appears on one finger in the one, on another finger in the other twin. Finally, one twin may have a pattern that is altogether lacking in the other. Wilder gives one case of especial significance in this respect. In a pair of pygopags, one foot had a quite diverging type of pattern, while the three other feet showed good resemblance (quot. Newman 1917). The resemblance of papillary patterns between twins, is generally admitted to be of the same order, as the resemblance between the body halves of one person (see p. 147).

Different points of view have been applied to the interpretation of the differences.

Poll, 1914, does not believe in separate characters for right and left side. The modificatory character of the divergencies is plain, he says.

Wilder, 1916, emphasizes the identity of heredity in monozygotic twins — consequently the differences must be environmentally conditioned. In some cases of like twins, he has found fairly large dissimilarity in the papillary patterns, and he sorts these out as dizygotic. Evidently, he does not think that these dissimilarities can be due to environment.

Newman, 1917, quoting Wilder, gives his opinion, above referred to, about somatic segregation of the characters, corresponding to the Mendelian segregation in the gametes.

With regard to these authors, once again the importance of the genotypical asymmetries must be emphasized. The symmetric hereditary characters and intra-uterine conditions, certainly play a part. But, besides, there are probably complicated asymmetric distributions of characters. The factors determining these characters, however, can manifest themselves only on hands and feet. If the factors in question could manifest themselves over the whole body, we should get an extremely complicated picture. We now see only a fragment of this picture, and we cannot be sure that we see corresponding fragments of it. No wonder the conditions are difficult of interpretation. In any case, the above should suffice to show that it is in no way justifiable to ascribe the dissimilarities between the papillary patterns of monozygotic twins, to environment; the genotypical asymmetries will have to be taken into account, their limitary planes running in unknown fashion, and with possibilities of reversal and displacement of these.

Contrary to what is the case with papillary patterns, the growth of hair manifests itself over nearly the whole body surface. Ludvig, 1922, has examined the run of the hair in two 28 cm. long monozygotic twins. He finds good correspondence, but not complete identity. His description shows that generally there is a symmetrical pattern arrangement in each individual, but that asymmetries between the two halves of the body, sometimes occur. Ludwig is of opinion that the dissimilarities between the twins, are of the same order as between the halves of the body of one individual.

In one monozygotic twin pair in my material (no. 92), one had straight hair in the nape of the neck, while the other one had a whirl in the same place.

Nettleship, 1912, gives a case of two monozygotic twin girls, identical in appearance. The monozygotism was attested to by the doctor and midwife, who had attended at the birth. The one is colour blind for red-green on both eyes, with blue-grey iris. The other one has normal colour sense, and a touch of brown in the sfincter circle of the iris. Siemen's

1924 a, regards the difference as due, not to different tendencies, but to disturbances in their manifestation. Probably, however, this also is a case of asymmetry, to be interpreted according to the principles above stated. Red-green blindness has been known to occur in only one eye of an individual. Asymmetrical colour blindness is not established for the family, but the pedigree shows a peculiarity that is of interest from this point of view, fig. 15. The mother of the twins must have had the tendency — be the conductor. She seems not to have got it from her mother, as the tendency, so far as known, does not occur in that side of the family. But the father's mother had the character manifest. Therefore, her father, too, ought to have had the character manifest — but this is not the case. If, now, her father had been genotypically asymmetrically colour blind, he has not himself suffered any inconvenience. His family, perhaps, had not noticed his defect, and Nettleship has received the information that he was not colour blind. This interpretation, of course, cannot now be proved, but it seems to me more probable than Siemens' hypothesis that the man had had the tendency, thought it had not manifested itself. This would then, as Siemens himself points out, be the first time it had been established that the manifestation of a recessive sex-coupled tendency in a man, had failed.

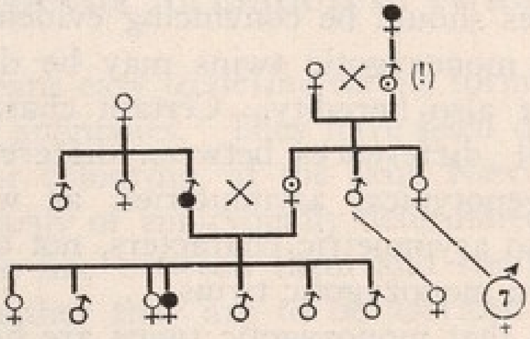

Fig. 15. Nettleship's pedigree showing red-green blindness in monozygotic twins. (Siemens 1924 a).

There are other examples of asymmetric distribution of anomalies of the eyes in monozygotic twins. Jablonski, 1922, has examined the refraction in monozygotic and dizygotic twins and finds small variation in monozygotic (for total refraction and astigmatism 2 diopt. at most). He assumes that their heredity is alike. However, he has two cases of monozygotic twins, where the total refraction was the same in three eyes, but far different in the fourth.

Heinonen, 1924, has some similar cases, well examined and exhaustively described. Diagnosis for monozygotism was founded on resemblance in appearance, and on anthropological measurements. Photographs are given. In two cases the refractional conditions are almost identical, in the other case, there is an astigmatism with inclination of the head plane 10°, in both twins on the right side. For the *left* eye, the head plane is vertical. In the mother also, there is an astigmatism of the cornea with inclination of the head plane in the left eye — vertical in the *right*. Thus there is reversal from mother to offspring. In a third twin pair, in one of the twins there is an abnormally long eye axis, in the other astigmatic cornea in one eye — in other respects the refraction is alike. These divergencies, now, may be due to external conditions, but Heinonen is of opinion that the probable reason is differing heredity. Either, it is a question of a mutation in the soma, or of asymmetric distribution of the characters at the first cell divisions, somewhat in analogy to the gynandromorphic phenomena. In a later work, 1925, Heinonen seems more inclined to ascribe the divergence to external factors.

These instances should be convincing evidence that dissimilarities between monozygotic twins may be due to, not only environment, but also heredity. Certain characters are of a nature to entail differences between different parts of the soma. These genotypical asymmetries, as we have termed them, give rise to asymmetric characters, not only in the individual, but also in monozygotic twins.

The statement that monozygotic twins are hereditarily identical, probably, at present, is taken too dogmatically. If it has been shown that a character is heritable, and can be followed regularly through several generations, and it is then found to be present in only one of two monozygotic twins, it is not, therefore, permissible to assume that the character in question in this case is environmentally conditioned, contrary to what has previously been established. First of all, it must be ascertained, if the character cannot be genotypically asymmetric, that is manifesting itself asymmetrically in its bearers.

On the other hand, it must be emphasized that there is no reason for this reservation to be made for characters that are always symmetrically distributed in their bearers. Newman and also Bond, have maintained the existence of a somatic segregation mechanism, causing asymmetric distribution of the character in the soma. As above pointed out, it cannot be taken for granted that the character is altogether absent from those parts of the soma where it does not manifest itself.

The mechanism for the asymmetry we do not know, and it is well conceivable that the difference is occasioned by the relation of the gen to other gens, etc. (see p. 161). Above all, however, it must be stressed that it is not a question of segmentation that can push aside and suppress any character. In that case, the somatic segregation, now and again would conceal a character altogether, and under such conditions, of course, the heredity would not show regular Mendelian figures. The segregation must not be taken in too wide a sense, and does not controvert the fact that for most characters, monozygotic twins have the same heredity.

Nævus formation in twins.

It is by no means easy to define nævus formations as against other cutaneous anomalies. They have been described as congenital marks, or colouring, of the skin. Nævi have been stated to be hereditarily or embryonally determined, but it is difficult to draw the line between them and similar anomalies of later date. Whether they are to be ascribed to intra-uterine conditions or hereditary tendencies, cannot easily be decided, even with regard to the congenital ones. Possibly nævi must be taken to include anomalies of differing genesis, caused in some cases by extra- or intra-uterine conditions, in other cases dependent on heredity in a more limited sense.

Meirowsky and Leven, 1921, have compiled a large material, and attempted to prove that heredity is the decisive factor, while at the same time they attempt to set apart all such anomalies as are dependent on external factors. They point out the correspondence between nævi and pie-baldness in animals, and further cite some cases where a nævus has been found in several generations, and in the members of the same family.

Siemens, 1924 c, again takes the question into consideration. He has investigated the occurrence of nævi in monozygotic and dizygotic twins. A dissimilarity in regard to illness in monozygotic twins, as above stated, Siemens regards as proof, that the illness is not hereditarily determined. Siemens has 45 identical twin pairs (the diagnosis based on similarity or dissimilarity in appearence) and 23 dizygotic. He counts the number of nævi of different types (elevated, smooth, etc.) and in almost every case finds dissimilarities between the twins. Therefore he concludes that nævi are occasioned by external conditions, and are not due to heredity (both as regards smooth elevated, large hairy and non-hairy, nævi depigmentosi, etc.).

However, he finds that the correlation in monozygotic is + 0,4 ± 0,13 *, in dizygotic 0,25 ± 0,18, and in persons from different families 0,08 ± 0,2, and he regards this as indicating an idiotypical disposition to nævus growth.

As a matter of fact, Siemens' results are in good accordance with what would be expected for genotypical asymmetries. First of all, Siemens thinks heredity has been established for ephellides and teleangiektasies. These anomalies, however, have been symmetrically localized. The other anomalies are decidedly asymmetric. Siemens is inclined even, to define nævi as all essentially stable, circumscribed cutaneous anomalies, as a rule occurring asymmetrically and of unknown etiology. Now, it appears that the correlation consistently is as great between monozygotic twins, as between the halves of the body of an individual (73,2 per cent ± 1,0 for monozygotic twins in the whole material, 72,6 ± 1,4 for right and left half of the body), but considerably larger than for dizygotic twins, and other brothers or sisters, as above mentioned. This is exactly what should be expected of genotypical asymmetries.

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* Actually + 0.82 ± 0.05 and 0.42 ± 0.16 (see p. 176).

Siemens rather has given support for Leven's and Meirowsky's hypotheses about hereditability of nævi. Poll's opinion, quoted by Siemens, "there are no separate characters for left and right", as above stated, is by no means self-evident.

Leven, 1924, raises some objections against Siemens' work, emphasizing that we are not justified in assuming the same hereditary mass in monozygotic twins. The papillary patterns are heritable, but not identical, in monozygotic twins.

Siemens, 1924 (f), replies that the papillary patterns have not been proved to be heritable. External conditions are of more importance than has been thought possible. Further, he gives one case of nystagmus in monozygotic twins, where only one of the twins has shown signs of the malady. In this case, however, Siemens does not draw the conclusion that the malady is not heritable. On the contrary, it is due to a dominant character, and the case shows a disturbance of its manifestation, with suppression of the character in one twin.

Bauer, 1924, points out that one-sided, hereditary characters ought to cause dissimilarities between monozygotic twins. Siemens' conclusions that nævi are due to environment, he does not regard as justified. He further gives a case of monozygotic twins where the one is brown-eyed, the other has blue-grey eyes, and he regards this as due to hereditary heterochromia.

Siemens, 1924 (g), admits that if asymmetries are heritable, this may conceivably cause dissimilarities, but so far this is only grey theory. Bauer's objections have not sufficient foundation.

Leven, 1924, once again points to the differences between monozygotic twins in regard to papillary patterns, and is of opinion that these differences possibly can be interpreted as suggested by Bauer.

Cohen, 1924, has made a controlling examination of Bauer's case of twins with different eye colouring. The statement about monozygotic after-birth he finds not quite reliable. Furthermore, the twins are very unlike, they have different hair and skin colour, features, etc., and are never confused; therefore he does not think they can be monozygotic.

Leven, 1925, once again offers opposition to Siemens, using in the main the same arguments as before. Besides, he has had Siemens' correlation figures controlled, and found that the Bravais-Pearson formula for the coefficient of correlation has been incorrectly used, and should give 0,82 ± 0,05 for nævus frequency in monozygotic, instead of + 0,4 ± 0,13.

Siemens, 1925, replies that he was already aware of this, and in a lecture (in Münchener Gesellschaft für Morphologie) has corrected the error, but in other respects maintains his position, that isolated nævi are less rigidly determined by heredity than has previously been assumed, and that monozygotic twins as a rule are hereditarily alike.

With regard to heredity of the papillary patterns, I refer to p. 168. Regarding nævi, it should be pointed out that the dissimilarities certainly may be interpreted as due to environment, but it is also possible to regard them as genotypical asymmetries. As against Leven, it has been pointed out by Siemens, that the *number* of nævi seems to be hereditarily determined, while the *localization* is not the same in monozygotic twins. External factors, thus would decide where on the skin, nævi appear, while their number would chiefly depend on hereditary disposition. There is a certain inconsistency in this, but that will disappear, on the assumption of genotypical asymmetries. In that case, as will be easily apprehended, the localization may vary, although the number on the whole is hereditarily determined. Reversals, and displacements of the limits of the genotypical asymmetries, must be expected to give a very varying localization; there is, perhaps, therefore greater reason to assume the presence of genotypical asymmetries, than entirely unknown environmental factors.

Meirowsky, 1925, claims to have established heredity for dimples on the chin and cheek. In the families examined by him, there are some monozygotic twin pairs. In one monozygotic pair (the diagnosis ascertained by examination of the egg membrane), the one has dimples on both cheeks, and the other on one only. In the rest of the family, dimples are to be found on one as well as on both cheeks. In one pair of identical twins, one has dimples on both cheeks, the other none at all. Regarding the family, it is only stated that mother and grandmother have dimples on both cheeks.

Finally two cases are given of monozygotic twins both dimpled on the chin, and one case where these dimples are somewhat differently developed in the twins. From these cases Meirowsky concludes that these dissimilarities between the twins, either are environmentally determined, or that monozygotic twins are not idiotypically identical. He will not give an opinion, which of these alternatives is the most probable.

First as regards the case with differently dimpled chins it must be pointed out that Meirowsky has seen one of the twins on a photograph only. Neither the diagnosis for monozygotism, nor the difference between the dimples, therefore, can be regarded as quite certain. If it were, we should be inclined to think of genotypical asymmetry. This explanation is made the more probable by the difference in dimples on the cheeks, in the other twins. In accordance with our asymmetry rules, in one case the character is to be found on three sides of the twins, and is entirely lacking on one side, and in the other case, the character is to be found on both sides of one twin, and is lacking altogether in the other one. Finally, in the family of one of the twin pairs, the character sometimes comes to light one-sidedly, as an asymmetric character, and the pedigrees given by Meirowsky indicate hereditability. Further reversal of the asymmetry plane, sometimes occurs at inheritance from one generation to another. Meirowsky's case, thus, is in good accordance with the rules for genotypical asymmetries.

I may remark that in my material, there are two pairs of monozygotic twins, where both twins have a very marked dimple on the chin (no. 72 and 94).

Right- and left-handedness in twins.

Bardeleben, 1909, has given a very thorough survey of the different theories proposed for left- and right-handedness, and comes to the conclusion that there is no satisfactory explanation of the origin of these characters. He claims to have established heredity for them both.

Some investigations have later been made on this question of heredity. Jordan, 1915, on a very large material finds that left-handedness is inherited as a recessive character. Ramaley, 1913, comes to the same conclusion, as do also Stier, 1911, Sieben, 1922, Heilig—Steiner 1912, and others.

It is difficult to decide what the nature of the character really is. Right- or left-handedness is the ability to perform complicated movements better with one arm, than with the other. This may, to begin with, be due to a better development of the muscles of one arm, this being the reason for preferring that arm at movements from the first, in turn causing better development of the arm centre in the corresponding brain hemisphere. On the other hand, one arm centre might have been better, from the first, that is, right- or left-handedness is a primary brain asymmetry. The circumstance, that the functioning lingual centre generally lies in the same hemisphere as the "better" arm centre, seems to indicate that the character is based on a brain asymmetry.

In any case, it may be regarded as fairly well established that the functional asymmetry constituting right- or left-handedness, is based on hereditary dispositions, occasioning an asymmetric development of the soma. When it comes to analysing this inheritance, however, the interpretation of the pedigrees is not so simple. If it is a question of a unit character, and right-handedness is dominant, as maintained by Jordan and Ramaley, left-handed parents should have only left-handed children. In some cases, however, Jordan, like Stier and Ramaley, found rigt-handed children of such marriages. But probably it is a case of genotypical asymmetries, and then reversals of the asymmetry plane are only to be expected. Viewed thus, the divergencies are easily explained. However, there is another doubtful point. Some persons use right and left hand with the same ease, they are what is called ambidextrous. How are these persons to be regarded from the point of view of heredity? The ambidextrous might be regarded as lacking the asymmetric dispositions that give rise to right- or left-handedness. It is further possible that the ambidexter really are left-handed who have been exceptionally trained in the use of the right hand. Another possibility is that, where the disposition is present for both right- and left-handedness, this will cause ambidexterity. Right-handedness in that case would not be dominant, the heterozygotes instead being ambidextrous. The number of left-handed is differently estimated by different authors. Beeley, 1919, puts the figure at 4 per cent. Stier, 1911, finds 4,6 per cent among 5,000 soldiers. Putting the number of left-handed in the population at 5 per cent, the heterozygotes should be put at 34,7 per cent after the schema p. 87. For the number of ambidextrous, reliable figures are difficult to get. As grown-ups probably many of these by training will have aquired right-handedness. So far, consequently, a figure of 35 per cent ambidexter can not be called impossible. In any case, the possibility must be taken into account that ambidexter counted as right-handed, help to cloud the issue. With regard taken to these sources of error, reversal of the asymmetry, and the possible occurrence of a hereditary symmetry that through conditions has become functional asymmetry, it should not surprise to find the heredity conditions somewhat complicated.

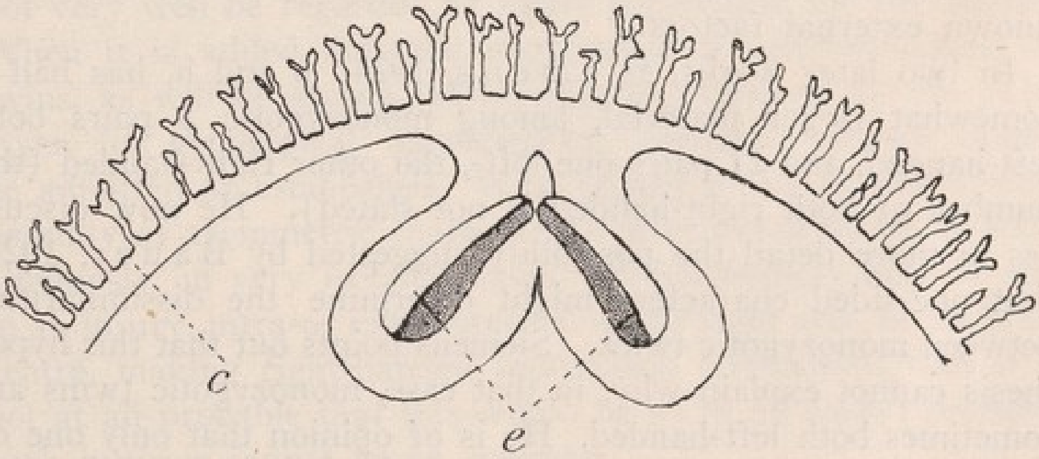

Fig. 16. Showing the development of monozygotic twins, one being right-handed, the other left-handed. C = chorion. E = fetus. The median (shaded) halves represent the "better" functioning sides of the twins.

With regard to monozygotic twins, also, reversal of the asymmetry must be reckoned with. The schema fig. 16, gives an instance of such reversal. Ambidexterity hardly should make one twin appear left-handed and the other right-handed, usually both would be trained to right-handedness.

Evidently, in monozygotic twins, as in other cases, the possibility must be reckoned with, that the better arm or its brain centre, is injured, and in this way, right-handed individuals grow left-handed, and vice versa. If right- and left-handedness depend on hereditary factors, we should expect to find right-handed monozygotic pairs, a small number of left-handed pairs, and perhaps not too small a number of pairs, where one is right-handed, the other left-handed, owing to reversal of the genotypical asymmetry. It is difficult to predict anything about the size of this last group. An apparent difference, owing to one twin having been injured, probably is not very common. It is not known how often reversal of the asymmetry occurs.

Siemens, 1924 a, finds that in 10 pairs, one is left-, the other right-handed. In 1 pair, both are left-handed, and in 26 pairs, both right-handed. Siemens regards this as proving the absence of heredity. In spite of this, he holds right-handedness to be a hereditarily fixed disposition and that left-handedness is due not to an opposite disposition, but to unknown external factors.

In two later works, Siemens, 1924, b and h, has had a somewhat larger material, among monozygotic 3 pairs both left-handed, and 21 pairs one left-, the other right-handed (the number of both right-handed is not stated). He now discusses in more detail the possibility suggested by Bauer, 1924, that one-sided characters might determine the dissimilarities between monozygotic twins. Siemens points out that this hypothesis cannot explain why, in that case, monozygotic twins are sometimes both left-handed. He is of opinion that only one of the twins can get such a character. He states, further, that to his knowledge there is no case, in animals or man, where hereditary asymmetries have been established. The genealogical statistical results of other investigators, indicating heredity, according to Siemens, are accounted for in part by the selection of families with chance accumulation of left-handedness, in part by the fact that left-handed, more than right-handed, notice left-handedness in others, and consequently give an apparent increase of left-handedness in their families. Siemens himself has made an investigation on the occurrence of left-handedness in the families of left-handed, and got the following figures:

Twin pairs with left-handedness 8,5 ± 3 % left-handed brothers & sisters.
Twin pairs without left-handedness 6,8 ± 1,8 % left-handed brothers & sisters.
Fraternities with left-handedness 9,1 ± 3,6 % left-handed parents.
Fraternities without left-handedness 8,6 ± 3 % left-handed parents.

The differences lie well within the limits of error, and Siemens takes the figures as evidence that his opinion is correct: left-handedness surely is not hereditary, contrary to what has earlier been assumed.

However, it must be pointed out that in Siemens' figures, a small displacement indicating heredity, is noticeable, although, on account of the smallness of the material, the differences cannot be regarded as statistically established. It is not impossible that a larger material would give established differences. The figures of other investigators decidedly favour the assumption of heredity. Even if the errors pointed out by Siemens, may have played a certain part in their investigations, they can not very well be regarded as solely accounting for the results. When it is added that the occurrence of left-handedness in twins, as will be shown below, can be explained by the rules given for genotypical asymmetries, Siemens' opinion cannot be admitted as established. With regard to his doubts against heredity of asymmetric characters, I refer to the above (p. 160). Obviously, in very isolated cases, left-handedness may be due to an injury, intra-or extra-uterine, in the right arm, or its brain centre, making right-handed individuals left-handed, but it is not at all probable that this would be so in all cases; probably such injuries cannot be so common.

Weitz, 1924, among 18 monozygotic twin pairs, found one pair both left-handed, 7 pairs one right-, the other left-handed, and 10 pairs both right-handed. Weitz finds the number of left-handed unusually large, and perhaps connected with the monozygotism. He does not try an explanation of the conditions.

In my material, I have found the following figures: 4 pairs both left-handed, 12 pairs one left-handed, 53 pairs both right-handed. As a rule, I have diagnosed left-handedness, by asking with which hand the person in question throws a stone, or cuts his bread.

If Siemens', Weitz' and my own figures, are added, the result is:

6 pairs both left-handed, 4,8 %
29 pairs, one left-handed, 23,4 %
89 pairs, both right-handed, 71,8 %.

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124 pairs.

As Weitz has observed, the number of left-handed among monozygotic twins, is remarkably great — in this material 16,5 ± 2,4 per cent.

This might be taken to mean, that there is a particularly strong tendency to reversal of the asymmetry in one of two monozygotic twins. Suppose, that reversal in one of the twins, takes place for instance in $^1/_6$ of the cases. Properly, there would have been 5 per cent left-handed, and 95 per cent right-handed pairs. In $^1/_6$ reversal takes place, and of the right-handed remain, 79 per cent both right-handed, 16 per cent with one left-handed. Of the left-handed 0,8 per cent are reversed, that is one twin remains left-handed. The result is 4,2 per cent both left-handed, 79 per cent both right-handed, and 16,8 per cent one right-, the other left-handed. (As above pointed out, possibly some of the right-handed are ambidextrous in disposition — in that case, perhaps, reversal in the asymmetri would be still more frequent). Such a mechanism, then, explains not only the increase of left-handed among monozygotic twins, but also makes clear that the increase is due especially to pairs where only one is left-handed, and thus explains the occurrence of such pairs as a whole.

In dizygotic twins, I have found the following figures:

Both left-handed 1 pair, 0,8 %. One left-handed 16 pairs, 12,5 %. Both right-handed 111 pairs, 86,7 %. In all, 256 individuals, of which 18 left-handed

$$= 7{,}3\ \% \pm 1{,}6.$$

In dizygotic twins, the frequency of left-handedness then, is fairly normal. We must expect left-handedness or right-handedness (as well as ambidexterity) to be determined in one twin independently of these characters in the other one. If so, the probability of pairs both left-handed, is $\left(\frac{5}{100}\right)^2 = 0{,}25$ per cent, the probability of pairs both right-handed, $\left(\frac{95}{100}\right)^2 = 90{,}25$ per cent, and the probability of pairs with one left-handed, $\frac{2 \cdot 5 \cdot 95}{100 \cdot 100} = 9{,}5$ per cent. The empirical figures will be seen to accord pretty well with these theoretical ones.

Siemens, however, on examination of dizygotic twins, has found 2 pairs both left-handed, 13 pairs one left-handed, and 16 pairs both right-handed. This means 27,4 per cent left-handed among the twins in his material. The material, of course, is small, but seems to indicate an increase of left-handedness among the dizygotic twins. In a later work, 1924 c, Siemens gives the figure 16,4 ± 3,6 per cent left-handed among the dizygotic. He has now one pair both left-handed, and 16 pairs one left-handed (one pair both left-handed seems to have dropped out?). The increase of left-handedness, in this case, is less, but still quite distinct. Siemens' result, consequently, does not accord with the results I have arrived at. The contradiction is not easily explained, but as my material is larger, the figures deduced from it, so far might be regarded as more reliable.

Clasping hands.

In clasping the hands, some persons place the fingers, so that the right thumb comes on top, and the left finger below. As a rule only one way is used — the other way is declared to feel repulsive, awkward, queer. Gates, 1923, says it has been established that in a population, about half the people do it one way, with right thumb on top, and half, the other way, with left thumb on top; further, that genealogical investigations have shown, that these characters are hereditary. As people always clasp their hands in the same way, and find the other way repugnant, of course it does not seem improbable that hereditary characters have something to do with the matter. As far as

I have been able to find, only in very isolated cases people state that they clasp their hands equally well in both ways.

It is curious however, that as many place the right thumb on top as the left one. If the custom developed haphazard, just such a proportion would be expected, while, for hereditary characters a more asymmetric distribution within the population would be more probable. As I have not myself been able to find any exact figures in the literature, I examined 854 school-children, to find how they clasped their hands. 426 clasped with right thumb on top, and 428 with left thumb on top. Thus just 50 per cent were using the one way, and 50 per cent the other.

If the matter were settled by chance, it would be found, in both monozygotic and dizygotic twins, that ¼ both clasp their hands with right thumb on top, ¼ both with left thumb on top, and ½ one with left, one with right thumb on top.

In my material I got the following figures:

	Both right thumb on top	One left thumb.	Both left.
Monozygotic (69 pairs)	18	34	17
Dizygotic (123 pairs)	34	56	33

These figures are very much what would be expected on a chance distribution. If heredity played any part, we should expect the same figures as before in the dizygotic, but greater similarity in the monozygotic, that is, more frequently both clasping with right or with left thumb on top. Of course, it might be argued that certainly half the pairs should clasp with right thumb on top, and half the pairs with left thumb, but that in half of the cases reversal has taken place in one twin. However, it seams more probable that it is not a question of hereditary dispositions at all. It would be very strange indeed, if a hereditary disposition not only were distributed in the population at large in the same way as if determined by chance, but also had a tendency to reversal in monozygotic twins, giving the same result. Under these circumstances, there is hardly reason to presume heredity.

Functional superiority of one leg.

Just as we prefer right or left hand for difficult movements, we also prefer right or left foot for movements demanding precision and strength. In my twin material, I inquired which foot was used to start, or to hop. A few were indifferent as to which foot they used. The other cases were divided in the following manner:

	Both right fot.	One right foot.	Both left foot.
Monozygotic (54 pairs)	34	13	7
Dizygotic (97 pairs)	70	22	5

The material is comparatively small (less than for clasping of the hands, and for right-handedness) chiefly because I had not from the start paid attention to this point.

Among 194 dizygotic twins, there are 34 left-footed. According to these figures, about $^1/_6$ of the population would be left-footed. The number of pairs both left-footed, or both right-footed, in relation to those with one left-footed, and one right-footed, is what would be expected under this assumption.

In monozygotic, there is a considerably higher proportion of left-footed, about ¼ of the material. The most likely explanation is the one here suggested for left-handedness. It is a question of a genotypical asymmetry, that primarily should give $^1/_6$ both left-footed, and $^5/_6$ both right-footed. In some of these cases, reversal af the asymmetry takes place in one of the twins only. Thus, a certain number of pairs have one left-footed, the other right-footed, consequently, to some degree the group both left-footed, but above all the group both right-footed, are reduced. The net result is, that the number of left-footed are considerably increased. (If reversal in one of the twins happened in all cases, of course, we should get 50 per cent left-footed.)

Résumé of genotypical asymmetries.

We have above demonstrated that certain characters (heterochromia iridis in cats and in men, supernumerary toes in fowls) appear asymmetrically and that those asymmetries probably are due to hereditary factors causing different characters in different parts of the soma, independent of environmental influence. I have called those characters genotypical asymmetries.

Issueing from the above observations I set forth certain rules for the appearance of genotypical asymmetries in monozygotic twins (see p. 165), causing differences between them. By help of those rules we are able to explain many dissimilarities in monozygotic twins, dissimilarities which can hardly be interpreted as originating from environmental factors. This, for instance, applies to double formations of scutes in armadillo, to dissimilarities of the papillary patterns of monozygotic twins in man, and further to dissimilarities of colour-blindness and of the pigment of iris, to refraction differences and to nævus formations and left-handedness.

The accordance we have found can be said to give a probability approaching to certainty that genotypical asymmetries, as we have assumed, sometimes cause hereditarily conditioned dissimilarities in monozygotic twins. With regard to symmetrical characters there is, on the contrary, no reason to part with the generally adopted opinion as to the hereditary similarity of monozygotic twins. When question of dissimilarities in monozygotic twins, the possibility of a genotypical asymmetry must however be reckoned with in each individual character. Further investigations into genotypical asymmetries, therefore, would be of great interest, especially as it may be expected that such investigations to a certain extent would help to throw light upon the asymmetries in the development of the soma, constituting the normal differentiation of the organs.

ENVIRONMENT AND ANTHROPOLOGICAL CHARACTERISTICS.

The question to what extent racial characters may be influenced by environment, has always been an object of speculation. In the early days of anthropology, however, this problem was confused with the question if, and to what degree, environment can provoke changes of the hereditary mass itself.

For instance, it was discussed what rôle the sunlight had played for the skin colour of the negroes, but the two questions were not kept distinct, whether the sunlight can be imagined to change the hereditary structure, by selection or by other means, so as to give the race a tendency to dark skin colour, and whether the sharp light causes a darker skin colour of the individual, than a weaker light would do. Obviously, a certain hereditary mass will give rise to a certain skin colour, stature, etc., in one environment, while the same hereditary mass may cause a different stature and a different skin colour (darker or lighter) in another environment. This latter variability, in itself cannot alter the hereditary mass, that is, cause a continuous change of the average type from generation to generation. Only when the genetic problems hade been more firmly grasped, the question of the influence of environment could be put in that way. In the anthropological literature of the last decades it has received some attention and raised a certain amount of discussion. In principle nobody denies that at least some such modifying influence must be ascribed to environment. However, it seems as if, in one quarter there were a tendency more or less to neglect the influence of environment, in another to attribute almost all racial differences and changes to environment. At any rate the investigations *directly* bearing on the problem are very few — but they have been the cause of lively discussion.

Walcher, 1905, explains the principles underlying an investigation on the modifiability of the shape of the head in early childhood. Letting a child lie on its back with the occipital part of the skull resting on a soft pillow, would cause brachycephaly, a hard pillow (hair pillow) and lateral position, dolichocephaly.

Elsässer, 1906, gives a closer account of the results of the experiments. In one half of the cases it was attempted in the above way to cause brachycephaly, in the other half, dolichocephaly. The children were measured at birth, on the third day, and on the thirteenth day, when they were removed. The material comprised 550 children.

Among those who had been lying on their backs, 84,1 % showed an increase towards brachycephaly. Among those who had been lying on their sides, 62,7 % had increased towards dolichocephaly. The index had grown in the former case (the 84,1 % group) on an average 3,75 units, and had decreased in the latter case (the 62,7 group) 2,56 units. The remaining 15,9 % of the first half, showed an average increase towards dolichocephaly of 1,39 units, the 37,3 % of the second half, an increase towards brachycephaly of 1,66.

Undoubtedly the figures give an impression that the shape of the head has been affected. Also, it is quite conceivable that just as the skull of a child has a certain plasticity at partus, it may to some degree be moulded by mechanical factors during the time immediately after birth. It cannot be stated, however, how far this remoulding will remain at an adult age, as the experiments were discontinued already on the 13th day.

Two singly born children and 3 pairs of dizygotic twins were observed for a somewhat longer period, and the figures for these cases seem to indicate that the shape of the skull is more permanently influenced. The cases, however, are too few, and possibly the external influences may have coincided with a hereditary tendency.

For one pair of monozygotic twins the figures were as follows:

Days			lateral position	dorsal position
1	Cephalic index	....	84,39	85,08
23	,,	....	87,50	86,48
8	,,	.....	86,72	87,71
16	,,	....	85,12	88,35
31	,,	....	84,80	86,05

The one in lateral position shows a distinct and continuous change towards dolichocephaly. The one in dorsal position during the first days shows the expected change towards brachycephaly, but during the latter half of the month the change is on the return, and the skull is getting more dolichocephalic. The impression is that the environmental influence has been "vanquished" by heredity. The final difference after a month, is not large, 1,25 units, perhaps not exceeding the error in measuring. In any case it is not improbable that the final result on prolonged observation would have been no difference.

This case, therefore, if anything, speaks against a permanent influence. However, Walcher 1911 states that in a pair of monozygotic twins, he has found in the one an index of 78,4, in the other 86,2 at 2½ years of age. The result conflicts with the previous case of monozygotic twins. The displacement is so great that it is permissible to ask, if it is not a result of some abnormal process, or if a mistake has not been made in judging the membranes, so that the twins, as a matter of fact, were dizygotic.

Martin 1914 is of opinion that Walcher has proved the possibility of influencing the shape of the skull, but that his experiments belong to the intentional deformations, and thus do not count as evidence on the normal course of things. This I think is hardly correct — a variation of conditions like in Walcher's experiments cannot be put down as lying beyond the normal. Experiences from savage tribes undoubtedly show that powerful mechanical influences may cause deformation. In these cases on the contrary there is more reason to consider the injuries as lying beyond "normal" conditions.

Mollisson 1923 rejects Walcher's results, citing investigations of Pearson, which indicate that the cephalic index is hereditarily determined. As to that it seems to me that it can never be maintained that Walcher's results, if they should prove correct, disprove the hereditary influence on the shape of the skull (even though Walcher himself has given a hint that way). If a character has a certain variability when manifesting itself in differing environments, this does not mean that its hereditary nature is without importance.

Fischer, 1923 a, accepts Walcher's experiments, and regards it as proved that the means employed by him do influence the shape of the skull. He attributes special importance to Walcher's last case of monozygotic twins. This one case, however, hardly justifies so far-reaching conclusions, especially as it is in distinct conflict with another case as I have mentioned before.

Boas 1912 has examined immigrants to the United States and their offspring. With the exception of the Scots he finds in all races "certain differences between the measurements of individuals born in America and the measurements of those born abroad". He has put his results into the following table:

Measurements of American-born minus measurements of foreign-born, weighted according to number of cases. All types measured.

(Quoted, Boas 1912.)

Race and sex	Length of head	Width of head	Cephalic index	Width of face	Stature	Weight
	Mm.	*Mm.*		*Mm.*	*Cm.*	
Bohemians:						
Males	— 0,7	— 2,3	— 1,0	— 2,1	+ 2,9	*170*
Females	— 0,6	— 1,5	— 0,6	— 1,7	+ 2,2	*180*
Hungarians and Slovaks:						
Males	— 0,5	— 1,1	— 0,7	— 1,0	+ 5,9	*54*
Females	— 0,3	— 0,9	— 1,0	— 2,2	+ 1,0	*38*
Poles:						
Males	— 0,3	+ 0,2	+ 0,2	+ 0,7	+ 4,2	*22*
Females	+ 0,9	— 1,6	— 1,4	— 1,3	+ 1,7	*27*
Hebrews:						
Males	+ 2,2	— 1,8	— 2,0	— 1,1	+ 1,7	*654*
Females	+ 1,9	— 2,0	— 2,0	— 1,3	+ 1,5	*259*
Sicilians:						
Males	— 2,4	+ 0,7	+ 1,3	— 1,2	— 0,1	*188*
Females	— 3,0	+ 0.8	+ 1,8	— 2,0	— 0,5	*144*
Neapolitans:						
Males	— 0,9	+ 0,9	+ 0,9	— 1,2	+ 0,6	*248*
Females	— 1,7	+ 1,0	+ 1,4	— 0,6	— 1,8	*126*
Scotch:						
Males	+ 1,4	— 0,5	— 0,8	— 1,5	+ 1,8	*39*
Females	— 0,3	+ 0,3	+ 0,2	+ 1,9	+ 3,9	*33*

Boas makes the following comments on the table:

"The central European type, represented in our series by the Bohemians, Hungarians, Slovaks, and Poles, shows a decrease of the cephalic index for those born in America, which is due to a decrease of both length of head and width of head. The width of face shows a considerable decrease, while the stature increases. The Hebrews differ in their behaviour from the preceding group in showing a much larger decrease in cephalic index, which is due to the fact that the length of the head increases, while the width of the head decreases. The decrease in width of face is also considerable, and the stature shows a marked increase. The third group is formed by the two south Italian divisions — the Neapolitans and Sicilians. In both of these cases we find an increase of the cephalic index, which is more marked among the long-headed Sicilians than among the more round-headed Neapolitans. This increase is due to a widening of the head, combined with a loss in length. The face of both groups also loses in width. The stature of the American-born is less than the stature of the foreign-born. These data show that the changes in the dimensions of the head, do not depend by any means upon the absolute or relative measurements which are found among the foreign-born, but that heads which are nearly of the same length, like those of the Bohemians and of the Hebrews, behave quite differently in this country, the length of the one increasing, while the length of the other decreases."

The question now is: is this change due 1) to errors of measurement, or accidental displacements, that is, insufficient material, 2) to a modifying influence of environment, or 3) to a change in heredity, in that case presumably by selection?

In the discussion that has followed, all these explanations have been advanced.

Radosavljevich, 1911, regards the results as due to errors, untrained measurers, etc. Wilser 1913 and Sergi 1912 find the material insufficient. (Quoted Boas 1913.)

Backman, 1911, regards the change from town to country life of the immigrants as mainly responsible, and believes that a consequent selection might affect the averages in the way demonstrated by Boas. Sergi 1912 also points to selection as an explanation. (Quoted Boas 1913.)

Steinmetz (quoted Boas 1913) emphasizes the influence of environment; the immigrants in their home countries have a pauper type, and the improved environments in U. S. A. have let the healthy natural type emerge.

Alsberg, 1912, enthusiastically agrees with the environment theory; the permanency of the races is perhaps only apparent and due to constant environment.

Boas, 1912 and 1913, has answered the criticism. By figures for errors of measurement and average error he claims to have eliminated the possibility of the results being due to insufficient material or wrong measurements. With regard to the part played by selection he states that the same change has been found on a comparison of children born in and outside America by the same parents.

Boas is very cautious in interpreting the results. He has never denied the permanency of the races, but only pointed out the possibility of changes within certain limits. The manner of bedding the children does not account for the differences, as the removal has affected children who have been taken to America after their infancy.

If errors of measurement and selection of the material can be disregarded, nothing remains but to admit that the characteristics in question are changed by environment. It is strange, however, that dolichocephalics (south Italians) should be changed towards brachycephaly, and brachycephalics (e. g. Poles) towards dolichocephaly, or both towards mesecephaly. It would have been expected that a certain environment acting in one direction, should act in the same direction for both groups. Otherwise there is nothing improbable in the assumption that the racial characters in question are variable under the influence of differing environment. The changes are not very large, 1 or 2 mm. for the head measurements, and 1 or 2 cm. for stature (4 mm. and 5 cm. respectively for less numerously represented groups). In any case environmental modification must be considered as the only possible explanation, if selection, errors of measurement and accidental variation, can be excluded. It is very improbable that the environment should be able to change the hereditary mass (idiovariation), and quite precluded in the case of children born in Europe and then moved to America.

To stretch this interpretation, however, to a general explanation of racial differences by environment, is not permissible. The differences caused by environment, as brought out by Boas, are not of a magnitude to allow such conclusions, and his investigation does not in any way prove that the changes can continue ad infinitum, being added up from one generation to another. Nor is there any reason to assume such a process.

Boas, 1920, shows on material from Porto Rico that the Spaniards are dolichocephalic, the native population brachycephalic, and the descendants of the Spaniards medium. This may be due to the descendants for a large part being bastards between the natives and Spaniards, but Boas lays stress on the possibility of the change being due to environment.

In the text-books Boas' results like those of Walcher have been differently judged.

Martin, 1914, does not regard selective processes as entirely excluded as causing the changes demonstrated by Boas.

Mollisson, 1923, finds the change in cephalic index explained by the changes in stature, but admits that this does not fully account for the results, and for the rest only emphasizes the value of the cephalic index as a racial characteristic, without further entering upon the question of environment and its influence.

Fischer, 1923 (a), quotes Boas' results, saying that although conflicting with the common view, they must not therefore be doubted. He does not consider the matter as settled.

Fischer, 1923 (b), says the only explanation of Boas' results is some modification of the shape of the skull by environment — in what way, we do not know.

From a general anthropological point of view, of course, it must be considered as established that the characteristics upon which the different anthropological measurements are founded, are hereditarily determined. Dolichocephaly is to be found in different parts of the world under the most varying environments, the same is the case with brachycephaly, etc. Lately attempts have been made more directly to demonstrate the hereditability of these characteristics. Among others, Fretz, 1917, has tried to show that the shape of the skull is heritable after Mendelian laws. Fischer's, 1923, examinations of Rehoboth bastards point in the same direction. Nevertheless, of course, as pointed out by Boas, there may exist a certain variability under the influence of differing environment. This variability cannot be very great, and the investigations of Boas himself seem to show that it is small. The problem is of great importance for anthropology. If a small difference seems to be established between two materials, hereditary and racial difference cannot therefore be taken for granted. How large a difference can be conditioned by environment? This question cannot yet be answered.

Under these conditions an investigation of the differences between monozygotic twins, may be of great interest. If the various characters are symmetric, the differences between monozygotic twins must be due to environment.

TWINS FROM AN ANTHROPOLOGICAL POINT OF VIEW.

History.

Anthropological examinations of twins have been very scarce, in spite of the interest attaching to the subject.

Thorndike 1905 has measured some 40 twins, and concludes that the variability in his material is continuous and does not indicate an essential difference between one kind more alike and another kind more differing. He is inclined to think that monozygotic twins are rather exceptional.

Fischer 1923 gives some head measurements from a pair of monozygotic twins in order to exemplify their hereditary resemblance and the negligible influence of environment.

Scheidt 1925 gives some anthropological measurements of 7 pairs of twins of very close resemblance, and further of 3 pairs probably dizygotic twins, as well as of 3 pairs which he has not been able to determine as monozygotic or dizygotic. Photographs are given.

Finally Verschuer 1925 has treated anthropological measurements of some 40 twins. Photographs are given of 32 pairs.

The results of these researches will be discussed below in connection with the results from my own investigations.

Collecting twin material.

I started to collect data about twins in 1923. The addresses of twins were obtained from the parish registers, to which circulars were sent. Employing these addresses, I then sought out and examined almost every monozygotic and several dizygotic twin pairs of Gotland (in all 102 pairs). Some twin pairs have been collected in other parts of Sweden with the aid of the addresses from the parish registers, in all 63 pairs. Finally I have received information from the head teachers in Stockholm about twin pairs in their schools, and out of these 78 pairs have been examined. Thus the total material is 243 pairs.

At the examination of the twins anthropological measurements were taken. Name and date of birth of the twins and their brothers and sisters were taken down, to serve as basis of the genealogical research mentioned p. 114. Further, information was sought about which twin was first born, which diseases they had gone through, whether they had been separated for any longer period, and other points of interest. It was noted whether they were right- or left-handed, which way they clasped their hands, and which leg was functionally preferred (see p. 177). Lastly, special characteristics, like or unlike, were noted. Diagnosis of monozygotism or dizygotism was made in accordance with the conditions laid down above (p. 148). Of course, collecting data in this way, by personal examination, is costly both in time and money, and, however desirable, with the means at my disposal it has not been possible to enlarge the material.

Measuring method.

The measurements of the twins have been taken in accordance with the directions of Martin 1914. (See Appendix I, head of Table I). It has not always been possible entirely to undress the subjects, but their clothes have been loosened, so that all measurements have been taken directly on the body. Both twins have always been measured at the same time. The following measurements have been taken: stature, sternal height, height of symphysis, height of acromion, height of tip of middle finger, bi-acromial diameter, bi-cristal diameter, length of head, breadth of head, frontal minimum diameter, face breadth, bigonial diameter, morphological face length. These are the measures that have been fixed for the examination of conscripts by the State Institute of Race-Biology. As my wife and myself have performed measurings for the Institute (both together over 30,000 persons), we were specially trained for these measurements. Partly for this reason, partly because I thought it of interest to analyse these measurements with regard to the measurings of the Institute, I decided to employ them at my examinations of twins.

Error in measuring.

The measurements, as mentioned, have been taken by my wife and myself. As a rule I (mark GD) have measured the male, my wife (mark SD) the female material. In no case, apart from the body measures of the opposite-sexed, measurements of one twin have been taken by one examiner and measurements of the other twin by the other. Systematic errors in measuring, therefore, do not affect the differences found between the twins except for body measurements of opposite-sexed pairs. As the twins have always been measured at the same time, the change taking place in stature and other measurements during the day, is eliminated as far as the differences are concerned.

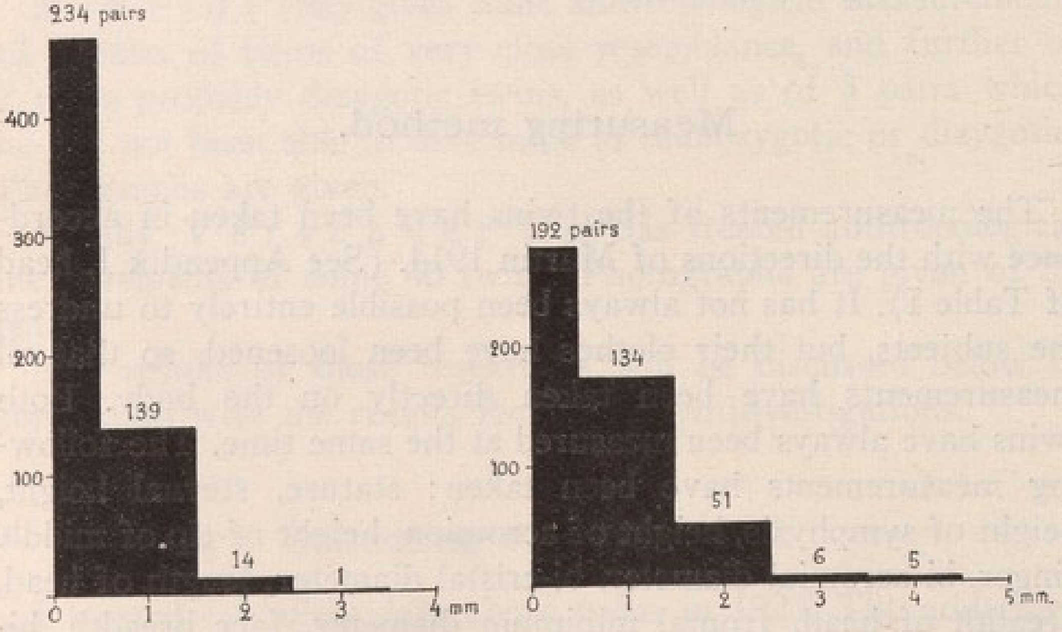

Fig. 17. The distribution of the differences (in mm.) for errors in measuring. Length of head to the left, frontal minimum diameter to the right.

In order to ascertain the accidental error in measuring, we measured a number of persons twice. After the measurements had been taken a first time, the person measured had to stand aside while another was measured, then the first one was measured again, and then the second one for the second time. On account of local conditions the measurements at these double measurings had to be taken somewhat quicker than usual, consequently the measuring error possibly was slightly higher than should be the case in my twin material.

The distribution of the differences between the two measurings are shown in the diagram Fig. 17. The differences will be seen to distribute themselves after a so-called B curve (Charlier 1910). The curve may in this case be assumed to be derived from a normal curve by omitting the signs for the differences, that is, so to speak, by folding up a normal curve. The individual values in this normal curve may in their turn have been obtained by chance subtraction, regard being had to the signs of the individual values in a normal curve for individual error values. In other words, every difference in the B curve is a difference between two chance measurings. Therefore the standard deviation for the individual measuring error, can be evolved from the standard deviation of the B curve, counting from 0, through division by $\sqrt{2}$. It must be remembered that in this case the standard deviation is the measurement within which in two cases out of three the difference between two measurings of an individual or (after division by $\sqrt{2}$) the deviation from the real value, will be found to lie (cp. Irwin 1925).

An idea of the reliability of the individual measurements may be formed by comparing the averages of the differences or the standard deviations counting from 0. In table 11 are to be found these averages for various measurements and their error, and besides the standard deviations from 0, and their error.

In this table, the error for the averages $= m_1$ is given, as calculated by the formula

$$m_1 = 1{,}0685 \cdot \frac{M}{\sqrt{2N}},$$

M being the average of the differences, and N the number of differences. This formula (Charlier 1910) has always been applied in the following by calculation of the error of averages for the differences, which corresponds to the error of the mean deviation from the average in a normal curve.

The error of the standard deviation is calculated here and in the following after the formula

$$m_2 = \frac{\sigma}{\sqrt{2N}},$$

where m_2 = the error, σ = standard deviation, and N = the number of observations.

If the average corresponds to the mean in a normal curve (Tables 14, 18, 29, and 34) the error of the average (mean) is calculated after the formula

$$m_3 = \frac{\sigma}{\sqrt{N}},$$

m_3 being the error, σ = the standard deviation, and N = the number of observations.

The figures in Table 11 show that among the *head measurements,* length and breadth are the most precise, the average difference being about 0,5 mm., the standard deviation from 0 about 0,8 mm. Least precise are morphological face length and frontal minimum diameter with an average difference of about 1,5 mm., standard deviation about 2 mm.

Among the *body measurements,* bi-cristal and bi-acromial diameter are comparatively certain, with an average measuring error of 2--3 mm. and standard deviation under 5 mm. Stature, sternal height, height of symphysis and acromion, and height of tip of middle finger are less precise, average of the differences about 5—7 mm., standard deviation 7—10 mm. As for length of trunk and arms, however, the errors to a certain extent cancel each other, and the standard deviation for these measurements is on a level with the measurements of which they are composed (length of arm = height of acromion minus height of tip of middle finger; length of trunk = sternal height minus height of symphysis).

Table 11.

Differences between Two Repeated Measurements of the Same Individual.

G. D. = head measurements: 126 pairs of measurements
body » : 265 » » »
S. D. = head » : 262 » » »
body » : 160 » » »

Measurements		Average of the differences ± standard error in mm.	Standard deviation of the differences from 0 ± error of average in mm.
Length of head	G. D.	0,51 ± 0,03	0,81 ± 0,05
	S. D.	0,40 ± 0,02	0,69 ± 0,03
Breadth » »	G. D.	0,54 ± 0,04	0,84 ± 0,05
	S. D.	0,54 ± 0,03	0,82 ± 0,04
Frontal minimum diameter	G. D.	1,38 ± 0,09	1,84 ± 0,12
	S. D.	1,25 ± 0,06	1,64 ± 0,07
Face breadth	G. D.	0,69 ± 0,05	1,01 ± 0,06
	S. D.	0,44 + 0,02	0,81 ± 0,04
Bigonial diameter	G. D.	0,65 ± 0,04	1,04 ± 0,07
	S. D.	0,73 ± 0,03	1,13 ± 0,05
Face length.....................	G. D.	1,52 ± 0,10	2,03 ± 0,13
	S. D.	1,36 ± 0,06	1,76 ± 0,08
Stature..........................	G. D.	3,56 ± 0,17	4,70 ± 0,20
	S. D.	4,57 ± 0,27	6,06 ± 0,34
Sternal height................	G. D.	4,25 ± 0,20	5,56 ± 0,24
	S. D.	5,39 ± 0,32	7,22 ± 0,40
Height of symphysis	G. D.	4,53 ± 0,21	5,59 ± 0,24
	S. D.	8,06 ± 0,48	10,57 ± 0,59
Height of acromion	G. D.	4,61 ± 0,21	5,79 ± 0,25
	S. D.	6,00 ± 0,36	7,91 ± 0,44
Height of tip of middle finger	G. D.	5,09 ± 0,24	6,49 ± 0,28
	S. D.	6,38 ± 0,38	8,27 ± 0,46
Length of arm	G. D.	4,03 ± 0,19	5,20 ± 0,23
	S. D.	6,41 ± 0,38	8,30 ± 0,46
Length of trunk..............	G. D.	5,83 ± 0,27	7,53 ± 0,33
	S. D.	9,09 ± 0,54	11,63 ± 0,65
Biacromial diameter	G. D.	3,31 ± 0,15	4,51 ± 0,20
	S. D.	2,99 ± 0,18	4,70 ± 0,26
Bicristal diameter	G. D.	1,64 ± 0,08	2,44 ± 0,11
	S. D.	1,81 ± 0,11	2,61 ± 0,15

A matter of interest, finally, is that SD throughout has more precise head measurements than GD (except for face length). The conditions are reversed for the body measurements. Probably this is so because GD has had more training on body measurements, while SD has been better trained on head measurements. Both the measurers, however, have measured a couple of thousand persons even for those measurements on which they have had least training. This indicates that the skill will still increase after having measured so large a number of persons.

Table 12.

Error in Measuring with grouping of the Material (Table II) in Three Groups of about Equal Size after the Magnitude of Corresponding Measurements for G. D.

Measurements		Number	Average ± error of average in mm.	Measurements		Number	Average ± error of average in mm.
Length of head……	173—189	39	0,31 ± 0,04	Sternal height …	1214—1379	85	3,92 ± 0,32
	190—196	56	0,66 ± 0,07		1380—1430	93	4,66 ± 0,37
	197—212	31	0,48 ± 0,07		1431—1538	87	4.14 ± 0,34
Breadth of head ……	138—147	38	0,53 ± 0,06	Height of symphysis	745—874	84	4,00 ± 0,33
	148—152	44	0,59 ± 0,07		875—904	83	4,48 ± 0,37
	153—164	44	0,50 ± 0,06		905—1032	98	5,03 ± 0,38
Frontal minimum diameter …	89—98	43	1,40 ± 0,16	Height of acromion	1200—1364	86	4,20 ± 0,34
	99—102	46	1,43 ± 0,16		1365—1414	85	4,79 ± 0,39
	103—120	37	1,30 ± 0,16		1415—1530	94	4,82 ± 0,38
Face breadth ……	123—131	39	0,79 ± 0,10	Height of tip of middle finger	517—604	93	5,37 ± 0,42
	132—136	40	0,53 ± 0,06		605—629	93	4,89 ± 0,38
	137—152	47	0,74 ± 0,08		630—712	79	5,01 ± 0,43
Bigonial diameter	90—100	40	0,88 ± 0,11	Length of arm ……	656—759	87	4,52 ± 0,37
	101—107	47	0,55 ± 0,06		760—789	92	4,05 ± 0,32
	108—117	39	0,54 ± 0,07		790—871	86	3,52 ± 0,29
Face length	107—118	45	1,67 ± 0,19	Length of trunk …	453—499	89	5,88 ± 0,47
	119—127	41	1,59 ± 0,19		500—519	80	5,16 ± 0,44
	128—144	40	1,30 ± 0,16		520—580	96	6,35 ± 0,49
				Biacromial diameter	346—379	76	3,40 ± 0,29
					380—394	87	3,44 ± 0,28
					395—439	102	2,96 ± 0,22
Stature…	1525—1684	85	2,64 ± 0,22	Bicristal diameter	224—279	92	1,75 ± 0,14
	1685—1744	103	4,04 ± 0,30		280—294	89	1,64 ± 0,13
	1745—1864	77	3,93 ± 0,34		295—337	84	1,52 ± 0,13

Table 13.

Error in Measuring with grouping of the Material (in Table II) in Three Groups of about Equal Size after the Magnitude of Corresponding Measurements for S. D.

Measurements		Number	Average ± error of average in mm.	Measurements		Number	Average ± error of average in mm.
Length of head	174—190	77	0,43 ± 0,04	Sternal height ...	1175—1304	53	6,43 ± 0,67
	191—196	108	0,39 ± 0,03		1305—1664	67	4,12 ± 0,38
	197—212	77	0,40 ± 0,03		1665—1827	40	5,74 ± 0,69
Breadth of head	140—148	78	0,53 ± 0,05	Height of symphysis	725—829	51	6,98 ± 0,74
	149—152	89	0,46 ± 0,04		830—859	53	9,74 ± 1,01
	153—166	95	0,62 ± 0,05		860 - 869	56	7,43 ± 0,75
Frontal minimum diameter...	93—101	106	1,27 ± 0,09	Height of acromion	1190—1299	53	3,75 ± 0,39
	102—105	90	1,20 ± 0,10		1300—1339	52	6,37 ± 0,67
	106—114	66	1,27 ± 0,12		1340—1529	55	5,87 ± 0,60
Face breadth	123—133	90	0,33 ± 0,03	Height of tip of middle finger	538—593	54	5,98 ± 0,61
	134—137	82	0,48 ± 0,04		594—623	52	6,06 ± 0,64
	138—151	90	0,50 ± 0,04		624—725	54	7,07 ± 0,73
Bigonial diameter...	92—101	79	0,80 ± 0,07	Length of arm	644—497	52	6,58 ± 0,69
	102—107	104	0,81 ± 0,06		698—722	55	5,96 ± 0,61
	108—115	79	0,57 ± 0,05		723—803	53	6,69 ± 0,69
Face length	109—119	80	1,31 ± 0,11	Length of trunk ...	410—467	50	9,84 ± 1,05
	120—124	92	1,30 ± 0,10		468—494	51	10,35 ± 1,10
	125—139	90	1,43 ± 0,11		495—551	59	8,51 ± 0,84
				Biacromial diameter	310—339	52	3,71 ± 0,39
					340—354	57	2,70 ± 0,27
					355—389	51	2,59 ± 0,27
Stature ...	1461—1604	53	4 51 ± 0,47	Bicristal diameter	262—282	59	1,49 ± 0,15
	1605—1664	67	4,76 ± 0,44		283—294	49	1,92 ± 0,21
	1665—1827	40	4,33 ± 0,52		295—339	52	2,06 ± 0,22

It is of interest to find whether the error in measuring increases, when the magnitude of the measurements in question increases, whether, for instance, the error in measuring is different for small persons and tall, etc. Therefore the material has been arranged after rising magnitude of the measurements, and divided into three roughly equal groups. In table 12 and 13 the averages of the differences and error of these averages are given for these groups. On the whole they seem to vary quite irregularly. The variation of the averages of the differences as a rule does not exceed the error range, sometimes the error in measuring increases when the measurement increases, sometimes it decreases. Apparently it is not necessary to reckon with very great variations in connection with variations of the measurements; *the errors in measuring are equally large* for persons of different size.

Finally it is important to know any *systematical deviations* between the two examiners' manner of measuring, as the body measurements of the opposite-sexed twins were measured by different examiners. It has been impossible to get material for comparison of body measurements, but a small number of heads were measured by both SD and GD. The results of the calculations on this material are to be found in table 14. The deviation has been calculated on the measurement of GD. Where SD's measurement was larger, the difference is counted as positive, where SD's measurement was smaller, it is counted as negative. The table shows that there are no systematic deviations for length and breadth of head and breadth of face; the mean of the differences is small, and does not exceed the error range. For the other head measurements, the mean of the differences clearly exceeds three times the error of the mean. SD measures the frontal minimum diameter on an average 2,5 mm. larger than GD, while GD measures the morphological face length 2,5 mm., and the bi-gonial diameter 1 mm. larger than SD.

Table 14.

Systematic Errors in Measuring.

If the measurement of SD is larger than that of GD the difference is calculated with plus sign; if not, with minus sign. Material: 57 differences.

Measurements	Average ± standard error in mm.
Length of head ..	— 0,07 ± 0,15
Breadth » »	— 0,09 ± 0,11
Frontal minimum diameter	+ 2.44 ± 0,32
Face breadth	— 0,21 ± 0,13
Bigonial diameter	— 0,95 ± 0,18
Face length	— 2,5 ± 0,31

Having regard to this result, naturally the existence of differences between the respective measurings of body dimensions, cannot be precluded, and as in the case of head measurements, such systematic differences are to be suspected chiefly in the less precise measurements. Their amount cannot, in the absence of material for comparison, be exactly estimated.

Anthropological differences in absolute measures.

The differences in measurements between monozygotic and dizygotic twins, distribute themselves after a *B* curve of the same type as for the error in measuring. As an instance the differences in monozygotic and dizygotic twins for frontal minimum diameter, are graphically represented in fig 18. Most of the pairs will be seen to have little or no difference, and as the difference increases, the number of pairs decreases. For the nature of the curve, I refer to what was said p. 197 about the distribution of the differences between the error in measuring.

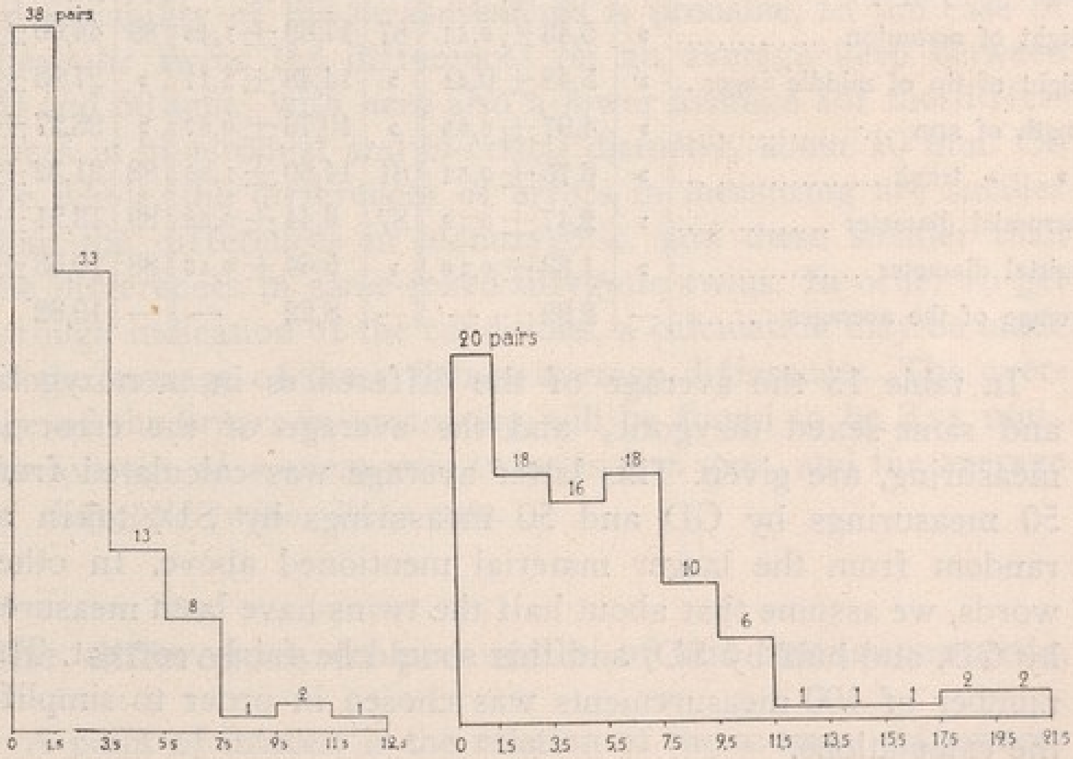

Fig. 18. The distribution of the differences (in mm.) of length of head for monozygotic (to the left), and for dizygotic (to the right).

Table 15.

Comparison between the Averages of the Differences of Errors in Measuring and among Monozygotic and Same-sexed Dizygotic, expressed in millimeter.

Measurements	Errors in measuring		Monozygotic		Same-sexed Dizygotic	
	Number	Average of the differences ± error of average mm.	Number	Average of the differences ± error of average mm.	Number	Average of the differences ± error of average mm.
Length of head	100	0,40 ± 0,03	96	2,57 ± 0,20	95	5,42 ± 0,42
Breadth » »	»	0,55 ± 0,04	»	1,74 ± 0,13	»	3,95 ± 0,31
Frontal minimum diameter	»	1,42 ± 0,11	»	1,55 ± 0,12	»	3,73 ± 0,29
Face breadth	»	0.56 ± 0,04	»	1,59 ± 0,12	»	3,53 ± 0,27
Bigonial diameter	»	0,69 ± 0,05	»	1,56 ± 0,12	»	3,82 ± 0,30
Face length	»	1,55 ± 0,12	»	2,46 ± 0,19	»	4,26 ± 0,33
Stature	»	3,54 ± 0,27	93	16,27 ± 1,28	91	50,66 ± 4,01
Sternal height	»	4,16 ± 0,31	86	14,65 ± 1,19	89	44,20 ± 3,54
Height of symphysis	»	5,37 ± 0,41	81	11,23 ± 0,94	88	35,53 ± 2,86
Height of acromion	»	5,43 ± 0,41	87	17,69 ± 1,43	89	44,00 ± 3,52
Height of tip of middle finger	»	5,48 ± 0,41	»	14,48 ± 1,17	»	27,93 ± 2,24
Length of arm	»	4,97 ± 0,38	»	10,76 ± 0,87	»	25,27 ± 2,02
» » trunk	»	6,75 ± 0,51	81	14,60 ± 1,23	88	21,32 ± 1,72
Biacromial diameter	»	2,47 ± 0,19	87	6,44 ± 0,52	89	13,21 ± 1,06
Bicristal diameter	»	1,33 ± 0,10	»	5,64 ± 0,46	88	10,53 ± 0,85
Average of the averages	—	2,98 —	—	8,22 —	—	19,82 —

In table 15 the average of the differences in monozygotic and same-sexed dizygotic, and the average of the error in measuring, are given. This latter average was calculated from 50 measurings by GD and 50 measurings by SD, taken at random from the larger material mentioned above. In other words, we assume that about half the twins have been measured by GD, and half by SD, and this should be fairly correct. The number of 100 measurements was chosen in order to simplify the calculations.

First, in regard to the *head measurements,* the average of the differences between *monozygotic* twins, keeps at about 1,5 mm.

For length of head and face, however, this difference amounts to about 2,5 mm. It will be found that the average of the *errors in measuring* is about 0,5, except in the case of frontal minimum diameter and face length, where it approaches 1,5 mm. This may, then, help to increase the variation of this latter measurements in monozygotic. The larger error for frontal minimum diameter, however, does not seem to entail any increase of the mean difference. A comparison with the *same-sexed dizygotic* shows that the average for head measurements keeps somewhat below 4 mm., while the figures for length of head and face are a little larger, than those for the other measurements (face length 4,26 mm., and length of head 5,42 mm.).

For the *body measurements* the *error in measuring* lies between 4 and 6 mm., for bi-acromial and bi-cristal diameter, however, about 2 mm. In the case of *monozygotic* twins the average difference is about 15 mm., but considerably less for bi-acromial and bi-cristal diameter, not quite 7 mm. This low figure of course is partly to be explained by the smaller error in measuring for these dimensions. On the other hand, a lessened variability of the measurements is probable. In the case of *dizygotic* twins the differences on an average keep between 20 and 50 mm., with here also a lower average for the differences in bi-acromial and bi-cristal diameter, about 10 mm. On the whole, the differences of errors in measuring are smaller than the differences in monozygotic, and these smaller than the differences in same-sexed dizygotic twins. In order to get a rough indication of the conditions, a calculation may be made of the average of these fifteen average differences. The average of the *errors in measuring* will be found to be 2,98 mm., the average of *monozygotic* twins is 8,22 mm., and the average of *dizygotic* twins, 19,82 mm.

The differences in pro mille of the measurements.

A point of interest is the relation of the average differences to the measurements in question. Therefore the differences have been calculated in pro mille of the average of the two corresponding measurements. (To get the deviation from this average, thus, the pro mille figures given should be halved).

In table 16 the averages and their errors expressed in pro mille are given.

Table 16.

Comparison between the Averages of the Differences of Errors in Measuring and among Monozygotic and Same-sexed Dizygotic, expressed in pro mille of Corresponding Measurements.

Measurements	Errors in measuring		Monozygotic		Same-sexed Dizygotic	
	Number	Average of the differences ± error of average mm.	Number	Average of the differences ± error of average mm.	Number	Average of the differences ± error of average mm.
Length of head	100	2,01 ± 0,15	96	14,22 ± 1,10	95	29,98 ± 2,32
Breadth » »	»	3,67 ± 0,28	»	11,99 ± 0,92	»	27,36 ± 2,12
Frontal minimum diameter	»	14,06 ± 1,06	»	15,95 ± 1,23	»	38,05 ± 2,95
Face breadth	»	4,17 ± 0,32	»	12,43 ± 0,96	»	28,62 ± 2,22
Bigonial diameter	»	6,74 ± 0,51	»	16,46 ± 1,27	»	40,63 ± 3,15
Face length	»	12,96 ± 0,98	»	21,67 ± 1,67	»	38,46 ± 2,98
Stature	»	2,21 ± 0,17	93	11,34 ± 0,89	91	35,39 ± 2,80
Sternal height	»	3,06 ± 0,23	86	11.68 ± 0,95	89	37,33 ± 2,99
Height of symphysis	»	6,15 ± 0,46	81	15,90 ± 1,34	88	47,38 ± 3,81
Height of acromion	»	3,97 ± 0,30	87	14,93 ± 1,21	89	37,37 ± 2,99
Height of tip of middle finger	»	8,85 ± 0,67	»	27,21 ± 2,20	»	52,89 ± 4,23
Length of arm	»	6,71 ± 0,51	»	16,75 ± 1,36	»	40,04 ± 3,21
» » trunk	»	13,90 ± 1,05	81	33,18 ± 2,79	88	49,80 ± 4,01
Biacromial diameter	»	6,50 ± 0,49	87	19,69 ± 1,59	89	47,53 ± 3,81
Bicristal diameter	»	4,57 ± 0,35	»	21,72 ± 1,76	88	41,47 ± 3,34
Average of the averages	—	6,64 —	—	17,69 —	—	39,49 —

First, as to *head measurements* for *error in measuring,* here also frontal diameter and face length show remarkably large average differences, 14,06 $^0/_{00}$ and 12,96 $^0/_{00}$ while other measurements have averages from 6,74 pro mille or less. In *monozygotic* too, we find remarkably large average of the differences for length of face, 21,67 pro mille. The difference for length of the head is not so large, about the same as for breadth of face and head, 10—15 °/₀₀. For frontal and bigonial diameter it is a little larger, 16—17 °/₀₀. The case is similar with the *same-sexed dizygotic*. Length and breadth of head and face breadth lie comparatively low, with average differences below 30 °/₀₀. For frontal and bigonial diameter and face length they are higher, about 40 °/₀₀, but the difference for face length is not, as in the case of the monozygotic, larger than for the other measurements.

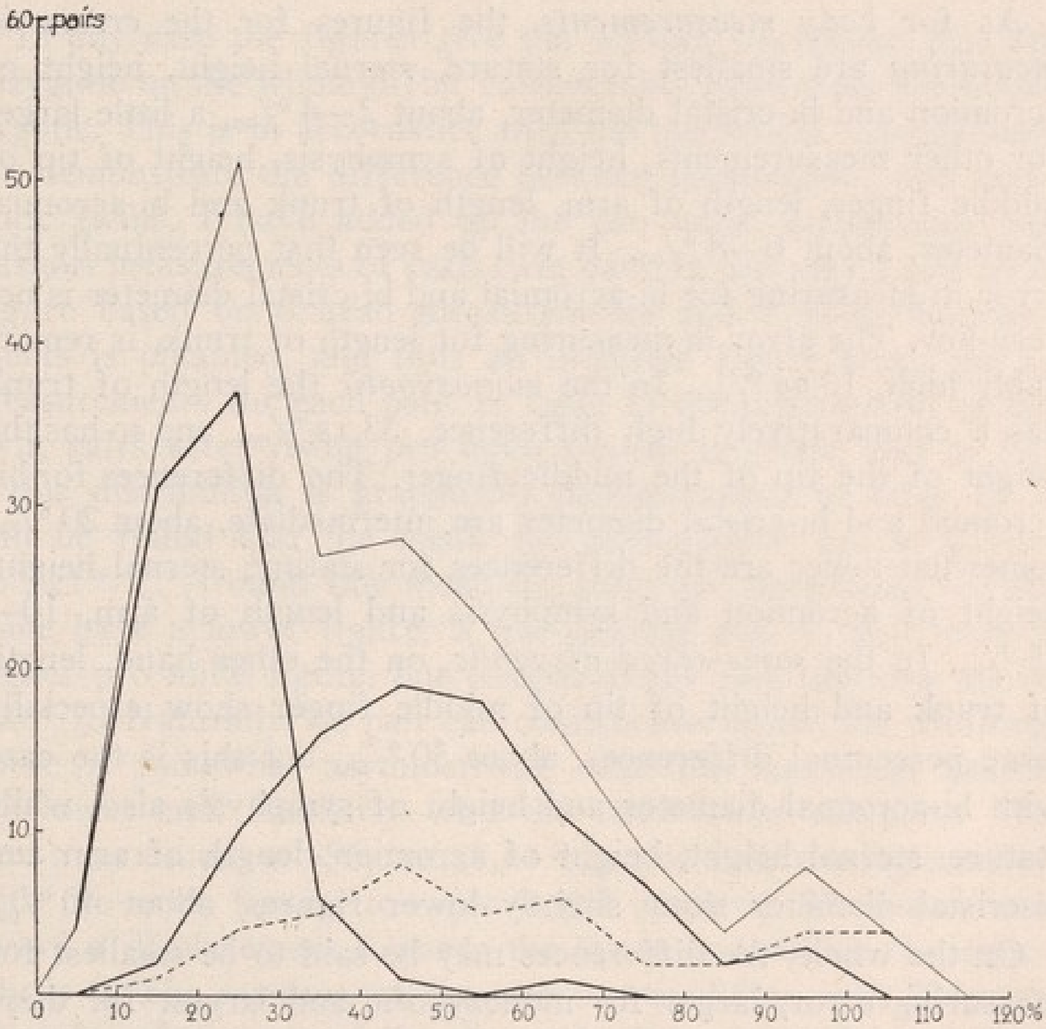

Fig. 19. Curves showing the distribution of total differences of twins, expressed in per cent. The left thick line shows the distribution of monozygotic around an average of 211 °/₀₀. The right thick line shows the distribution of same-sexed dizygotic around an average of 496 °/₀₀. The thin line shows the distribution of both monozygotic and dizygotic, and the dotted line the distribution of opposite-sexed dizygotic.

Table

Distribution after the Magnitude of the pro mille Differences in Total

Percentage	0	50	100	150	200	250	300	350	400	450
Monozygotic (number of pairs)...........	—	4	11	20	31	6	4	2	1	
Same-sexed dizygotic (number of pairs)				2	7	3	3	13	12	
Opposite-sexed dizygotic (number of pairs)				1	1	3	2	3	3	

As for *body measurements,* the figures for the *errors in measuring* are smallest for stature, sternal height, height of acromion and bi-cristal diameter, about 2—4 °/₀₀, a little larger for other measurements, height of symphysis, height of tip of middle finger, length of arm, length of trunk and bi-acromial diameter, about 6—8 °/₀₀. It will be seen that percentually the error in measuring for bi-acromial and bi-cristal diameter is not very low. The error in measuring for length of trunk, is remarkably high, 13,90 °/₀₀. In the *monozygotic* the length of trunk has a comparatively high difference, 33,18 °/₀₀, and so has the height of the tip of the middle finger. The differences for bi-acromial and bi-cristal diameter are intermediate, about 20 °/₀₀, somewhat lower are the differences for stature, sternal height, height of acromion and symphysis and length of arm, 10—15 °/₀₀. In the *same-sexed dizygotic,* on the other hand, length of trunk and height of tip of middle finger show especially large percentual differences, about 50 °/₀₀, but this is the case with bi-acromial diameter and height of symphysis also, while stature, sternal height, height of acromion, length of arm and bi-cristal diameter show slightly lower figures, about 40 °/₀₀.

On the whole, the differences may be said to be smallest for measuring error, larger for monozygotic and largest for dizygotic. If the average of these different mean figures is calculated, it will be found that the average difference for *error in measuring* amounts to 6,64 °/₀₀, for *monozygotic* 17,69 °/₀₀, and for *dizygotic* 39,49 °/₀₀. These figures are rough and undifferentiated, but may give some idea of the degree of difference to be reckoned with.

17.

among Monozygotic, Same-sexed and Opposite-sexed Dizygotic.

450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	Total
—	—	—	—	1	—	—	—	—	—	—	—	—		80
7	8	10	5	6	4	3	2	—	1	2	—	—		88
5	2	3	2	4	1	1	2	—	3	1	3	1		41

In any case the figures give the distinct impression that the dizygotic on the whole differ considerably more than the monozygotic. This is in accordance with the theoretical expectations. To demonstrate the difference between monozygotic and dizygotic twins, I have added up the pro mille differences for various measurements of each twin pair. In this way a pro mille figure based on 6 head measurements and 7 body measurements is obtained, and thus an inclusive figure based on 13 measurements for each pair. In table 17 the distribution of the twin pairs after rising pro mille figures is given, and in fig. 6 this distribution is graphically demonstrated. In table 18 it will be found that the mean for *monozygotic* lies at 211,58 ± 9,27 °/₀₀. Around this mean the pairs are distributed, so that some have a lower figure, a few coming near 0, and some a higher pro mille figure, but comparatively few reaching above 300 °/₀₀. Naturally, no pair can come below 0, and the resulting curve is somewhat asymmetrical, with the maximum nearer the lower end. Similarly with the *same-sexed dizygotic*. We find a maximum at 496,09 ± 18,60 °/₀₀, and a decreasing number with pro mille figures towards 0 and upwards. The maximum shows a displacement towards the lower end, which theoretically is 0. The maxima of the two curves differ with 284,41 ± 20,78 °/₀₀, but some of the dizygotic show values lying within the range of the monozygotic. The curves have part of their surface in common. The matter may be thus stated, that a small number of dizygotic have values as low as monozygotic, but only a small number. A figure for this coincidence can be obtained by calculating how large a part of the surface of the respective curves, lies beyond the point of intersection. Judging from the distribution of the material, it may be stated that the point of intersection will be found to lie at about 300 $^0/_{00}$. Now it will be found that 8 out of 80 monozygotic pairs lie above this figure, and 12 out of 88 dizygotic pairs below. In other words, about 10,0 % of the monozygotic fall above 300 $^0/_{00}$ and 13,6 % of the dizygotic fall under 300 $^0/_{00}$. If on measuring, a pair of twins is found to lie above 300 $^0/_{00}$, the probability that they are dizygotic is at least 90 %, and the higher this value, the greater the probability for their being dizygotic. Inversely, if the twins are found to have a percentual difference under 300 $^0/_{00}$, the probability for their being monozygotic is at least 86 %, and the lower the value, the surer the diagnosis.

Table 18.

Total of the Differences of the Different Measurements expressed in pro mille of the Corresponding Measurements for Monozygotic and Same-sexed and Opposite-sexed Dizygotic, and grouped in Male and Female and after Age.

	Number	Head measurements Mean ± error of mean	Number	Body measurements Mean ± error of mean	Number	Total Mean ± error of mean
Monozygotic	96	92,65 ± 4,98	80	120,50 ± 6,92	80	211,58 ± 9,27
Same-sexed dizygotic.....	95	201,24 ± 8,87	88	293,57 ± 15,30	88	496,09 ± 18,60
Opposite-sexed dizygotic...	52	258,12 ± 16,76	41	341,55 ± 30,39	41	594,37 ± 38,72
Monozygotic boys	46	93,80 ± 8,50	39	124,37 ± 10,01	39	214,15 ± 15,21
» girls	50	91,60 ± 5,50	41	116,82 ± 9,52	41	209,13 ± 10,89
Same-sexed dizygotic boys	38	171,35 ± 10,89	37	290,99 ± 24,10	37	463,63 ± 27,68
» » girls.	57	221,17 ± 12,20	51	295,44 ± 19,77	51	519,64 ± 24,52
Monozygotic under $10^1/_2$ years	31	78,50 ± 6,78	21	114,54 ± 10,23	21	186,41 ± 13,94
Monozygotic $10^1/_2$—$15^1/_2$ years.....................	36	92,89 ± 6,89	33	126,42 ± 11,08	33	217,81 ± 12,42
Monozygotic over $15^1/_2$ years.....................	29	107,49 ± 11,43	26	117,80 ± 13,57	26	224,00 ± 20,27
Dizygotic under $10^1/_2$ years	31	207,58 ± 16,59	25	309,86 ± 28,11	25	516,35 ± 33,60
Dizygotic $10^1/_2$—$15^1/_2$ »	39	206,52 ± 13,22	38	290,27 ± 23,35	38	501,60 ± 29,88
» over $15^1/_2$ »	25	185,16 ± 16,62	25	282,29 ± 28,91	25	467,46 ± 32,30

Thus, it will be seen that the difference in degree of resemblance, on which the diagnosis of monozygotism or dizygotism has been founded, is accompanied by a corresponding difference in anthropological resemblance. If, for instance, from the dizygotic some had been selected as showing closer resemblance in appearance, it is of course not improbable that this group would have shown a somewhat larger resemblance in measurements, but a difference in the anthropological resemblance so pronounced as the one here found, cannot be explained in that way. Naturally, it is not impossible that some isolated twin pairs may have been counted as dizygotic though being monozygotic and vice versa. This might be suspected in the few cases where dizygotic have a percentage under 300 $^0/_{00}$, and vice versa. From this point of view it is of interest to see the distribution of the *opposite-sexed dizygotic*. These have a mean percentage of 594,37±38,72 $^0/_{00}$, that is higher than the same-sexed dizygotic, though the difference of the means is not statistically established (98,28±42,96). That was to be expected. One would of course suppose that a dizygotic pair of boy-girl would differ more in anthropological measurements, than a dizygotic pair of the same sex. Also it is to be expected that isolated opposite-sexed pairs will reach considerably higher values in difference percentage, than same-sexed dizygotic, that is the curve for their distribution (see fig. 19) will reach farther from 0. It is, however, particularly important to notice that even among opposite-sexed and thus definitely dizygotic, isolated pairs have a percentage figure lower than 300 $^0/_{00}$, and come within the range of the monozygotic to the same extent as the same-sexed dizygotic. 5 pairs out of 41 fall below 300 $^0/_{00}$, that is 12,2 % of the opposite-sexed (see table 17). The material is small, and the figures of course not very exact, but perhaps enough so to prove that the two groups, opposite-sexed dizygotic, and such same-sexed as have been judged from appearance to be dizygotic, show a degree of conformity that further strengthens the previous conclusions about the existence of a fundamental difference in degree of resemblance between monozygotic and dizygotic, the differences in measurements in the monozygotic being in the main due to environment, in the dizygotic besides to hereditary variability. The theoretical assumption of greater hereditary resemblance between monozygotic twins, may be said to have been anthropologically verified.

By means of the photographs in Appendix II, I have tried to demonstrate the resemblance in appearance of the monozygotic twins in my material. As mentioned before, I have not been able to get photographs from some pairs. Photographs of a small number of dizygotic are also given. These are in no way selected, and therefore can be said to give an illustrating example of the degree of resemblance of dizygotic twins.

Comparisons between dizygotic twins and brothers.

Some interest should attach to a comparison of the anthropological differences between dizygotic twins and the differences of brothers of the same age.

On a comparison of the percentual differences between *dizygotic same-sexed and opposite-sexed,* table 19, the averages will be found to lie a little higher, about 5—10 % for opposite-sexed, than for same-sexed. The error of the averages, of course is very large, especially for the opposite-sexed, so the differences between the averages are not statistically established, but the fact that the averages for the opposite-sexed are higher in all the 15 measurements, cannot be overlooked, especially as it accords with the theoretical expectations.

Next we are going to compare the absolute values of the average differences between *same-sexed and opposite-sexed dizygotic twins, and between brothers.* The brothers were conscripts, serving in most cases during consecutive years and measured during their time of service. Consequently they were measured at roughly the same age (about 21 years) but at different times. The material is derived from the anthropological material of the State Institute of Race-Biology, and is in part measured by GD and SD, in part by other examiners. It will be found that brothers (born at different times) have nearly the same average differences as same-sexed dizygotic, but lower differences than opposite-sexed dizygotic. This is in accordance with the theoretical presumptions. It might be thought that brothers have grown up under somewhat more differing environments than same-sexed twins. If this is the case, however, it makes no perceivable difference in the figures. The differences between the average measurements are nowhere statistically established, and among 15 measurements the brothers show higher differences than same-sexed dizygotic in 8 and lower in 7. No decided tendency can be concluded. On a comparison with opposite-sexed dizygotic the averages of the differences will be found to lie considerably higher for opposite-sexed dizygotic than for brothers. This was to be expected, as in that case there is another source of difference in the measurements, namely sex. See Table 20.

Table 19.

Comparison between the Averages of the Differences among Same-sexed Dizygotic and among Opposite-sexed Dizygotic, expressed in pro mille of Corresponding Measurements.

Measurements	Same-sexed Dizygotic		Opposite-sexed Dizygotic	
	Number	Average of the differences ± error of average	Number	Average of the differences ± error of average
Length of head	95	29,98 ± 2,32	52	38,99 ± 4,09
Breadth of head	»	27,36 ± 2,12	»	36,58 ± 3,83
Frontal minimum diameter	»	38,05 ± 2,95	»	42,90 ± 4,50
Face breadth	»	28,62 ± 2,22	»	41,76 ± 4,38
Bigonial diameter	»	40,63 ± 3,15	»	46,49 ± 4,87
Face length	»	38,46 ± 2,98	»	51,92 ± 5,44
Stature	91	35,39 ± 2,80	46	42,46 ± 4,73
Sternal height	89	37,33 ± 2,99	42	43,60 ± 5,08
Height of symphysis	88	47,38 ± 3,81	»	54,90 ± 6,40
Height of acromion	89	37,37 ± 2,99	»	44,18 ± 5,15
Height of tip of middle finger	»	52,89 ± 4,23	»	57,50 ± 6,70
Length of arm	»	40,04 ± 3,21	»	56,01 ± 6,53
Length of trunk	88	49,80 ± 4,01	»	59,45 ± 6,93
Biacromial diameter	89	47,53 ± 3,81	»	60,51 ± 7,05
Bicristal diameter	88	41,47 ± 3,34	41	55,32 ± 6,53
Average of the averages	—	39,49	—	48,84

Table 20.

Comparison between the Averages of the Differences among Same-sexed Dizygotic, among Brothers, and among Opposite-sexed Dizygotic, expressed in millimeter.

Measurements	Same-sexed Dizygotic		Brothers		Opposite-sexed Dizygotic	
	Number	Average of the differences ± error of average	Number	Average of the differences ± error of average	Number	Average of the differences ± error of average
Length of head	95	5,42 ± 0,42	117	5,32 ± 0,37	52	7,10 ± 0,74
Breadth of head	»	3,95 ± 0,31	»	4,09 ± 0,29	»	5,15 ± 0,54
Frontal minimum diameter	»	3,73 ± 0,29	»	3,35 ± 0,23	»	4,02 ± 0,42
Face breadth	»	3,53 ± 0,27	»	3,91 ± 0,27	»	5,17 ± 0,54
Bigonial diameter	»	3,82 ± 0,30	»	4,15 ± 0,29	»	4,35 ± 0,46
Face length	»	4,26 ± 0,33	»	5,39 ± 0,38	»	5,79 ± 0,61
Stature	91	50,66 ± 4,01	»	46,77 ± 3,27	46	57,60 ± 6,41
Sternal height	89	44,20 ± 3,54	»	40,91 ± 2,86	42	50,71 ± 5,91
Height of symphysis	88	35,53 ± 2,86	»	32,63 ± 2,28	»	40,12 ± 4,68
Height of acromion	89	44,00 ± 3,52	»	43,62 ± 3,05	»	52,00 ± 6,06
Height of tip of middle finger	»	27,93 ± 2,24	»	25,96 ± 1,81	»	29,52 ± 3,44
Length of arm	»	25,27 ± 2,02	»	28,21 ± 1,97	»	37,24 ± 4,34
Length of trunk	88	21,32 ± 1,72	»	22,57 ± 1,58	»	25,36 ± 2,96
Biacromial diameter	89	13,21 ± 1,06	»	14,42 ± 1,01	»	18,60 ± 2,17
Bicristal diameter	88	10,53 ± 0,85	»	12,50 ± 0,87	41	13,54 ± 1,60
Average of the averages	—	19,82	—	19,59	—	23,75

To obtain a rough indicator of the conditions, here also the averages may be calculated of the averages for the 15 various measurements. It will then be found that *same-sexed dizygotic* differ 19,8 mm. and *brothers* 19,6 mm., thus showing very good accordance. *Opposite-sexed dizygotic* differ 23,8 mm., considerably more than the other two groups. This is a manifestation of the greater differences entailed by different sex determination.

Error in measuring, environment and heredity.

The anthropological differences found between monozygotic twins, are to some degree due to errors in measuring. If the twins were exactly alike, the only differences would be measuring errors. To these are now added differences due to environment. Varying environment, as above pointed out, must be expected to condition some kind of differences between the twins. The average difference between monozygotic twins being so much smaller than that of dizygotic twins, naturally seems to indicate that the monozygotic twins in the anthropological respects here in question, are hereditarily alike, having solely differences occasioned by environment. The dizygotic vary more, having in addition some hereditary differences. If the characters deciding these anthropological traits are symmetrically distributed, there seem from a theoretical point of view to be no objections to this interpretation. However, it cannot be absolutely definitely said that no genotypical asymmetries are present. For instance, it is very common that the head in its configuration is more or less asymmetric, and this gives a certain reason to suspect that genotypical asymmetries play their part among the characters that decide the shape of head and face. To some degree these asymmetries may, however, as will be shown below, be due to deformation at birth. I have not been able to find any direct investigations on the heredity of such deformities, and positive proof of the existence of genotypical asymmetries such as would cause differences in the anthropological measurements, hardly exists. This does not justify direct denial of the possibility that genotypical asymmetries to some degree contribute to the differences between monozygotic twins. For instance, it does not seem impossible that this might be the explanation of two cases given by Siemens 1924, where the head of one twin was much shorter and more pointed (in one case 6 mm. difference for length of head, in the other case 19 mm. difference. As far as can be seen from the photographs given, the configuration of the ears is in the last case remarkably differing for monozygotic twins). Weitz 1924 gives a case where one twin has much higher but shorter and thinner head. If these cases are to be interpreted as due to environment, it should be expected that the environment had been in some way strikingly dissimilar, but no indication is given of this being the case. There remains the possibility that the environmental factors influencing the development have not been accessible to observation, it may, for instance, be a question of intra-uterine influences, etc. In the face of such extreme and puzzling cases of differing shape of head in monozygotic twins*, however, it is not possible to uphold a categorical denial of the possible influence of genotypical asymmetries, and conceivably this influence also might be responsible for some of the small differences that normally appear in monozygotic twins. When below I interpret the differences between monozygotic and dizygotic twins as conditioned by environment, this is with express reservation, which only to avoid repetition I shall forbear every time to repeat. There may be genotypical asymmetries among the characters deciding the anthropological measurements, and if so the influence of environment on monozygotic twins is put somewhat too high. On the other hand, it can definitely be said that for a pair of monozygotic twins environment differs rather inconsiderably, less than for two chance individuals of a population, and from this point of view the measures found on the influence of environment, rather are too low.

In any case we can provisionally reckon with the differences between monozygotic twins being ascribable partly to errors in measuring, partly to environment. In the same-sexed dizygotic, differences caused by varying hereditary factors are added. In opposite-sexed dizygotic, finally, are further added dissimilarities due to sex factors. On the material at our disposal, the influence of these various factors can be read.

We take for starting-point the standard deviation counted from 0. This is the measure within which in two thirds of the cases a

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* Siemens, 1924 g, discusses in more detail some such extreme cases of dissimilarities in head form, and finds, issueing from the hereditary resemblance of monozygotic twins, that we here meet with the effect of intra-uterine conditions.

chance measurement will fall. While the average of the differences is a measure of the average deviation, the standard deviation can be said to constitute the twothirds deviation. If a factor gives a certain standard deviation (twothirds deviation) and another factor gives a different standard deviation, acting together and independently of each other they will give a standard deviation smaller than their sum total. Sometimes the deviations cancel each other, and add up only in some cases. The resulting standard deviation is equal to the root of the squares of both the individual deviations:

$$\sigma_1 = \sqrt{\sigma_e^2 + \sigma_m^2};$$

σ_1 is the resulting standard deviation, σ_m and σ_e the standard deviations for the individual factors.

Applying this to the monozygotic, in the above equation σ_1 stands for the standard deviation in monozygotic twins, σ_e for the standard deviation for the measuring errors alone, and σ_m for the standard deviation conditioned by environment. Both the first factors are known, and it is thus possible to calculate the last one, that is the standard deviation for external influences.

In this way a figure is found for the influence of environment on an anthropological measurement. In two individuals selected on chance, the difference between them due to external influence in two cases out of three will fall within this value, and in one case out of three beyond it. In the same way the variability in dizygotic, is constituted by the standard deviation for error in measuring, environment, heredity and sex factors.

The influence of these factors on the various anthropological measurements calculated in standard deviation (twothirds deviation) of the differences conditioned by each one individually, is to be found in Tables 21 and 22.

In Table 21 the deviations are given in mm. The differences are largest for opposite-sexed dizygotic, smaller for same-sexed dizygotic, smaller still for monozygotic, and smallest for errors in measuring. This was previously found to be so by means of the average of the differences. The standard deviation calculated for *environmental* influence will be seen to lie

Table 21.

Dispersion for the Differences between Opposite-sexed Dizygotic, Same-Sexed Dizygotic, Monozygotic, Errors in Measuring, and Dispersion calculated out of those for Environment, Heredity, and Sex, expressed in millimeter.

Measurements	Standard deviation from 0 for opposite-sexed dizygotic ± error of standard deviation	Standard deviation from 0 for same-sexed dizygotic ± error of standard deviation	Standard deviation from 0 for monozygotic ± error of standard deviation	Standard deviation from 0 for errors in measuring ± error of standard deviation	Standard deviation from 0 for environment ± error of standard deviation	Standard deviation from 0 for heredity ± error of standard deviation	Standard deviation from 0 for sex ± error of standard deviation
Length of head …………	8,83 ± 0,87	7,07 ± 0,51	3,49 ± 0,25	0,68 ± 0,05	3,42 ± 0,24	6,21 ± 0,45	5,26 ± 0,52
Breadth of heat .. ………	6,08 ± 0,60	5,10 ± 0,37	2,31 ± 0,17	0,87 ± 0,06	2,14 ± 0,16	4,55 ± 0,33	3,36 ± 0,32
Frontal minimum diameter	5,39 ± 0,53	4,47 ± 0,32	2,05 ± 0,15	1,83 ± 0,13	0,92 ± 0,07	4,06 ± 0,28	2,93 ± 0,30
Face breadth ……………	6,56 ± 0,64	4,47 ± 0,32	2,20 ± 0,16	0,87 ± 0,06	2,01 ± 0,15	3,92 ± 0,28	4,69 ± 0,47
Bigonial diameter ………	5,71 ± 0,56	4,90 ± 0,36	2,30 ± 0,17	1,02 ± 0,07	2,05 ± 0,15	4,42 ± 0,32	2,93 ± 0,28
Face length… ……………	7,07 ± 0,69	5,39 ± 0,39	3,36 ± 0,24	2,01 ± 0,14	2,69 ± 0,19	4,26 ± 0,31	4,56 ± 0,45
Stature……………………	73,65 ± 7,68	68,39 ± 5,07	21,89 ± 1,61	4,89 ± 0,35	21,34 ± 1,57	64,79 ± 4,80	27,34 ± 3,04
Sternal height……………	62,38 ± 6,80	53,60 ± 4,02	19,42 ± 1,48	5,84 ± 0,41	18,49 ± 1,41	49,95 ± 3,81	31,91 ± 3,72
Height of symphysis ……	49,24 ± 5,37	42,50 ± 3,20	14,69 ± 1,16	6,56 ± 0,46	13,12 ± 1,03	39,88 ± 3,13	24,87 ± 2,90
Height of acromion ……	66,39 ± 7,24	54,05 ± 4,05	22,62 ± 1,71	7,17 ± 0,51	21,45 ± 1,63	49,09 ± 3,72	38,55 ± 4,49
Height of tip of middle finger …………………	37,91 ± 4,13	32,94 ± 2,47	19,12 ± 1,45	6,91 ± 0,49	17,80 ± 1,35	26,81 ± 2,03	18,77 ± 2,19
Length of arm …………	46,50 ± 5,07	32,06 ± 2,41	14,39 ± 1,09	6,78 ± 0,48	12,69 ± 0,96	28,64 ± 2,17	33,68 ± 3,93
Length of trunk…………	30,70 ± 3,35	26,21 ± 1,97	18,38 ± 1,44	8,74 ± 0,62	16,16 ± 1,27	18,68 ± 1,47	15,99 ± 1,86
Biacromial diameter ……	24,12 ± 2,63	16,94 ± 1,27	9,26 ± 0,70	3,63 ± 0,26	8,52 ± 0,65	14,18 ± 1,08	17,17 ± 2,00
Bicristal diameter ………	16,90 ± 1,87	13,07 ± 0,99	8,28 ± 0,63	2,03 ± 0,14	8,03 ± 0,61	10,20 ± 0,77	10,71 ± 1,26
Average of the standard deviations ……………	29,83	24,75	10,92	3,99	10,07	21,97	16,18

considerably higher than that calculated for the errors in measuring. Taking the *head measurements* first, we find that the influence of *environment* is particularly large for length of head and face, about 3 mm. standard deviation (3,42 and 2,69 mm. respectively). The influence is remarkably small for frontal diameter, below 1 mm. standard deviation, while the standard deviation for other measurements is about 2 mm.

For the *body measurements* the environmental influence keeps at a standard deviation of 1—2 cm., approaching 2 cm. for stature, sternal height, height of acromion, height of tip of middle finger, and length of trunk, nearer 1 cm. for height of symphysis, length of arm, and bi-acromial and bi-cristal diameter.

Passing to the influence of the *hereditary* factors on *head measurements,* we find them responsible for a standard deviation of about 4 mm., being a little higher for length of head, about 6 mm. For the *body measurements* the standard deviation is about 3—4 cm., but it is particularly high for stature, above 6 cm., and a little lower for length of trunk and bi-acromial diameter, 1—2 cm.

Finally as to the influence of *sex determination,* the figures show that if two individuals have the same measuring error, environmental and hereditary influence, and then are determined to different sex, in two thirds of the cases the resulting difference will lie within the value here found and in one third of the cases beyond. Their being determined to different sex, does not mean that only in these respects they are influenced by one or more sex determining factors, but probably entails their being influenced by correlating factors more or less fixedly coupled to the sex factors. The matter might be expressed thus: the standard deviation is a measure of the influence, direct or indirect, of the tendencies contained in the sex chromosome.

It will be seen from the table that the effect on the *head measurements* amounts to 3—5 mm. standard deviation, being highest for length of head and for length and breadth of face (about 5 mm.). For the *body measurements* the effect is 2—4 cm., somewhat less for length of trunk and bi-acromial and bi-cristal diameter, 1---2 cm.

Table 22.

Dispersion for the Differences between Opposite-sexed Dizygotic, Same-sexed Dizygotic, Monozygotic, Errors in Measuring, and Dispersion calculated out of those for Environment, Heredity, and Sex, expressed in pro mille of Corresponding Measurements.

Measurements	Standard deviation from 0 for opposite-sexed dizygotic ± error of standard deviation.	Standard deviation from 0 for same-sexed dizygotic ± error of standard deviation.	Standard deviation from 0 for monozygotic ± error of standard deviation.	Standard deviation from 0 for errors in measuring ± error of standard deviation.	Standard deviation from 0 for environment ± error of standard deviation.	Standard deviation from 0 for heredity ± error of standard deviation.	Standard deviation from 0 for sex ± error of standard deviation.
Length of head	48,61 ± 4,76	39,58 ± 2,87	19,21 ± 1,39	3,38 ± 0,24	18,92 ± 1,37	34,59 ± 2,51	28,23 ± 2,76
Breadth of head	43,76 ± 4,29	23,17 ± 1,68	15,84 ± 1,14	5,77 ± 0,41	14.77 ± 1,06	32,16 ± 1,23	25,08 ± 3,65
Frontal minimum diameter	57,20 ± 5,61	46,55 ± 3,38	21,02 ± 1,52	18,19 ± 1,29	10,54 ± 0,80	41,53 ± 3,02	33,23 ± 3,25
Face breadth..................	51,95 ± 5,09	23,15 ± 1,68	16,97 ± 1,22	6,29 ± 0,44	15,78 ± 1,14	32,67 ± 0,58	36,64 ± 4,56
Bigonial diameter............	61,54 ± 6,03	33,13 ± 2,40	23,69 ± 1,71	10,10 ± 0,71	24,50 ± 1,56	46,77 ± 1,68	32,23 ± 5,08
Face length	63,52 ± 6,23	48,51 ± 3,52	29,00 ± 2,09	16,97 ± 1,20	23,50 ± 1,71	38,89 ± 2,83	41,00 ± 4,02
Stature	50,62 ± 5,28	46,29 ± 3,43	15,39 ± 1,13	3,11 ± 0,22	15,07 ± 1,11	43,65 ± 3,24	20,48 ± 2,28
Sternal height	52,34 ± 5,71	45,71 ± 3,43	15,63 ± 1,19	4,34 ± 0,31	14,97 ± 1,14	42,95 ± 3,28	25,50 ± 2,97
Height of symphysis	67,96 ± 7,41	56,15 ± 4,24	22,21 ± 1,74	7,54 ± 0,53	20,88 ± 1,64	51,57 ± 4,06	38,28 ± 4,46
Height of acromion.........	52,73 ± 5,75	46,16 ± 3,46	18,93 ± 1,43	5,25 ± 0,37	18,30 ± 1,38	42,04 ± 3,19	25,49 ± 2,97
Height of tip of middle finger	73,42 ± 8,01	62,44 ± 4,68	35,66 ± 2,71	11,18 ± 0,79	33,86 ± 2,57	51,25 ± 3,88	38,62 ± 4,50
Length of arm	74,46 ± 8,12	50,68 ± 3,80	22,61 ± 1,71	9,27 ± 0,66	20,62 ± 1,56	45,35 ± 3,44	54,55 ± 6,36
Length of trunk	71.03 ± 7,75	64,28 ± 4,85	42,41 ± 3,33	17,89 ± 1,27	38,45 ± 3,02	48,30 ± 3,80	30,22 ± 3,52
Biacromial diameter.........	70,26 ± 7,66	54,93 ± 3,12	27,94 ± 2,12	9,44 ± 0,67	26,31 ± 1,99	47,29 ± 3,58	43.81 ± 5,11
Bicristal »	72,10 ± 7,96	51,05 ± 3,85	31,01 ± 2,35	6,99 ± 0,49	30,22 ± 2,29	40,55 ± 3,08	50,92 ± 6,01
Average of the standard deviations	60,77	46,12	23,84	9,05	21,78	42,71	34,95

On a comparison of the influences by environment and heredity, the effect of heredity will be found to be much stronger than the effect of environment. The influence of sex factors and heredity, keeps on roughly the same level. In order to get an approximate figure, we once again calculate the averages for the various measurements. We then find that the standard deviation for opposite-sexed dizygotic, is on an average 29,38 mm., for same-sexed dizygotic 24,75 mm., for monozygotic 10,92 mm., and for the measuring error 3,99 mm.

Finally, the standard deviation for the influence of environment is on an average 10,07 mm., while the effect of hereditary factors keeps at 21,97 mm., and of the sex factors 16,18 mm.

If instead we reckon with the differences calculated in pro mille of the respective measurements (i. e. of the average of the two measurements of a pair) the same conditions will be found to recur (Table 22). The standard deviation for opposite-sexed dizygotic lies at 60,77 $^{0}/_{00}$, for same-sexed dizygotic at 46,12 $^{0}/_{00}$, for monozygotic at 23,84 $^{0}/_{00}$, and for measuring error at 9,05 $^{0}/_{00}$. Further, the standard deviation for environment is 21,78 $^{0}/_{00}$, while being considerably larger for hereditary and sex factors, though somewhat smaller for the latter, 42,71 $^{0}/_{00}$ for heredity, 34,95 $^{0}/_{00}$ for sex. In other words, heredity and sex have each about double the effect of environment alone.

Proceeding to the detailed figures, we find that the influence of *environment* on the *head measurements* keeps at 10—20 $^{0}/_{00}$, still being lowest for frontal minimum diameter, but not so markedly high for length of head, as when calculated in absolute measures. For the *body measurements* the effect lies between 10—30 $^{0}/_{00}$, in this case not being especially low for length of trunk, and bi-cristal and bi-acromial diameter (on the contrary approaching 30 $^{0}/_{00}$). The influence on stature and sternal height is rather small.

It will be found that the effect of *heredity* on the *head measurements* is about 30—40 $^{0}/_{00}$, and on the *body measurements* 40—50 $^{0}/_{00}$, and that the variation in the various figures is remarkably small. The same is the case with regard to the *sex factors*. The effect on *head measurements* occasions a standard deviation of 25—40 $^0/_{00}$, and on *body measurements* 20—50 $^0/_{00}$. The standard deviation is particularly high for length of arm, 54,55 $^0/_{00}$, and particularly low for stature 20,43 $^0/_{00}$. The effect of heredity and sex factors is not particularly low for length of trunk, bi-cristal and bi-acromial diameter, though it was so in the case of absolute measures.

Above we have reckoned with the standard deviation between two individuals, i. e. the values resulting in two thirds of the cases on a comparison between two individuals selected on chance from a population.

It would be simpler to express conditions in the standard deviation for this population. Now the standard deviation of the population, σ_p, is equal to the standard deviation, σ_o, for the differences between individuals paired on chance, divided by $\sqrt{2}$.

$$\text{Thus } \sigma_p = \frac{\sigma_o}{\sqrt{2}};$$

Employing this formula we are able to calculate the amount of the standard deviation for environment, heredity, and sex factors, each of these supposed to act by itself in a population. The values obtained in this way are to be found in table 23 and 24; their import is that in two thirds of the cases environment, or heredity, or sex, occasion a deviation from the mean for the population lying beyond these values, and in one third of the cases the deviation from the mean will lie within these values. It is quite evident that these measurements refer to the conditions in our original material, i. e. to the environmental and hereditary variations, etc., obtaining in this material. As regards environmental variation, it has already been pointed out that in these cases this ought to vary rather less than in the general material. Also, obviously, larger values are to be expected for a population whose members live under extremely variable conditions.

In connection with the influence of age it is pointed out below that the composition of our material in regard to age, possibly will give too low values for the effect of environment. Further, once again it must be emphasized that we do not with certainty know whether the environmental variability may not in part be due to genotypical asymmetries, i. e. to a certain extent include a hereditary variation. From this point of view the measure for environment might on the contrary be considered too large. The measurements for the effects of heredity, naturally include a hereditary variation depending only on symmetrical factors, and approximately corresponding to Swedish population. This hereditary variability, however, probably is rather low, since Swedish population is considered comparatively homogeneous in racial structure. A more heterogeneous population should have somewhat larger hereditary variability. Finally, it may be pointed out that, with regard to sex factors, the error in measuring, affecting the opposite-sexed material on which we have made our calculations, is, for body measurements, higher than the error we have employed. Those measurements are taken by different measurers (the male twin by GD, the female twin by SD), and here, therefore, is added systematic errors in measuring, the magnitude of which we do not know. Further, it might well be expected that the opposite-sexed have grown up under somewhat more differing environmental conditions than the same-sexed, and that the environmental variability therefore is somewhat larger than the variability assumed by us. From these points of view, we therefore must emphasize that the variability found by us for sex factors, is rather too high, owing to the circumstance that the variability for errors in measuring and for environment, subtracted from the variability of opposite-sexed twins, is rather too low. The material of opposite-sexed twins at our disposal, is smaller than for other categories of twins, for which reason the standard errors, as appears from the tables, are comparatively large. In spite of those sources of error, the figures we have found ought to give a fairly good approximate conception also of the magnitude of sex-linked variability.

On comparison between dizygotic twins and brothers, good accordance was found for the averages of the differences. In both these materials, consequently, error in measuring, environment, and heredity give about equal variation. This accordance between two chance, isolated parts of the population material, indicates that the figures found are fairly representative for same-sexed Swedish population.

Table 23.

Dispersion for Errors in Measuring. Environment, Heredity, Sex, and for Same-sexed Population, expressed in millimeter.

Measurements	Standard deviation from mean for same-sexed population ± error of standard deviation	Standard deviation from mean for error in measuring ± error of standard deviation	Standard deviation from mean for environment ± error of standard deviation	Standard deviation from mean for heredity ± error of standard deviation	Standard deviation from mean for sex ± error of standard deviation
Length of head	5,00 ± 0,36	0,48 ± 0,04	2,42 ± 0,17	4,39 ± 0,32	3.72 ± 0,37
Breadth of head	3,61 ± 0,26	0,62 ± 0,04	1,51 ± 0,11	3,22 ± 0,23	2,38 ± 0,23
Frontal minimum diameter	3,16 ± 0,23	1,29 ± 0,09	0,65 ± 0,05	2,87 ± 0,20	2,07 ± 0,21
Face breadth ...	3,16 ± 0,23	0,62 ± 0,04	1,42 ± 0,11	2,77 ± 0,20	3,32 ± 0,33
Bigonial diam. ..	3,47 ± 0,26	0,72 ± 0,05	1,45 ± 0,11	3,13 ± 0,23	2,07 ± 0,20
Face length	3,81 ± 0,28	1,42 ± 0,10	1,90 ± 0,13	3,01 ± 0,22	3.22 ± 0,32
Stature............	48,37 ± 3,60	3,46 ± 0,25	15,08 ± 1,11	45,82 ± 3,39	19,34 ± 2,15
Sternal height...	37,90 ± 2,85	4,13 ± 0,29	13,07 ± 1,00	35.28 ± 2,69	22,57 ± 2,63
Height of symphysis	30,05 ± 2,27	4,64 ± 0,33	9,28 ± 0,73	28,22 ± 2,21	17,59 ± 2,05
Height of acromion	38,25 ± 2,87	5,07 ± 0,36	15,17 ± 1,15	34,72 ± 2,63	27,26 ± 3,18
Height of tip of middle finger	23,26 ± 1,75	4,89 ± 0,35	12,59 ± 0,95	18,96 ± 1,44	13,27 ± 1,55
Length of arm ..	22,70 ± 1,71	4,79 ± 0,34	8.97 ± 0,68	20,25 ± 1,53	23,82 ± 2,78
Length of trunk	18,53 ± 1,40	6,18 ± 0,44	11,43 ± 0,90	13,21 ± 1,04	11,31 ± 1,32
Biacromial diam.	11,98 ± 0,90	2,57 ± 0,18	6,02 ± 0,46	10,03 ± 0,76	12,14 ± 1,41
Bicristal diam. ..	9,24 ± 0,70	1,44 ± 0,10	5,68 ± 0,43	7,21 ± 0,54	7,57 ± 0,89
Average of the standard deviations	17,50	2,82	7,12	15.54	11,44

The figures we have obtained (table 23, 24) with our above formula naturally reflect the conditions as previously worked out both in absolute and percentual measures. The effect of *environment* on *head measurements,* varies from a standard deviation (twothirds deviation) of a little more than ½ mm. for frontal minimum diameter and 1½ mm. for breadth of head and face and bigonial diameter, to nearer 2 and 2½ mm. for length of head and face. Percentually the figure for frontal diameter, 7,45 $^{0}/_{00}$, still is remarkably low and the figure for length of face, 16,62 $^{0}/_{00}$, comparatively high. The percentual variation of length of head is not so high, 13,38 $^{0}/_{00}$, while on the other hand the effect on bigonial diameter is comparatively high at 17,32 $^{0}/_{00}$. The low effect on frontal diameter is a peculiarity at present hardly to be explained. The strong influence on length of face, percentual and absolute, and on length of head in absolute measure, is a phenomenon that will be treated below (p. 246).

Table 24.

Dispersion for Errors in Measuring. Environment, Heredity, Sex, and for Same-sexed Population, expressed in pro mille of Corresponding Measurements.

Measurements	Standard deviation from mean for same-sexed population ± error of standard deviation	Standard deviation from mean for error in measuring ± error of standard deviation	Standard deviation from mean for environment ± error of standard deviation	Standard deviation from mean for heredity ± error of standard deviation	Standard deviation from mean for sex ± error of standard deviation
Length of head.	28,00 ± 2,04	2,39 ± 0,17	13,38 ± 0,97	24,47 ± 1,78	19,96 ± 1,95
Breadth of head	16,38 ± 1,19	4,08 ± 0,29	10,44 ± 0,75	22,77 ± 0,87	17,73 ± 2,58
Frontal minimum diameter	32,95 ± 2,40	12,86 ± 0,91	7,45 ± 0,57	29,35 ± 2,14	23,48 ± 2,30
Face breadth …	16,37 ± 1,19	4,45 ± 0,31	11,16 ± 0,81	23,12 ± 0,41	25,88 ± 3,22
Bigonial diam. ..	23,41 ± 1,70	7,14 ± 0,50	17,32 ± 1,11	33,09 ± 1,19	22,77 ± 3,59
Face length……	34,39 ± 2,50	12,00 ± 0,85	16,62 ± 1,21	27,51 ± 2,01	28,92 ± 2,84
Stature…………	32,74 ± 2,43	2,20 ± 0,16	10,66 ± 0,79	30,90 ± 2,29	14,48 ± 1,61
Sternal height…	32,31 ± 2,43	3,07 ± 0,22	10,58 ± 0,81	30,33 ± 2,32	18,03 ± 2,10
Height of symphysis ………	39,74 ± 3,01	5,33 ± 0,38	14,76 ± 1,16	36,49 ± 2,87	27,07 ± 3,15
Height of acromion ………	32,60 ± 2,45	3,71 ± 0,26	12,94 ± 0,98	29,77 ± 2,26	18,03 ± 2,10
Height of tip of middle finger.	44,12 ± 3,32	7,91 ± 0,56	23,97 ± 1,82	36,27 ± 2,74	27,31 ± 3,18
Length of arm..	35,85 ± 2,70	6,55 ± 0,47	14,58 ± 1,10	32,03 ± 2,43	38,58 ± 4,50
Length of trunk	45,47 ± 3,44	12,65 ± 0,90	27,15 ± 2,14	34,51 ± 2,69	21,37 ± 2,49
Biacromial diameter ………	38,82 ± 2,21	6,68 ± 0,48	18,60 ± 1,41	33,80 ± 2,53	30,98 ± 3,61
Bicristal diam. ..	36,13 ± 2,73	4,94 ± 0,35	21,37 ± 1,62	28,64 ± 2,18	36,01 ± 4,25
Average of the standard deviations ……	32,61	6,40	15,40	30,20	24,71

For the *body measurements* the standard deviation for environments is 1—1,5 cm.; bi-acromial and bi-cristal diameter show comparatively low deviation, about ½ cm. Percentually the standard deviation keeps between 10—30 ‰, and the figures for bi-acromial and bi-cristal diameter keep on the same level (about 20 ‰) as the other measurements.

The figures for *heredity* will be found to lie for *head measurements* at about 3—4 mm. and for *body measurements* at about 2—4 cm., somewhat lower for length of trunk, bi-acromial, and bi-cristal diameter, about 1 cm. Percentually the deviation for *head measurements* lies between 20—30 ‰, and for body measurements between 30—40 ‰, length of trunk, and bi-acromial, and bi-cristal diameter not showing specially low values. On the contrary the figures are remarkably even.

For the sex factors the standard deviation is 2—3 mm. for *head measurements,* and 1;5—2,5 cm. for *body measurements,* with length of trunk, bi-acromial, and bi-cristal diameter somewhat lower, about 1 cm. Percentually the deviation for *head measurements* amounts to 20—30 ‰, and for *body measurements* to 20—40 ‰, length of trunk, bi-acromial, and bi-cristal diameter not lying specially low. It will be easily apprehended that the shorter body measurements having low absolute differences, show equally large percentual difference.

Employing the averages of the standard deviation for the various measurements in order to form a rough idea of the situation, we find, as before, that the error in measuring has the smallest effect with 2,82 mm. or 6,40 ‰ standard deviation. The effect of environment gives an average of 7,12 mm. or 15,40 ‰ standard deviation, and the effect of heredity 15,54 mm. or 30,2 ‰ standard deviation, figures that are approximately on a level with the figures for sex factors, 11,44 mm. and 24,71 ‰ standard deviation.

For comparison the figures for a same-sexed population are given in the table as calculated from the dizygotic, and thus including variations for measuring error, environment, and heredity. It will be seen from the table that the standard deviation keeps between 1—4 cm. for body measurements, or 30—50 ‰, and for head measurements between 3—5 mm. or 15—35 ‰, and that on an average the standard deviation for the various measurements amounts to 17,50 mm. or 32,61 ‰.

Obviously these averages give only a very approximate figure. The different measurements do not behave in absolutely like manner, and consequently adding up of the standard deviations or the average differences for the various measurements in order to get common averages, can give only a rough and undifferentiated conception of the conditions. Keeping this reservation in mind, however, we can state that environment affects the anthropological measurements in question about half as strongly as hereditary or sex factors respectively. In two thirds of the cases environment alone occasions a deviation of the individual from the average type of less than 7 mm. or 15 $^0/_{00}$ of the measurements, and in ⅓ of the cases a deviation larger than these measures. Hereditary and sex factors separately in ⅔ of the cases occasion a deviation in the individual less than 15 mm. or 30 $^0/_{00}$ (heredity), 11 mm. or 25 $^0/_{00}$ (sex), and in ⅓ of the cases a larger deviation. In the individual sometimes these deviations add up, sometimes they cancel each other, the final result being in ⅔ of the cases a deviation of about 18 mm. or 33 $^0/_{00}$, and in ⅓ of the cases a deviation larger than these values. Evidently, however, these conditions may vary not only in the individual, but also within different populations. In a population the individual may live under more ore less uniform environmental conditions and have a more or less uniform hereditary nature than in our material, which may naturally cause changes in the figures for variability. Even if these figures thus must not be overestimated, the results are of great general interest, illustrating the extent to which environment and heredity affect anthropological measurements employed as racial characteristics.

The influence of sex.

Above we have been concerned with material that is not quite homogeneous. There are variations in age, and further both the dizygotic and monozygotic twin material is composed of male and female pairs. Conceivably, both age and sex may influence the result, i. e. another composition of the material would have given other results.

Table 25.

Comparison between the Averages of the Differences of Monozygotic Boys and Girls, expressed in millimeter.

Measurements	Boys		Girls		Difference between averages of the differences for boys and girls ± error of the difference
	Number	Average of the differences ± error of the average	Average of the differences ± error of the average	Number	
Length of head	45	2,44 ± 0,27	2,69 ± 0,28	51	− 0,25 ± 0,39
Breadth of head	»	1,91 ± 0,22	1,59 ± 0,17	»	+ 0,22 ± 0,28
Frontal minimum diameter	»	1,47 ± 0,17	1,63 ± 0,17	»	− 0,16 ± 0,24
Face breadth	»	1,84 ± 0,21	1,37 ± 0,14	»	+ 0,47 ± 0,25
Bigonial diameter	»	1,84 ± 0,21	1,31 ± 0,14	»	+ 0,53 ± 0,25
Face length	»	2,49 ± 0,28	2,43 ± 0,26	»	+ 0,06 ± 0,38
Stature	44	14,63 ± 1,67	17,73 ± 1,91	49	− 3,10 ± 2,54
Sternal height	42	14,36 ± 1,67	14,93 ± 1,70	44	− 0,57 ± 2,38
Height of symphysis	40	10,40 ± 1,24	12,05 ± 1,42	41	− 1,65 ± 1,89
Height of acromion	42	18,48 ± 2,15	16,96 ± 1,91	45	+ 1,52 ± 2,88
Height of tip of middle finger	»	16,48 ± 1,92	12,62 ± 1,42	»	+ 3,86 ± 2,39
Length of trunk	40	13,63 ± 1,63	15,56 ± 1,84	41	− 1,93 ± 2,46
Length of arm	42	11,26 ± 1,31	10,29 ± 1,16	45	+ 0,97 ± 1,75
Biacromial diameter	41	7,17 ± 0,85	5,78 ± 0,64	46	+ 1,39 ± 1,06
Bicristal diameter	»	6,20 ± 0,73	5,15 ± 0,57	»	+ 1,05 ± 0,93
Average of the means of the differences	—	8,31 —	8,14 —	—	—

First, as regards sex, the material has been divided into two groups, pairs of two boys in one group, and pairs of two girls in the other. The average differences for the various measurements of both the groups expressed in millimeter in the case of *monozygotic* (table 25), will be found to keep at roughly the same level. For some measurements the boys show higher values (9 measurements), for other measurements the girls show higher values (6 measurements), the difference nowhere exceeding the error range. Calculating the differences in per cent (table 26) we arrive at the same picture. For 9 measurements the boys show higher values, for 6 measurements the girls, and

Table 26.

Comparison between the Averages of the Differences of Monozygotic Boys and Girls, expressed in pro mille.

Measurements	Boys		Girls		Difference between ayerages of the differences for boys and girls ± error of the difference
	Number	Average of the differences ± error of the average	Average of the differences ± error of the average	Number	
Length of head	46	13,42 ± 1,49	14,94 ± 1,60	50	— 1,52 ± 2,19
Breadth of head	»	12.71 ± 1,42	11,33 ± 1,21	»	+ 1,38 ± 1,87
Frontal minimum diameter	»	14,73 ± 1,64	17,07 ± 1,82	»	— 2,34 ± 2,45
Face breadth	»	13,56 ± 1,51	11,38 ± 1,22	»	+ 2,18 ± 1,94
Bigonial diameter	»	18,74 ± 2,09	14,36 ± 1,53	»	+ 4,38 ± 2,59
Face length..............................	»	20,74 ± 2,31	22,52 ± 2,41	»	— 1,78 ± 3,34
Stature....................................	44	10,45 ± 1,19	12,15 ± 1,31	49	— 1,70 ± 1,77
Sternal height.......	42	11,46 ± 1,34	11,90 ± 1,36	44	— 0,44 ± 1,91
Height of symphysis	40	13,80 ± 1,65	17,95 ± 2,12	41	— 4,15 ± 2,69
Height of acromion	42	15,54 ± 1,81	14,37 ± 1,62	45	+ 1,17 ± 2,43
Height of tip of middle finger ...	»	31,74 ± 3,70	22,98 ± 2,59	»	+ 8,76 ± 4,52
Length of trunk.........................	40	30,60 ± 3,66	35,69 ± 4,21	41	— 5,09 ± 5,58
Length of arm	42	17,23 ± 2,01	16,32 ± 1,84	45	+ 0,91 ± 2,73
Biacromial diameter	41	21,80 ± 2,92	17,82 ± 1,98	46	+ 3,98 ± 3,53
Bicristal diameter	»	24,08 ± 2,84	19,62 ± 2,18	»	+ 4,46 ± 3,58
Average of the means of the differences	—	18,04 —	17,36 —	—	—

the differences are roughly on a level with the averages. In a way, this seems to be a contradiction. If males and females show the same difference of for instance stature, expressed in mm., this would mean — as the female stature is smaller than the male — that the percentual difference would be somewhat larger in women. The difference in measurements between men and women, responsible for this condition, is largest in the adults. However the material for a large part is composed by youths, in whom the difference in stature and other measurements between the sexes, is not so large. Consequently it is not surprising that neither in absolute nor in percentual

Table 27.

Comparison between the Averages of the Differences of Same-sexed Dizygotic Boys and Girls, expressed in millimeter.

Measurements	Boys		Girls		Difference between averages of the differences for boys and girls ± error of the difference
	Number	Average of the differences ± error of the average	Average of the differences ± error of the average	Number	
Length of head	38	4,21 ± 0,52	6,23 ± 0,62	57	− 2,02 ± 0,81
Breadth of head	»	3,37 ± 0,41	4,33 ± 0,43	»	− 0,96 ± 0,59
Frontal minimum diameter	»	3,58 ± 0,44	3,82 ± 0,38	»	− 0,24 ± 0,58
Face breadth	»	2,50 ± 0,31	4,21 ± 0,42	»	− 1,71 ± 0,52
Bigonial diameter	»	3,76 ± 0,46	3,86 ± 0,39	»	− 0,10 ± 0,60
Face length	»	4,08 ± 0,50	4,39 ± 0,44	»	− 0,31 ± 0,67
Stature	37	50,24 ± 6,24	50,94 ± 5,24	54	− 0,70 ± 8,15
Sternal height	»	47,57 ± 5,91	41,81 ± 4,38	52	+ 5,76 ± 7,36
Height of symphysis	»	36,70 ± 4,56	34,69 ± 3,67	51	+ 2,01 ± 5,85
Height of acromion	»	46,57 ± 5,79	42,17 ± 4,42	52	+ 4,40 ± 7,29
Height of tip of middle finger	»	27,14 ± 3,37	28,50 ± 2,99	»	− 1,36 ± 4,51
Length of trunk	»	22,57 ± 2,80	20,41 ± 2,16	51	+ 2,16 ± 3,54
Length of arm	»	26,59 ± 3,30	24,33 ± 2,55	52	+ 2,26 ± 4,17
Biacromial diameter	»	13,84 ± 1,72	12,77 ± 1,34	»	+ 1,07 ± 2,18
Bicristal diameter	»	8,65 ± 1,07	11,90 ± 1,26	51	− 3,25 ± 1,65
Average of the means of the differences		20,09	19,62		

measures, a sex difference has been found. Naturally, some disparity in absolute or percentual average differences will however be found on a larger material. Finally, it must be pointed out that a differing age distribution within the two groups, may level out a small difference.

Neither do the *dizygotic* exhibit any marked influence of sex on their variability (Table 27, 28). Both the absolute and the percentual average differences for boys and girls, are on a level, with the differences within the limits of the error range, except for face breadth, which in girls shows a statistically established greater average difference. It is, however, a strik-

Table 28.

Comparison between the Averages of the Differences of Same-sexed Dizygotic Boys and Girls, expressed in pro mille.

Measurements	Boys		Girls		Difference between averages of the differences for boys and girls ± error of the difference
	Number	Average of the differences ± error of the average	Average of the differences ± error of the average	Number	
Length of head	38	22,41 ± 2,75	35,03 ± 3,51	57	— 12,62 ± 4,46
Breadth of head	»	23,00 ± 2,82	30,26 ± 3,03	»	— 7,26 ± 4,14
Frontal minimum diameter	»	36,38 ± 4,46	39,17 ± 3,92	»	— 2,79 ± 5,94
Face breadth	»	20.12 ± 2,47	34,29 ± 3,43	»	— 14,17 ± 4,23
Bigonial diameter	»	39,44 ± 4,83	41,42 ± 4,15	»	— 1,98 ± 6,37
Face length	»	34,65 ± 4,25	41,00 ± 4,10	»	— 6,35 ± 5,91
Stature	37	33,23 ± 4,13	36,86 ± 3,79	54	— 3,63 ± 5,61
Sternal height	»	38,38 ± 4,77	36,59 ± 3,84	52	+ 1,79 ± 6,12
Height of symphysis	»	47,63 ± 5,92	47,19 ± 4,99	51	+ 0,44 ± 7,74
Height of acromion	»	38,80 ± 4,82	36,36 ± 3,81	52	+ 2,44 ± 6,14
Height of tip of middle finger	»	51,22 ± 6,36	54,09 ± 5,67	»	— 2,87 ± 8,52
Length of trunk	»	51,35 ± 6,38	48,67 ± 5,15	51	+ 2,68 ± 8,19
Length of arm	»	40,79 ± 5,07	39,50 ± 4,14	52	+ 1,29 ± 6,55
Biacromial diameter	»	43,71 ± 5,43	41,60 ± 4,36	»	+ 2,11 ± 6,96
Bicristal diameter	»	34,18 ± 4,25	46,76 ± 4,95	51	— 12,58 ± 6,52
Average of the means of the differences		37,02	40,59		

ing fact that for all *head measurements* the average differences are lower for boys. We cannot notice any such pervading tendency as regards the body measurements. The averages are higher for boys in six out of nine measurements. As in monozygotic there does not exist such an increase of the differences of head measurements in girls compared to those of boys, heredity should be decisive for this divergence between female and male pairs in dizygotic. Women have one x-chromosome more than men, and therefore, one should expect a larger hereditary variability in women than in men. The genes of the x-chromosome should play their part in the ensemble of genes, causing the hereditary variability as to the anthropological measurements. The more numerous the genes are, the larger is the variability. The starting-point — the increased hereditary variability in women — is not established, however, and we therefore have to content ourselves with pointing out the possibility that if women have greater variability than men, this may be caused by the surplus of genes they possess through the x-chromosome.

The fact, however, that you can notice the same tendency even in the total percentual differences (Table 18), is of a certain significance. In monozygotic, there is a very slight difference between male and female pairs — and the figures of the boys lie even a trifle above those of the girls. In dizygotic, on the contrary, the female pairs universally show higher figures for *both* head and body measurements (and total). Especially for the head measurements, the difference is comparatively marked, 49,82±16,35, that is almost established from a statistical stand-point.

In any case, it should be possible to sum up the results in this way: the distribution on male and female of the monozygotic and same-sexed dizygotic in our material, has not proved to produce any markedly differing variation of the difference within male and female pairs. However, it is not precluded that male and female pairs have a somewhat differing tendency to variation under the influence of heredity, or environment, or both. Especially for heredity it is not improbable that girls have a slightly greater variability. Such a difference between the sexes, however, if it exists, is not very large, and in any case of no marked importance for our material. The distribution on the sexes cannot be said to have had any noticeable influence on the results from our total material.

For the above calculations of the effect of the sex determining factors, we assumed that the environmental influence was equally large for boys and girls. Even if this is not an absolutely proved presumption, under these conditions it should be quite justifiable. Even with regard to the influence of heredity such a presumption may be on the whole permissible. Further it has been pointed out that during an earlier age the dissimilarities in anthropological measurements between boys and girls are rather less than in adults. In so far as a systematic difference between boys and girls exists, it should entail systematic differences in the opposite-sexed pairs. Therefore, I collated the differences in the opposite-sexed, calculated with positive sign where the boy was larger, and with negative sign where the girl was larger. The result will be found in table 29.

Table 29.

Differences in Average between Boy and Girl in Opposite-sexed Twin Pairs, marked with plus sign when the Measurement of the Boy exceed that of the Girl (otherwise minus sign), and expressed in millimeter.

Measurements	Mean of the differences ± error of mean
Length of head	+ 4,71 ± 1,04
Breadth of head	+ 3,15 ± 0,73
Frontal minimum diameter	+ 2,48 ± 0,67
Face breadth	+ 2,13 ± 0,85
Bigonial diameter	+ 2,81 ± 0,69
Face length	+ 1,71 ± 0,95
Stature	+ 18,80 ± 10,50
Sternal height	+ 13,57 ± 9,40
Height of symphysis	+ 17,31 ± 7,11
Height of acromion	+ 13,81 ± 10,02
Height of tip of middle finger	— 6,86 ± 5,75
Length of trunk	+ 2,36 ± 4,73
Length of arm	+ 20,67 ± 6,43
Biacromial diameter	+ 9,45 ± 3,42
Bicristal diameter	— 1,39 ± 2,64

The boys will be seen throughout to have larger measurements than the girls, apart from bi-cristal diameter. The girls have equally broad or broader pelvis than the boys. Further, the girls have considerably shorter arms than the boys, and thus, in spite of smaller height of acromion, equally large or larger height of tip of middle finger. With regard to the error of the means it should be stated that the differences are statistically established only for length and breadth of head, frontal diameter, bigonial diameter, and bi-acromial diameter.

The tendency, however, is so persistent that the results definitely can be summed up as follows: the males in our material are throughout larger than the females (possibly apart from bi-cristal diameter). This of course is a matter of common knowledge, I only want to confirm that it is the case in my material also. The systematic displacement found, probably has been reduced by some girls being taller than the boys during growth, but has not been entirely eliminated. Consequently, the variability that would be occasioned by the sex factors alone, is not a purely irregular variability, but consists partly of systematic differences between the sexes, that is of a tendency to displacement towards higher measurements in the males, towards lower in the females. At the same time, however, it is to be expected that hereditary factors coupled to the sex determination, would produce a variability around these systematically displaced means. To sort out these systematic tendencies from the values for variability here found, naturally, is not possible. Only, it must once again be emphasized that the variability (dispersion) found, includes not only a chance distribution on the sexes, with consequent displacement in the males towards higher values, and in the females towards lower values, but that the figure includes also an irregular variability consequent on sex determination, due to tendencies coupled to that character.

The influence of age.

It was pointed out above that a differing age distribution of the material, might cause changes in the results founded on the total material. In our material the average age for monozygotic is 15½ years, for dizygotic 14 years. The individuals on the whole have been young, but the accordance between the two groups in regard to average age, is good.

With regard to age, the material has been divided into three groups: group I — under 10½ years, group II — 10½—15½ years, and group III — above 15½ years. The number of pairs within the various groups is given in table 30, and even in this respect the accordance between monozygotic and dizygotic in the different groups, is quite good.

First, as regards the *monozygotic,* the average differences expressed in mm., table 30, for the *head measurements* nowhere give an established displacement with age. However, the averages for the youngest group, are rather lower than those for the older groups; for five measures (not length of head) the average is largest in the oldest group. This seems to indicate an increase with age. It has already been pointed out that the measuring error, expressed in mm., does not seem to be influenced by the magnitude of the measurement in question. Thus the tendency found, rather would refer to the effect of environment, that is, the differences produced by environment, would be less in younger than in older individuals. We cannot, however, give a definite opinion, as the material is too small, and the differences are not statistically established.

Neither are the differences for *body measurements* statistically established. Here also the figures are lowest for the youngest group (8 out of 9 measurements).

Calculated in pro mille of the respective measurements for *monozygotic,* the average differences for *head measurements,* almost throughout will be found to be lowest for the youngest group (not bigonial diameter). The oldest group has the highest average in four out of six measurements. As regards *body measurements* the conditions are more irregular. No decided tendency seems to be indicated. See Table 31.

In all probability, thus, the head measurements — in absolute and percentual measures — are affected by environment more strongly in older individuals, and at least in absolute measures, the body measurements also. The increase with age, however, is only just observable, and probably not very strong. However, this means that the values found in the total material for the effect of environment, rather are too low than too high, and that higher values would have been obtained if only measurements from adults had been employed.

Table 30.

Comparison between the Averages of the Differences for Different Ages in Monozygotic Twins, expressed in millimeter.

Group I: under $10^{1}/_{2}$ years. Group II: $10^{1}/_{2}$--$15^{1}/_{2}$ years.
Group III: above $15^{1}/_{2}$ years.

Measurements	Group	Number	Average of the difference ± error of average
Length of head	I	31	2,13 ± 0,29
	II	36	2,95 ± 0,37
	III	29	2,59 ± 0,36
Breadth of head	I	31	1,10 ± 0,15
	II	36	2,03 ± 0,26
	III	29	2,07 ± 0,29
Frontal minimum diameter	I	31	1,45 ± 0,20
	II	36	1,53 ± 0,19
	III	29	1,69 ± 0,24
Face breadth	I	31	1,29 ± 0,18
	II	36	1,50 ± 0,19
	III	29	2,03 ± 0,28
Bigonial diameter	I	31	1,35 ± 0,18
	II	36	1,33 ± 0,17
	III	29	2,10 ± 0,29
Face length	I	31	1,71 ± 0,23
	II	36	2,36 ± 0,30
	III	29	3,38 ± 0,47
Stature	I	30	13,33 ± 1,84
	II	35	22,57 ± 2,88
	III	28	11,54 ± 1,65

Measurements	Group	Number	Average of the difference ± error of average
Sternal height	I	25	10,04 ± 1,52
	II	34	19,85 ± 2,57
	III	27	12,37 ± 1,80
Height of symphysis	I	22	10,45 ± 1,68
	II	33	11,82 ± 1,56
	III	26	11,15 ± 1,65
Height of acromion	I	25	14,44 ± 2,18
	II	34	21,44 ± 2,78
	III	28	16,04 ± 2,29
Height of tip of middle finger	I	25	11,96 ± 1,81
	II	34	14,62 ± 1,89
	III	28	17,07 ± 2,44
Length of trunk	I	22	12,86 ± 2,07
	II	33	16,36 ± 2,15
	III	26	13,85 ± 2,04
Length of arm	I	25	9,08 ± 1,37
	II	34	12,47 ± 1,62
	III	28	10,18 ± 1,45
Biacromial diameter	I	24	4,38 ± 0,68
	II	35	5,97 ± 0,76
	III	28	8,79 ± 1,26
Bicristal diameter	I	24	4,54 ± 0,71
	II	35	4,89 ± 0,62
	III	28	7,54 ± 1,08

Table 31.

Comparison between the Averages of the Differences for Different Ages in Monozygotic Twins, expressed in pro mille of Corresponding Measurements.

Group I: under 10½ years. Group II: 10½—15½ years.
Group III: above 15½ years.

Measurements	Group	Number	Average of the difference ± error of average
Length of head	I	31	12,45 ± 1,69
	II	36	16,06 ± 2,02
	III	29	13,81 ± 1,94
Breadth of head	I	31	7,42 ± 1,01
	II	36	14,10 ± 1,77
	III	29	13,92 ± 1,95
Frontal minimum diameter	I	31	15,65 ± 2,12
	II	36	15,50 ± 1,95
	III	29	16,82 ± 2,36
Face breadth	I	31	10,79 ± 1,46
	II	36	11,72 ± 1,48
	III	29	15,06 ± 2,11
Bigonial diameter	I	31	15,48 ± 2,10
	II	36	14,05 ± 1,77
	III	29	20,50 ± 2,88
Face length	I	31	16,42 ± 2,23
	II	36	21,46 ± 2,70
	III	29	27,54 ± 3,86
Stature	I	30	11,23 ± 1,55
	II	35	14,90 ± 1,90
	III	28	7,02 ± 1,00

Measurements	Group	Number	Average of the difference ± error of average
Sternal height	I	25	9,10 ± 1,37
	II	34	15,68 ± 2,03
	III	27	9,04 ± 1,31
Height of symphysis	I	22	20,35 ± 3,28
	II	33	15,25 ± 2,01
	III	26	12,95 ± 1,92
Height of acromion	I	25	14,65 ± 2,21
	II	34	17,57 ± 2,28
	III	28	11,98 ± 1,71
Height of tip of middle finger	I	25	25,19 ± 3,81
	II	34	27,98 ± 3,62
	III	28	28,06 ± 4,01
Length of trunk	I	22	35,64 ± 5,74
	II	33	36,73 ± 4,83
	III	26	26,57 ± 3,94
Length of arm	I	25	16,94 ± 2,56
	II	34	18,96 ± 2,46
	III	28	13,92 ± 1,99
Biacromial diameter	I	24	16,70 ± 2,58
	II	35	18,78 ± 2,40
	III	28	23,40 ± 3,34
Bicristal diameter	I	24	21,86 ± 3,37
	II	35	19,58 ± 2,50
	III	28	24,28 ± 3,47

Table 32.

Comparison between Averages of the Differences for Different Ages in Same-sexed Dizygotic Twins, expressed in millimeter.

Group I: under 10½ years. Group II: 10½—15½ years.
Group III: above 15½ years.

Measurements	Group	Number	Average of the difference ± error of average
Length of head	I	31	6,39 ± 0,89
	II	39	5,33 ± 0,64
	III	25	4,36 ± 0,66
Breadth of head	I	31	3,65 ± 0,50
	II	39	4,38 ± 0,53
	III	25	3,64 ± 0,55
Frontal minimum diameter	I	31	3,77 ± 0,51
	II	39	3,33 ± 0,40
	III	25	4,28 ± 0,65
Face breadth	I	31	3,32 ± 0,45
	II	39	3,87 ± 0,47
	III	25	3,24 ± 0,49
Bigonial diameter	I	31	3,71 ± 0,50
	II	39	3,69 ± 0,45
	III	25	4,16 ± 0,63
Face length	I	31	3,61 ± 0,49
	II	39	4,54 ± 0,55
	III	25	4,64 ± 0,70
Stature	I	28	41,79 ± 5,97
	II	38	58,05 ± 7,11
	III	25	49,36 ± 7,46

Measurements	Group	Number	Average of the difference ± error of average
Sternal height	I	26	42,42 ± 6,28
	II	38	45,89 ± 5,62
	III	25	43,48 ± 6,57
Height of symphysis	I	25	33,60 ± 5,08
	II	38	35,84 ± 4,39
	III	25	37,00 ± 5,59
Height of acromion	I	26	39,85 ± 5,90
	II	38	43,34 ± 5,31
	III	25	49,32 ± 7,45
Height of tip of middle finger	I	26	30,79 ± 4,56
	II	38	24,08 ± 2,95
	III	25	31,64 ± 4,78
Length of trunk	I	25	21,24 ± 3,21
	II	38	21,42 ± 2,63
	III	25	21,24 ± 3,21
Length of arm	I	26	24,04 ± 3,56
	II	38	28,52 ± 3,50
	III	25	21,60 ± 3,26
Biacromial diameter	I	26	11,04 ± 1,64
	II	38	13,45 ± 1,65
	III	25	15,12 ± 2,28
Bicristal diameter	I	25	8,45 ± 1,28
	II	38	10,82 ± 1,33
	III	25	12,16 ± 1,84

Table 33.

Comparison between the Averages of the Differences of Different Ages in Same-sexed Dizygotic Twins, expressed in pro mille of Corresponding Measurements.

Group I: under $10^{1}/_{2}$ years. Group II: $10^{1}/_{2}$—$15^{1}/_{2}$ years.
Group III: above $15^{1}/_{2}$ years.

Measurements	Group	Number	Average of the difference ± error of average
Length of head	I	31	36,04 ± 4,89
	II	39	29,57 ± 3,58
	III	25	23,11 ± 3,49
Breadth of head	I	31	26,19 ± 3,55
	II	39	30,88 ± 3,73
	III	25	23,31 ± 3,52
Frontal minimum diameter	I	31	39,88 ± 5,41
	II	39	34,16 ± 4,13
	III	25	41,87 ± 6,32
Face breadth	I	31	27,65 ± 3,75
	II	39	31,83 ± 3,85
	III	25	24,81 ± 3,75
Bigonial diameter	I	31	41,95 ± 5,69
	II	39	39,74 ± 4,81
	III	25	40,38 ± 6,10
Face length	I	31	36,01 ± 4,89
	II	39	40,36 ± 4,88
	III	25	38,54 ± 5,82
Stature	I	28	32,83 ± 4,69
	II	38	40,94 ± 5,02
	III	25	29,81 ± 4,50

Measurements	Group	Number	Average of the difference ± error of average
Sternal height	I	26	41,37 ± 6,13
	II	38	38,60 ± 4,73
	III	25	31,22 ± 4,72
Height of symphysis	I	25	50,69 ± 7,66
	II	38	47,90 ± 5,87
	III	25	43,26 ± 6,53
Height of acromion	I	26	38,98 ± 5,77
	II	38	36,61 ± 4,49
	III	25	36,85 ± 5,57
Height of tip of middle finger	I	26	66,02 ± 9,78
	II	38	44,52 ± 5,46
	III	25	51,96 ± 7,85
Length of trunk	I	25	58,44 ± 8,83
	II	38	48,98 ± 6,00
	III	25	42,40 ± 6,40
Length of arm	I	26	43,51 ± 6,45
	II	38	44,76 ± 5,49
	III	25	29,25 ± 4,68
Biacromial diameter	I	26	42,81 ± 6,34
	II	38	43,26 ± 5,30
	III	25	40,94 ± 6,18
Bicristal diameter	I	25	40,88 ± 6,18
	II	38	41,58 ± 5,10
	III	25	41,89 ± 6,33

Proceeding to the *dizygotic,* we find no established differences between the averages of the groups, neither for *head measurements,* nor for *body measurements.* Nor is any definite tendency to be read out of the figures (table 32). Calculating the differences in pro mille of the respective measurements, we get the same result, Table 33. The material is small, and a definite opinion cannot be given. However, a slight increase with age as shown above is probable for the effect of environment. The hereditary variability, however, is so large, compared with the environmental variability, that the variability of the dizygotic is decided chiefly by heredity, the small variations occasioned by environment being quite inconsiderable. Therefore, there is every justification for ascribing the conditions demonstrated to heredity, and we then must confine ourselves to the statement that in our material there is no indication of a change with age of the variability caused by hereditary factors (obviously, if the effect expressed in mm. is constant, the percentual effect will decrease with age).

It is of interest in this connection to look at our figures in table 18. In this table you find grouping after age with regard to total percentual differences for head measurements, body measurements, and for the total number of measurements. In monozygotic, we find that for head measurements, the figures rise with age, and a similar tendency is to be found in body measurements (the middle group shows the highest figure, however), and for total, too. This accords with what we have already stated — a slight increase with age of the effect of environment.

A comparison of the figures for dizygotic, divided in age groups, rather points to their differences' decreasing with age. This, on the other hand, might be interpreted as a sign of decrease with age of the variability caused by heredity. The differences between the age groups, however, are very small, and the result cannot be said to contradict the conclusion we have before drawn, that, in our material, there hardly exists any considerably change of the variability with age due to heredity.

The material of opposite-sexed at our disposal is too small to make an investigation on the influence of age worth while.

As above pointed out the differences between male and female individuals on the whole increased with age, being most pronounced in adults. In our material the average age is 12½ years. Consequently somewhat larger values for the effect of sex factors must be reckoned with in the case of adults.

It was mentioned above that the effect found for age may possibly include a difference between the average deviations in boys and in girls. The average age in our material is 15 years for monozygotic boys, and 16 years for monozygotic girls. Thus, we are concerned chiefly with young individuals, and the average age for the two groups does not differ very much. All the same, there are dissimilarities in the age distribution within the groups. As, however, the effect of age is so small as to be hardly observable in monozygotic, and smaller still for the dizygotic, it can hardly play any part for the average differences in males or females.

Before leaving the question of the influence of age, I must emphasize another point. As above pointed out, in connection with the differences at birth between monozygotic and dizygotic twins, the average differences for stature are nearly equal for these two groups, in the tenth month amounting to 2,2 cm. for monozygotic, and 1,6 cm. for dizygotic, in the ninth month to 1,8 cm. for both monozygotic and dizygotic (cf. table p. 153). The pronounced difference in older individuals between the average differences in monozygotic and dizygotic, consequently does not exist in the new-born. Above, this was ascribed to the greater dissimilarities in intra-uterine conditions for the twins in a monozygotic pair (circulatory asymmetries). A comparison between the new-born monozygotic and the older monozygotic in our material, will show that the average differences in absolute measure have somewhat higher values for the new-born (2,0 cm. for those born in the 9th and 10th month) than for adults (1,6 cm.). Percentually, the differences are about 40 $^{0}/_{00}$ in younger individuals, 11 $^{0}/_{00}$ in adults, that is to say, considerably larger in monozygotic new-born. Probably, the measuring errors are comparatively large in the case of new-born, and this may to some extent explain the larger absolute values, but it can hardly explain the average differences being percentually so much larger (about four times) than in adults. In regard to stature it can thus be stated that the effect of intra-uterine conditions, calculated in per cent of this measurement, is very strong. During the time immediately after birth, however, this difference is levelled out, and later on the differences due to environment may increase again. This would mean that when the development of one of a monozygotic twin pair has been retarded, and that of the other one accelerated, as a consequence of differing conditions, as they come into more equal conditions, the growth of the one previously retarded would tend to be hastened (percentually reckoned). It seems as if a disposition arrested by external factors would store up energy, getting relatively increased strength to break through when the retarding conditions have ceased to act. On the other hand, the smaller twin very probably will get somewhat *better* conditions after birth, being more carefully nursed. Thus, it is not possible to draw definite conclusions from the one observation at our disposal. For other measurements than stature, we have no figures, but considering the points here set forth, the importance of exact examinations of the anthropological measurements of new-born monozygotic twins must be emphasized.

Finally it should be mentioned that possibly part of the differences due to intra-uterine conditions will last into adult age, or in other words, that the larger twin of a new-born monozygotic pair, will grow up to be the larger.

Anthropological dissimilarities between first and second born twins.

Probably a great many environmental factors decide the anthropological dissimilarities between monozygotic twins. Naturally there are great difficulties in the way of an analysis of the whole complex of active factors. The effect of one factor, however can be approximatively estimated, namely the deformation of the head at birth. At twin births as well as at ordinary births head presentation is the most common. According to Strassmann 1904 the first twin would be born in head presenting in about 68 %. This posture generally causes considerable modification of the shape of the head in the direction of dolichocephaly, and conceivably this modification may be lasting. The twin born as no. 2 does not undergo at all so strong deformation, his birth being accomplished comparatively quickly.

I have collected some information about the order of the twins at birth. In some cases I have not been able to get any information; the material consists of 71 pairs.

If the differences for head measurements are calculated from the measurements of the second-born, with positive sign if the first born is larger, and with negative sign if the first born is smaller, the following figures appear (Table 34).

Table 34.

First-born Monozygotic Twins Compared to Later-born Monozygotic Twins.

The differences are calculated with plus sign, if the first-born twin is larger, otherwise with minus sign.

Measurements	Mean of the difference ± error of mean
Length of head	+ 1,25 ± 0,40
Breadth of head	+ 0,36 ± 0,32
Frontal minimum diameter	— 0,30 ± 0,25
Face breadth	— 0,04 ± 0,26
Bigonial diameter	+ 0,40 ± 0,26
Face length	+ 1,08 ± 0,38
Stature	+ 2,61 ± 2,33
Sternal height	+ 1,98 ± 2,30
Height of symphysis	+ 4,32 ± 1,84
Height of acromion	+ 1,66 ± 2,76
Height of tip of middle finger	+ 1,88 ± 2,43
Length of arm	— 0,19 ± 1,77
Length of trunk	— 2,59 ± 2,32
Biacromial diameter	+ 0,87 ± 1,19
Bicristal diameter	+ 1,31 ± 1,04

It will be seen from the figures that on an average the first-born have 1,25 mm. longer head, and 1,08 mm. longer face length than the second-born. For length of head the mean of the differences between first-born and second-born amounts to 3 times the error of the mean, and may thus be considered as established. For face length the mean of the differences is almost 3 times the error of the mean, and may be regarded as very nearly established. The mean of the differences for the other head measurements lie well within their error range.

A glance at table 15 p. 204 will show that in monozygotic twins the average of the differences for head measurements, amounts to about 1,5 mm., while on the other hand the averages for length of head and of face amount to 2,5 mm. This is what would be expected. A great many factors influence the head measurements, causing differences of about 1,5 mm., but length of head and face are increased in the first born with averagely 1 mm., and are then sometimes still more increased, sometimes reduced by other environmental factors, so that an average higher than that for the other measurements results. However, this difference in the case of face length may, at least in part, be due to the larger measuring error. To check the result, we pass on to the figures for influence of environment (table 21). We find that the effect of environment is particularly high for length of head, standard deviation, 3,42 mm., and length of face 2,69 mm., while for other measurements the effect is about 2 mm. (2,14—0,92). The increased effect of environment, consequently, is due to a lasting deformation at birth.

Naturally, the figures found are to be regarded as minimum figures. The first born twin in ⅔ of the cases, is born with head presenting. Even though the mortality at breech presentation and transversal presentation is comparatively large, and thus the percentage of those born with head presenting is larger among the living, all have not been born in that way. Further the deformation does not in every case of head presentation tend towards dolichocephaly, (e. g. face presentation). I have observed one such case of monozygotic twins, which is of interest from this point of view. The first born was said to have had the back of the head flattened, and at the examination (age 4 years) had 6 mm. smaller length of head. If those cases could be sorted out from the material that have had the head deformed at birth towards brachycephaly, the elongation for the remainder would certainly prove to be much larger. Furthermore, twin-bearing mothers comparatively often are multiparous, and thus the head of the child is not subjected to so heavy deformation, as at first births. Consequently, the general deformation of the head towards dolichocephaly in a population, probably is considerably more than 1 mm. both for length of head and length of face.

With regard to these results the investigations of Walcher, above mentioned (p. 187) are of great interest. Although the deformation of the head at partus is largely modified during the time immediately after birth, it does not completely disappear, and it seems probable that the position of the head and the kind of bedding also may have a certain influence on the shape of the head. A lateral position on hard bedding should be expected to make the deformation towards dolichocephaly, usually caused at birth, more lasting than in the case of back position on a soft bedding. Even if Walcher's results by themselves cannot be taken as evidence, (as was pointed out p. 188), they gain in probability by the results here set forth. Backman, 1912, in his work "Über Bathro- und Clinocephalie", has also emphasized the importance of partus deformation as regards changes in the shape of the head in adults.

Especially as regards the increase in face length, it must be emphasized that as far as I know no elongation of the face caused at birth, has previously been noticed. Therefore, it was with some surprise that I found evidence of such a deformation in the figures. On the other hand, it is not improbable, considering the direction of pressure at partus, that an elongation of the head may be accompanied by an elongation of the face. Schematically, the head in sagittal section may be regarded as a circle. At birth this circle is flattened out to a more eliptical shape, with the back of the head at one end of the longer axis, and the chin at the other end of the axis. This should cause an elongation of both the length of head, and the length of face.

In passing from this problem, one more matter must be pointed out. In adults a distinct asymmetry of the head is almost always to be observed, particularly noticeable in the shape of the front, and in the angle formed by a line drawn through the angles of the mandible and the perpendicular symmetry line of the face. At birth, of course, the deformation is not symmetric, the bones of the skull being displaced towards one side. It is not improbable that the asymmetry in the adult head (in the configuration both of skull and face) at least in part is due to this deformation. As an instance I may mention that in one of my cases the first born has a much more pronounced asymmetry than the second born. This may be seen in the photograph, nr. 94.

In the table 34, there is one striking peculiarity: the mean of the differences deviates in positive direction for most measurements even if length of head and face length are excluded. The first born is larger in 9 out of 13 measurements according to this table.

The deviations throughout lie within the limits of the mean error, but they tend so consistently in positive direction that it seems fair to conclude that the first born has larger average measurements.

This would be in accordance with the rule that in monozygotic twins the first-born weighs more than the second-born (according to Strassmann 1904 in 91 %). This difference in weight should be accompanied by a difference in size, which possibly has not been entirely levelled out even in adult twins. On this point, however, our above figures only give a certain probability, and cannot be regarded as absolutely binding. However, they strengthen the suspicions expressed at the end of the previous chapter.

The interrelation of the measurements.

We have pointed out above the displacements of different anthropological measurements, caused by environment, heredity and sex factors. It is further of particular interest to observe to what extent these displacements manifest themselves in the calculations of indices. In table 35 are given the averages of the differences for certain indices of head measurements in-

Table 35.

Differences of Index.

Averages for the Differences of Index.

	Number	Average of the difference ± error of average for errors in measuring	Number	Average of the difference ± error of average for monozygotic	Number	Average of the difference ± error of average for same-sexed dizygotic	Number	Average of the difference ± error of average for opposite-sexed dizygotic
No. 22. Length of head × breadth of head	100	0,35 ± 0,03	96	1,46 ± 0,11	95	2,70 ± 0,21	52	2,93 ± 0,31
No. 25. Face breadth × face length	»	1,24 ± 0,09	»	2,15 ± 0,17	»	4,05 ± 0,31	»	4,81 ± 0,50
No. 26. Frontal minimum diameter × face breadth	»	1,12 ± 0,09	»	1,33 ± 0,10	»	2,59 ± 0,20	»	2,89 ± 0,30
No. 27. Bigonial diameter × face breadth	»	0,63 ± 0,05	»	1,17 ± 0,10	»	2,51 ± 0,19	»	3,00 ± 0,31

Standard Deviation from 0 for the Differences of Index.

	Standard deviation from 0 ± error of deviation for opposite-sexed dizygotic	Standard deviation from 0 ± error of deviation for same-sexed dizygotic	Standard deviation from 0 ± error of deviation for monozygotic	Standard deviation from 0 ± error of deviation for errors in measuring	Standard deviation from 0 ± error of deviation for environment	Standard deviation from 0 ± error of deviation for heredity	Standard deviation from 0 ± error of deviation for sex factors
No. 22. Length of head × breadth of head	3,84 ± 0,03	3,65 ± 0,14	1,98 ± 0,26	0,49 ± 0,38	1,92 ± 0,14	3,06 ± 0,22	1,20 ± 0,12
No. 25. Face length × face breadth ...	6,05 ± 0,12	5,14 ± 0,21	2,89 ± 0,37	1,63 ± 0,59	2,39 ± 0,17	4,24 ± 0,31	3,19 ± 0,31
No. 26. Frontal minimum diameter × face breadth	3,64 ± 0,10	3,42 ± 0,12	1,65 ± 0,25	1,39 ± 0,36	0,89 ± 0,06	2,99 ± 0,22	1,26 ± 0,11
No. 27. Bigonial diameter × face breadth	4,00 ± 0,06	3,50 ± 0,11	1,55 ± 0,25	0,85 ± 0,39	1,29 ± 0,09	3,14 ± 0,23	1,94 ± 0,19

Standard Deviation of Index from Mean in a Population.

	Standard deviation from mean ± error of deviation for same-sexed population	Standard deviation from mean ± error of deviation for errors in measuring	Standard deviation from mean ± error of deviation for environment	Standard deviation from mean ± error of deviation for heredity	Standard deviation from mean ± error of deviation for sex factors
No. 22. Length of head × breadth of head	2,58 ± 0,10	0,35 ± 0,27	1,36 ± 0,10	2,16 ± 0,16	0,85 ± 0,08
No. 25. Face breadth × face length	3,63 ± 0,15	1,15 ± 0,42	1,69 ± 0,12	3,00 ± 0,22	2,26 ± 0,22
No. 26. Frontal minimum diameter × face breadth	2,42 ± 0,08	0,98 ± 0,25	0,63 ± 0,04	2,11 ± 0,16	0,89 ± 0,08
No. 27. Bigonial diameter × face breadth	2,47 ± 0,08	0,60 ± 0,28	0,91 ± 0,06	2,22 ± 0,16	1,37 ± 0,13

troduced through errors in measuring and averages of the differences for the monozygotic, the same-sexed dizygotic, and the opposite-sexed dizygotic twins.

As before, we find that the figures are lowest in the errors in measuring, higher for monozygotic, and still higher for same-sexed dizygotic, and highest for opposite-sexed dizygotic. Further, we find that the means of the differences are fairly comparable with those figures we obtained when calculating the differences of the measurements in pro mille of corresponding measurements (cp. table 16 p. 206). For errors in measuring, the means of indices lie at 0,35—1,24 units, for the head measurements, the means of the percentual differences lie at 0,201—1,406 %. For monozygotic, the means of indices are 1,33—2,55 units, for the head measurements of monozygotic, the means of the percentual differences are 1,199—2,167 %. For same-sexed dizygotic, the means of indices are 2,51—4,05 units, for the head measurements, 2,862—4,063 %. For opposite-sexed dizygotic, the means of indices 2,93—4,81, for the head measurements, the means of the percentual differences are 3,899—5,192 %.

In table 35, we meet with similar figures to the standard dispersion for index, counted from 0. It is lowest for errors in measuring, higher for monozygotic, and still higher for same-sexed dizygotic, and highest for opposite-sexed dizygotic twins. Further, the standard dispersion for index in the different groups is on a level with the standard dispersion for the percentual differences of the head measurements. Cp. table 22, p. 220.

The fact that the means of the differences of index percentually correspond fairly well with the means of the differences of the single measurements, points to the differences being independent of one another to a certain extent. If both measurements continually increased or decreased at the same time, there ought to be remarkably small displacements of their indices. If one measurement kept increasing while the other one was decreasing, there ought to be particularly large displacements of indices. Of course the values found do not exclude the possibility of a certain connection between the displacements of the measurements. It might well be imagined that the displacements go together to some extent, that if one twin is larger than the other as regards a certain measurement, he is frequently larger as regards another measurement, too.

In table 35, we have further, in the same way as before (p. 251), calculated the standard deviation counted from 0 that environmental, hereditary and sex factors were to cause in the indices. Observing first the figures for environment, we find that the effect of environment is larger for indices 22 and 25 (1,92 and 2,39 respectively), and smaller for indices 26 and 27 (0,89 and 1,29 respectively). This is fully explained by the fact that in the two first-mentioned indices are included head length, respectively face length, which measurements, as has been shown, are strongly influenced by environment (partus deformation!) For the hereditarily conditioned factors, the standard deviation for the differences keeps at 2,99—4,24 units, and for sex factors, at 1,20—3,19 units. In table 35 are given corresponding figures for the standard deviation from average in a population for errors in measuring, environment, heredity, sex factors, and for same-sexed population.

The circumstance that the figures for the index differences vary for hereditarily conditioned and sex-linked factors as well as for environment, may possibly be due to the occurrence in this connection of correlation, in addition to the fact that the measurements constituting indices are to different extent influenced by those factors. If the two measurements are continually influenced in the same direction, the index differences are small, etc., as we have above pointed out. We also emphasize that the figures obtained rather indicate that the correlation, if existing, is not especially strong. In order more closely to investigate the matter, we calculate the coefficient of correlation for the differences of the measurements. Such calculations are rather laborious, and I have therefore been forced to choose certain measurements for illustrating these points. Further, I have only chosen monozygotic, as they are of particular interest when considering the part played by environment, which is most strongly manifested in the monozygotic.

We find now that between length of head and breadth of head, there is a slight positive correlation, not however, fully established, $r = +0{,}17 \pm 0{,}07$. These measurements are expressed in index 22, and the result obtained accords with what we had expected, which was that there would be slight or no correlation. The same is true with regard to face length and face breadth (index 25) — $r = +0{,}13 \pm 0{,}07$. The correlation does not even amount to 2 times its standard error, and consequently is not at all established. For length of head and face length, on the contrary, we find a correlation manifestly established, $r = +0{,}22 \pm 0{,}07$. I think this ought to be explained by the circumstance that, as we have already mentioned, in the environmental influence on those measurements, is included a usual occurrence which generally acts in the same direction upon both measurements. Deformation at birth causes an elongation of length of head as well as of face length. Therefore, we ought to find particularly strong correlation between these measurements.

We find further that for the body measurements, an established positive correlation exists for stature and length of arm, $r = +0{,}46 \pm 0{,}06$, for length of arm and height of symphysis $r = +0{,}28 \pm 0{,}07$, for bi-acromial diameter and bi-gonial diameter $r = +0{,}26 \pm 0{,}07$, and finally for stature and length of head $r = +0{,}27 \pm 0{,}07$. These circumstances indicate that, if environment affects one of the twins so that one measurement becomes larger, the other measurements are often also influenced towards increase. This is especially the case with the body measurements, but possibly also true for the head measurements (length of head and face length, in any case). The differences between the monozygotic twins, however, are far from being principally due to the one being on the whole larger than the other. The correlation can be said to be slight or moderate. There exists also an independent variability of the measurements. In part this independent variability should be produced by the errors in measuring. As regards the head measurements, it should be expected that no correlation would exist in the errors of measuring. If one head measurement is more than usually incorrect there is no reason to suppose that any other head measurements will be especially incorrect. As regards the body measurements, one cannot a priori give such a definite statement. If, for instance, you take too small a measurement on account of deficiency in bearing in one of the twins, it is not excluded that you will, for the same reason, be forced to take too small a measurement of another part of the body. There is, consequently, reason to suspect that the correlation found between the body measurements is partly due to a correlation between the differences of errors in measuring. Now, errors in measuring constitute rather a small part of the differences found in monozygotic twins. The correlation found between the body measurements therefore ought to be referred chiefly to a real correlation between the measurements of monozygotic twins, that is, to effect of environment, as we have just done above. Of course it would have been desirable to investigate if there existed in my material a correlation between errors in measuring. For the present, however, I have not had the opportunity of extending the work to this, and I have to be content with the limited conclusions I have been able to draw above.

Eye and hair colour in twins.

In regard to colour of hair, skin and eyes I found very wide similarity in my *monozygotic* twins. In a few cases there has been a hardly noticeable difference of shade. Siemens, 1923 a, also has found very close resemblance: he emphasizes in particular the importance of pigmentation for the diagnosis of monozygotism.

In two cases, in especial, I have got information about dissimilarities that may be of interest. In one pair there was at birth a pronounced difference in eye colour. One is stated to have been brown-eyed, the other blue-eyed (nr. 38). In consequence they were christened Brunetta and Blondinetta. At the time of examination (15 years of age) no difference in eye colour was noticeable; both were distinctly brown-eyed. Probably, in this case one had been retarded in development by intra-uterine conditions, the pigmentation not having had time to develop. Especially at birth, as previously stated, the inequalities in development are very large.

In another case one twin had had erysipelas (no. 43). Afterwards her hair fell, and the new hair was stated to have been considerably darker than previously, and consequently darker than her sister's hair. By and by, however, the sister's hair also darkened, and at the examination, a few years later, at 19 years of age, both had the same hair colour. This is not apparent in their photographs (Appendix II) owing to an unequal distribution of the light. The case is of interest with regard to the points previously discussed in respect to growth. Its interpretation would be that the hair of one twin had undergone a quickened change, an acceleration of development. If one twin is accelerated or retarded in his development, as above pointed out, this should not involve any considerable lasting difference. When they are again under similar environment, possibly the conditions will be reversed, i. e. the development will be accelerated in the one previously retarded, and vice versa.

Spickernagel 1925 has given a case of monozygotic twins (common chorion), closely resembling each other in everything but hair colour. One was light blond, the other dark blond. One died 2½ months old, the other at 3 months. Spickernagel regards the case as proving that monozygotic twins are not necessarily hereditarily alike. It seems, however, rather to be a question of different stages of development, in analogy to the case mentioned above. Just about the time of birth the developmental inequalities are comparatively large, and it is not improbable that if the twins had lived longer, the inequality would have disappeared, the hair of the lighter twin darkening.

In dizygotic twins differences in the colour of hair and eyes are very common. All blue- and grey-eyed have been counted as light-eyed when no macroscopic pigmentation was visible. Pigmented eyes were counted as medium when parts of the iris were free from pigment. Those whose iris gave the impression of being pigmented over the whole surface, were counted as brown-eyed. Naturally these limits cannot be exactly drawn, and different examiners may give different decisions. Therefore, as a rule GD has diagnosed eye- and hair-colour. Hair colour has been divided into three classes: red, light, and dark. Between the two last-mentioned classes the limits have been drawn with the aid of a colour chart, related to that of Fischer, the limits being drawn between nos. 9—25 for light-haired, and 1 — 3 for red-haired.

With regard to eye colour the results were as follows:

	Brown-eyed (= b)	Medium (= m)	Light-eyed (= l)	Total
Number of twins	24	26	242	292
% of total number	8,2 %	8,9 %	82,9 %	100

From these figures can be calculated how many in the material will be both brown eyed = $\frac{(8,2)^2}{100}$; one brown-eyed, the other light-eyed = $\frac{2 \cdot 8,2 \cdot 82,9}{100^2}$ etc.

A comparison between these figures and the empirical figures, gives this result:

	b. × b.	b. × m.	b. × l.	m. × m.	m. × l.	l. × l.	Total
Number of twin pairs...	5	3	11	1	21	105	146
% of total number of pairs	3,42 ± 1,50	2,05 ± 1,17	7,53 ± 2,18	0,68 ± 0,68	14,38 ± 2,76	71,92 ± 3,72	99,99 %
Calculated percentage of twin pairs...	0,67	1,46	13,62	0,79	14,76	68,69	99,99 %

The basis of the calculation is the assumption of the eye colour of one twin being decided independently of the other. As the accordance in eye colour between monozygotic twins is so good, there is reason to assume that the differences are hereditarily determined in dizygotic. In that case, the above-mentioned basis for the theoretical figures, would be correct. So far as can be judged from the material, the theoretical and empirical figures are in good accordance. The theoretical figures do not exceed the mean error for the empirical values.

The same comparison for hair colour of dizygotic twins gives the following figures:

	Dark = d	Light = l	Red = r	Total
Number of twins	33	245	12	290
% of total number	11,38	84,48	4,14	100 %

The theoretical percentages calculated from these figures, compared with the empirical figures, give the following table:

	d. × d.	d. × l.	l. × l.	r. × d.	r. × l.	r. × r.	Total
Number of twin pairs	7	18	109	1	9	1	145
% of total number of pairs...	4,83 ± 1,78	12,41 ± 2,77	75,17 ± 3,59	0,69 ± 0,69	6,21 ± 2,00	0,69 ± 0,69	100
Calculated percentage of pairs	1,30	19,22	71,37	0,94	7,00	0,17	100,05

Here also the theoretical figures lie within three times the mean error for the observations.

This is in accordance with the conclusions drawn from the results in monozygotic twins. Eye and hair colour seem to be determined by hereditary dispositions and not readily modifiable by environment. There is of course nothing strikingly new in this. The fact has been demonstrated for animals and with regard to man also investigations have been performed that point in the same direction, though, perhaps, the mechanism of the heredity in this case has not been definitely ascertained.

Comparison with the results of other investigators.

A comparison of the above results with those of other investigators should be of interest.

Thorndike 1905 treats anthropological measurements from 39 twin pairs, of which 13 pairs stated to be "alike". This corresponds to a normal percentage of monozygotic (⅓) in the material. On statistical examination of the material, however, Thorndike finds that the differences give a continuous, asymmetric curve, with displacement of the maximum towards 0, i. e. complete identity. Therefore, he does not regard the results as indicating a difference in principle between like and unlike pairs, parallel to monozygotism and dizygotism, and although he does not deny the existence of monozygotism he regards it as more exceptional. Fischer 1919 has treated Thorndikes material in more detail, and finds that the twins certainly are on an average more like than brothers, but that the material cannot be divided into one group of more like, and one of more unlike. Fischer further says that no attempt has been made to show that twins sufficiently alike to be regarded as identical, really exist in sufficient numbers to explain the proportions of like sex among the twins. He propounds a theory according to which monozygotic twins originate from one egg fertilized by two sperms. The occurrence of like twins in numbers corresponding to the number of monozygotic, I have demonstrated above (p. 140); eggs fertilized by two sperms, as a rule are not capable of development, and further ought to produce opposite-sexed monozygotic twins, which of course do not exist. Besides, from Thorndikes tables (e. g. his table 19) it will be seen that the group of twins more alike in appearance, are more alike in regard to anthropological measurements, than the group of more unlike twins. That the distribution of the total material gives a continuous curve, has nothing to say. I refer to my material fig. 19, p. 207. The upper curve in the figure shows the distribution of the percentual differences of the twin pairs in our total material. Regarding the manner in which these percentages have been obtained, see p. 209. As will be seen from the diagram, the total material presents a fairly "unimodal" type. This notwithstanding, I have been able by grouping like (monozygotic), and unlike (dizygotic) separately, to show a very distinct difference. It is a common statistical phenomenon that essentially different groups on adding may give a continuous curve, which does not give any idea of its being composed by two separate materials. Thorndike's result, therefore, is not at variance with the results here found, and the conclusions drawn by himself and Fischer are hardly justified.

Scheidt's 1925 work is more casuistic in nature. His material consists of 7 identical pairs (monozygotic), 3 unlike pairs (dizygotic), and 3 pairs of whom Scheidt has not been able to decide, whether they are monozygotic or dizygotic. The material being so small, Scheidt has not been able to make more detailed comparisons. The measurements given by Scheidt accord with our result that the twins judged to be monozygotic show closer resemblance in measurements, than those judged dizygotic. Finally, it should be pointed out that Scheidt has carried out his anthropological examinations on twins from Siemens', 1924, material. In three out of 13 cases Scheidt has been uncertain about the diagnosis of monozygotism or dizygotism. This once again shows what I have already pointed out, that in the individual case it is not always possible to found a safe diagnosis on the degree of resemblance. Definite conclusions can be based only on a larger material, with the certainty that chiefly monozygotic are compared with chiefly dizygotic. Siemens is rather apt to over-estimate the reliability of a diagnosis founded on resemblance. Scheidt's doubts in this case are in accordance with my views on the question. As already mentioned I have felt doubtful about some cases in my material. In these cases I have had good assistance of a comparison between the ears, and as far as can be judged from the photographs given by Scheidt, I should feel inclined to count two of these cases (nos. 72 and 78) as monozygotic, and one case (no. 70) as dizygotic.

Verschuer 1925 has had a considerably larger material at his disposal, 42 like (monozygotic) pairs. In part he has taken other measurements than I have done. A comparison of the average differences for those measurements we have in common, gives the following table:

Table 36.

Comparison between the Differences of Errors in Measuring and between the Differences of Monozygotic Twins in the Materials of Verschuer and of Dahlberg, expressed in millimeter.

Measurements	Average of the difference ± error of average in errors in measuring for G. D. and S. D.	Average of the difference ± error of average in monozygotic for Verschuer	Average of the difference ± error of average in monozygotic for Dahlberg
Length of head	0,40 ± 0,03	1,7 ± 0,19	2,57 ± 0.20
Breadth of head	0,55 ± 0,04	1,2 ± 0,13	1,74 ± 0,13
Face breadth	0,56 ± 0,04	0,8 ± 0,09	1,59 ± 0,12
Bigonial diameter	0,69 ± 0,05	0,7 ± 0,08	1,56 ± 0,12
Face length	1,55 ± 0,12	0,6 ± 0,07	2,46 ± 0,19
Stature	3,54 ± 0,27	9,2 ± 1,02	16,27 ± 1,28
Height of symphysis (»Beinlänge»)	5,37 ± 0,41	5,8 ± 0,70	11,23 ± 0,94
Length of arm	4,97 ± 0,38	3,6 ± 0,41	10,76 ± 0,87
Length of trunk	6,75 ± 0,51	4,1 ± 0,48	14,60 ± 1,23
Biacromial diameter	2,47 ± 0,19	2,2 ± 0,25	6,44 ± 0,52
Bicristal diameter	1,33 ± 0,10	2,8 ± 0,33	5,64 ± 0,46

My averages will be found to lie higher than those of Verschuer. The difference is surprisingly great. There is a possibility that my twins have been living under less uniform environment, but à priori it is very improbable that twins from

Thuringia should have been living under environments so strikingly more uniform, than the twin pairs in my material. Most of my twins belong to country-side families, some part of them to Stockholm. In all cases I informed myself whether the twins, during growth or perhaps later, had been living apart for any considerable time. This was so only in a few cases. As a rule they had always been living together, at least till adult age, and as already pointed out, twin pairs must be expected to grow up under more than usually equal conditions, in any case this applies to the twins in my material. Now, it is possible that I have included some dizygotic in my material, and in a few cases I have really had my doubts about the diagnosis. All the same it seems to me very improbable that dizygotic twins should reach any considerable number in my material of monozygotic. In most cases the difference in the degree of resemblance between a monozygotic and a dizygotic pair, is so large that on a larger material erroneous diagnoses should be very rare, even if every individual diagnosis cannot be made with absolute certainty. Verschuer does not mention that he has felt doubtful about the diagnosis in his cases, and does not say that in this respect he has proceeded with particular exactitude, sorting out all the doubtful cases. It is thus very improbable that my difference averages should lie particularly high on account of dizygotic having been included among the monozygotic, or the monozygotic having been exposed to exceptionally varying external conditions.

Comparing the average differences in monozygotic twins, as found by Verschuer, with the differences above calculated for error in measuring, singularly enough Verschuer's figures will be seen in some cases to lie on the same level with our average differences for error in measuring (bigonial diameter, height of symphysis, bi-acromial diameter), and in some cases even considerably lower (face length, length of trunk and arm). As already mentioned, the measurings taken in order to fix the error in measuring, were executed a little quicker than the actual measurings of the twins, and this may have resulted in a slightly higher figure for our error in measuring. Verschuer does not give any figures for his error in measuring. However, it must be remembered that my material has been measured by extremely well-trained persons. During two years GD and SD had measured some 30,000 persons. Obviously such a training must produce a very high degree of measuring skill. (A systematic error for one measurement or another in this connection is of no importance). Even if the measuring error found, should lie a hair's breadth too high (cf. p. 197), it is, on the other hand, unlikely that an examiner with more ordinary training would show a lower error in measuring. A perusal of the measuring errors here ascertained rather gives the impression that they are surprisingly small.

On the other hand, if monozygotic twins, which are being measured, are throughout absolutely alike, naturally the average difference found, cannot be lower than the error in measuring resulting when one person is being measured twice. Besides, monozygotic twins are not so completely alike. An equally large or smaller difference between monozygotic twins, than between two measurings of the same person, therefore, is absurd. This, however, seems to be Verschuer's result. Taking the mean error into consideration, Verschuer's figure for face length will be found to lie 0,95 ± 0,14 mm. lower, for length of arm 1,37 ± 0,37 mm., and for length of trunk 2,65 ± 0,70 mm. lower than our measuring error, and for bigonial diameter, height of symphysis and bi-acromial diameter on a level with the error of the difference.

The most likely explanation of this situation, I think, is that Verschuer, when carrying out the measurings was unconsciously influenced by the resemblance of the twins. If one twin is measured, with the measurements of the first one in mind, the temptation, naturally, is very great, unconsciously to seek a reading of the instrument, according with the previous measurement, and to adjust the position of the instrument so as to get such a reading. This will tend to reduce the differences, and in this way it is possible to find values lying even below the measuring error. At our measurings this suggestive influence has been carefully avoided. One of the examiners has taken down the measurements for the one carrying out the measuring. The differences between the measurements have been calculated only when the whole material was collected. The diagnosis monozygotism or dizygotism was made before the measuring, and thus entirely independent of the measuring results.

In the absence of definite information how the measurings of Verschuer in these respects have been performed, it can reasonably be assumed that he has not observed these precautions. So far, therefore, his figures must be regarded as not reliable. As mentioned, Verschuer does not give figures for his measuring error, nor has he examined dizygotic twins. On the other hand, he gives averages for differences and index for some measurements not taken by me. Some of these, e. g. measurements of ears, nose, etc. seem to me of very doubtful importance. The average differences lie about 0,2 — 0,35 mm. In the earliest of my examinations of twins, I included some of these measurements, but I very soon found that the differences here in question were hardly measureable with available instruments. Even the reading error should give differences almost as great as those found by Verschuer (the instruments are graduated in whole mm., and positions between the lines of the scale may often be read as easily at the upper line as at the lower one). Added to this are the errors in adjustment of the instrument. Only on a large material and after careful determination of the measuring error, the differences here in question can be obtained. In order to get a material as reliable as possible, I confined myself to the measurements for which the examiners were trained.

Further, Verschuer does not find any established differences in his material, indicating an influence of age. He divides his material into one younger and one older group, and finds an average for the percentual deviation in the younger group of 0,75 ± 0,12 % and in the older group of 0,79 ± 0,30 %. The difference is small, and not established, but is not contrary to what has been made out as probable in our material — i. e. a small increase with age.

A division in males and females does not show any distinct difference between the sexes. The figures are a little higher for the females, 0,82 ± 0,12 %, than for the males, 0,73 ± 0,16 %, but the difference is not established. Neither has my material given any indication of males and females in monozygotic twins behaving differently.

In 17 cases Verschuer has been able to get information about the weight at birth, and in 5 of these cases the weight differences were particularly large. The measurement differences in these pairs are a little larger than in the other 12 pairs, but the material is so small that the difference is far from established. There was however reason to conclude from our material that the larger twin generally will be a little larger even in adult age.

Verschuer, finally, divides his material after degree of environmental difference into 3 groups, and he finds that the average differences are smallest for the group with most similar environment, largest for the group with most differing environment, without, however, being able to establish the differences.

It seems the rule should be that the younger the twins, the more similar the environment, and the older the twins, the more differing the environment. A division after dissimilarities in environment generally must be more or less subjective. It is, of course, difficult to give a well-founded judgement in each individual case. Therefore, I have not attempted a direct division, confining myself to a grouping after age. I have been inclined to ascribe the probable increase with rising age, to the greater dissimilarity in environment, and under this interpretation my results are in good accordance with those of Verschuer. It is not, of course, possible, to examine on my material the effect of differing environment at constant age and vice versa. The above interpretation must suffice, as the most probable in the present situation.

Finally Verschuer also finds that if a measurement in one twin is larger, other measurements, too, are often larger in this twin compared to the other. This result accords with what I have found at calculation of correlation coefficients between measurements of monozygotic twins.

With regard to those investigations above referred to that have a more direct bearing on the effect of environment on racial characteristics, they can be said to show good accordance with my results. As to deformation at birth, p. 249, it was pointed out above that Walcher's investigations on the influence of bedding on the shape of the head in new-born, although they cannot by themselves be accepted as binding evidence, gain in probability by the fact above demonstrated, that the deformation at birth may to some degree last into adult age.

Boas' examinations of U. S. A. immigrants have shown that environment may change stature and shape of head, and this accords with our results. The modifiability found by Boas, falls well within the limits here found. Obviously, such a modifiability under environment does not exclude an influence by hereditary dispositions. On the contrary, in our material it has been possible to make comparisons between the influence of heredity and environment, and to show that the hereditary factors have roughly double the effect of environment in causing deviations from the average of the population. Evidently, on the other hand, anthropological dissimilarities of different populations, must not be exclusively ascribed to heredity, and regarded as racial differences. It is also necessary to take into consideration environmental factors and possible consequent differences. Walcher's, Boas' and my results, in this respect give a clue. Especially my results go to show that environment is of rather more importance than expected.

TWINS FROM A PATHOLOGICAL POINT OF VIEW.

Monozygotic twins being genotypically alike, they seem to offer a promising material for research in regard to heredity of diseases. Already Ahlfeld, 1876, points out that monozygotic twins are strikingly alike, and that twins very closely resembling each other, i. e. presumably monozygotic, frequently suffer from the same diseases. From literature he collects a number of observations, besides giving some cases of his own. He thinks the explanation of their resemblance probably is their origin from one egg, but he gives no pronouncement on their heredity. Galton, 1883, purposely sought to read the influence of environment on monozygotic twins, to use them as a "criterion of the relative power of nature and nurture". He collected a good deal of information on twins. It seems, he did not make any direct observations, chiefly getting his facts by correspondence. This material made him distinguish between two different classes of twins, one class being characterized by striking resemblance, amounting almost to identity. It should be pointed out that Galton did not assume that monozygotic twins were more alike than dizygotic, and that he does not ascribe the facts brought out by him, to the different origin of the twins.

In literature are scattered numerous observations on diseases of twins.

Bauer, 1917, emphasizes the importance of examinations of twins with regard to heredity of diseases, and gives some cases from literature.

Siemens, 1924 (a), gives detailed results of examinations of 52 monozygotic and 36 dizygotic twin pairs, and makes an analytical compilation of cases from literature.

Further, Siemens, 1924 (c), has exhaustively treated nævus formations in twins (see p. 174), and, in cooperation with Xaver, 1924 (d), has published a work on diseases of the mouth cavity in twins.

Weitz, 1924, has made examinations (after Siemens) of 45 twin pairs.

For the casuistic of the subject, I must refer to Siemens' work. Below I am going to mention only some observations made on my own material. Generally, of course, I have had to be content with anamnetic information, which naturally has not the same value as direct observation. Examinations regarding diseases of twins are most conveniently made when the twins belong to the clientèle of a hospital, and it is to be hoped that the literature on the subject will quickly increase since attention has been directed to this point. Clinics, having the necessary technical resources for thorough examinations, of course are best adapted for the purpose. In this respect, as regarding research on the heredity of disease generally, cooperation between clinics and geneticists should be profitable.

Observations of twins of course always have their value, but their interpretation is not always easy. Now, the above scientists have in the main unreservedly accepted the dogma about the identity of monozygotic twins. This problem was discussed in some detail in the chapter on asymmetries. It was mentioned that there are strong reasons to think that some characters must be regarded as genotypical asymmetries. Therefore it is not admissible in every case to ascribe differences between monozygotic twins to environment. For every single character, it must first be determined whether there is any reason to assume the presence of a genotypical asymmetry. This will be further discussed in connection with some of my cases below.

Two cases are of special interest from these points of view. In two pairs of monozygotic twins, one of the pair is intellectually under-developed. Both have had to be put in special class (for defectives), as their twins have not, and on examination both gave an impression of imbecility. In the photos (n:o 33 and 71) a certain apathy can be discerned. With regard to resemblance, configuration of the ears, etc., they conform to the standards of monozygotism.

Siemens, 1924 (a), points out that in isolated cases differences of intellect may be very pronounced.

Weitz, 1924, states that in five of his cases, distinct differences of intellect were noticeable, especially in the marks at school.

As a rule, my monozygotic twins, like those of the above-mentioned authors, have shown great similarity in intellect, in so far as I have been able to form an opinion from personal observation and information from parents and teachers.

Originally it was my intention to work out a more objective measure of this resemblance by comparison of the school marks of twins. However, I soon found that the teachers felt very uncertain about their ability to distinguish between the twins, and therefore often choose the expedient of giving the same marks. Even in cases where different marks had been given, this was perhaps sometimes the result of an inclination to vary the marks, more than of really ascertained differences. Consequently, statistics of marks could not be built on, and I did not carry out my scheme. Personally, however, I got a strong impression that monozygotic twins are intellectually closely alike.*

The more surprising I found the differences in the case mentioned. The most likely explanation, perhaps, would be to assume an injury to the brain, intra-uterine or at partus, that had been sustained by the deficient twin. However, there are no symptoms of such an injury.

On the other hand, it may possibly be a case of a genotypical asymmetry. In connection with left-handedness it was pointed out that usually only one lingual centre of the left hemisphere is functioning. This is bound up with right-handedness (or left-handedness, in which case the lingual centre of the right side functions). If the mainly uni-lateral development of the lingual centre — in analogy to what seems to be the case with left- and right-handedness — should be due to a genotypical asymmetry, sometimes one of two monozygotic twins might accidentally get two well-developed lingual centres, while the other one had two deficient ones. The result would be not only that the latter one would be slower in learning to talk (which, I am told, was the case in the above-mentioned twin pairs), but the defect would almost certainly react on the general intelligence, such is the importance of the lingual centre as a medium for communication of images and ideas. No special lingual difficulties could be observed on examination of the deficient twins, though certainly they gave monosyllabic and slow answers to questions.

At present it does not seem possible to determine which of the alternatives proposed, is the true one. The cases, however, prove that the influence of environment must be interpreted

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* In this connection it may be mentioned that on examination of monozygotic twins, I have had an impression that, in regard to temperament (general mood, reaction to environment), the differences are comparatively important, and the more striking, as the intellectual resemblance is so close. It is difficult to find any objective and reliable measures of psychial characters, and anyhow emotional differences and power of apprehension are, perhaps, in a way incommensurable. I wish, therefore, to emphasize that I am speaking of purely subjective impressions. However, already Galton, 1883, had come to the same view, and an attempt to sound the question after more objective (perhaps psycho-technic) methods, might be worth while.

with great caution, and that differences cannot always be regarded as unequivocal.

In two cases one of the twins had a stammer, in one case very slight (13 years at the time of examination, both right-handed, n:o 73), in the other case very pronounced (8 years at examination, not known if right- or left-handed, n:o 54). In both cases the other twin had normal speech.

Stammering may be a hysterical or psychopathic symptom, and, further, may occur in connection with severe injuries to the brain (hemorrhage, etc.). On the other hand, stammering seems to be comparatively frequent among the relatives of the stammerer (Gutzmann 1913).

Gumpertz, 1925, says it is a question of a functional disturbance on a psychopathic basis, which however can be released by an organic alteration.

Lenz, 1923, says that stammering is largely hereditary.

Siemens, 1924, quotes from literature two cases of stammering in both the twins of monozygotic pairs. Siemens himself has found four monozygotic cases where only one twin is a stammerer. In all cases the stammerer was left-handed. In one case both had stammered at an earlier age, but the left-handed worse. Siemens regards these cases as proof that stammering is not necessarily due to heredity, but may be in the main paratypically conditioned.

This interpretation of the cases may be correct. On the other hand the possibility of a genotypical asymmetry, must be reckoned with. The connection with left-handedness, adduced by Siemens, would even seem to favour such an interpretation. In one of my cases, however, both were right-handed. I do not know whether left-handedness occurred in the other case. It cannot definitely be decided if this is a question of differences determined by environment, or of genotypical asymmetries. More careful research on the heredity of stammering, and on its mechanism, seems to be required. The connection with left-handedness, especially among monozygotic twins, also requires investigation on a larger material. At present the question must be left unsolved.

In one monozygotic pair both twins had an askew developed nail on the second toe of their left foot, but not on the right foot (n: o 3). Here the assumption of a genotypical asymmetry seems to be natural. In one monozygotic pair, one of the twins had strabism (n: o 60, see photograph Appendix II).

Further it may be mentioned that in one case both the twins had been operated on for left-sided hernia at the same time at 4 years of age n:o 58. In another case both had an operation for appendicitis only a few days between, n:o 42. Finally, as above mentioned (p. 256), in one case one twin had had erysipelas, but the other not, n: o 43. Weitz, 1924, mentions two cases where only one twin had had erysipelas, and one case where both had suffered.

For a future statistical treatment of the subject, naturally data for corresponding diseases in dizygotic twins are required. It would, of course, be of interest to see whether a disease, that sometimes occurs in one of two monozygotic twins, nevertheless is more frequent in two monozygotic, than in two dizygotic twins.

For dizygotic twins also I have only few reliable data.

There was no case of idiocy in my material. There was one case of stammering (n: o 208), an opposite-sexed pair of ten years where the boy had a slight stammer. The following cases may further be mentioned: Icterus was stated to have occurred in one of the twins of four pairs (n: o 121, 215, 220, 239). In two opposite-sexed pairs, of 11 and 17 years, the boys had had attacks of jaundice, in one opposite-sexed pair, 11 years, the girl had had jaundice, and in one same-sexed pair, 20 years, one sister had had jaundice. In one same-sexed pair (n: o 145), 18 years, one of the sisters had had Erythema nodosum. In one opposite-sexed pair, (n: o 234) 16 years, the girl had had pleurisy with tubercular spondylite that had healed with kyfos. (In the anthropological measurements her body measures naturally have not been included.) In three cases one of the twins had been operated on for appendicitis (in two opposite-sexed pairs, 35 and 21 years, the male twins, and in one same-sexed pair, 15 years, the girl) (n: o 189, 190, 238). In one same-sexed pair, (n: o 112) girls, 11 years, one was said to have suffered from asthma, with attacks of 2—3 days, since her infancy, while her sister has not had asthma. Finally, in one opposite-sexed pair, 13 years, the boy had been operated on for cheilochisis at the age of 11, while the girl did not exhibit any sign of malformation (n:o 225).

Evidently, these data, for the most part based on summary statements by the patients, are of very limited value. Nevertheless, I thought right to give them in this place, and hope they may meet with some interest from clinici, who have greater facilities for observations in this field. Cooperation of a large number of scientists is needed, if definite conclusions on the subject are to be reached, but no doubt a large and reliable material would yield much valuable information.

RÉSUMÉ OF RESULTS.

Part I.

1. Twin frequency increases with rising order of birth. It has been shown on material from the official statistics of Australia that this increase is due to the simultaneous rise in age. *No influence by the birth number,* is noticeable that, independently of age could alter the chances for twin birth in a primiparous mother, as compared to a multiparous. (Cf. p. 32). But if twin mothers have increased fertility, this entails an increase of the twin frequency with the number of births independently of age. Therefore the result obtained also shows that twin mothers have no increased *real fertility.* An examination of figures available in the literature also indicates that the increase of the fertility of twin mothers is only apparent (the increase when existing being caused by influence of the mother's age). Cf. p. 38.

2. On figures from the official statistics of France it was shown that an inclusion of still-born, to some extent will reduce the increase of twin frequency with age of the mother, both for dizygotic and monozygotic. Among the still-born dizygotic there is usually a less increase with age, than among the live-born. Regarding the frequency of still-born monozygotic, a decrease with rising age of the mother has been shown. Con-

sequently, an inclusion of the abortions (if analogous to stillborn) probably would entail some reduction of the increase with age of the dizygotic. Finally, it is not improbable that an inclusion of the abortions would entirely neutralize the increase with age of the monozygotic, i. e. the frequency of monozygotic at conception would be *constant.* (Cf. p. 43—51).

3. The varying twin frequency of different countries is partly due to differing regulations for registration, and to differing age distribution of the mothers. It has been shown that if these factors are eliminated there is a difference between France, on the one hand, and Finland and Denmark on the other, France having the lower twin frequency. This may possibly be due to racial differences between the countries. On figures from Germany, France and Italy a correlation has been proved to exist between twin frequency (both monozygotic and dizygotic) and eye colour — the higher the percentage of light-eyed in a district, the higher, generally, is the twin percentage. These facts indicate a *stronger average tendency to twinning in Nordic race,* than in Alpine and Mediterranean (dark eyed). (Cf. p. 52—62).

4. The prevailing theories on the causes of twinning, are very unsatisfactory. On a critical examination both the atavism theory and the intoxication and degeneration theories prove to be without foundation. The connections they assume between twin births and doubling of genitals or polymasti, respectively mental and nervous diseases, syphilis, tuberculosis, alcohol, etc., are unproved. As a matter of fact, the data in the literature rather disprove the existence of such connections.

On the basis of the hereditary influence proved by other investigators, a *twin hypothesis* has been set forth. Its essential principle is that twin pregnancy is due to the existence of a doubling tendency which sometimes manifests itself before the reducing division, causing dizygotic twin pregnancy, sometimes after the reducing division, causing monozygotic twin pregnancy. In some cases dizygotic pregnancy is caused by the simultaneous bursting of two follicles. Possibly these last-mentioned dizygotic pregnancies are not hereditarily determined, and possibly, too, these may be the cause of the increase with age in the frequency of dizygotic. For further details see p. 119.

5. A consequence of this theory would be that mothers who have once borne dizygotic twins, in the future will bear twins comparatively frequently, and that an increased twin percentage would be noticeable in their later births, not only for dizygotic, but for monozygotic as well. On my material I have been able to show, that among their later births about 6 % are twin births (figure a little too low); calculated from the sex proportion, half of these proved to be monozygotic. This indicates *a real, strongly increased tendency in mothers bearing dizygotic twins to monozygotic twin pregnancy also.* However, the material is small; the difference amounts to not quite 3 times the standard error, and the result must be regarded as not absolutely established, although highly probable.

It has been calculated from the above-mentioned figures for repetition of twin births that *15 % of the mothers have the twinning tendency. For each individual birth their chance of twinning is about 10 %* (in my material, as above mentioned, 6 %, but probably this figure is some 4 % too low). The final result is that twin births constitute about 1,5 % of the total births. (Cf. p. 125—131).

6. An examination of the principles for distribution of hereditary characters in a population, gave the following result:

a. It is known that in the absence of selection the percentage of homozygotes and heterozygotes will keep constant in a population (assumed that the number of mutations arising is inconsiderable). In that case, the percentage of heterozygotes for a monohybride character can be calculated from the percentage of homozygotes after formula I:

$$b = -2a \,{}^{+}_{(-)}\, 20\sqrt{a} \quad \text{or} \quad a = \frac{100-b}{2} \,{}^{+}_{(-)}\, 5\sqrt{100-2b},$$

where a = % homozygotes and b = % heterozygotes. For a simple recessive character a is known, for a simple dominant character $a + b$ is known. From the equation appears that if a increases, b will increase to a maximum at $a = 25$ % (the homozygotes with the character being 25 %, the heterozygotes 50 % and the free homozygotes 25 % i. e. simple Mendelian proportions exist in the population). If a further increases, b will decrease, and when $a = 100\ \%$, there are naturally no heterozygotes in the population. (Cf. p. 86 and diagram fig. 5).

b. If the reproduction of homozygotes for a simple Mendelian character is prevented, the percentage of heterozygotes also will diminish. Complete prevention of the reproduction of homozygotes, will cause a displacement of the number of heterozygotes and free homozygotes after formula II:

$$\frac{yn}{xn} = \frac{2y + nx}{2x},$$

x being the number of heterozygotes, y the number of free homozygotes and n the number of generations. If $n = \infty$, y in relation to x will be infinitely great. The curve approaches asymptotically the x-axis. If homozygotes with the character are entirely prevented from reproduction, the heterozygotes will diminish, at first rapidly, then more slowly, but will never be completely exterminated. In reality some small percentage of heterozygotes will always remain, and in consequence very isolated homozygotes will occur. Even with less radical measures against manifest character bearers, the latent character bearers can be almost entirely exterminated, although more slowly.

c. In the fraternities of persons with a simple recessive character taken on chance from a population the number of homozygotes in relation to the total number, can be found after formula III a:

$$\frac{\text{number of character bearers}}{\text{total number of children}} = \frac{1}{4}\left(\frac{1}{10}\sqrt{a} + 1\right)^2;$$

$a =$ the percentage of homozygotes with the character in the population. It will be seen from the equation that when a approaches $0\ \%$, the proportion will be ¼, i. e. the parents are chiefly heterozygotes. For $a = 100\ \%$ the relation is 1, i. e. the parents are homozygotes. As a increases, the proportion will increase from ¼ to 1, owing to the increase of homozygotes among the parents. With the aid of Weinberg's proband method the proportion in question can be calculated for these fraternities.

According to this formula, character bearers taken on chance in a population should all be given equal weight, and if several character bearers belonging to the same family are included in the primary material, their fraternities should be counted several times. If a whole population is examined, and the fraternities of character bearers are only counted once, the relation between character bearers and the total number of children in their fraternities is found after the formula III b.

$$\frac{\text{number of character bearers}}{\text{total number of children}} = \left[\frac{10}{20 - \sqrt{a}}\right]^2$$

The number of character bearers in these fraternities also increases from 25 % to 100 % as *a* increases from 0 % to 100 %, but the increase is not so marked. Weinberg's "Geschwister" method must be used to correct the results.

d. The number of homozygotes for a recessive character taken on chance in a population among the parents' fraternities, can be calculated after formula IV:

$$\frac{\text{number of homozygotes}}{\text{total number of children in parents' fraternities}} = \frac{1}{16}\left[\frac{3}{10}\sqrt{a} + 1\right]^2;$$

a = the percentage of homozygotes in the population. It follows from the equation that when *a* increases from 0 to 100 %, the proportion of character bearers in the parents' fraternities will increase from $^1/_{16}$ to 1.

With regard to these formulas it may be emphasized that if it is a question of more common characters, *the composition of the population from which the material is brought together, must be considered.* Otherwise it is hardly possible to determine if the figures found in a certain material prove heredity for the character. These formulas are therefore of practical importance for the methodics of hereditary research. For further details I refer to p. 101.

Part II.

7. From data from the parish registers regarding twin pairs, it appears that among those pairs about whom information on degree of resemblance has been given (1,115 pairs) the "identical" twins (365 pairs) amount to the *same* number, as the number of monozygotic calculated after Weinberg's differential method from the number of opposite-sexed (363 pairs). Cf. p. 140.

8. Monozygotic twins are very closely alike, but dizygotic twins, too, may sometimes show pretty close resemblance. In doubtful cases an inspection of the *configuration of the ear* is of good assistance. The configuration of the ear is extremely varying, and is never exactly alike in two persons. From photographs of 100 persons, the ten pairs which seemed most alike, have been picked out. Further, photographs are given of ears from 6 pairs of dizygotic twins, these being rather less alike. Finally photographs are given of the ears of 6 pairs of monozygotic twins, which consequently present considerably closer resemblance — about the same as between ears from right and left side of the same person. Such unusually unlike pairs of ears are given in 10 cases. Cf. Appendix II and p. 144.

9. For a diagnosis of monozygotism the following conditions have been set out:

a) In appearance the twins must be alike to confusion, or show a high degree of resemblance.

b) During growth and later they must have been difficult to distinguish, and sometimes been mistaken by neighbours and school-fellows.

c) The configuration of the ear must not show too great differences (as between left and right ear of each twin).

d) The finger prints must show a certain correspondence (as between left and right hand in each twin).

e) The anthropological measurements must not show considerable divergences (see below). In this work, however, the diagnosis has been made without regard to the degree of resemblance between the anthropological measurements.

At publication if possible full face and profile photographs should be given. *Photographs* of monozygotic twins (77 out of 96 pairs) are given in Appendix II. Likewise some photographs of dizygotic twins (12 pairs) are given. These photographs show the degree of resemblance existing in the twin pairs, and therefore give some possibility for other investigators to control the material. Naturally, information about the after-birth also is of interest.

10. A collection of figures on stature and weight of twins at birth, confirms the result obtained by other investigators, that monozygotic twins in these respects show as large differences at birth as dizygotic twins. The only interpretation possible is that in monozygotic twins *intra-uterine conditions* alone are responsible for the same degree of variability, as is produced by intra-uterine conditions and heredity in dizygotic twins. (Cf. p. 149—154).

On figures from the official statistics of France regarding still-births it has been shown that monozygotic twins more frequently than dizygotic go together, i. e. *both die, or both live* (Cf. p. 156—160).

11. Employing observations of heterochromia in cats and man, and of heredity of supernumerary toes in fowls, it has been shown that probably some dispositions have a tendency to asymmetric distribution in the soma, independently of environment. I have termed these characters *genotypical asymmetries.* On the basis of the above-mentioned observations, the following rules for dissimilarities in monozygotic twins caused by genotypical asymmetries have been set forth.

1) The character may be found in both twins on the same side.

2) The character may be found in both twins on opposite sides.

3) The character may be found in both sides of one twin, being absent in the other twin.

4) The character may be found in only one side of one twin.

5) The character may be found in both sides of one twin and in one side of the other. Cf. p. 165 and fig. 13.

With the aid of the above rules, a number of differences between monozygotic twins can be explained, differences which hardly can be interpreted as environmental phenomena. This applies to observations of doubling of scutes in armadilloes, dissimilarities in the papillary patterns of monozygotic human twins, colour blindness, differences in pigmentation of the iris in monozygotic twins (Nettleship), irregularities of refraction in monozygotic twins, and further:

a) *nævus formations* in twins, where the peculiarity observed by Siemens — the number of nævi being hereditarily determined, but not their localization — is most reasonably explained on this principle;

b) left-handedness, the increase of which among monozygotic twins as observed by me and noticed also by Weitz (17 %, compared to 5 % in the population) can be explained by the assumption of a genotypical asymmetry, comparatively frequently causing reversal in one twin compared to the other. This entails a rather large number of pairs with one left-handed, the other right-handed. Together with the pairs both left-handed (4 %), they cause the *increase of left-handed* in the total number of monozygotic. The case is similar with regard to functional superiority of one foot. On the other hand, it has been shown on the figures found for the different ways of clasping the hands (with right or left thumb on top) that probably it is decided by chance which way a person will use. Hereditary dispositions seem to be of no importance in this respect. (Cf. p. 160—186).

12. An *anthropological* examination of twins gave the following result:

a) On measuring the same person twice, the difference was on an average 0,5 — 1,5 mm. for head measurements, and 3—7 mm. for body measurements (table 11). A division of the material after magnitude of the measurements does not indicate any change in the differences as the respective measurements increase or decrease, i. e. on measuring persons of different size. (Cf. p. 196—203).

b) In monozygotic twins the average of the differences are considerably less than in dizygotic, both in absolute measure (mm.) and percentually. Brothers who have been measured at the same age, have the same average differences as dizygotic; opposite-sexed twins have considerably larger differences (Cf. p. 203—214).

c) By calculating the differences in pro mille of the respective measurements, and adding these figures, a pro mille value for each pair can be obtained, which on an average is considerably smaller for monozygotic (211,58 ± 9,27 ‰), than for same-sexed dizygotic (496,09 ± 18,60 ‰), and opposite-sexed dizygotic (594,37 ± 38,72 ‰). Further, it has been found that pairs with total anthropological differences below 300 ‰, in 86,4 % are monozygotic while the pairs reaching beyond the 300 ‰ limit, in 90 % are dizygotic. This proves that close resemblance in appearance, is accompanied by resemblance in anthropological measurements, and indicates that in this respect there exists a fundamental difference between like and unlike twin pairs, which is in accordance with the assumption of hereditary resemblance of monozygotic and hereditary dissimilarity of dizygotic twins. (Cf. page 209).

d) In monozygotic twins the differences found are determined by error in measuring and environment. (Theoretically it cannot be entirely precluded that genotypical asymmetries play some part. However, there is no positive evidence for such an assumption.) In dizygotic twins the differences are due to error in measuring, environment and heredity, and in opposite-sexed dizygotic to error in measuring, environment, heredity and sex factors. From this basis it has been calculated that the environment gives a standard deviation for head measurements of 1 — 3 mm. or 10 — 20 ‰, and for head measurements 1 — 2 cm., or 10 — 30 ‰. Further, for hereditary factors the corresponding figures are, for body measurements about 4 mm., or 30 — 40 ‰, and for body measurements 3 — 4 cm., or 40 — 50 ‰. Sex factors, finally, and correlated hereditary characters, give a standard deviation for head measurements of 3 — 5 mm., or 25 — 40 ‰ and for body measurements 2 — 4 cm. or 20 — 50 ‰.

Finally, it is possible from these figures to calculate the standard deviation of the individual from the average in a population, and here also it will be found that environment alone gives roughly double the effect of hereditary and sex factors separately. Environment gives in ⅔ of the cases a deviation less than 2,5 mm., or 5 — 15 $^0/_{00}$ for head measurements, and in ⅓ of the cases larger deviation. For body measurements the standard deviation is 1 — 1,5 cm. or 10 — 30 $^0/_{00}$. Heredity gives a standard deviation for head measurements of 3 — 4 mm. or 20 — 30 $^0/_{00}$, and for body measurements 2 — 4 cm. or 25 — 35 $^0/_{00}$. Sex factors give a standard deviation for head measurements (twothirds deviation) of 2 — 3 mm., or 20 — 30 $^0/_{00}$, and for body measurements 1,5 — 2,5 cm. or 20 — 40 $^0/_{00}$. In reality these deviations will sometimes be added to each other, sometimes they will cancel each other, and thus the resulting standard deviation for a same-sexed population is equal to (or rather a little larger than) that of same-sexed dizygotic. (Cf. p. 224).

e) A division of the material after age indicates somewhat increased effect of environment with age, and thus the above figures for effect of environment would be slightly too low for an adult population. This increase with age probably is due to increased strength of the environmental factors. A change with age of the hereditary influence is not noticeable in our material.

f) A grouping of the material into male and female, does not give figures indicating a different variability under environment in male and female. On the other hand, the figures seem to indicate a slightly larger hereditary variability in women than in men, at least for head measurements. The interpretation would be that women have one chromosome (the x-chromosome) more than men, and that this would produce greater hereditary variability.

g) A comparison between first-born and second-born among monozygotic, shows that possibly the first born is on an average a little larger. Further, the first-born has 1,25 ± 0,40 mm. longer head (established difference), and 1,08 ± 0,38 mm. longer face (nearly established difference), which shows that the deformation at birth, generally in the direction of dolicocephaly, will remain into adult age, and that very probably there is a similar permanent deformation towards elongation of the face. As a deformation towards asymmetry also is produced at birth, possibly the asymmetries in the shape of head and face found in adults, are partly due to this deformation.

h) Figures showing differences of indices are given for errors in measuring as well as for monozygotic, same-sexed and opposite-sexed dizygotic, environment, heredity, and sex factors. By calculations of correlation coefficients it is shown that if one twin has one measurement larger than the other twin, other measurements, too, are often larger. This connection, however, is not particularly strong, and the measurements have a large variability independent of each other. A more pronounced correlation is shown between length of head and face length, which accords with the fact that these measurements are influenced in the same direction by deformations at birth.

13. Some statemens about diseases in monozygotic and dizygotic twins are given. With regard to some of these cases it is emphasized that one cannot a priori consider different diseases in monozygotic as due to the effect of environment. It is possible that the disease is caused by a genotypical asymmetry, and that the differences between monozygotic twins regarding diseases can be hereditarily conditioned.

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MEASUREMENTS ON TWINS

MONOZYGOTIC TWIN PAIRS

(Table I, page 3—7)

SAME-SEXED DIZYGOTIC PAIRS

(Table II, page 8—12)

OPPOSITE-SEXED DIZYGOTIC PAIRS

(Table III, page 13—15)

Table I.

Measurements of Monozygotic Twins.

Age = years. Sex: f = female, m = male. Born: 1 = first-born, 2 = second-born. Column 1 = stature (1); 2 = sternal height (4); 3 = height of symphysis (6); 4 = height of acromion (8); 5 = height of tip of middle finger (11); 6 = biacromial diameter (35); 7 = bicristal diameter (40); 8 = length of head (1); 9 = breadth of head (3); 10 = frontal minimum diameter (4); 11 = face breadth (6); 12 = bigonial diameter (8); 13 = face length (18). Obs. Length of arm (45 a), length of trunk (27). The numbers between ( ) refer to Rudolf Martin: Lehrbuch der Anthropologie, Jena 1914.

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
1	3	f	1	1,014	—	—	—	—	—	—	173	129	87	105	81	92
			2	1,019	—	—	—	—	—	—	173	129	91	108	79	93
2	4	»	1	1,052	823	508	812	397	232	194	162	142	97	115	86	98
			2	1,058	827	464	823	412	225	182	168	142	98	115	84	102
3	4	»	1	—	—	—	—	—	—	—	171	136	92	108	82	91
			2	—	—	—	—	—	—	—	167	135	88	107	81	93
4	7	»	1	1,273	1,022	620	1,012	463	294	232	172	146	98	121	94	100
			2	1,290	1,030	618	1,030	475	298	238	171	146	99	125	93	99
5	8	»	1	1,219	972	634	977	449	255	209	177	144	92	123	88	100
			2	1,219	989	642	973	447	254	196	172	142	93	121	86	96
6	8	»	—	1,186	926	581	916	423	251	193	157	136	92	116	87	90
			—	1,179	926	581	922	424	246	201	157	134	93	115	88	90
7	8	»	1	1,253	—	—	—	—	—	—	166	136	92	112	84	101
			2	1,252	—	—	—	—	—	—	167	136	94	113	86	100
8	8	»	—	1,245	1,004	656	1,003	477	253	219	170	134	91	111	83	101
			—	1,244	1,004	659	1,014	480	254	217	168	134	92	110	82	102
9	8	»	—	1,182	933	564	917	418	257	200	172	136	94	114	85	94
			—	1,147	928	547	894	415	258	195	174	134	94	112	84	98
10	9	»	1	1,273	1,012	649	1,014	474	214	278	181	136	94	114	81	98
			2	1,262	1,007	653	999	456	208	274	181	137	93	115	82	95
11	10	»	—	1,375	1,114	—	1,061	520	297	246	179	144	93	121	93	104
			—	1,390	1,113	—	1,096	514	304	241	184	142	94	122	95	107
12	10	»	—	1,194	—	—	—	—	—	—	179	139	93	115	88	102
			—	1,250	—	—	—	—	—	—	179	137	92	114	84	100
13	10	»	—	1,354	1,109	—	1,083	521	276	231	181	144	97	114	86	103
			—	1,350	1,091	—	1,076	518	276	232	179	144	96	114	86	104
14	10	»	1	1,245	999	641	990	458	262	204	182	139	93	113	84	96
			2	1,261	1,018	653	999	453	265	208	183	139	94	115	84	98
15	10	»	1	1,348	1,088	671	1,078	482	291	210	178	148	104	118	87	110
			2	1,334	1,068	674	1,078	478	293	207	178	147	100	118	87	111

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
16	10	f	1	1,396	1,113	721	1,101	508	279	223	193	145	97	122	93	108
			2	1,396	1,116	708	1,109	514	286	221	191	144	99	120	91	108
17	11	»	1	1,380	1,112	688	1,119	537	296	225	175	148	93	124	94	106
			2	1,377	1,103	701	1,103	527	299	233	178	145	98	125	94	107
18	11	»	1	1,409	1,134	724	1,133	530	286	228	181	146	96	117	86	103
			2	1,400	1,130	726	1,135	532	290	228	182	142	92	115	85	101
19	11	»	1	1.426	1,162	726	1,136	519	298	234	181	151	102	122	92	108
			2	1,417	1,152	729	1,149	537	298	234	181	148	100	118	91	106
20	12	»	1	1,357	1,091	691	1,087	509	290	235	171	141	94	117	83	103
			2	1,340	1,093	692	1,086	519	288	234	168	143	97	119	86	101
21	12	»	1	1,443	1,154	773	1,143	539	280	241	179	137	97	118	91	109
			2	1,446	1,158	741	1,159	549	269	243	177	137	99	121	89	111
22	12	»	1	1,356	1,087	703	1,084	507	300	231	187	139	97	118	91	102
			2	1,364	1,108	711	1,106	522	299	226	184	140	99	119	87	104
23	12	»	1	1,377	—	—	—	—	290	236	171	141	99	121	83	101
			2	1,362	—	—	—	—	284	224	175	139	100	121	82	98
24	13	»	1	1,522	1,243	793	1,238	575	319	243	179	141	96	120	91	106
			2	1,538	1,250	796	1,242	592	324	247	185	136	95	121	93	107
25	13	»	1	1,454	1,168	754	1,151	538	305	228	184	134	94	118	85	109
			2	1,434	1,165	730	1,134	524	304	228	182	135	95	119	85	102
26	13	»	1	1.504	1,207	770	1,191	559	306	245	193	147	98	121	100	106
			2	1,520	1,211	764	1,222	586	309	245	191	147	97	120	99	105
27	13	»	1	1,592	1,297	831	1.284	604	318	262	197	148	97	127	99	109
			2	1,534	1,253	836	1,236	578	316	261	187	149	97	129	101	107
28	13	»	1	1,458	1,186	744	1,184	552	302	249	168	133	91	118	86	102
			2	1,497	1,211	767	1,187	544	315	250	167	131	93	117	86	103
29	13	»	—	1,553	1,262	795	1,259	584	334	288	174	140	91	128	98	111
			—	1,512	1,221	781	1,207	544	334	283	178	138	92	127	96	110
30	14	»	1	1,510	1,220	778	1,210	539	331	260	184	139	96	123	94	109
			2	1,525	1,231	791	1,221	545	330	261	183	139	96	123	94	109
31	14	»	1	1,503	1,232	766	1,186	539	318	240	179	143	101	127	87	114
			2	1,498	1,221	769	1,202	558	314	237	184	145	102	126	87	111
32	14	»	1	1,460	1,173	742	1,160	515	289	234	180	144	104	125	90	101
			2	1,424	1,154	714	1,128	512	284	229	180	145	100	121	88	102
33	14	»	1	1,612	1,304	821	1,284	597	346	290	183	151	102	131	102	119
			2	1,557	1,254	799	1,271	599	328	273	177	148	104	133	109	122
34	14	»	1	1,594	1,293	833	1.289	597	339	271	184	143	101	125	93	107
			2	1,619	1,317	845	1,306	597	347	281	180	146	101	126	93	101
35	15	»	1	1,682	1,386	907	1,382	644	332	263	185	146	105	126	93	118
			2	1,716	1,406	904	1,396	641	335	287	187	148	107	126	94	116
35	15	»	1	1,637	1,331	868	1,302	599	343	259	184	137	94	124	95	121
			2	1,667	1,357	866	1,361	658	324	269	184	137	97	124	95	119

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
37	15	f	—	1,520	1,237	777	1,227	554	312	258	186	154	102	127	98	108
			—	1,596	1,307	815	1.272	576	318	258	189	149	102	126	98	109
38	15	»	1	1,625	1,303	826	1,306	604	340	282	185	142	96	123	93	121
			2	1,614	1,296	818	1.290	610	337	282	177	139	97	126	94	112
39	16	»	1	1.591	1,264	803	1,272	601	342	291	182	137	98	126	102	116
			2	1,582	1,268	791	1,279	599	345	274	176	139	95	123	99	109
40	16	»	1	1,532	1,241	757	1,252	593	317	277	178	139	99	130	96	111
			2	1.537	1,245	779	1,241	572	324	272	184	141	97	129	96	110
41	17	»	—	1,619	1,336	815	1,302	619	324	286	189	147	93	129	97	117
			—	1,604	1,321	819	1,308	624	329	282	185	146	94	131	95	114
42	18	»	1	1,584	1,293	807	1,292	601	324	270	186	139	102	124	94	114
			2	1,567	1,274	817	1,278	591	315	265	183	143	103	126	94	108
43	19	»	—	1,611	1,310	848	1.305	574	342	253	189	146	95	123	94	132
			—	1,607	1,310	845	1,294	581	346	257	190	145	93	124	95	127
44	19	»	1	1,581	1,297	827	1,282	571	338	282	188	147	101	131	96	119
			2	1,577	1,289	809	1,267	551	337	281	188	148	101	130	96	120
45	20	»	1	1,597	1,298	818	1,318	659	310	271	192	143	102	133	93	112
			2	1,611	1.313	814	1,313	639	343	270	193	144	103	134	93	112
46	21	»	1	1,704	1,409	884	1,400	666	358	296	184	142	102	127	99	113
			2	1.709	1,409	880	1,409	654	346	301	186	144	103	125	96	120
47	48	»	1	1,601	1,287	738	1,300	583	376	317	184	142	98	134	99	118
			2	1,597	1,310	732	1,311	601	354	319	181	143	95	135	100	119
48	57	»	1	1,676	1,403	847	1,387	676	355	347	200	152	104	129	99	116
			2	1,647	1,366	811	1,362	658	356	334	195	146	104	128	98	116
49	65	»	1	1,534	1.255	—	1,221	564	351	326	184	142	93	135	104	112
			2	1,534	1,254	—	1,241	572	356	324	184	143	97	135	104	114
50	80	»	1	1,470	—	—	1,199	506	333	322	181	147	104	131	98	121
			2	1,503	—	—	1,221	538	326	326	184	147	104	131	95	115
51	4	m	—	998	—	—	—	—	—	—	179	138	96	109	85	88
			—	957	—	—	—	—	—	—	178	139	93	109	83	91
52	5	»	1	1,042	801	482	781	363	217	179	193	147	94	114	82	94
			2	1,036	806	472	790	357	216	172	191	147	94	113	81	95
53	5	»	1	1,061	—	—	—	—	—	—	181	136	87	107	84	99
			2	1,036	—	—	—	—	—	—	182	136	89	106	83	97
54	8	»	—	1.244	978	629	948	428	—	—	188	151	100	119	95	107
			—	1,242	992	626	977	460	—	—	184	148	101	119	92	104
55	8	»	1	1,267	998	613	987	465	238	208	174	140	101	121	85	99
			2	1.259	995	581	988	466	254	210	176	140	101	121	84	99
56	8	»	1	1,234	1,007	645	1,009	460	267	202	189	143	98	118	91	107
			2	1,263	1,008	647	984	431	260	204	188	144	98	119	91	107
57	8	»	1	1.204	952	584	933	415	264	207	185	141	97	119	87	100
			2	1.200	950	575	938	421	269	210	185	141	96	119	86	100

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
58	8	m	1	1,234	997	596	984	461	256	206	178	134	93	112	84	96
			2	1,231	974	581	952	428	258	202	177	136	95	115	84	97
59	8	»	1	1,241	987	—	979	439	267	190	181	139	100	122	91	102
			2	1,248	1,000	—	1,014	456	277	194	180	136	102	120	93	104
60	9	»	1	1,314	1,041	649	1,006	453	277	214	189	139	98	114	86	97
			2	1,332	1,057	669	1,015	464	279	215	188	139	99	114	86	99
61	9	»	—	1,286	1,018	653	1,020	439	290	224	193	138	92	119	86	105
			—	1,271	996	647	1,009	437	281	218	188	138	94	119	87	105
62	9	»	1	1,354	1,075	689	1,083	486	301	214	178	144	92	124	95	110
			2	1,369	1,100	694	1,099	499	300	211	175	148	94	129	99	110
63	9	»	1	1,237	969	623	956	428	274	205	192	141	99	113	91	102
			2	1,207	948	613	933	415	272	200	192	140	99	115	90	100
64	9	»	1	1,323	1,054	682	1,053	478	283	214	188	136	97	115	85	112
			2	1,326	1,056	679	1,048	501	279	210	176	137	95	113	82	109
65	10	»	1	1,373	1,108	698	1,094	478	295	239	183	153	108	126	96	106
			2	1,364	1,104	707	1,096	500	293	242	179	149	106	126	96	103
66	11	»	1	1,306	1,056	686	1,044	451	283	216	186	146	107	121	91	106
			2	1,279	1,029	678	1,039	419	284	216	180	148	106	122	93	104
67	11	»	1	1,422	1,149	750	1,144	528	303	225	188	136	94	119	91	111
			—	1,435	1,152	741	1,148	529	301	227	188	137	94	121	90	110
68	12	»	1	1,549	1,256	827	1,281	572	317	239	195	142	100	123	96	109
			2	1,526	1,231	813	1,228	557	310	228	191	143	101	124	96	110
69	12	»	1	1,333	1,082	676	1,064	486	294	228	181	139	94	121	95	102
			2	1,317	1,054	652	1,052	476	282	240	179	140	94	123	95	102
70	12	»	1	1,447	1,167	764	1,141	526	315	225	183	153	104	126	94	108
			2	1,467	1,197	778	1,192	528	314	228	186	153	103	129	94	109
71	13	»	1	1,547	1,255	805	1,240	542	354	270	183	139	89	123	96	123
			2	1,504	1,222	801	1,224	525	320	260	182	135	88	123	97	117
72	13	»	1	1,489	1,207	770	1,214	578	320	231	180	148	102	125	85	105
			2	1,486	1,212	766	1,217	569	316	228	178	146	102	125	87	107
73	13	»	1	1,361	1,102	690	1,091	497	298	216	188	140	97	115	94	117
			2	1,352	1,084	691	1,072	473	297	216	184	141	100	117	93	114
74	14	»	—	—	—	—	—	—	—	—	186	146	104	125	92	118
			—	—	—	—	—	—	—	—	187	148	102	125	94	117
75	14	»	—	1,450	1,184	755	1,184	547	301	243	177	152	102	130	95	103
			—	1,464	1,200	738	1,209	566	307	244	180	150	102	128	95	105
76	15	»	1	1,603	1,312	836	1,327	627	325	265	194	151	108	130	102	118
			2	1,600	1,298	842	1,314	621	317	260	192	148	107	129	102	117
77	15	»	1	1,550	1,264	—	1,280	593	326	251	190	148	99	126	99	103
			2	1,517	1,238	—	1,223	558	323	256	189	146	105	128	101	109
78	15	»	—	1,668	1,360	879	1,348	639	358	268	198	144	102	133	109	117
			—	1,634	1,349	864	1,332	613	359	264	197	142	102	129	105	119

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
79	15	m	1	1,694	1,386	904	1,395	615	359	273	194	141	103	126	102	124
			2	1,704	1,386	915	1,388	619	348	267	188	146	102	128	99	121
80	16	»	1	1,630	1,323	883	1,326	588	343	270	190	149	98	132	96	124
			2	1,660	1,360	888	1,352	616	360	280	191	150	99	131	96	123
81	16	»	1	1,685	1.387	864	1,375	612	352	284	194	149	102	128	102	124
			2	1,667	1,361	847	1,336	582	366	281	188	146	100	125	98	120
82	17	»	1	1,803	1,487	982	1,451	632	388	315	194	153	106	138	113	143
			2	1,785	1,474	965	1,435	624	375	320	193	145	104	133	106	131
83	17	»	—	1,752	1,444	916	1,419	651	397	274	190	153	101	133	104	131
			—	1,768	1,461	909	1,443	683	399	286	190	154	102	139	106	133
84	19	»	—	1,720	1,404	864	1,408	692	330	273	186	159	103	135	103	115
			—	1,736	1,416	895	1,417	684	373	271	188	157	101	134	104	115
85	20	»	1	1,746	1,434	919	1,430	634	395	287	192	146	98	134	109	124
			2	1,762	1,465	910	1,447	645	404	288	192	146	104	135	108	124
86	20	»	—	1,645	1,345	877	1,326	570	379	281	188	143	104	134	102	131
			—	1,655	1,356	887	1,357	593	373	276	191	141	104	133	100	128
87	21	»	—	1,688	1,394	833	1,370	623	395	291	194	154	108	144	113	135
			—	1,679	1,386	853	1,377	620	395	307	195	153	110	143	115	125
88	21	»	—	1,640	1,335	834	1,318	560	378	284	188	150	103	137	104	128
			—	1,639	1,335	835	1,324	568	374	273	178	147	100	139	105	129
89	21	»	—	1,729	1,419	870	1,409	628	386	282	186	141	101	133	102	114
			—	1,730	1,421	872	1,404	626	387	286	185	141	100	131	100	117
90	21	»	1	1,684	1,380	877	1,378	630	383	278	192	157	110	143	113	127
			2	1,666	1,362	852	1.360	604	377	266	189	156	111	142	114	126
91	21	»	—	1,621	1,336	800	1,334	600	387	274	194	159	104	139	103	131
			—	1,620	1,324	805	1,321	592	391	281	192	157	106	137	105	134
92	23	»	1	1,754	1,432	924	1,410	611	418	285	196	158	105	145	107	127
			2	1,750	1,435	920	1.405	638	414	283	193	155	101	141	105	123
93	23	»	1	1,775	1,455	900	1,455	661	393	300	193	155	103	143	107	127
			2	1,776	1,457	892	1,452	643	405	310	193	153	103	143	107	127
94	24	»	1	1,672	1,372	861	1,319	595	419	274	192	149	103	133	102	118
			2	1,681	1,375	860	1,340	599	413	280	190	153	103	133	105	121
95	36	»	1	1,660	1,376	869	1,375	659	381	305	194	157	108	143	103	124
			2	1,634	1,364	866	1,322	590	360	263	191	153	106	134	94	117
96	41	»	—	—	—	—	—	—	—	—	195	160	103	152	110	124
			—	—	—	—	—	—	—	—	192	159	101	147	102	129

Table II.

Measurements of Same-sexed Dizygotic Twins.

Explanation of the abbreviations, see under the heading of table I.

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
97	5	f	1	957	701	—	731	343	214	173	166	137	84	107	78	87
			2	1,001	768	—	741	354	227	181	164	133	91	111	81	90
98	6	»	1	1,548	1,302	947	1,292	832	236	178	164	135	90	113	83	87
			2	1,558	1,321	1,003	1,311	785	235	193	183	138	93	112	86	92
99	7	»	—	1,295	—	—	—	—	—	—	178	137	94	114	89	96
			—	1,246	—	—	—	—	—	—	167	134	92	112	87	102
100	7	»	1	1,214	958	618	963	442	234	194	176	137	84	114	87	100
			2	1,244	982	602	980	456	254	203	183	137	80	112	92	104
101	8	»	1	1,228	—	—	—	—	—	—	177	134	92	110	84	89
			2	1,181	—	—	—	—	—	—	166	125	93	108	78	94
102	8	»	1	1,231	980	592	966	436	267	225	167	135	92	112	84	95
			2	1,277	1,016	638	1,012	457	273	214	174	137	94	113	84	92
103	8	»	1	1,331	1,061	658	1,002	478	281	220	187	148	101	122	93	95
			2	1,256	1,009	634	997	431	262	211	187	146	103	122	92	93
104	9	»	1	1,318	1,048	669	1,056	484	283	223	183	139	97	117	86	101
			2	1,268	1,010	661	992	437	270	209	177	140	97	118	87	100
105	9	»	1	1,287	1,024	651	987	450	290	213	189	137	94	112	89	98
			2	1,362	1,100	704	1,080	509	297	223	186	139	96	121	94	95
106	9	»	1	1,276	1,003	654	1,001	468	281	216	182	153	104	126	96	102
			2	1,251	983	623	990	442	279	211	166	138	97	114	83	98
107	9	»	1	1,252	1,012	646	993	438	272	208	176	136	99	116	88	93
			2	1,233	991	658	991	460	265	194	173	148	91	115	87	99
108	9	»	1	1,382	1,111	703	1,082	489	296	224	186	143	107	128	97	103
			2	1,336	1,071	683	1,059	499	269	211	175	141	103	123	93	96
109	9	»	—	1,278	1,017	595	996	450	293	—	182	138	99	117	91	108
			—	1,290	1,027	611	1,003	462	290	—	184	136	96	115	92	108
110	9	»	—	—	—	—	—	—	—	—	169	147	94	124	94	106
			—	—	—	—	—	—	—	—	177	144	93	119	94	98
111	9	»	1	—	—	—	—	—	—	—	171	143	101	116	86	105
			2	—	—	—	—	—	—	—	182	146	96	116	89	101
112	10	»	1	1,460	1,183	766	1,174	552	289	246	181	136	98	123	93	112
			2	1,386	1,124	708	1,104	516	320	247	174	138	96	119	89	113
113	10	»	—	1,263	1,004	612	975	466	274	214	160	145	98	123	94	108
			—	1,151	910	557	895	376	291	221	163	142	90	114	89	106
114	10	»	1	1,291	1,028	669	1,024	484	260	225	178	143	98	121	89	97
			2	1,311	1,046	648	1,018	449	278	224	167	138	96	119	94	107

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
115	10	f	1	1,341	1,077	711	1,108	527	276	224	189	146	101	122	96	101
			2	1.292	1,033	686	1,044	501	274	204	184	140	94	112	90	99
116	11	»	1	1,559	1,282	824	1,278	638	311	261	184	148	107	126	94	107
			2	1,495	1,224	793	1,216	604	301	238	178	139	108	116	86	108
117	11	»	1	—	—	—	—	—	—	—	187	139	98	122	90	106
			2	—	—	—	—	—	—	—	185	140	100	126	94	105
118	11	»	1	1,331	1,076	669	1,060	512	276	202	171	135	96	118	90	94
			2	1,442	1.161	747	1,132	547	290	215	176	132	92	114	86	100
119	11	»	1	1,317	1,058	665	1,027	475	293	222	188	146	100	126	97	106
			2	1,312	1,062	632	1,018	484	280	233	168	135	97	115	86	105
120	11	»	1	1,320	1,059	688	1,034	479	293	216	172	134	92	112	83	97
			2	1,310	1,046	655	1,035	474	274	208	172	139	97	121	90	96
121	11	»	1	1,763	1,453	953	1,444	667	339	303	187	143	97	131	102	120
			2	1,683	1,403	—	1,373	651	318	287	184	149	97	128	103	112
122	12	»	—	1,453	1,172	754	1,169	526	314	248	179	144	95	124	92	111
			—	1,337	1,078	671	1,067	490	284	224	169	139	89	118	89	105
123	12	»	—	1,678	1,111	732	1,128	528	301	240	165	147	98	121	87	92
			—	1,323	1,072	666	1,067	491	290	224	174	137	91	117	89	103
124	12	»	1	1,462	1,188	748	1,174	522	301	245	180	141	99	124	95	108
			2	1,347	1,098	699	1,088	488	291	224	185	142	96	116	87	102
125	12	»	1	1,386	1,123	706	1,089	486	284	236	173	151	97	120	90	106
			2	1,425	1,157	731	1,139	526	274	238	178	136	94	117	91	105
126	12	»	1	1,418	1,155	726	1,145	512	297	226	180	140	99	120	90	104
			2	1,388	1,120	702	1,115	538	283	224	185	139	97	116	92	101
127	12	»	1	1,419	1,152	729	1,162	544	308	235	189	138	93	117	97	106
			2	1,369	1,107	692	1,091	509	277	228	186	142	98	123	101	108
128	12	»	1	1,409	1,139	772	1,133	541	297	241	188	142	98	123	94	106
			2	1,323	1,064	681	1,080	503	293	220	181	143	100	122	96	107
129	13	»	1	1,471	1,192	762	1,200	553	288	231	163	136	94	119	91	109
			2	1,514	1,223	792	1,231	559	289	354	181	148	100	124	91	111
130	13	»	1	1,449	1,187	731	1,173	543	297	250	178	145	98	124	91	110
			2	1,447	1,163	728	1,171	542	318	236	182	136	101	121	93	106
131	13	»	1	1,454	1,188	748	1,190	548	306	241	176	138	101	123	92	108
			2	1,466	1.197	741	1,179	521	318	235	177	142	98	123	96	112
132	13	»	1	1,394	1,124	680	1,102	543	272	214	182	146	104	123	93	95
			2	1,341	1,082	686	1,060	501	277	206	176	144	100	118	87	98
133	13	»	1	1,496	1,202	773	1,194	565	316	248	188	142	98	121	93	111
			2	1,581	1,276	839	1,289	609	336	275	191	143	104	127	104	106
134	14	»	1	1,523	1,227	774	1,219	573	320	247	184	142	97	123	96	113
			2	1,551	1,249	790	1,237	581	313	241	175	142	96	123	95	114
135	14	»	1	1,432	1,164	731	1,169	512	307	251	174	142	97	126	94	109
			2	1,544	1,254	778	1,244	544	333	271	181	147	99	129	99	121

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
136	15	f	1	1,573	1,281	820	1,277	551	348	267	192	145	105	131	101	105
			2	1,613	1,308	831	1,299	583	340	266	183	139	99	125	99	119
137	15	»	1	1,486	1,200	726	1,189	554	327	257	192	147	93	125	102	115
			—	1.511	1,219	784	1,196	547	330	265	177	140	102	127	103	116
138	15	»	1	1.502	1,209	776	1,213	526	330	269	181	141	94	119	91	105
			—	1,686	1,268	814	1,263	566	348	264	187	143	102	127	95	102
139	15	»	1	1,551	1,277	797	1,279	579	314	268	184	149	108	133	101	108
			2	1,639	1,330	869	1,344	597	321	271	184	141	102	131	98	119
140	15	»	1	1,661	1,361	891	1,353	587	348	288	198	137	99	126	99	123
			2	1,633	1,342	873	1,342	592	343	308	197	143	101	127	100	128
141	15	»	1	1,626	1,323	823	1,327	622	331	262	188	144	104	127	93	119
			2	1,566	1,287	819	1,284	622	333	276	182	143	102	131	92	115
142	17	»	—	1,550	1,266	805	1,243	563	308	288	171	142	103	122	96	101
			—	1,493	1,203	778	1,195	537	341	296	179	146	92	124	100	110
143	17	»	1	1,594	1,308	821	1,296	611	326	282	186	146	97	131	101	111
			2	1,540	1,250	766	1,238	581	333	294	177	143	98	127	94	107
144	18	»	1	1,587	1,318	829	1,263	540	362	281	181	146	99	129	96	104
			2	1,596	1,344	833	1,304	606	343	268	185	148	96	124	97	107
145	18	»	1	1,705	1,403	882	1,389	631	362	335	184	147	108	134	114	123
			2	1,661	1,369	846	1,331	610	339	313	179	144	106	131	101	117
146	18	»	1	1,612	1,294	791	1,290	564	354	302	187	147	103	131	98	127
			2	1,530	1,239	757	1,242	547	341	258	178	139	98	119	98	127
147	19	»	1	1,517	1,236	756	1,231	568	354	281	187	149	104	132	98	113
			2	1,627	1,341	845	1,337	641	338	280	191	147	104	136	105	116
148	19	»	1	1,556	1,269	772	1,250	571	329	269	187	148	98	129	102	115
			2	1,594	1,284	814	1,297	616	331	282	187	146	104	131	103	117
149	19	»	1	1,558	1,276	799	1,284	596	351	281	178	149	102	129	102	107
			2	1,554	1,272	825	1,261	572	334	285	184	143	97	124	89	114
150	20	»	—	1,667	1,370	896	1,366	634	337	316	183	148	112	140	103	111
			—	1,641	1,340	842	1,328	611	346	299	186	143	103	134	101	112
151	26	»	—	1,590	1,311	806	1,289	603	343	289	184	144	96	131	103	124
			—	1,631	1,324	814	1,325	612	354	284	184	145	103	128	99	116
152	27	»	1	1,540	1,262	826	1,283	590	332	274	173	143	94	129	101	114
			2	1,562	1,277	804	1,291	602	324	281	176	144	93	131	104	112
153	38	»	1	1,547	1,256	806	1,262	572	339	296	183	152	103	134	101	113
			2	1,558	1,267	811	1,279	597	346	301	183	156	101	136	101	111
154	4	m	—	—	—	—	—	—	—	—	174	136	89	106	77	84
			—	—	—	—	—	—	—	—	192	134	88	110	79	86
155	7	»	—	1,197	950	603	951	418	278	192	176	136	96	119	91	96
			—	1,153	897	562	890	387	250	182	176	140	93	117	86	96
156	8	»	—	1,221	972	603	973	436	248	193	166	136	91	112	84	93
			—	1,087	865	552	853	401	225	177	166	135	82	109	81	89

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
157	8	m	—	1,220	983	624	999	438	262	203	173	134	93	115	87	95
			—	1,191	954	604	952	422	266	198	179	146	87	115	85	95
158	8	»	—	1,254	1,002	641	991	463	269	209	182	139	93	117	84	104
			—	1,211	959	608	941	411	259	204	182	137	94	114	81	104
159	9	»	—	1,203	955	585	921	442	264	208	177	144	96	115	99	102
			—	1,187	925	564	923	419	262	207	178	141	97	114	86	100
160	9	»	—	1,328	1,076	687	1,069	466	282	223	186	143	98	117	91	91
			—	1,348	1,097	728	1,082	489	283	217	182	144	96	119	92	94
161	10	»	—	1,613	1,331	826	1.309	566	384	274	204	136	110	130	101	126
			—	1,669	1,381	874	1,364	615	376	271	184	147	103	135	100	117
162	10	»	—	1,381	1,114	708	1,095	494	286	233	173	148	104	124	94	103
			—	1,312	1,042	656	1,045	479	292	214	181	143	97	119	91	107
163	10	»	—	1,357	1,104	708	1,095	501	309	216	179	145	91	122	98	111
			—	1,323	1,066	660	1,034	464	297	220	179	145	96	120	95	107
164	10	»	—	1,339	1,108	745	1,130	507	310	240	170	143	90	123	90	116
			—	1,373	1,109	715	1,097	482	310	245	179	142	88	123	94	112
165	10	»	—	1,350	1,091	664	1.077	485	297	210	179	132	95	119	92	103
			—	1,324	1,055	648	1,050	484	274	211	184	142	98	123	85	107
166	11	»	—	1,322	1,052	654	1,048	506	274	212	185	139	103	117	91	106
			—	1,340	1,074	656	1,056	480	277	215	186	142	105	119	89	104
167	11	»	—	1,423	1,150	735	1,139	503	305	218	187	143	06	119	85	104
			—	1,324	1,062	659	1,074	486	292	217	188	137	97	121	82	109
168	12	»	—	1,371	1,104	714	1,104	491	299	227	187	141	103	121	95	109
			—	1,391	1,128	764	1,111	462	304	236	181	142	107	119	91	113
169	12	»	—	1,455	1,160	729	1,160	515	318	255	186	147	98	126	102	116
			—	1,366	1,081	704	1,091	491	311	245	181	142	96	128	104	106
170	13	»	—	1,466	1,196	742	1,172	572	305	240	183	143	93	119	96	105
			—	1,428	1,158	707	1,148	544	306	246	184	144	98	117	90	103
171	13	»	—	1,505	1,227	789	1,214	553	304	236	178	138	99	122	93	111
			—	1,527	1,238	805	1,234	577	326	245	185	140	99	127	96	114
172	13	»	—	1,479	1,163	734	1,165	512	312	231	183	145	97	123	92	103
			—	1,399	1,123	703	1,140	534	299	218	179	145	90	118	83	105
173	14	»	—	1,575	1,290	855	1,289	592	345	243	174	145	95	129	100	114
			—	1,577	1,293	832	1,265	574	348	248	174	146	97	128	98	119
174	14	»	—	1,629	1.334	839	1,352	664	321	260	192	146	109	134	104	122
			—	1,611	1,306	840	1,311	620	336	270	196	148	111	134	100	118
175	15	»	—	1,512	1,238	818	1,220	569	339	238	185	143	97	125	95	117
			—	1,489	1,209	770	1,213	557	325	230	183	139	90	118	90	117
176	15	»	—	1,456	1,172	774	1,184	539	297	234	186	146	102	124	98	127
			—	1,526	1,246	796	1,240	558	339	239	182	137	103	121	99	113
177	15	»	—	1,522	1,252	833	1,248	561	279	259	183	146	100	129	95	115
			—	1,660	1.375	885	1,369	597	343	268	188	147	101	131	101	117

N:o	Age	Sex	Born	1	2	3	4	5	6	7	8	9	10	11	12	13
178	15	m	—	1,548	1,261	830	1,235	564	333	261	186	148	99	126	94	115
			—	1,464	1,203	775	1,185	555	332	265	179	149	99	127	94	108
179	16	»	—	1,732	1,421	903	1,414	644	355	293	206	143	99	129	100	129
			—	1,749	1,415	938	1,425	631	366	278	200	151	107	131	100	135
180	16	»	—	1,580	1,302	817	1,290	583	348	269	187	140	97	126	98	109
			—	1,733	1,435	907	1,390	637	379	284	192	147	99	131	99	110
181	19	»	—	1,817	1,495	917	1,468	644	396	320	188	147	108	140	101	130
			—	1,761	1,432	917	1,418	623	390	311	188	142	107	138	98	129
182	21	»	—	1,749	1,449	914	1,428	631	364	308	204	151	114	142	103	131
			—	1,687	1,391	880	1,373	594	395	320	191	154	114	141	106	128
183	21	»	—	1,755	1,442	901	1,428	619	409	300	196	154	103	141	114	129
			—	1,744	1,444	876	1,461	660	387	294	194	154	112	138	107	133
184	21	»	—	1,810	1,497	926	1,472	634	418	304	196	147	104	130	107	136
			—	1,682	1,382	859	1,357	599	392	283	202	140	97	124	103	130
185	21	»	—	1,797	1,483	960	1,484	687	375	305	191	145	98	133	108	127
			—	1,682	1,376	857	1,348	619	400	267	188	144	97	129	98	129
186	21	»	—	1,675	1,378	855	1,358	624	384	278	192	146	101	133	107	123
			—	1,653	1,356	840	1,335	600	369	272	190	148	103	135	108	123
187	22	»	—	1,728	1,425	944	1,421	610	408	296	193	146	103	138	108	142
			—	1,689	1,396	902	1,377	583	402	290	191	150	106	139	109	128
188	22	»	—	1,664	1,359	827	1,370	625	363	278	197	157	108	143	109	139
			—	1,642	1,335	810	1,322	594	365	269	197	156	111	141	108	140
189	22	»	—	1,782	1,464	941	1,449	641	399	280	208	159	111	142	105	134
			—	1,722	1,416	909	1,409	610	390	277	199	152	96	141	102	129
190	35	»	—	1,681	1,380	900	1,371	636	350	302	191	152	104	141	104	134
			—	1,651	1,364	903	1,380	637	362	304	184	154	97	142	113	129
191	51	»	—	1,666	1,377	872	1,393	614	369	318	196	157	107	147	114	141
			—	1,712	1,419	922	1,411	622	389	308	193	154	114	147	108	130

Table III.

Measurements of Opposite-sexed Dizygotic Twins.

Explanation of abbreviations see under the heading of table I.

N:o	Age	Sex	1	2	3	4	5	6	7	8	9	10	11	12	13
192	5	m	1,068	—	—	—	—	—	—	180	139	92	112	85	87
		f	1,136	—	—	—	—	—	—	176	139	99	117	86	95
193	5	m	1,042	826	486	793	364	226	191	181	136	91	112	79	96
		f	959	749	418	752	332	211	174	163	131	91	102	78	83
194	6	m	1,151	907	571	901	382	244	198	184	144	102	114	81	90
		f	1,168	934	614	913	417	244	184	183	134	92	106	83	101
195	6	m	—	—	—	—	—	—	—	186	142	87	119	90	92
		f	—	—	—	—	—	—	—	174	137	93	131	81	94
196	7	m	1,200	—	—	—	—	—	—	185	137	100	117	91	105
		f	1,295	—	—	—	—	—	—	177	140	100	120	85	107
197	7	m	1,130	899	589	861	378	246	196	185	145	97	114	80	96
		f	1,191	943	587	928	437	261	207	179	142	91	114	86	92
198	8	m	1,143	898	544	891	406	235	203	177	139	93	110	81	91
		f	1,172	923	574	942	424	256	189	179	136	93	110	82	92
199	8	m	1,189	—	—	—	—	—	—	175	145	94	117	92	99
		f	1,192	—	—	—	—	—	—	164	138	96	116	82	94
200	8	m	1,215	970	614	955	435	273	219	179	145	96	121	92	95
		f	1,129	895	564	891	416	224	196	179	134	91	109	79	91
201	8	m	1,184	936	574	921	396	278	202	186	148	100	116	89	105
		f	1,244	989	629	984	447	284	216	183	146	103	121	88	101
202	9	m	1,318	1,048	667	1,036	444	291	231	186	141	98	118	90	108
		f	1,307	1,045	674	1,041	459	284	223	187	140	99	120	90	106
203	9	m	1,252	989	616	983	442	277	215	174	151	98	123	97	90
		f	1,248	1,011	611	991	473	267	209	176	142	101	118	92	96
204	9	m	1,302	1,041	644	1,013	452	290	217	176	136	98	117	87	96
		f	1,332	1,090	666	1,052	481	276	225	180	134	99	114	88	106
205	9	m	1,350	1,072	708	1,080	501	292	228	184	153	107	128	99	108
		f	1,317	1,046	671	1,036	470	284	216	178	142	103	121	91	101
206	9	m	1,313	1,046	657	1,031	465	284	—	187	148	98	117	89	109
		f	1,282	1,020	631	1,008	559	290	—	172	139	98	118	84	98
207	10	m	—	—	—	—	—	—	—	183	145	93	120	92	100
		f	—	—	—	—	—	—	—	175	140	91	113	90	100
208	10	m	1,432	1,151	715	1,163	529	314	236	188	144	98	125	91	118
		f	1,434	1,152	730	1,158	533	297	238	187	141	100	124	97	110
209	10	m	1,357	1,085	686	1,078	502	267	220	176	143	94	123	95	103
		f	1,338	1,083	691	1,064	498	275	221	170	139	93	116	84	96

N:o	Age	Sex	1	2	3	4	5	6	7	8	9	10	11	12	13
210	10	m	1,255	1,026	684	1,013	414	280	219	174	134	96	117	87	96
		f	1,269	1,011	634	981	431	289	221	174	133	92	112	88	101
211	10	m	1,444	1,171	779	1,173	488	318	261	177	149	102	129	96	104
		f	1,394	1,121	718	1,116	495	294	231	173	154	97	125	97	106
212	10	m	1,330	1,076	688	1,074	516	278	221	182	145	102	124	92	102
		f	1,362	1,107	699	1,094	522	294	229	169	144	99	127	91	102
213	11	m	—	—	—	—	—	—	—	178	150	99	123	92	103
		f	—	—	—	—	—	—	—	173	147	99	122	91	108
214	11	m	1,352	1,078	700	1,074	495	290	217	194	132	92	118	88	108
		f	1,369	1,097	674	1,061	491	292	217	187	142	92	119	88	109
215	11	m	—	—	—	—	—	—	—	194	148	101	124	99	114
		f	—	—	—	—	—	—	—	176	138	92	116	86	108
216	11	m	1,455	1,176	748	1,154	537	319	230	192	142	101	128	98	109
		f	1,355	1,110	689	1,104	543	289	234	181	136	93	118	91	99
217	11	m	1,305	1,041	647	1,014	455	290	204	174	141	101	120	92	103
		f	1,308	1,051	663	1,019	469	291	214	179	142	95	123	92	100
218	11	m	1,390	1,126	688	1,116	526	295	228	187	148	99	119	92	102
		f	1,301	1,046	625	1,054	484	271	227	180	139	91	115	87	101
219	11	m	1,377	1,103	690	1,098	496	305	237	182	145	105	121	94	100
		f	1,219	986	591	959	456	270	200	170	140	99	117	86	93
220	11	m	1,284	1,030	654	1,010	466	261	207	175	138	91	114	84	94
		f	1,397	1,132	724	1,106	490	285	214	183	144	103	119	89	104
221	12	m	1.456	1,169	747	1,183	522	308	231	185	143	98	124	94	122
		f	1,459	1,200	760	1,194	530	296	230	186	146	94	118	89	111
222	12	m	1.435	1,157	697	1,137	519	298	239	197	140	101	125	97	108
		f	1,516	1,223	770	1,214	556	331	242	189	144	101	122	89	105
223	13	m	1,448	1,162	764	1,161	520	306	231	189	142	97	117	92	107
		f	1,478	1,194	738	1,192	544	318	248	183	135	92	120	93	109
224	13	m	1,393	1,134	741	1,125	491	303	231	182	136	95	121	96	101
		f	1,477	1,181	731	1,174	563	309	254	186	142	95	127	98	113
225	13	m	1,449	1,171	733	1,183	558	323	236	168	153	104	127	95	111
		f	1,556	1,264	792	1,249	586	332	261	184	148	98	127	92	104
226	13	m	1,521	1,241	818	1,229	572	321	231	188	146	101	124	99	109
		f	1,451	1,181	786	1,207	576	293	231	187	139	103	118	91	112
227	13	m	1,529	1,247	811	1,250	578	340	242	184	151	101	134	99	111
		f	1,480	1,208	803	1,211	562	322	241	189	143	101	129	94	101
228	14	m	1,493	1,246	820	1,246	576	309	268	194	154	107	132	102	118
		f	1,567	1,279	816	1,272	574	321	276	189	159	104	138	106	119
229	14	m	1,586	1,296	850	1,298	587	327	243	196	141	98	123	92	112
		f	1,620	1,320	832	1,322	592	339	275	191	144	99	124	96	107
230	14	m	1,769	1,476	942	1,488	700	358	266	187	146	99	134	100	110
		f	1,634	1,340	836	1,329	624	332	260	175	131	96	123	94	113

N:o	Age	Sex	1	2	3	4	5	6	7	8	9	10	11	12	13
231	15	m	1,570	1,271	806	1,236	569	318	271	188	148	99	131	99	101
		f	1,502	1,232	794	1,220	574	311	256	186	149	94	130	98	117
232	15	m	1,482	1,198	781	1,182	513	318	261	169	150	94	131	99	108
		f	1,539	1,255	824	1,264	579	309	274	173	146	97	132	99	109
233	16	m	1,670	1,371	909	1,359	602	357	264	186	148	103	124	94	119
		f	1,697	1,337	866	1,419	656	296	294	179	144	102	133	98	118
234	16	m	—	—	—	—	—	—	—	198	151	101	134	100	122
		f	—	—	—	—	—	—	—	178	144	91	120	90	117
235	17	m	1,161	—	—	—	—	—	—	180	134	94	113	84	96
		f	1,163	—	—	—	—	—	—	177	135	94	113	84	96
236	17	m	1,726	1,407	913	1,381	609	377	284	193	151	102	133	99	116
		f	1,561	1,264	833	1,239	530	351	272	183	143	87	127	99	121
237	17	m	1,591	1,293	852	1,294	551	359	261	188	148	94	125	95	117
		f	1,606	1,307	818	1,304	593	353	283	181	140	88	123	92	112
238	17	m	1,704	1,385	879	1,375	618	383	287	198	149	106	132	104	132
		f	1,603	1,301	818	1,301	599	372	314	194	149	104	133	104	119
239	17	m	1,707	1,394	896	1,384	575	358	289	196	147	102	137	101	129
		f	1,552	1,256	801	1,226	531	342	256	187	144	99	126	101	118
240	19	m	1,731	1,422	934	1,442	620	398	293	189	149	100	135	103	124
		f	1,629	1,342	842	1,359	629	323	274	181	144	99	129	97	115
241	22	m	1,781	1,469	914	1,455	663	405	278	199	144	102	136	114	127
		f	1,634	1,361	879	1,343	608	367	299	177	148	106	143	108	115
242	36	m	1,705	1,414	896	1,414	616	379	284	184	153	106	137	103	118
		f	1,674	1,362	882	1,381	603	356	302	186	151	97	126	97	116
243	41	m	—	—	—	—	—	—	—	194	162	114	155	114	127
		f	—	—	—	—	—	—	—	180	154	102	139	100	118

PHOTOGRAPHS

MONOZYGOTIC TWIN PAIRS
(Page 3—53)

DIZYGOTIC TWIN PAIRS
(Page 54—61)

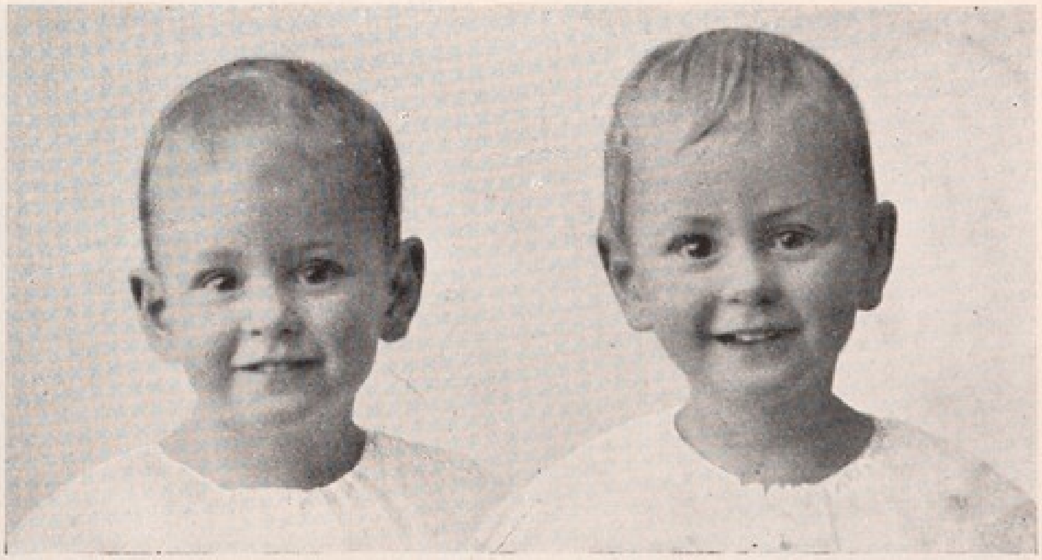
EARS ON NATURAL SCALE
(Page 64—85)

The numbers on the photographs correspond to the numbers on the twin pairs in the tables of appendix I. The measurements and the photographs are not always taken at the same time and therefore the ages here and in appendix I do not always accord.

MONOZYGOTIC TWINS

14, 23, 45, 49, 79, 86 and 95 are not photographed on the same plate and therefore these portraits are not on exactly the same scale.

1



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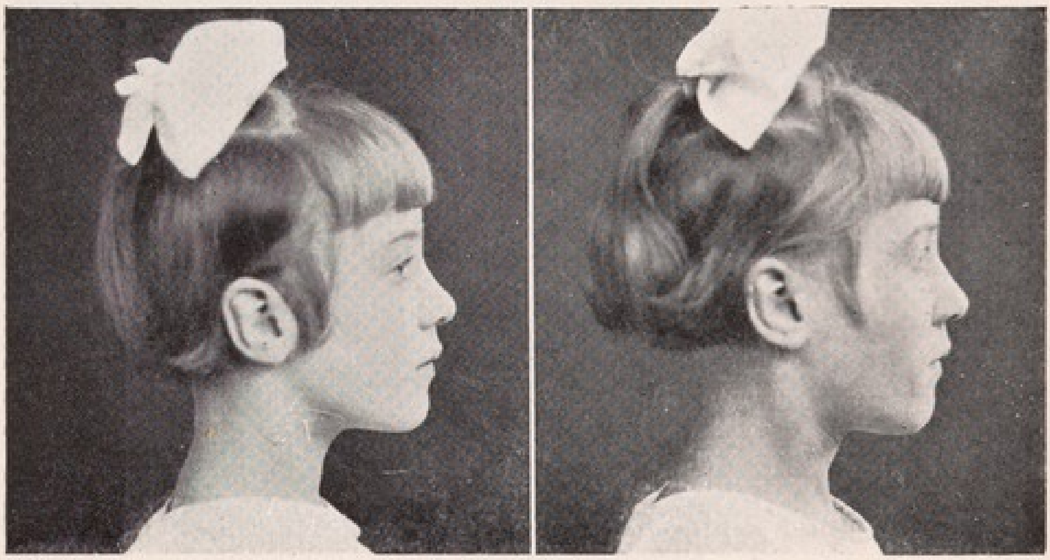

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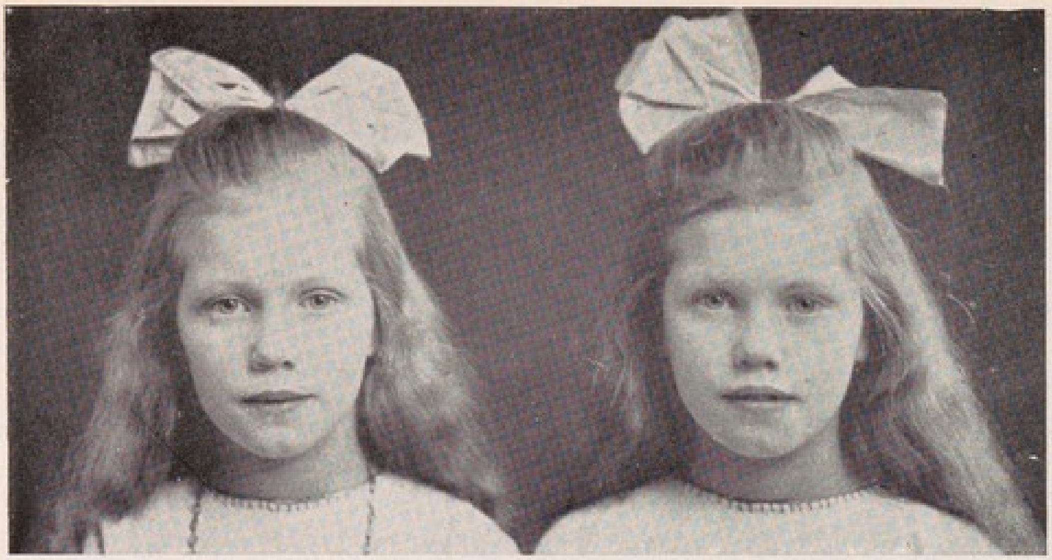

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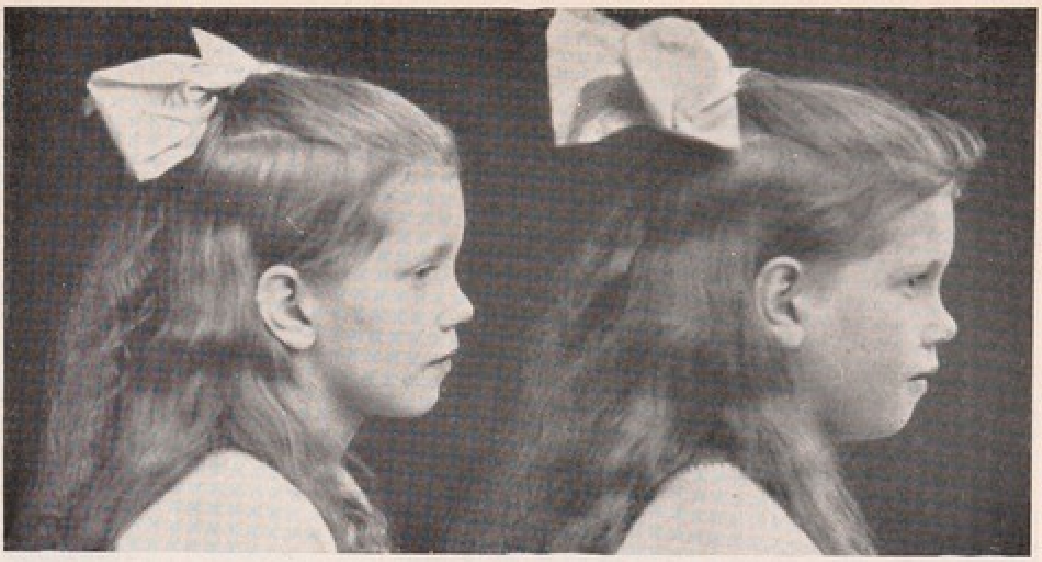

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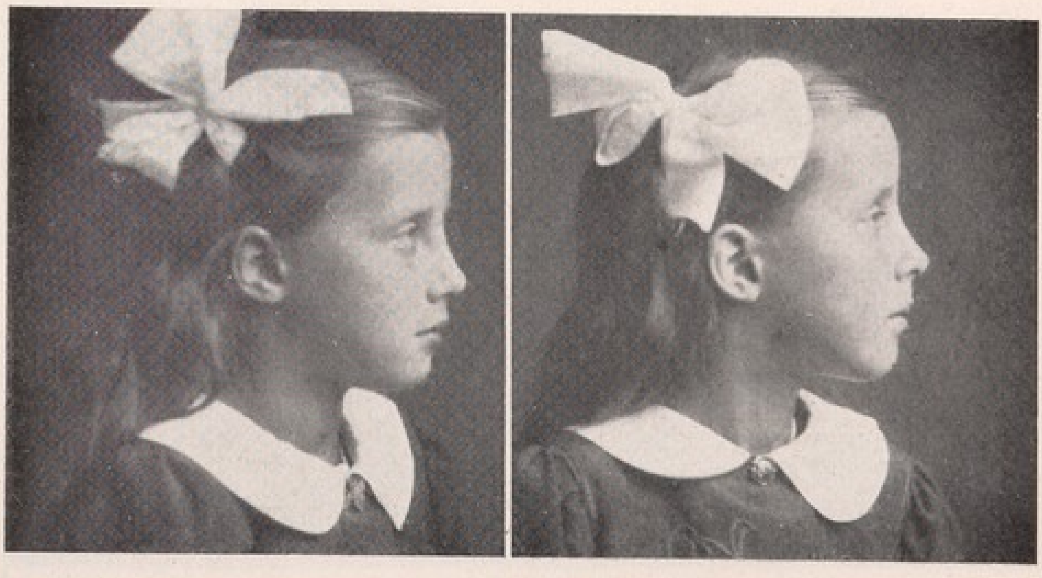

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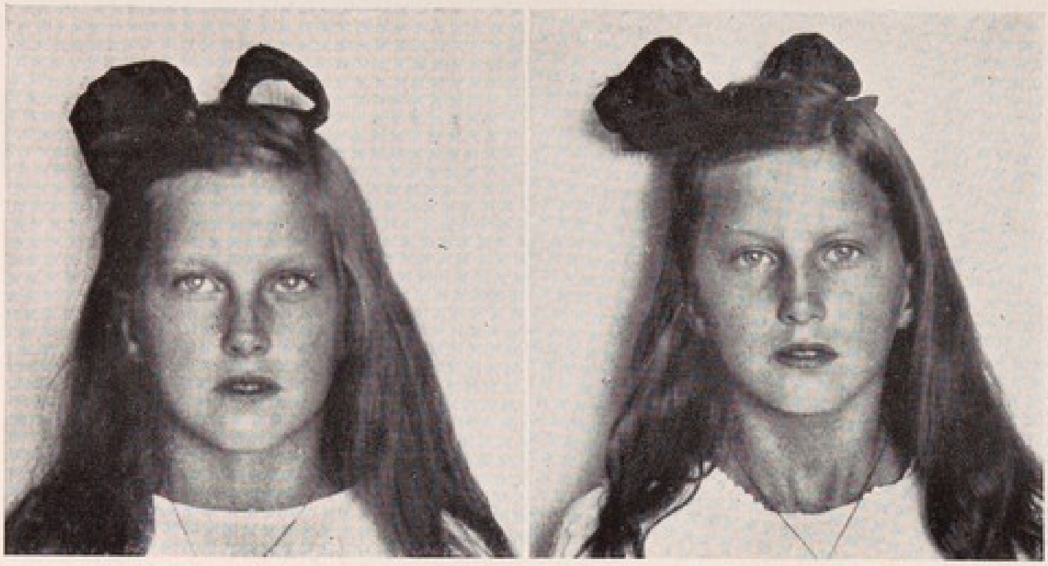

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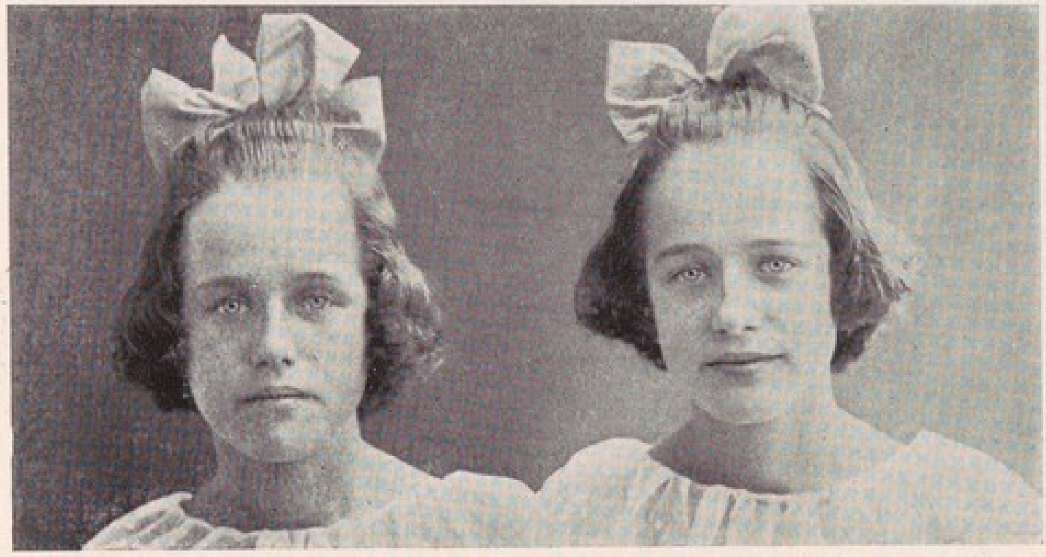

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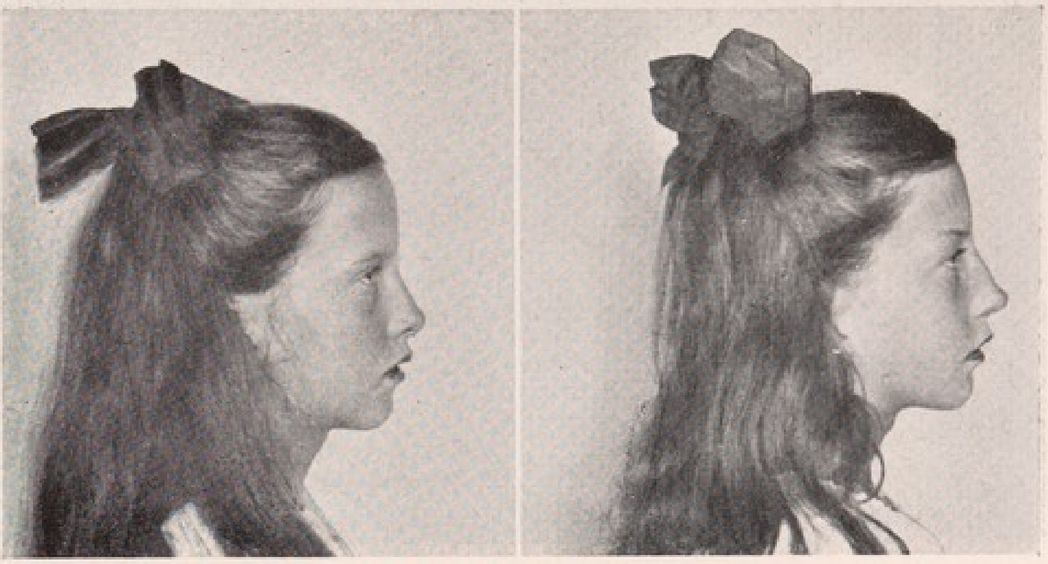

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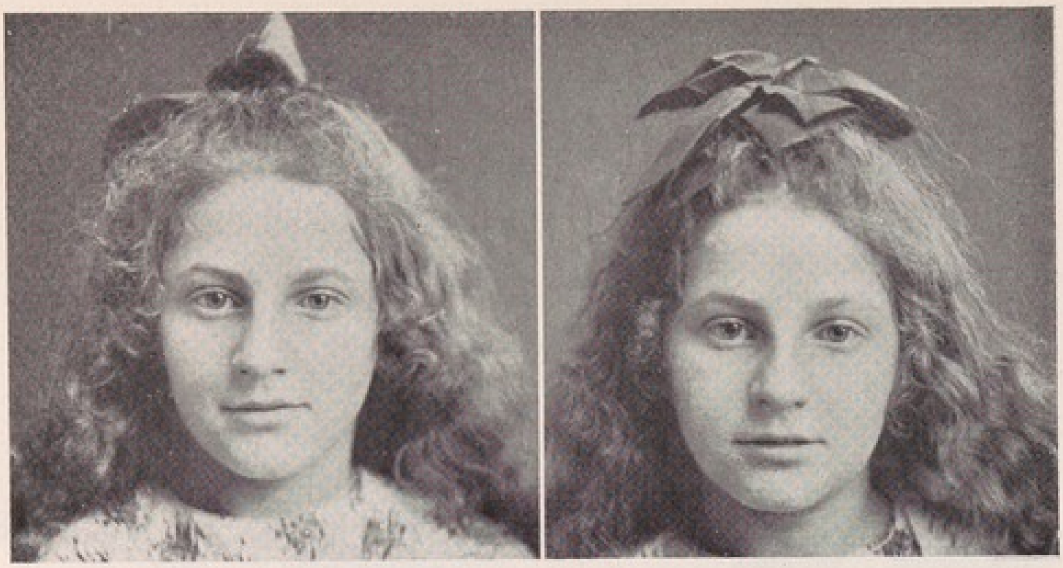

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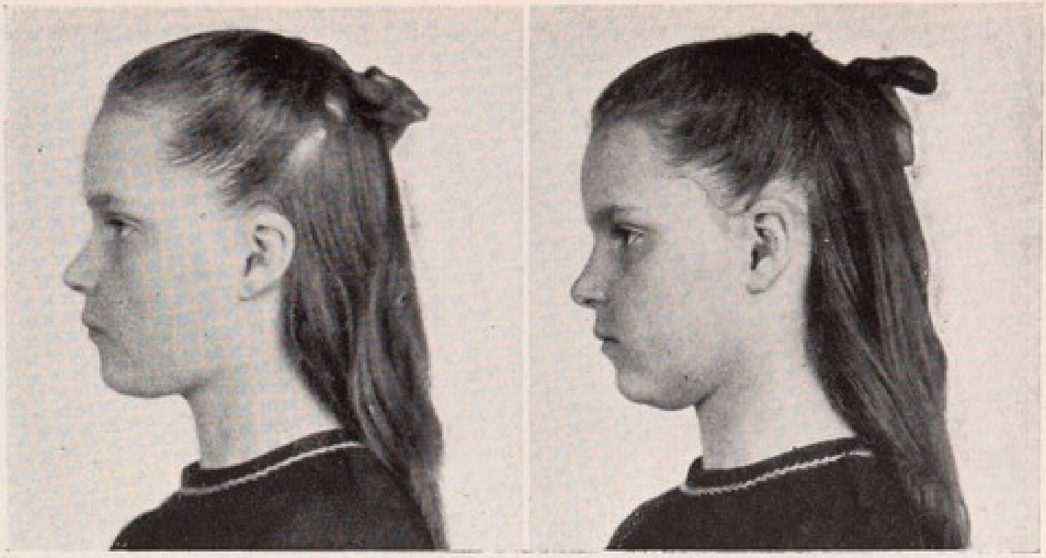

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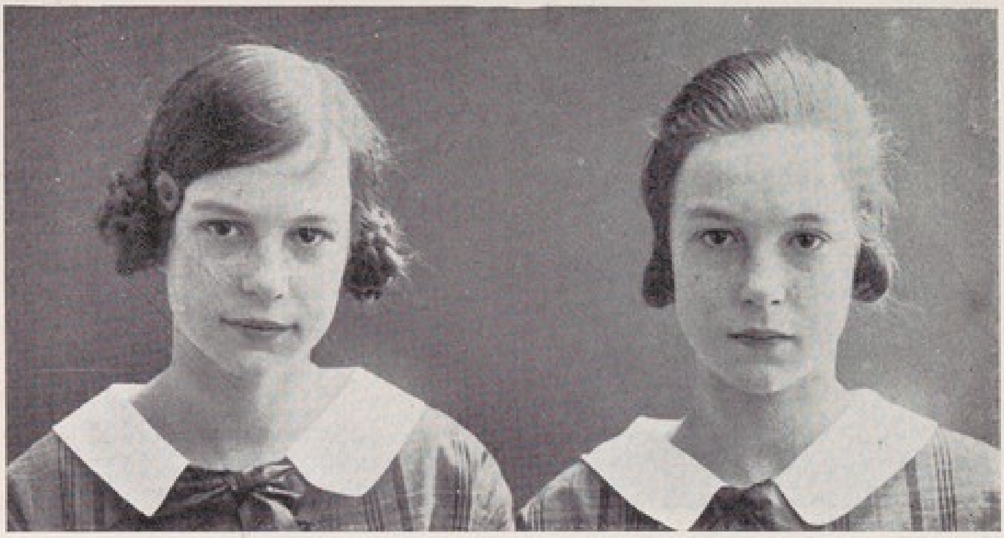

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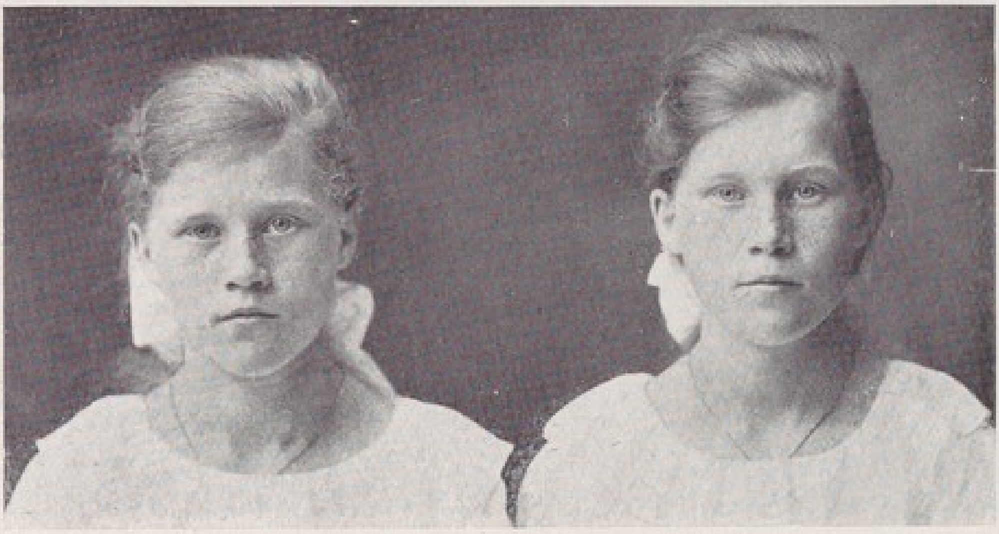

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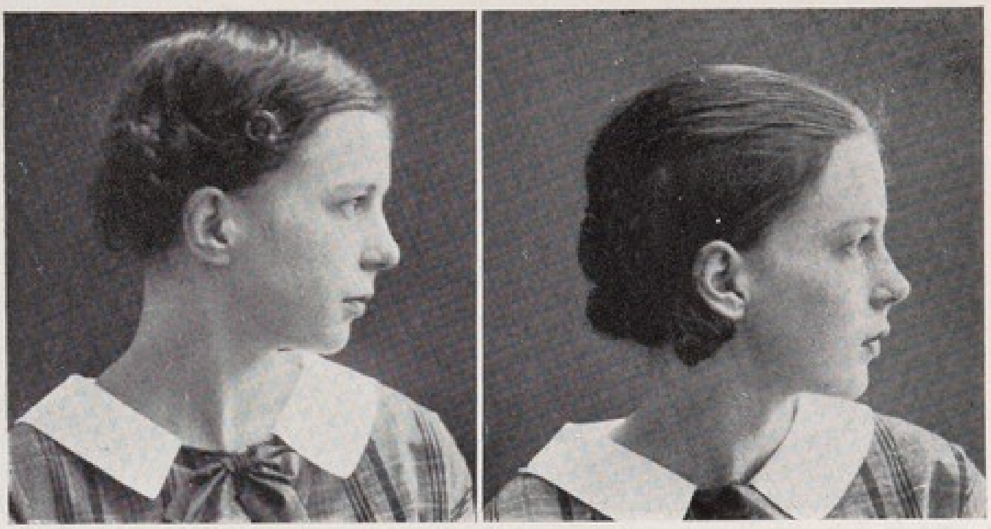

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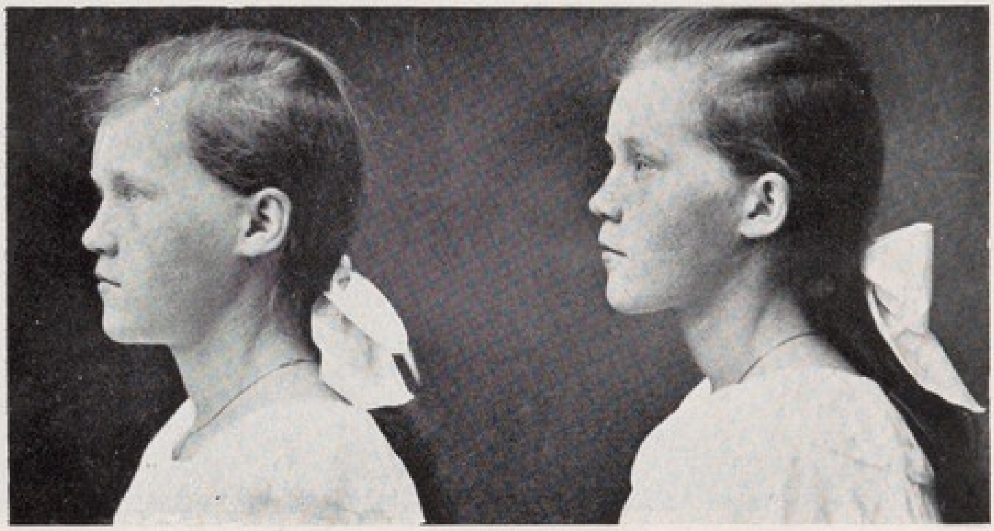

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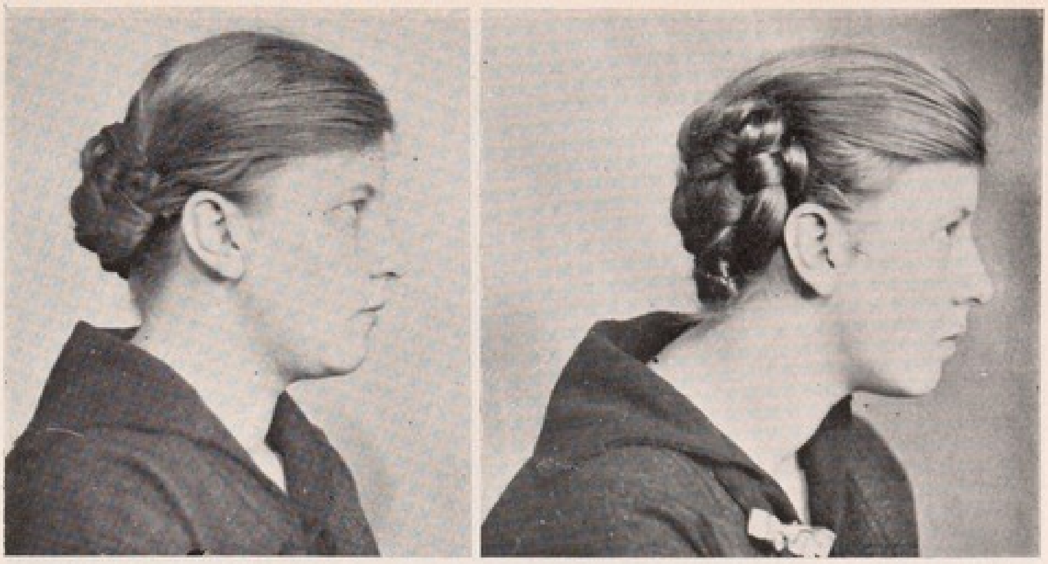

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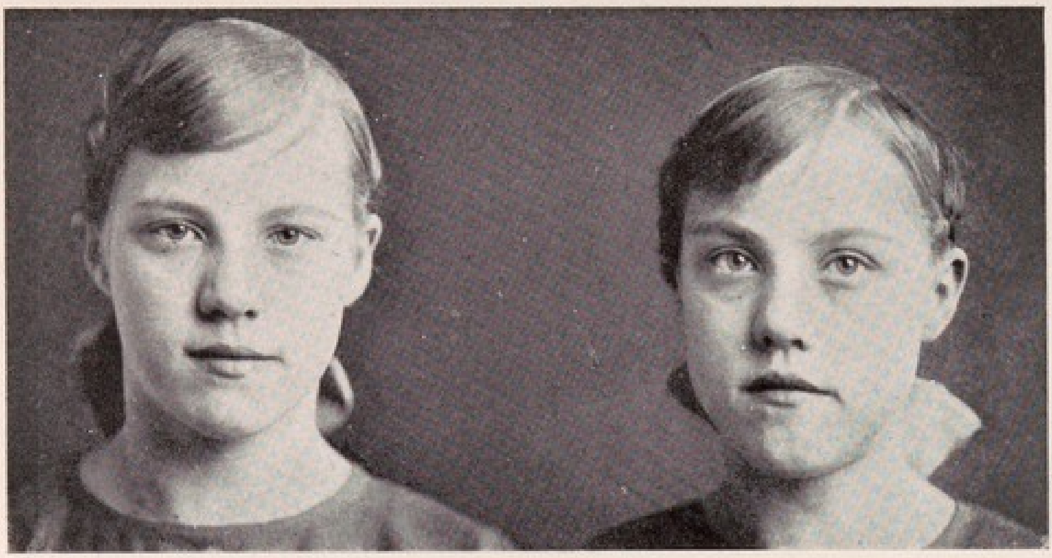

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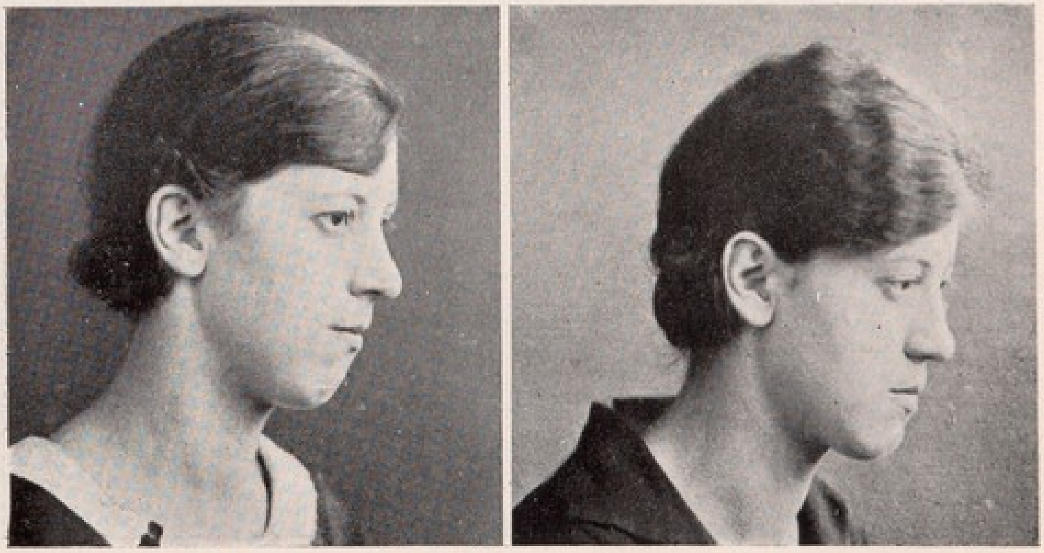

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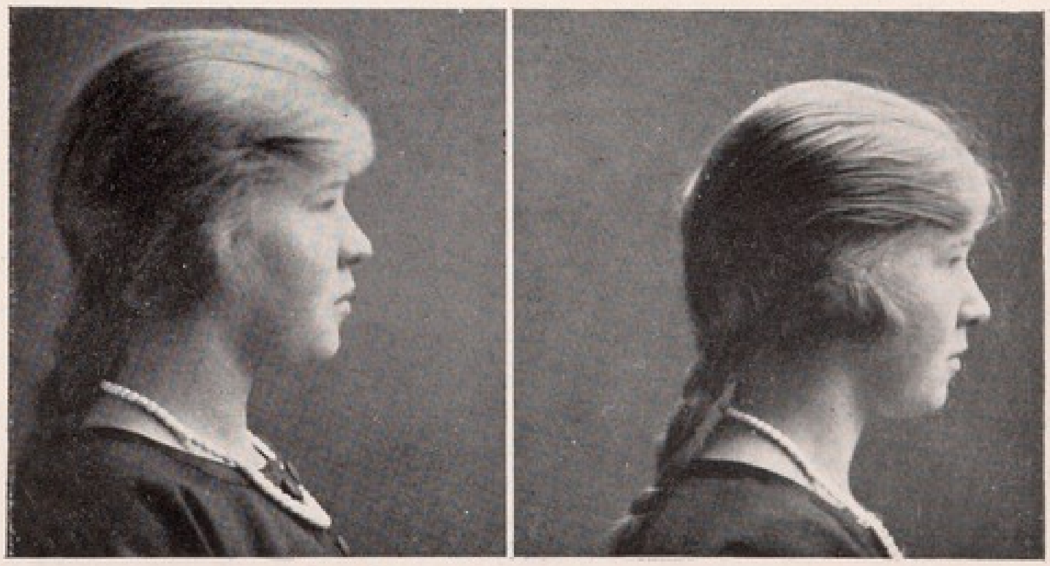

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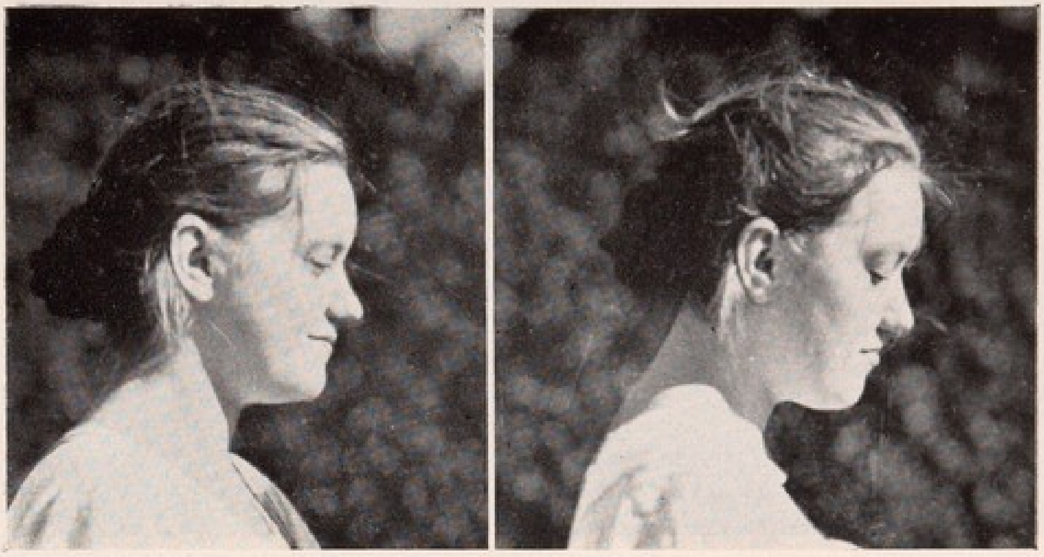

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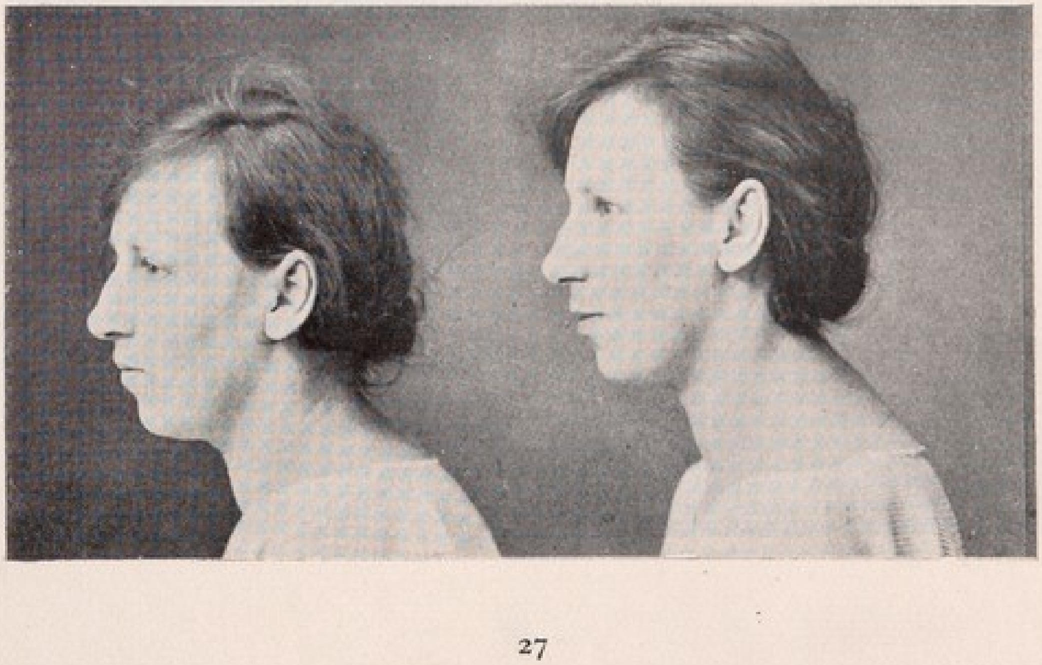

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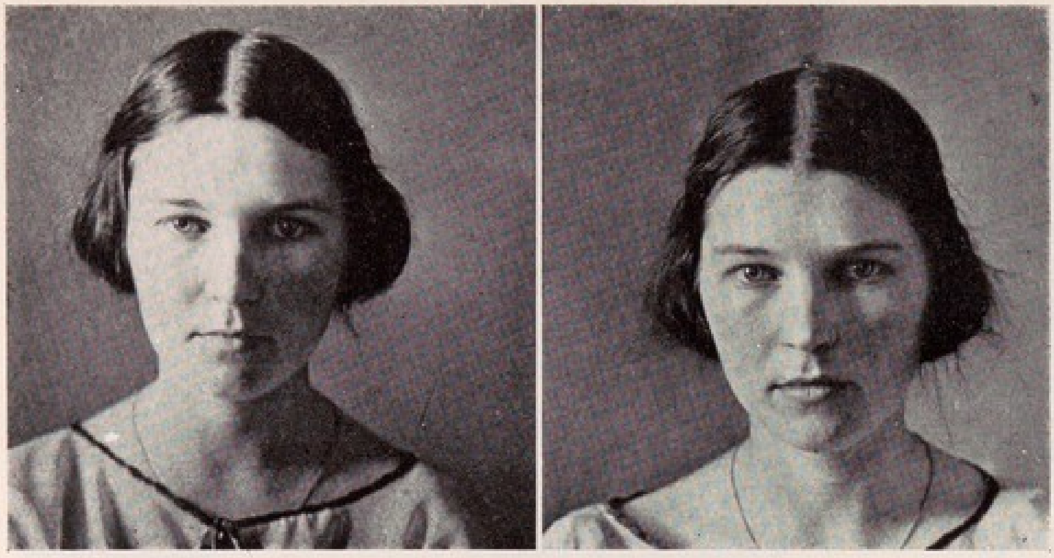

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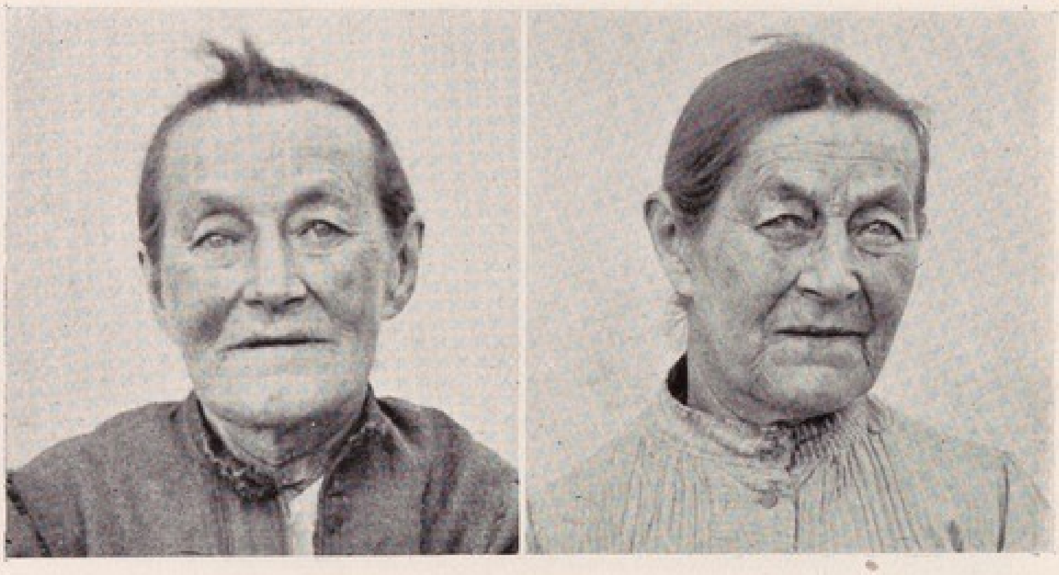

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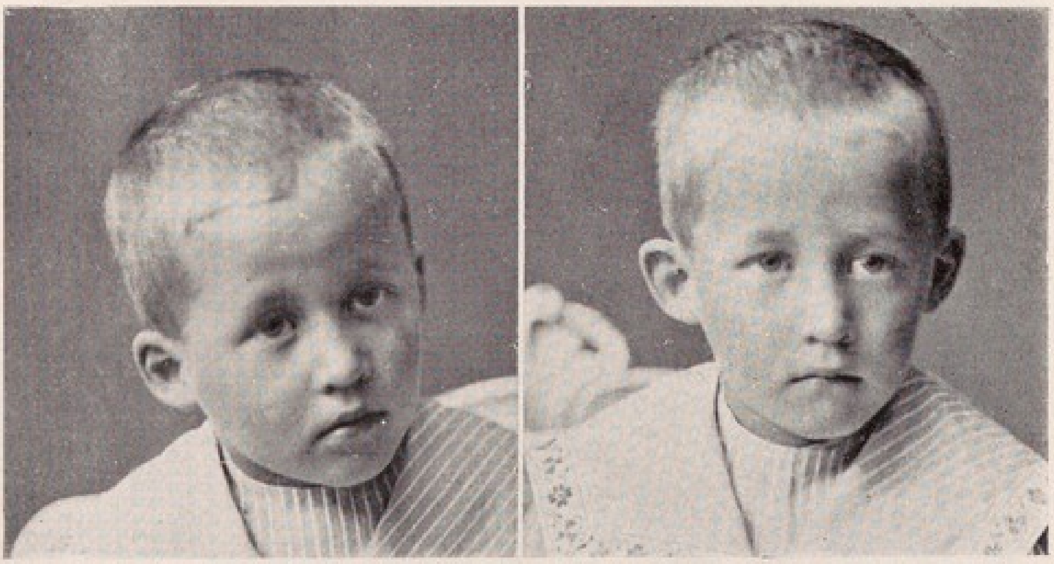

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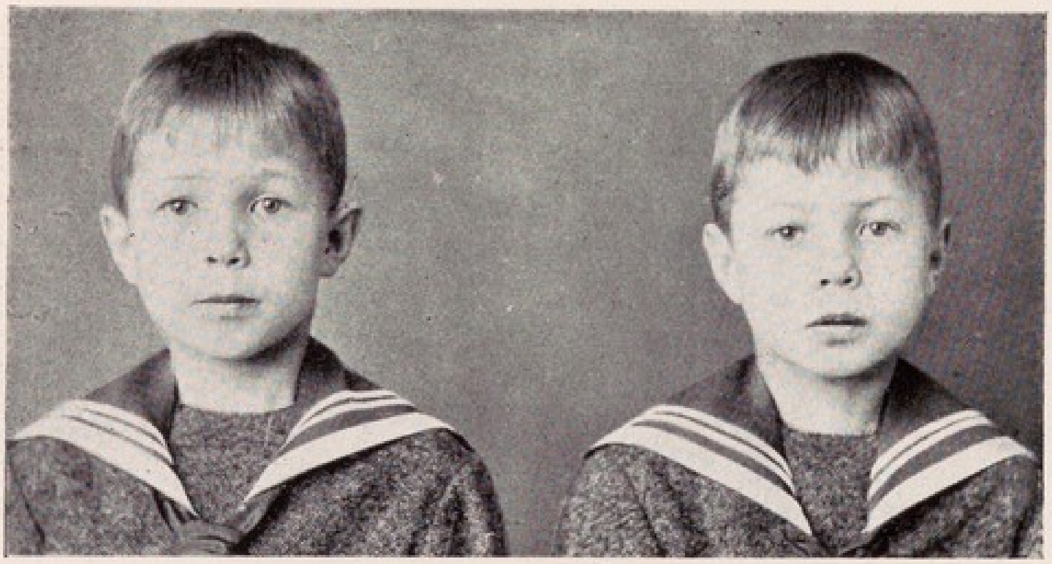

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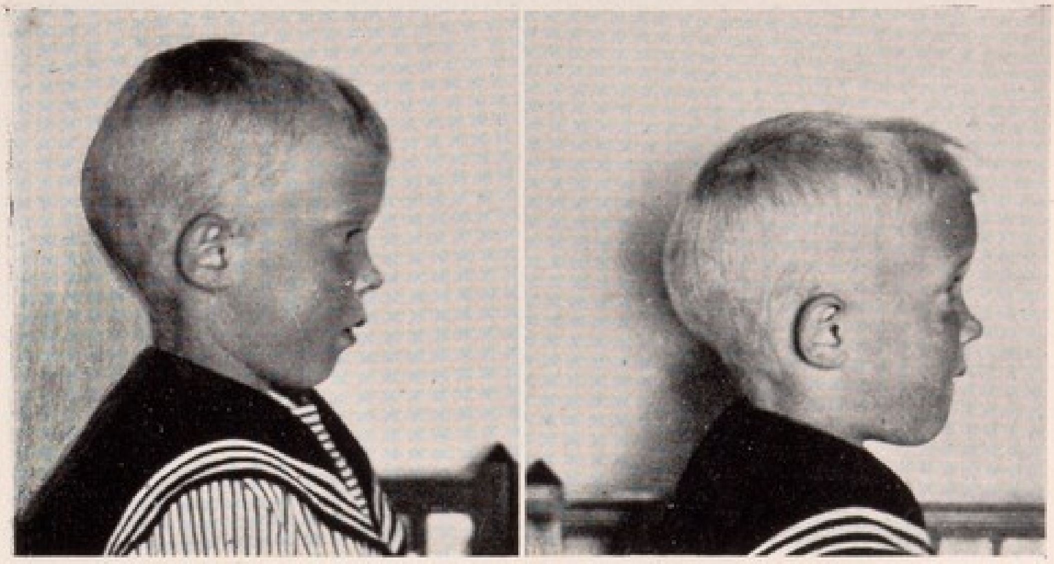

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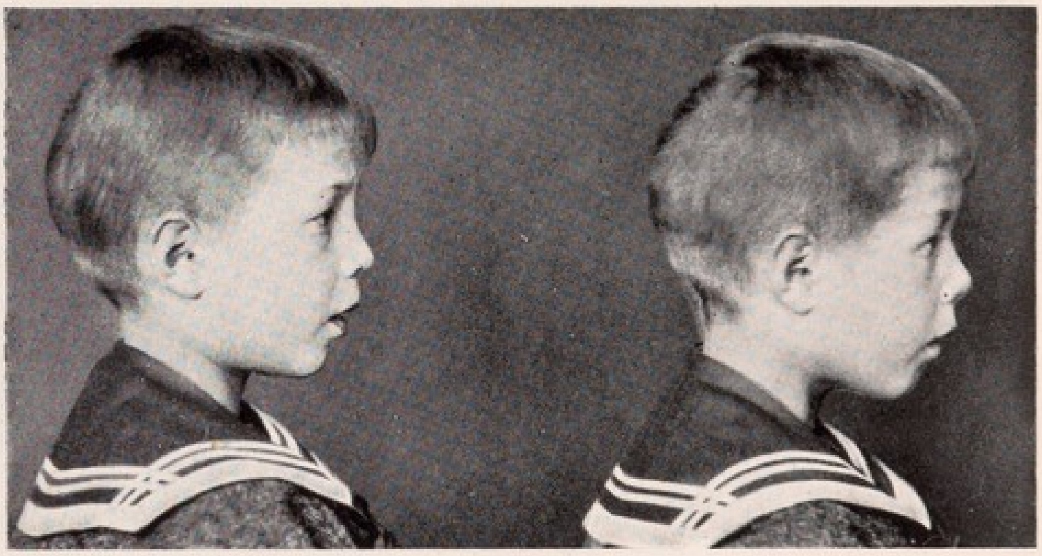

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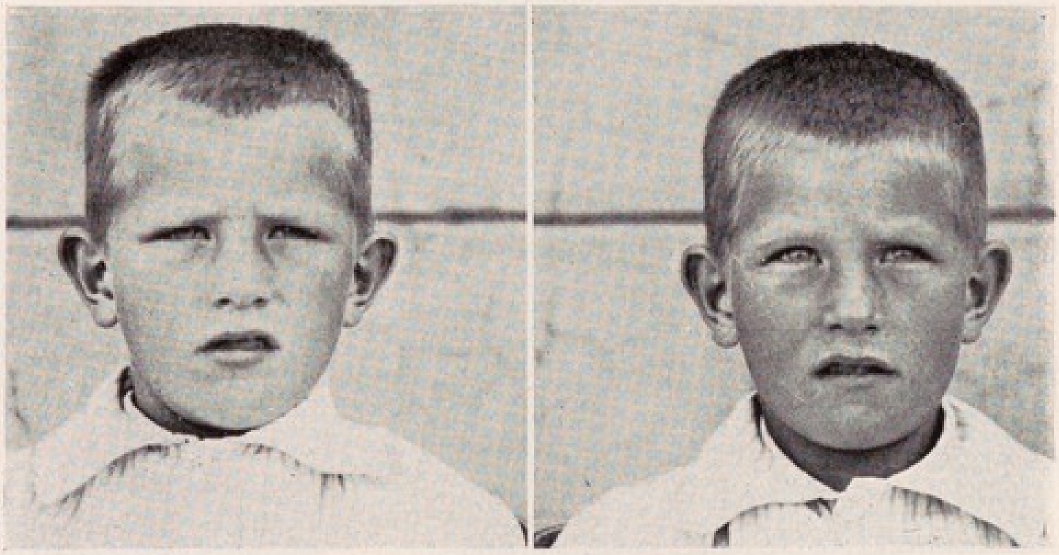

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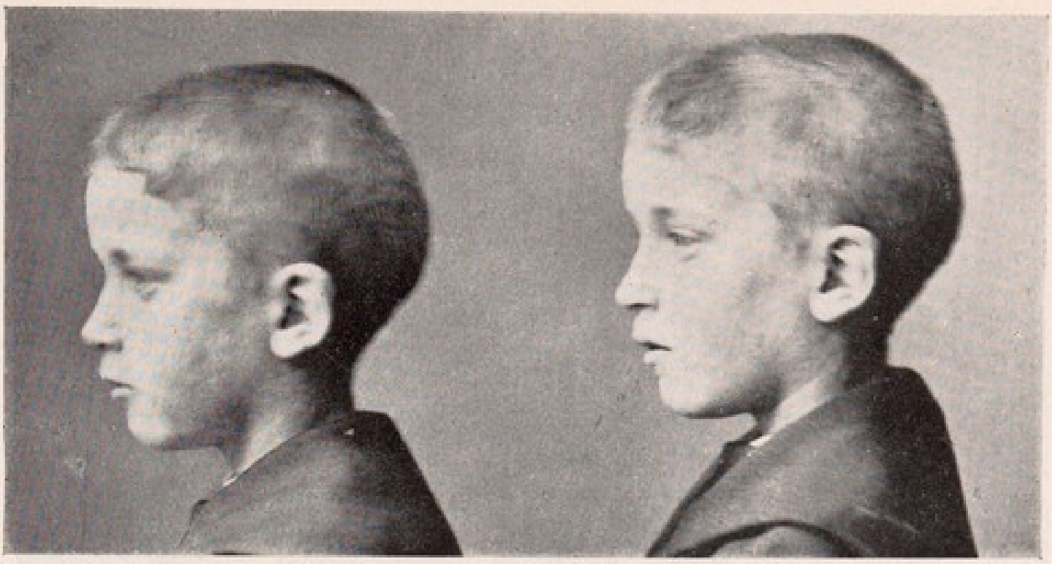

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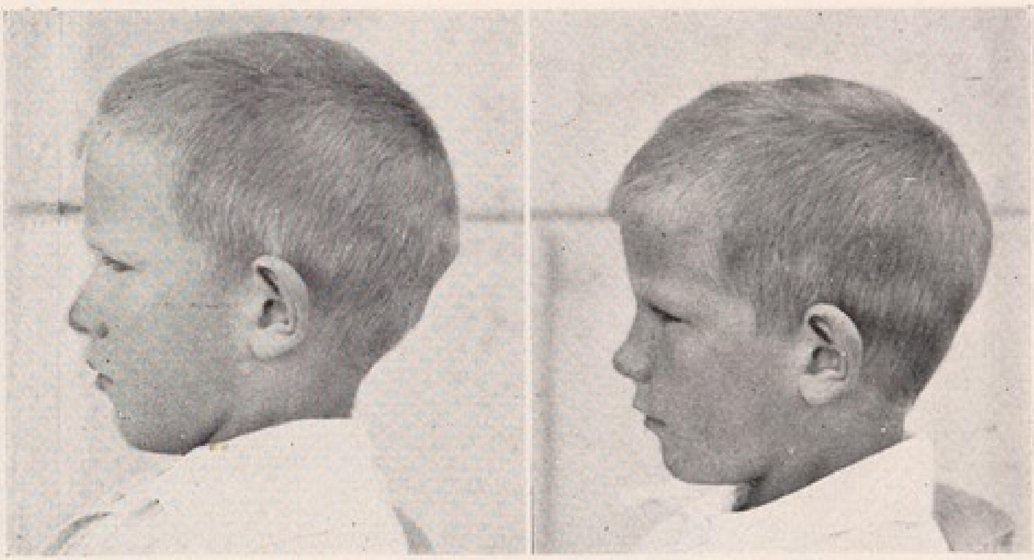

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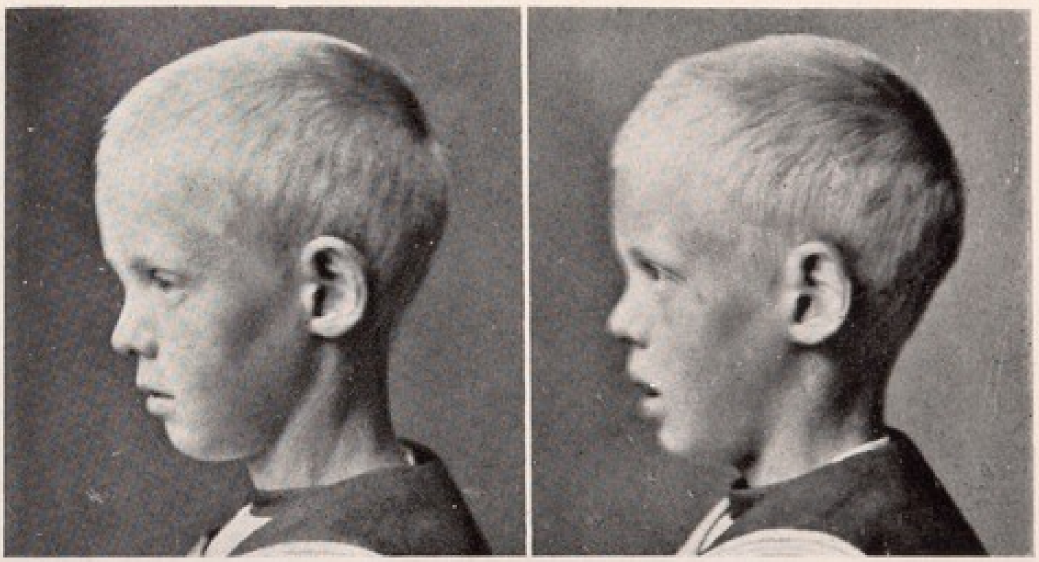

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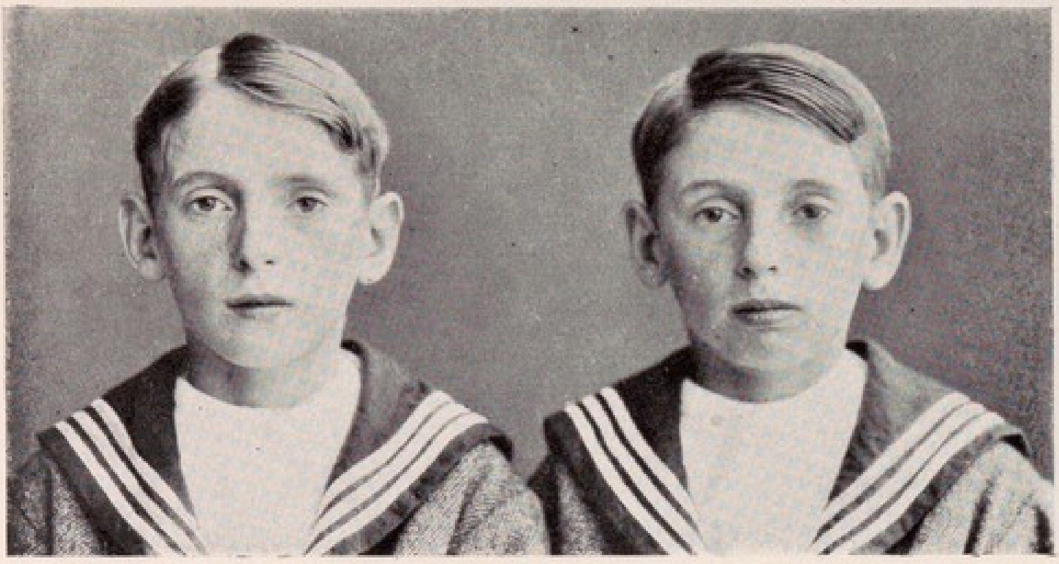

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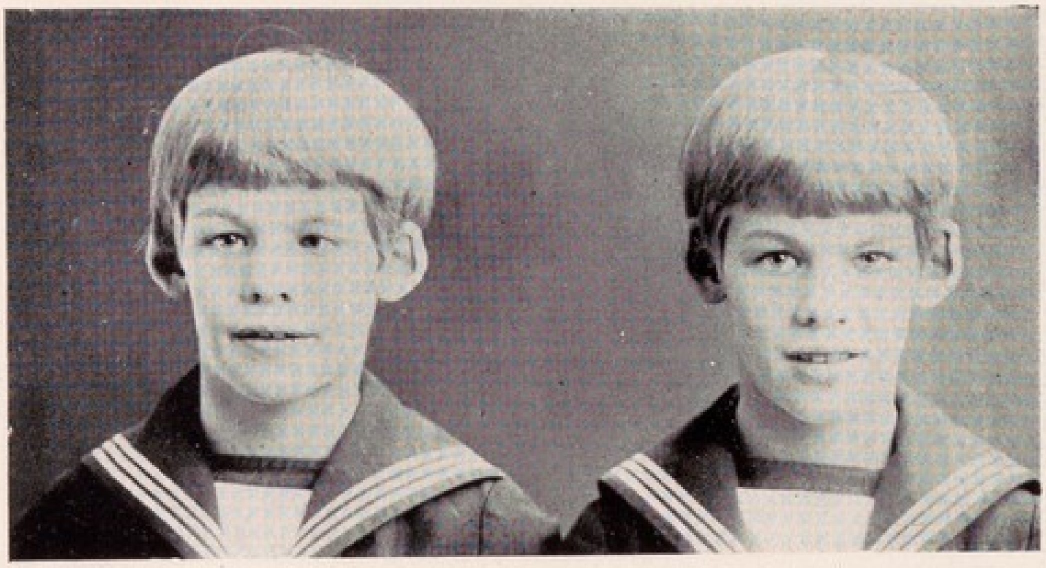

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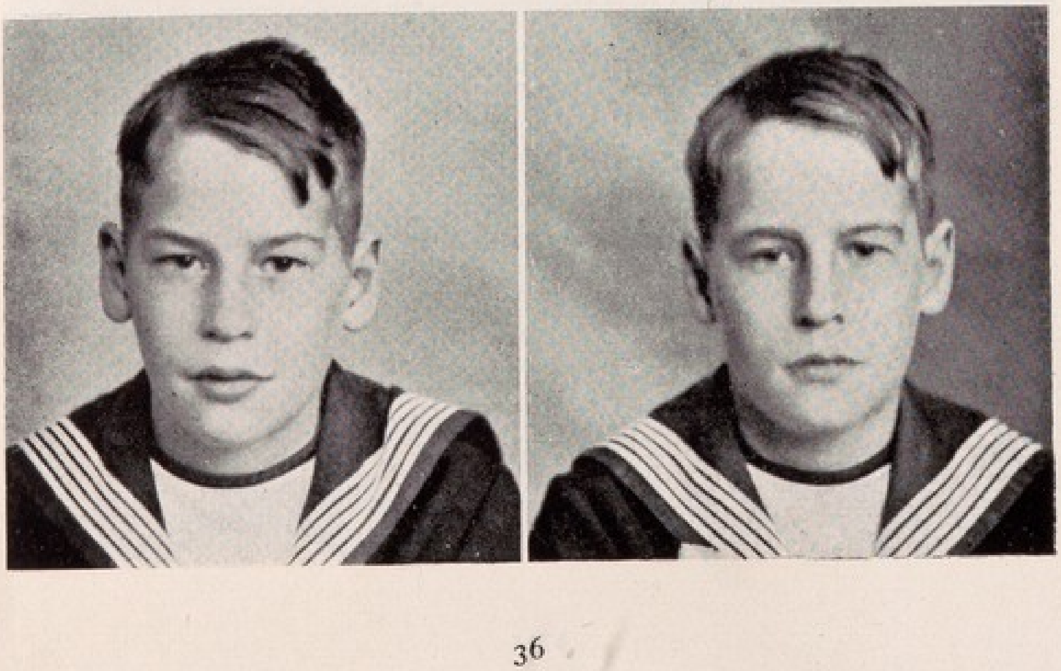

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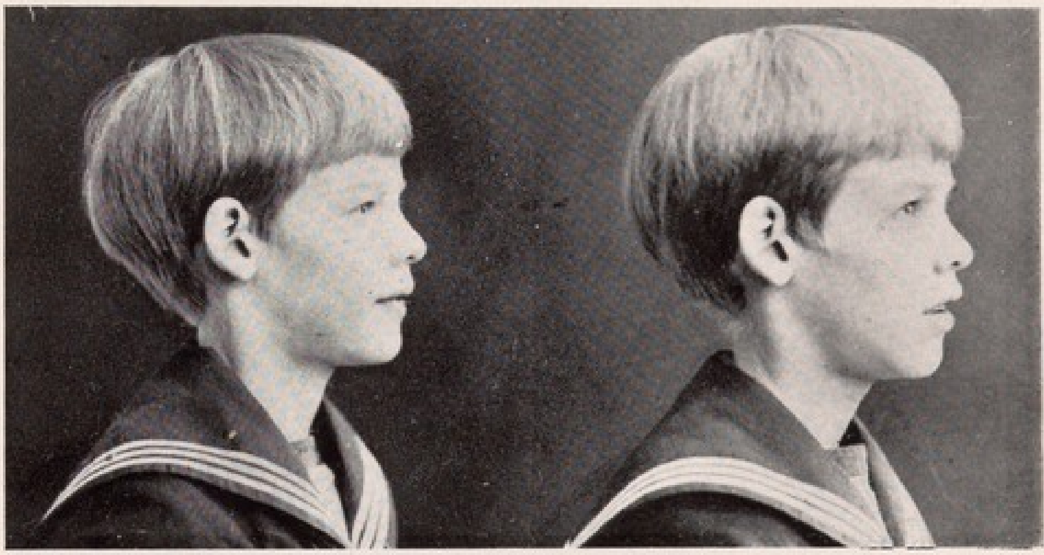

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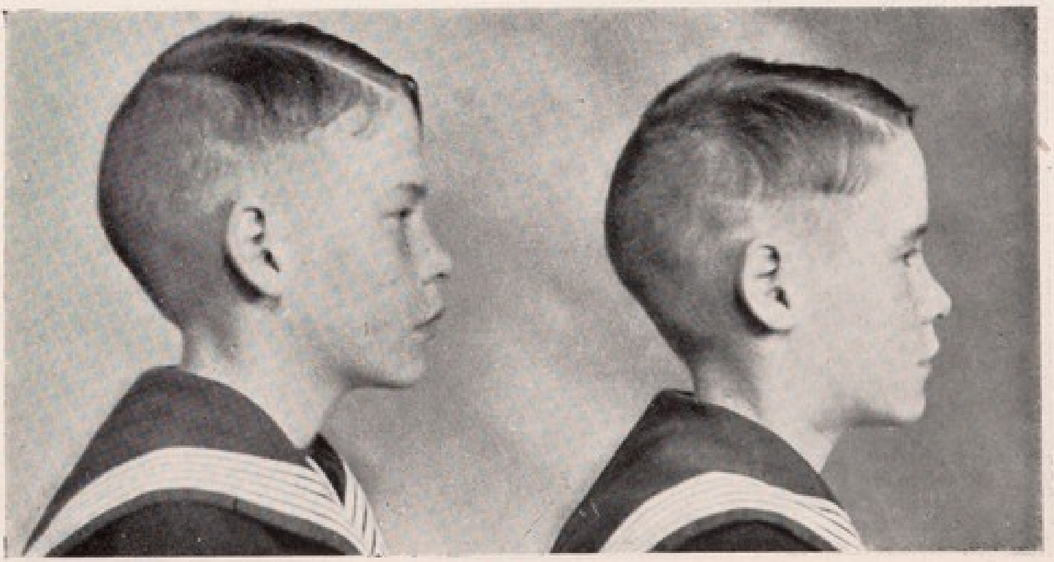

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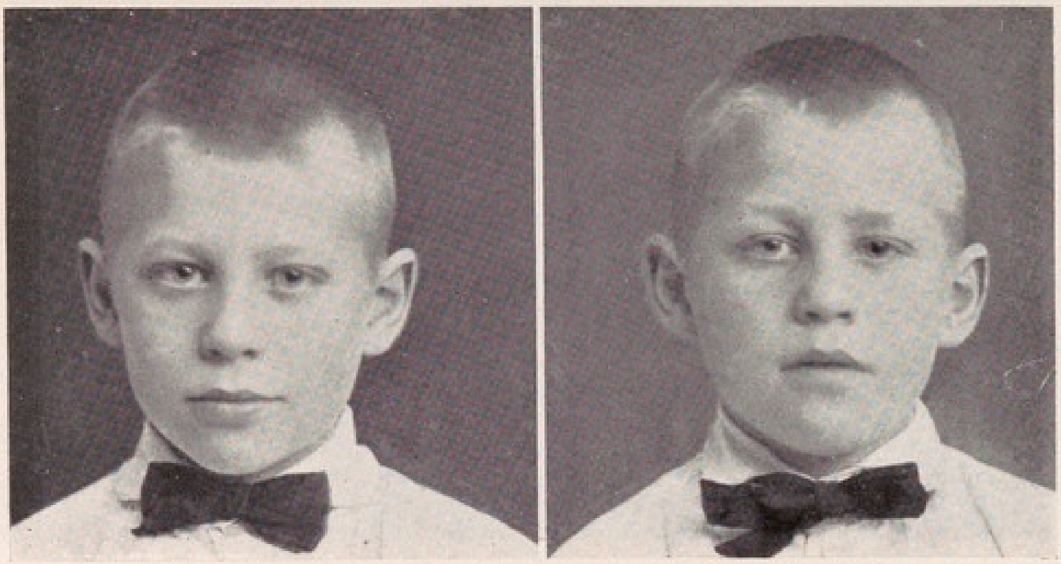

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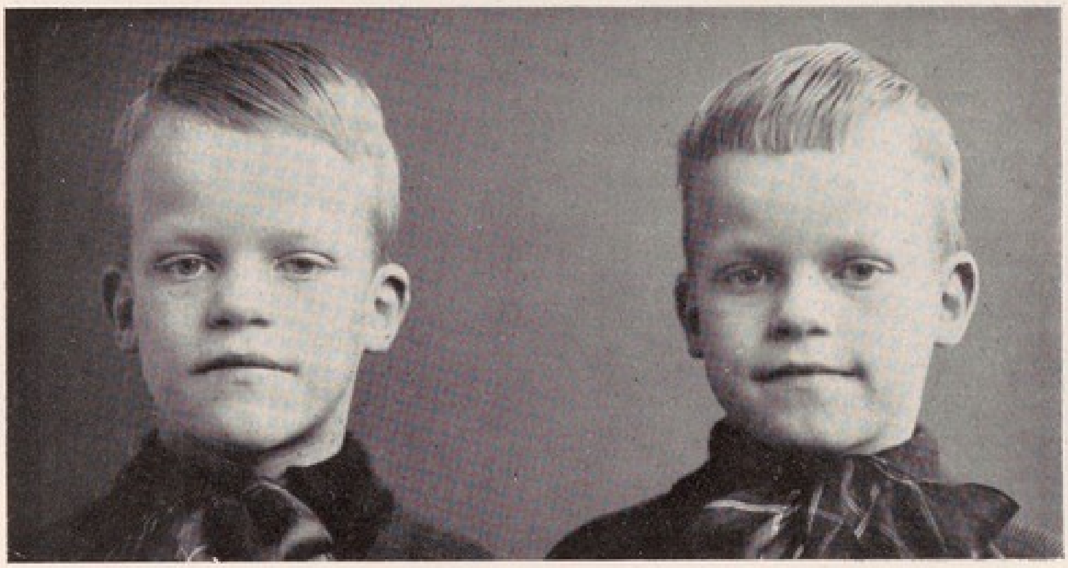

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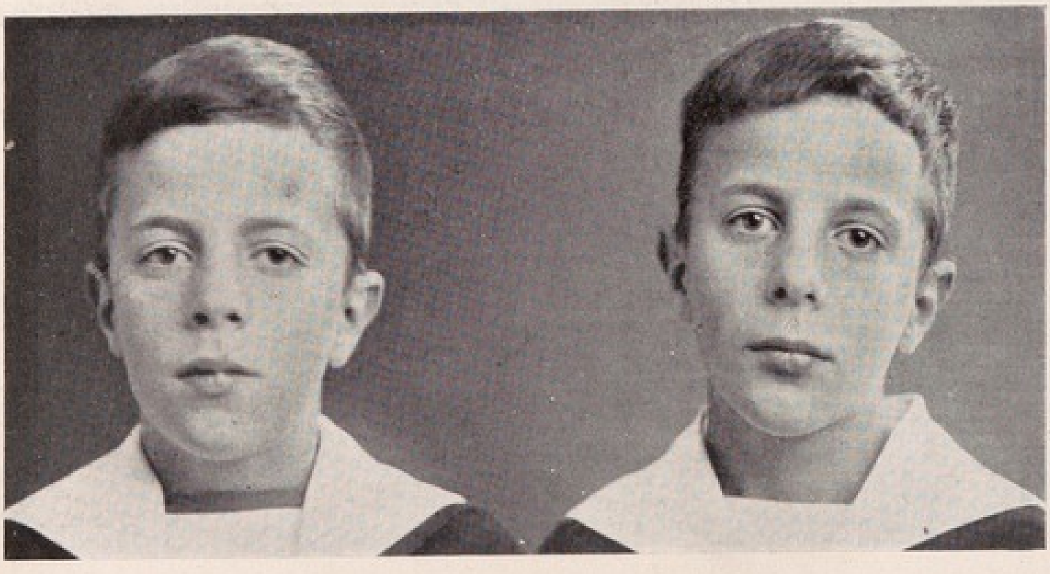

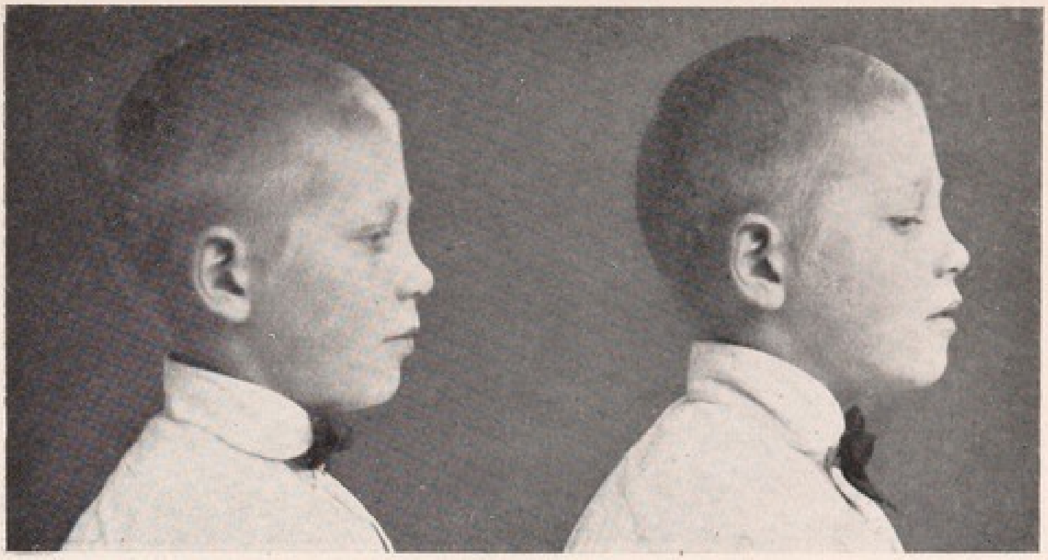

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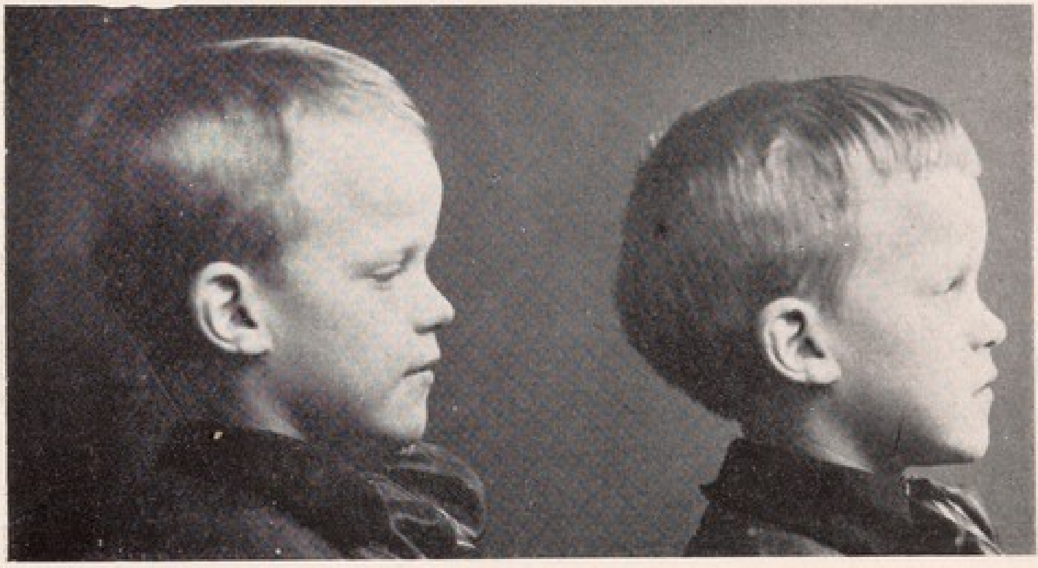

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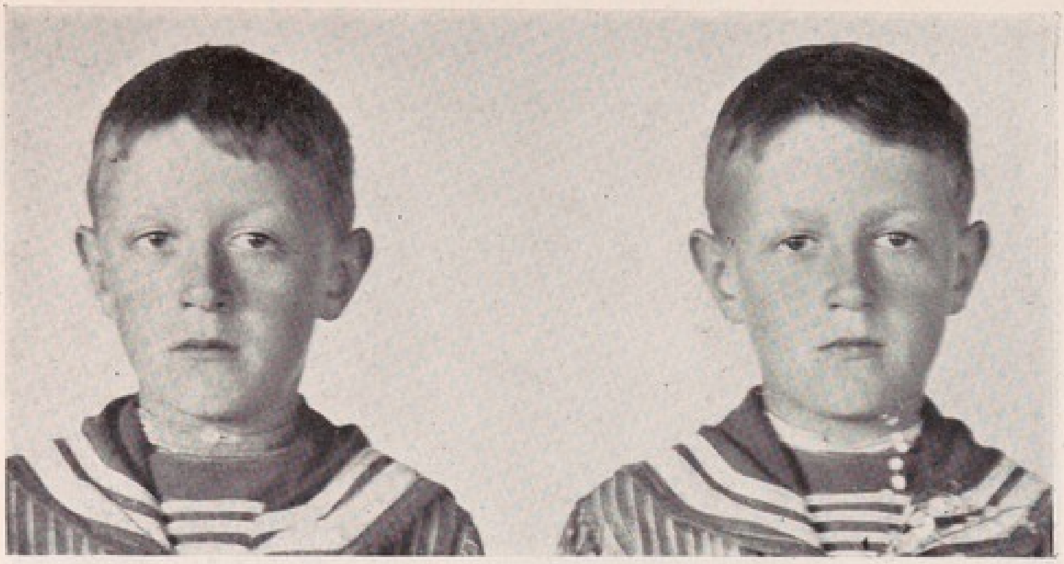

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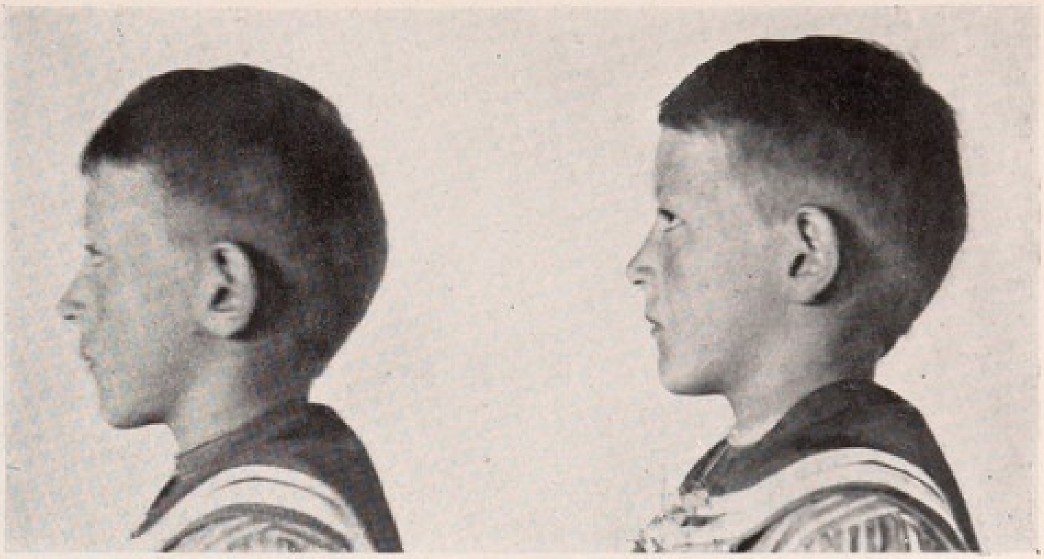

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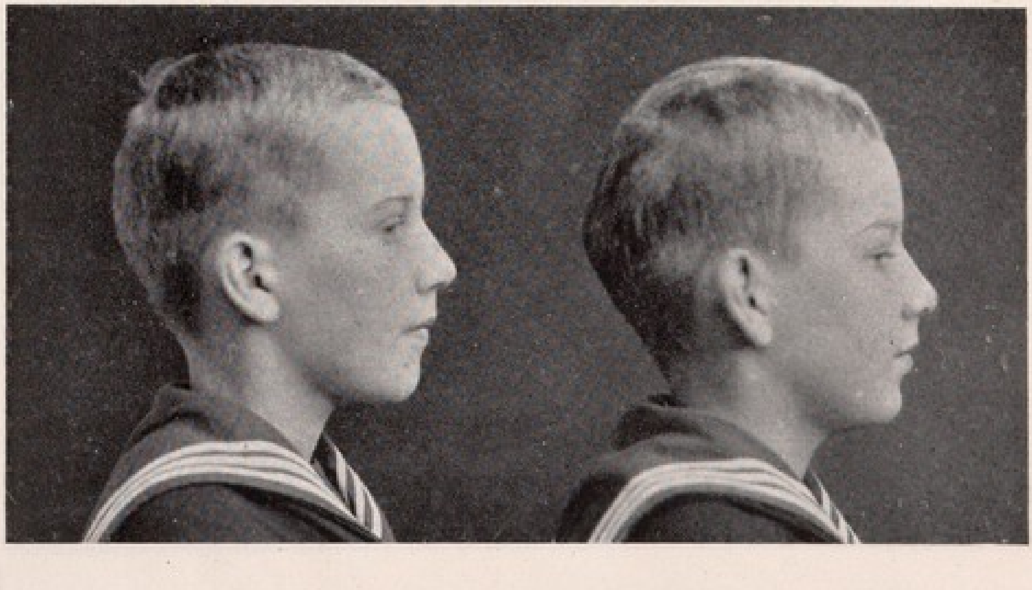

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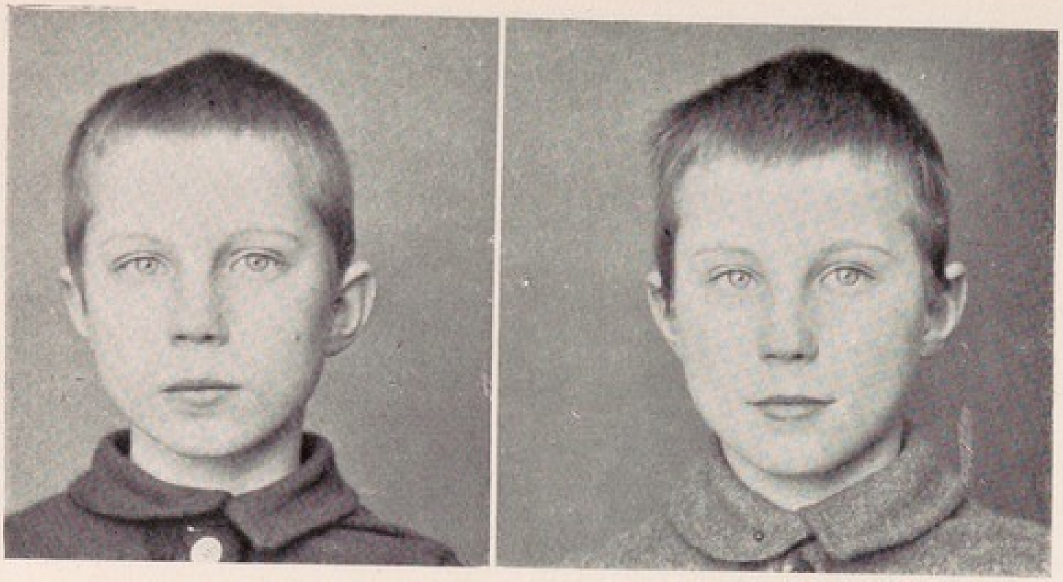

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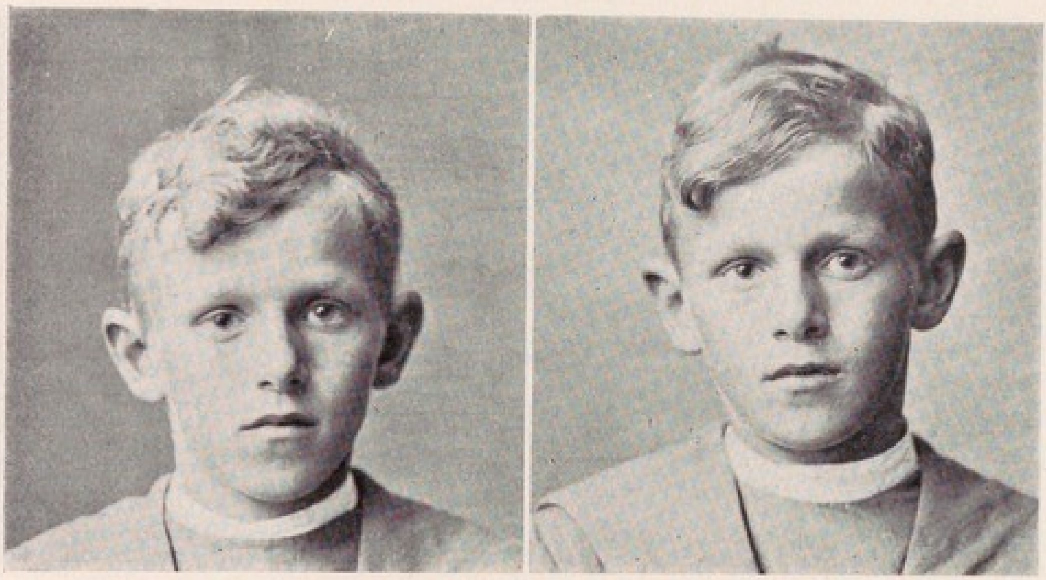

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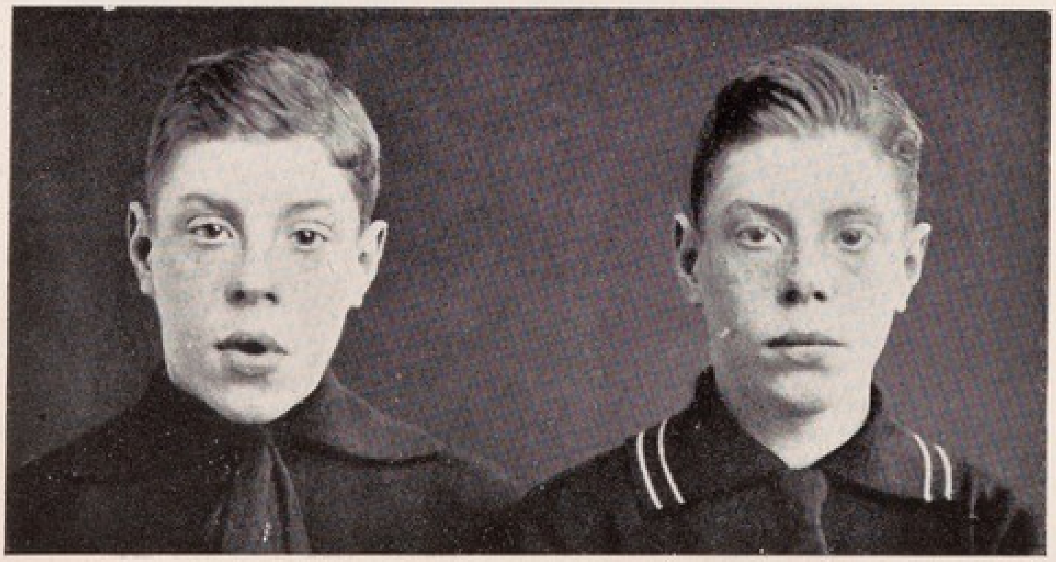

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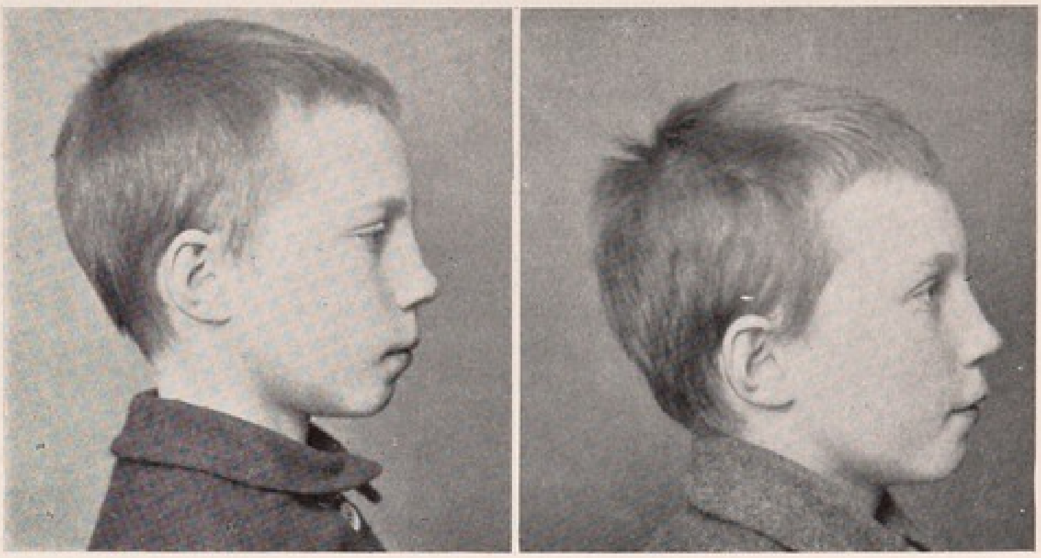

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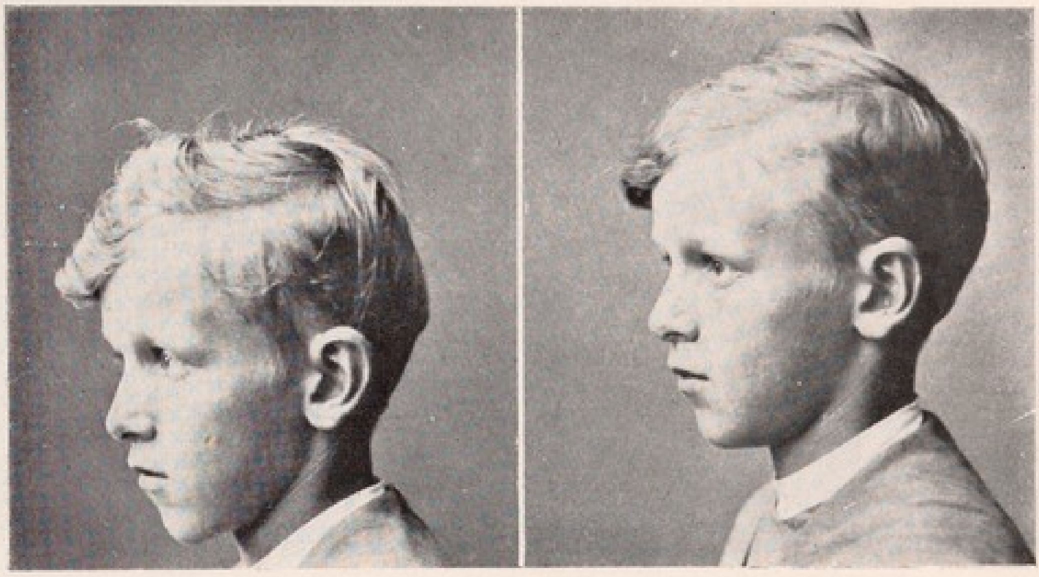

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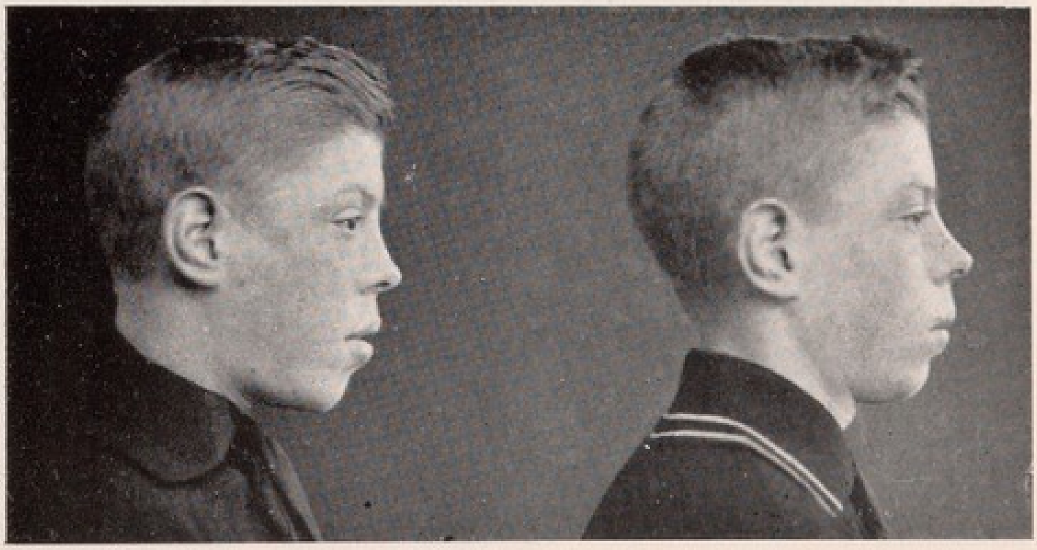

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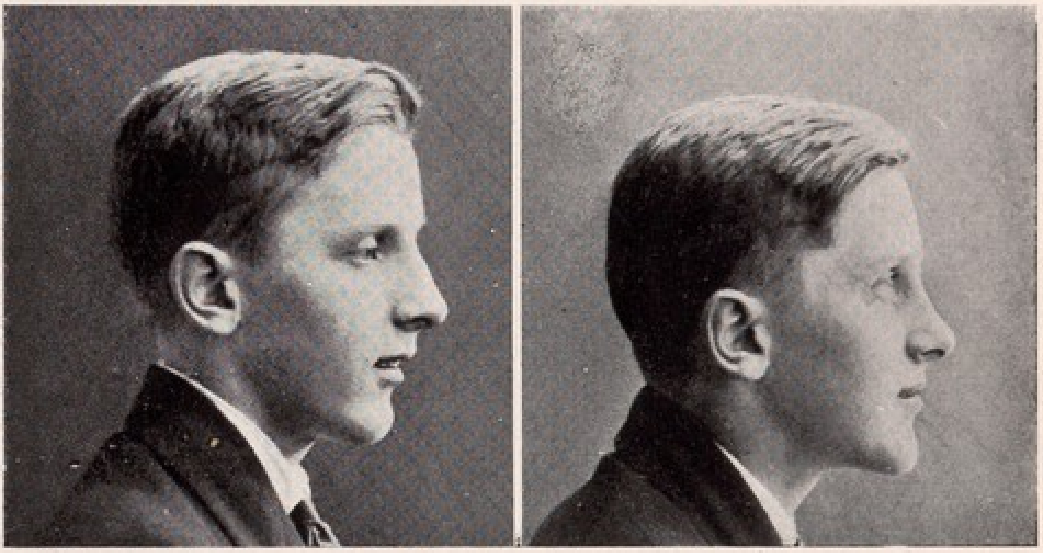

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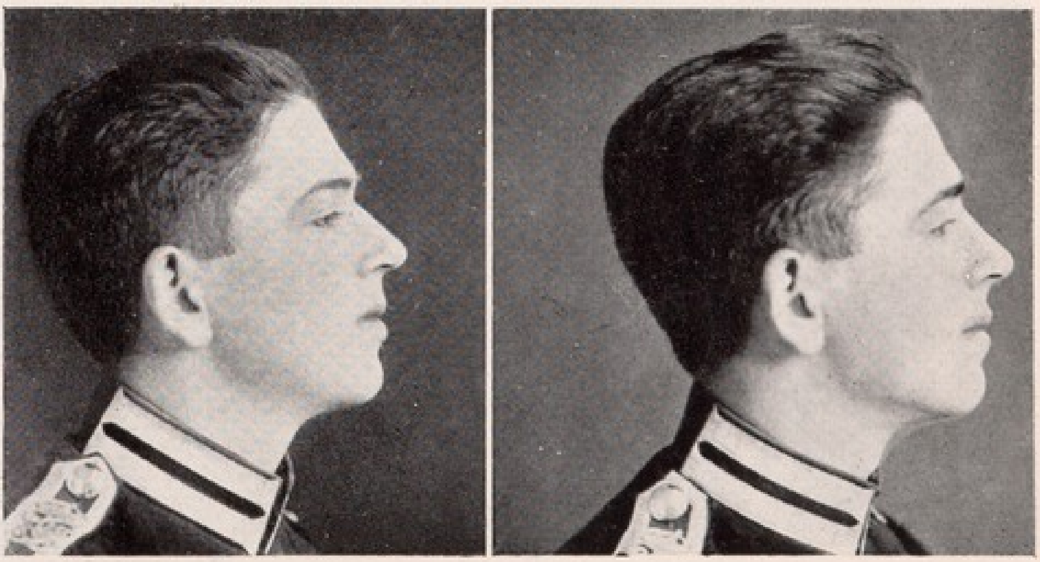

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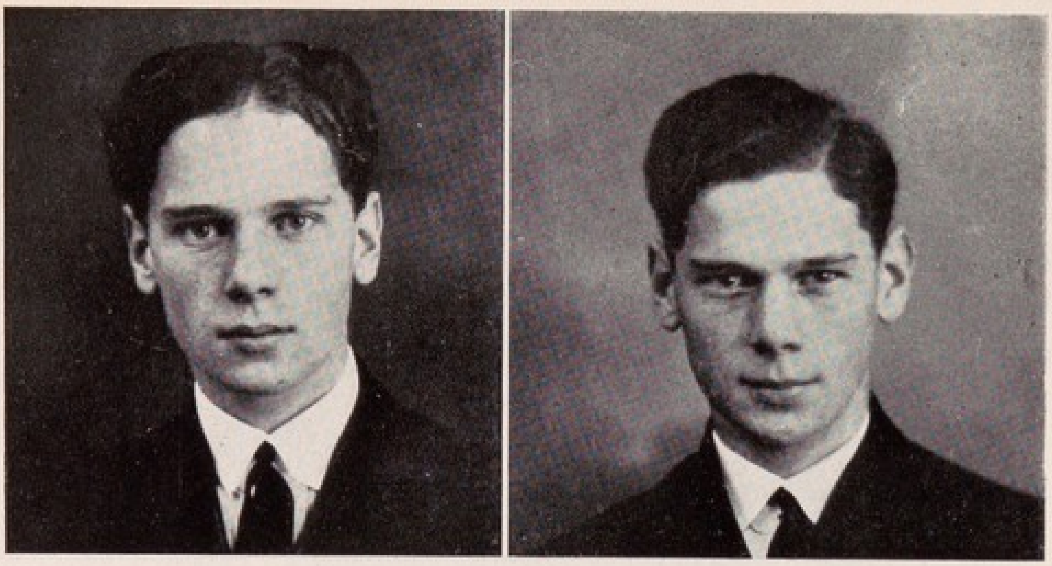

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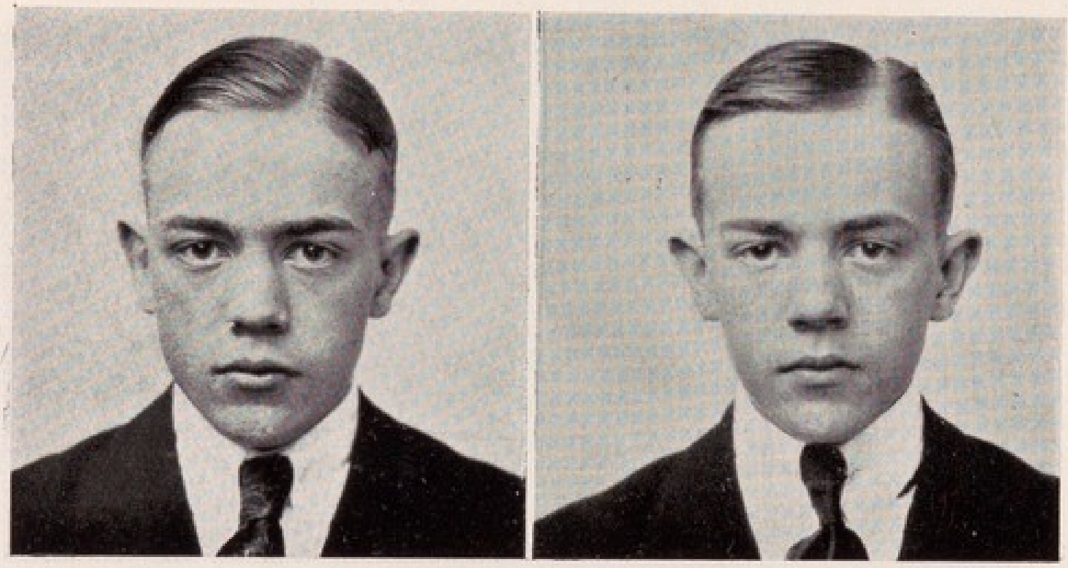

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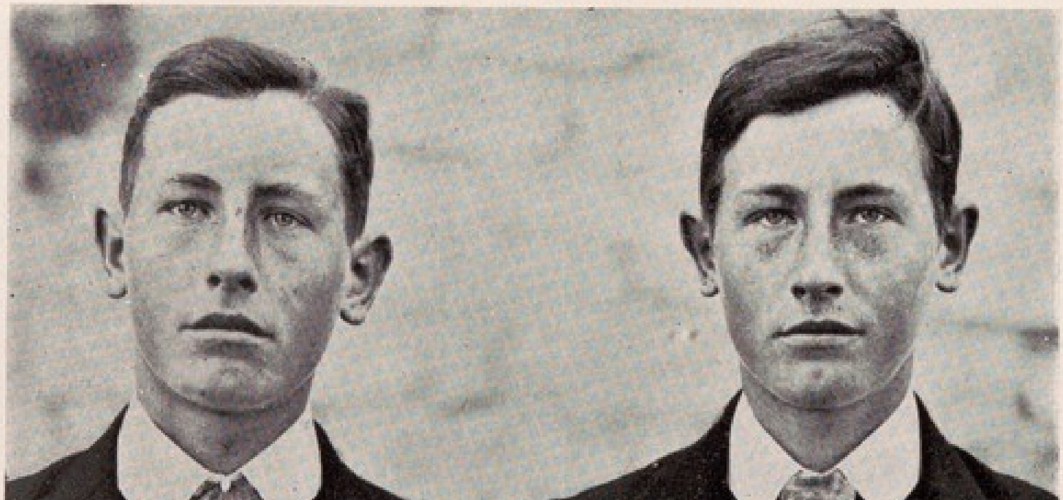

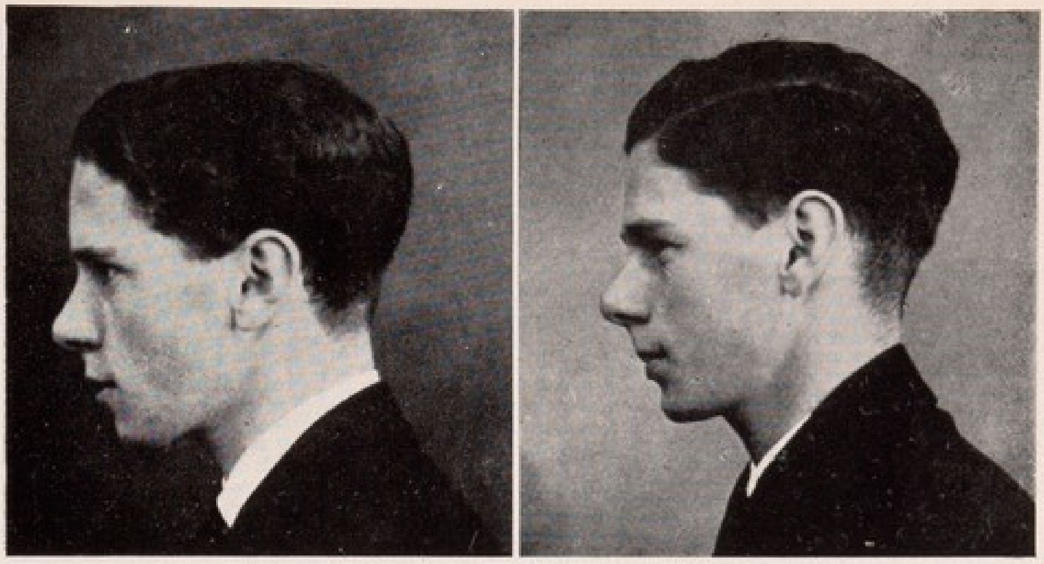

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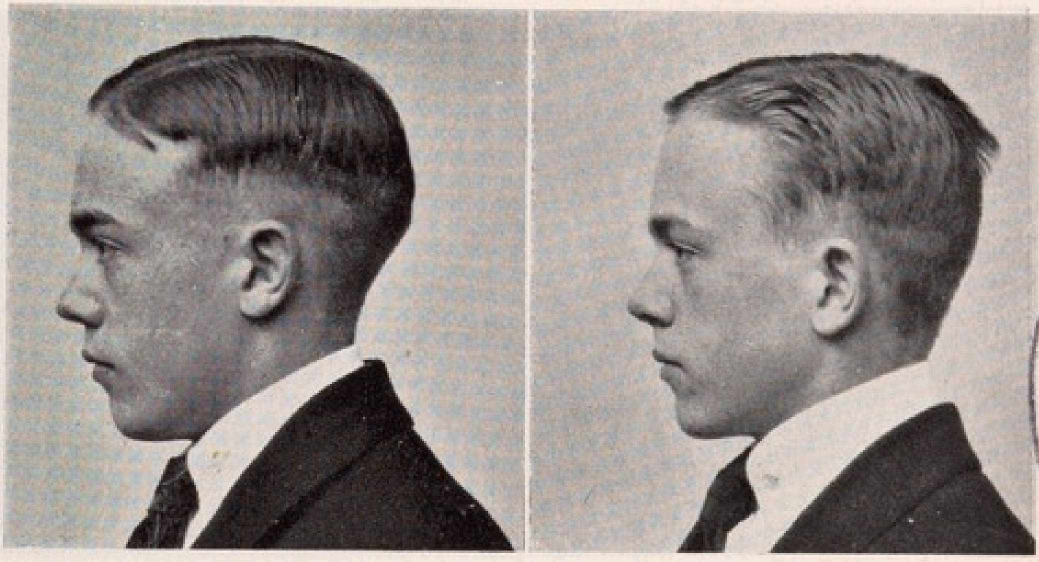

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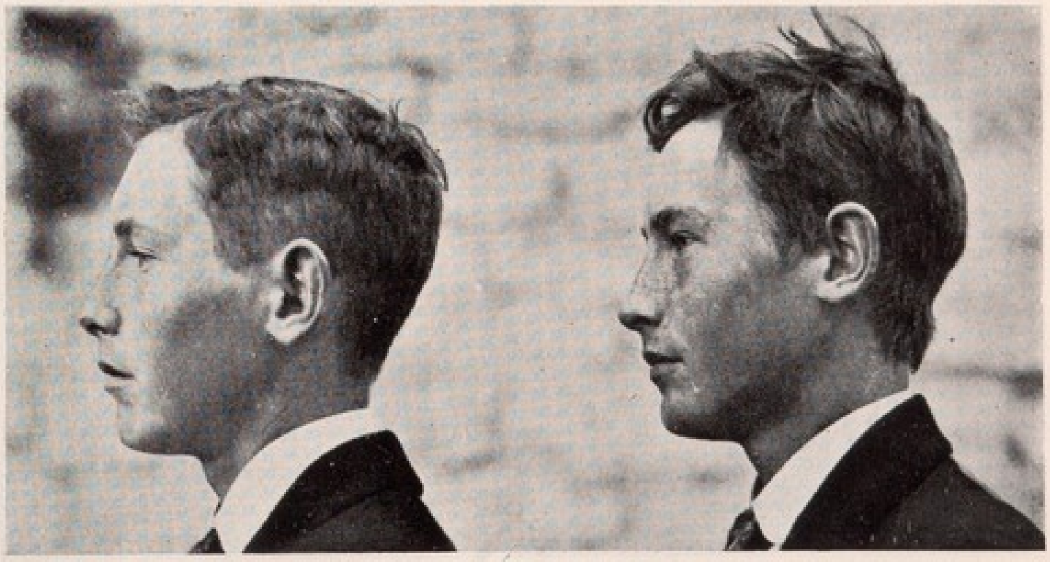

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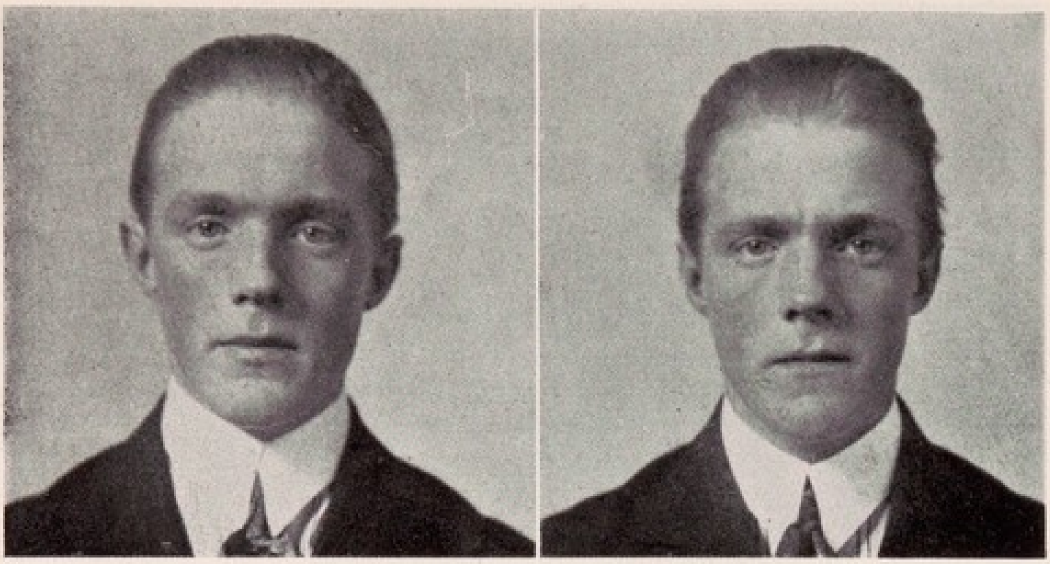

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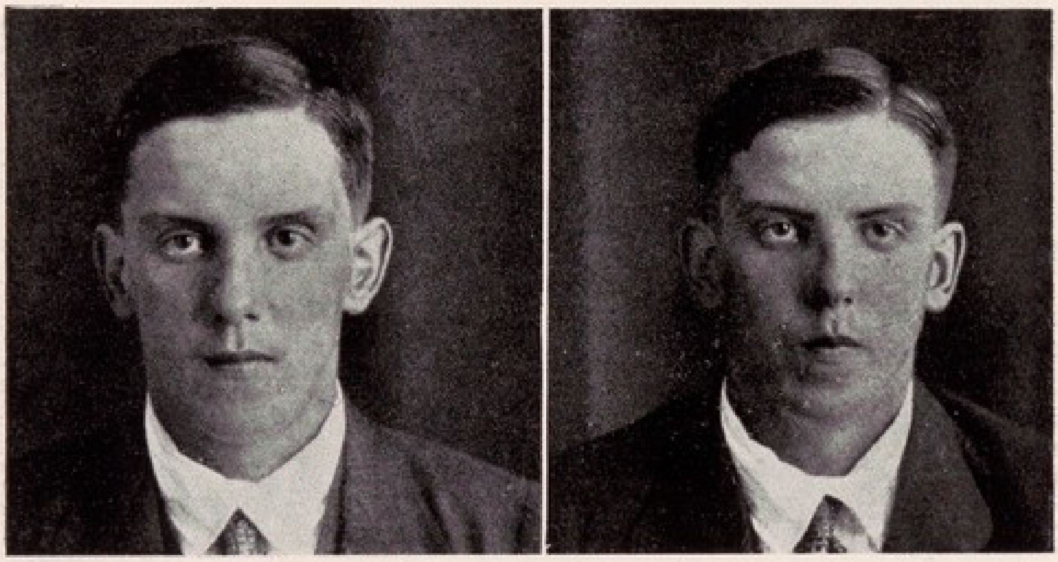

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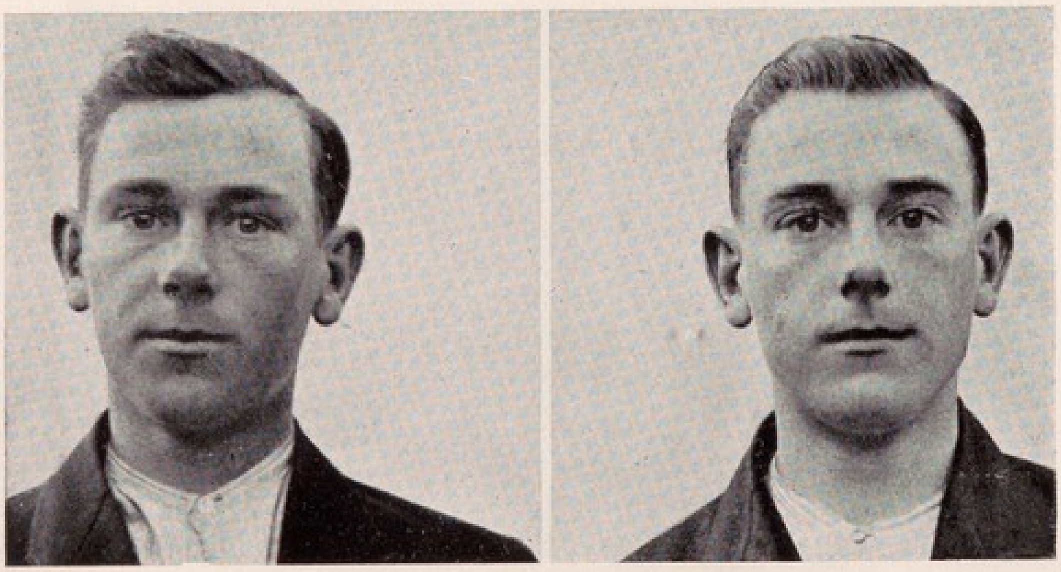

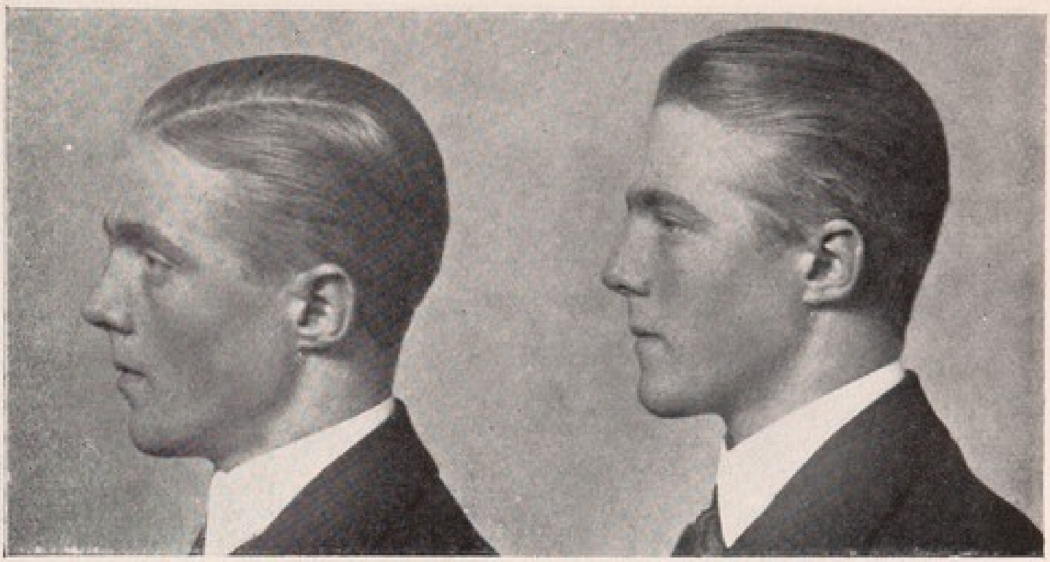

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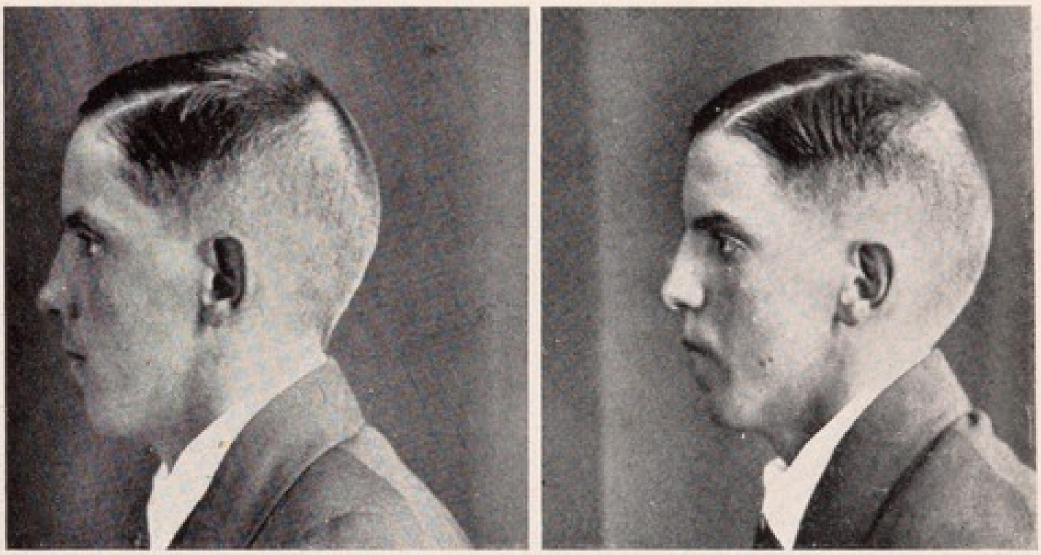

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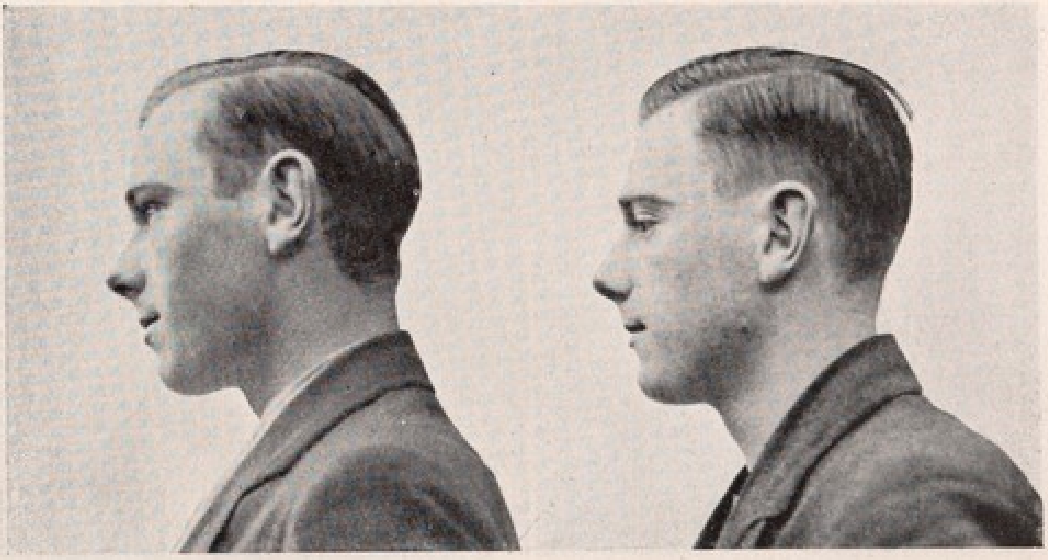

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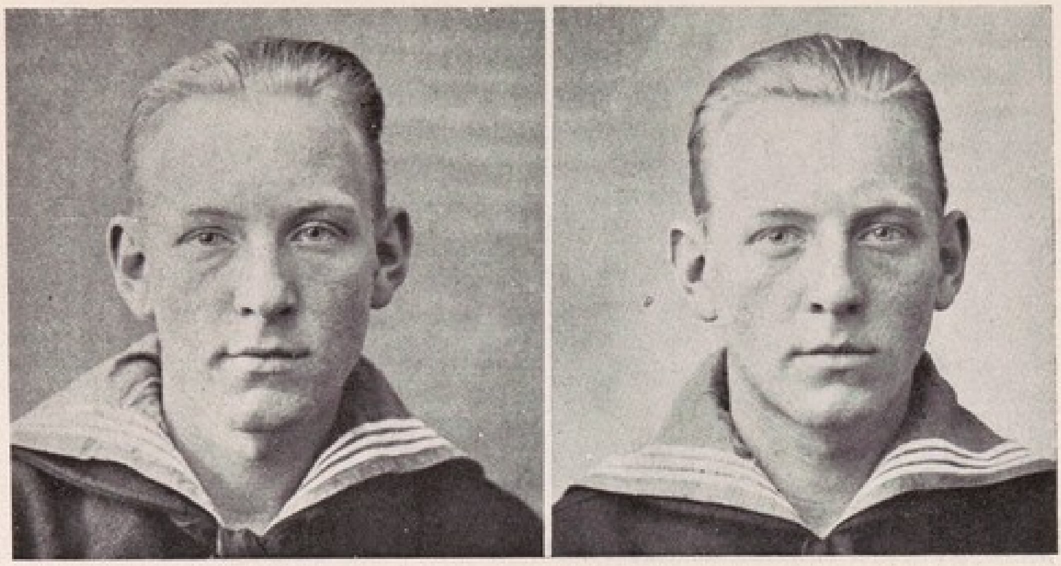

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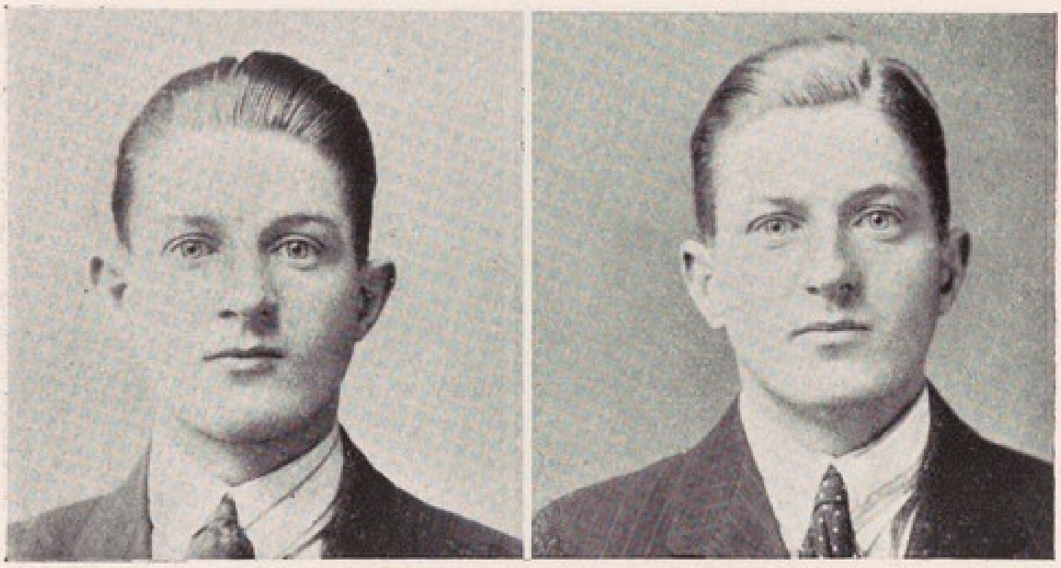

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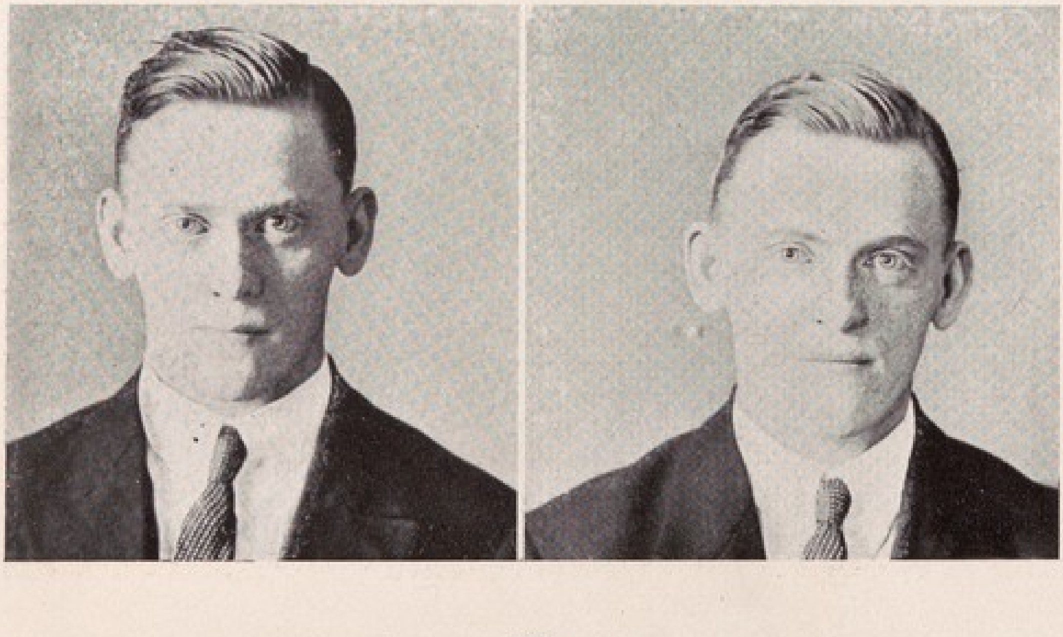

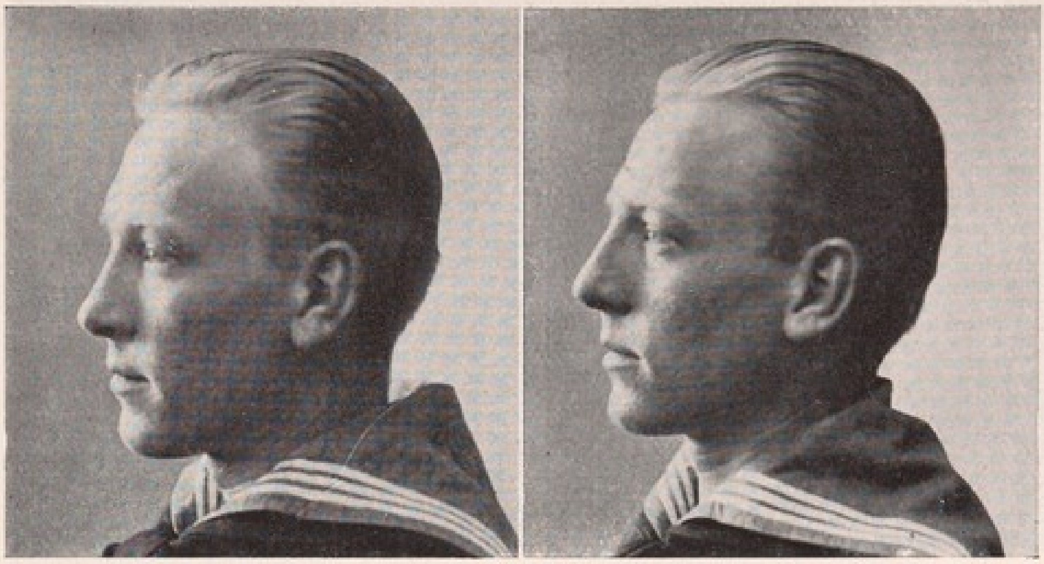

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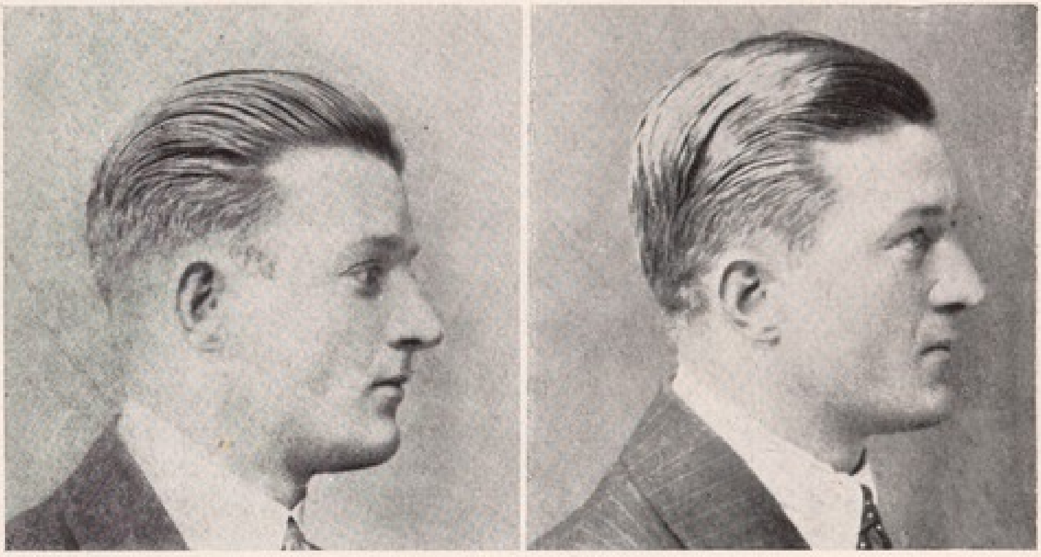

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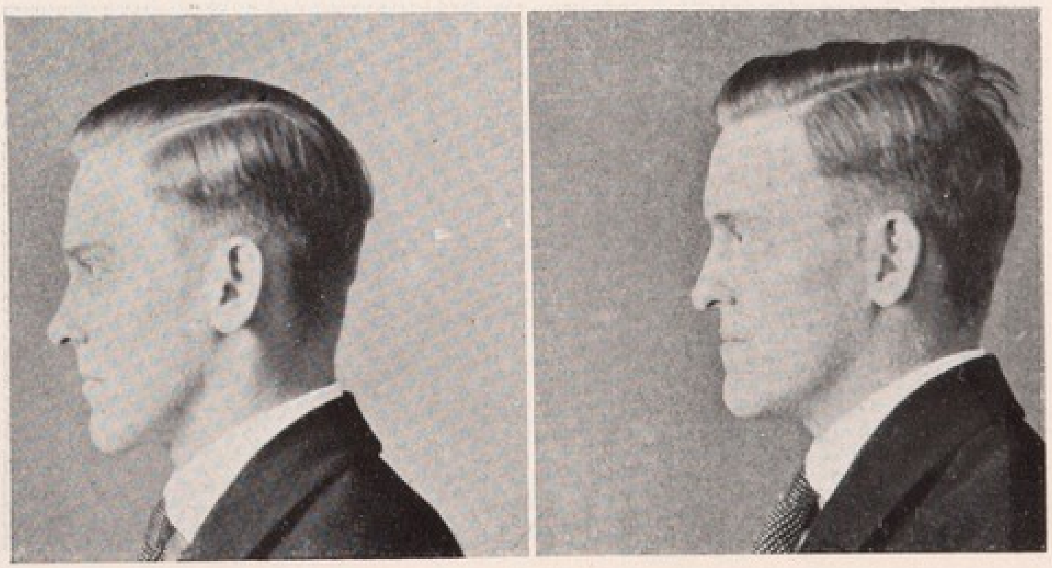

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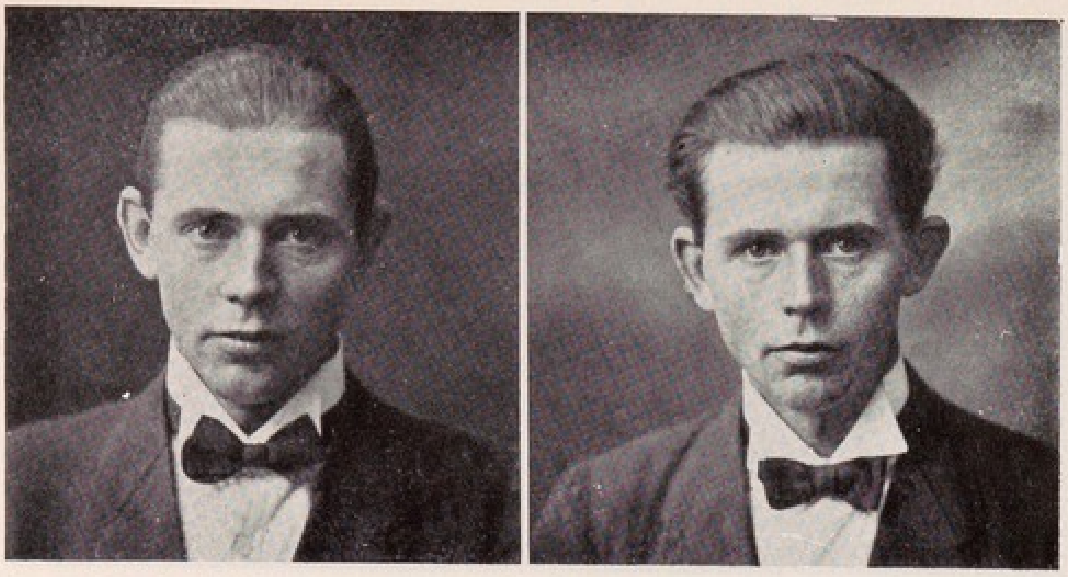

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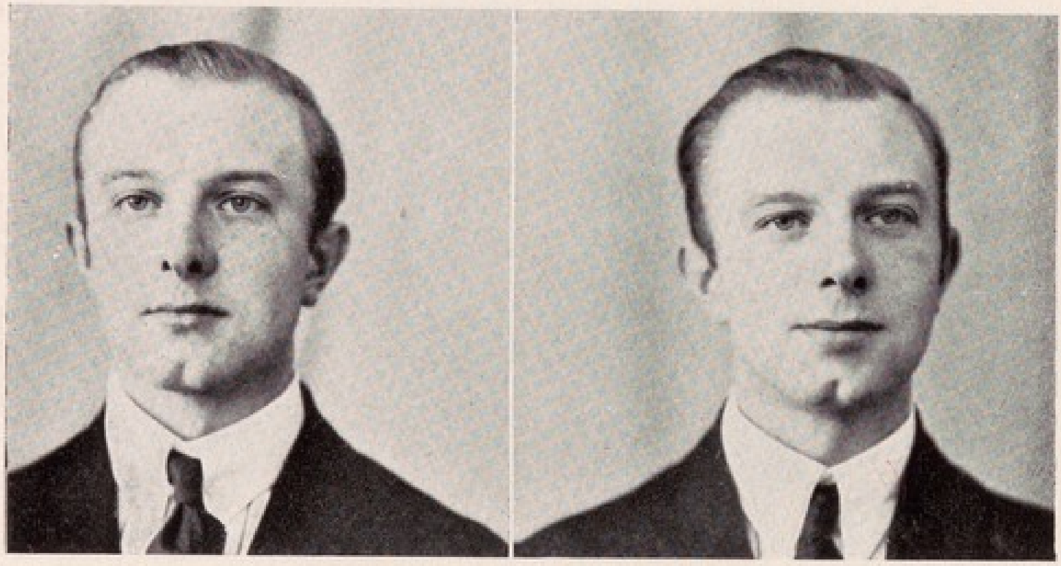

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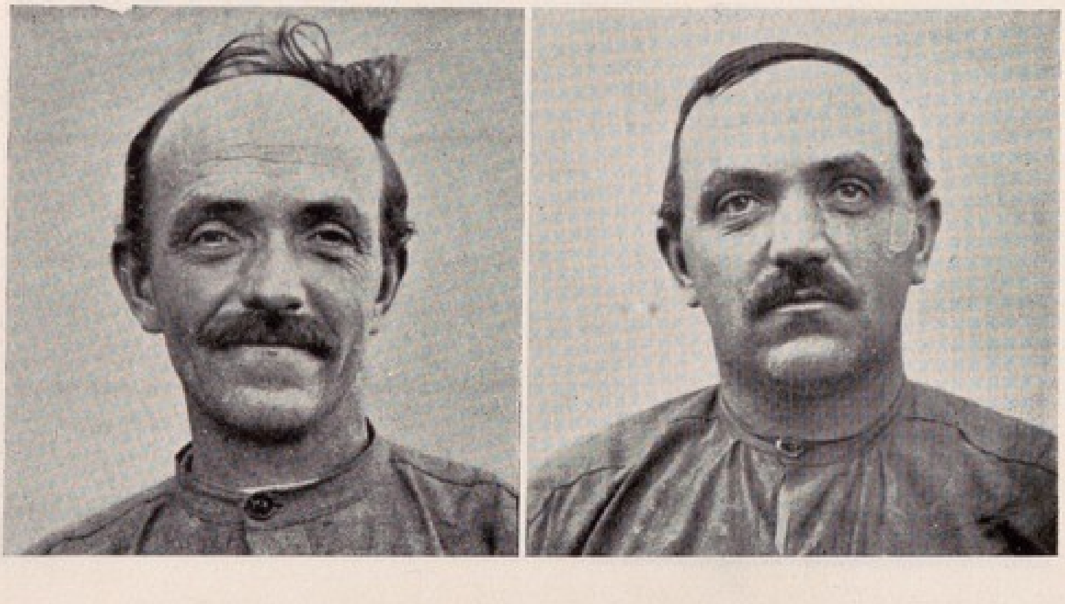

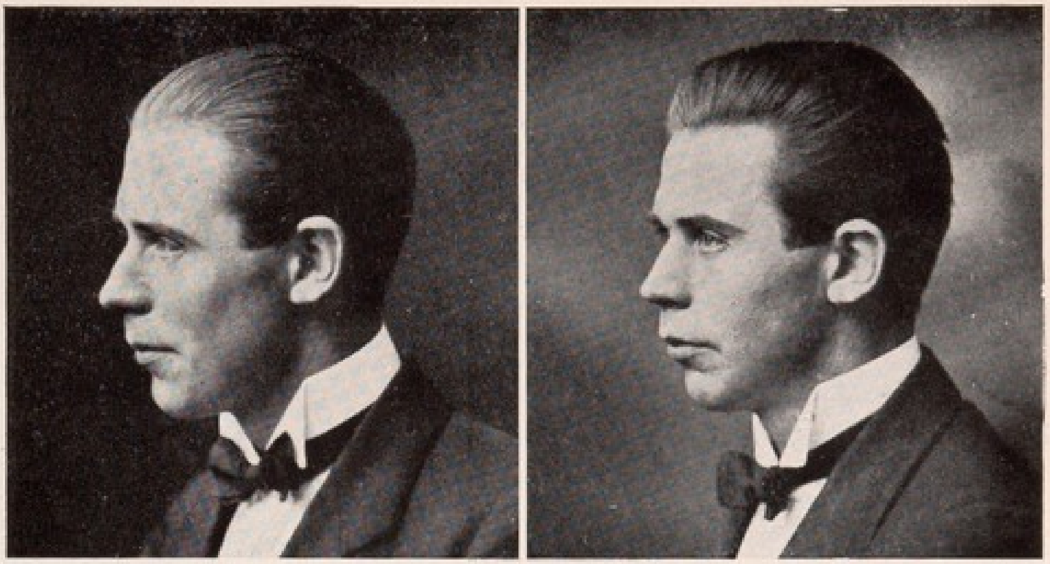

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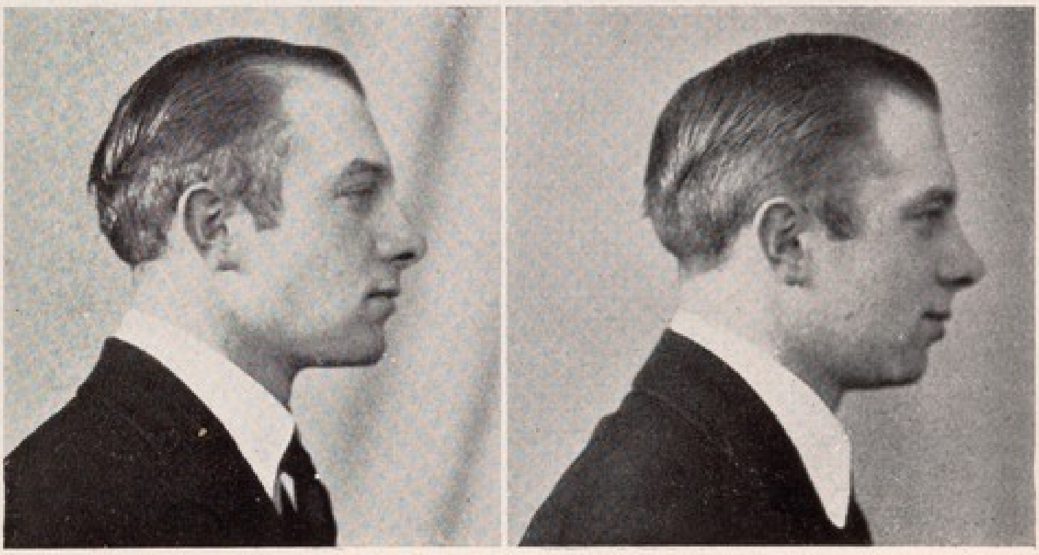

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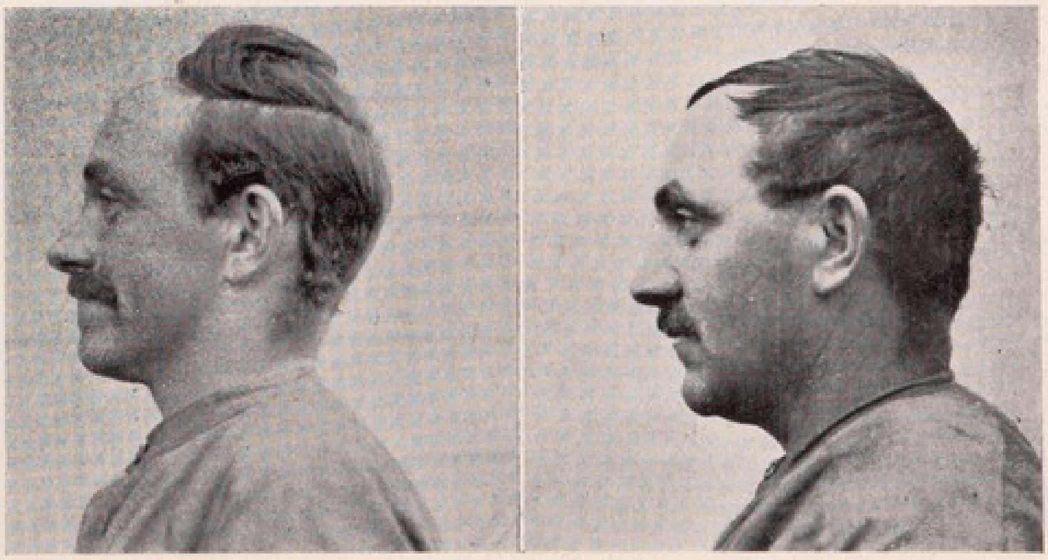

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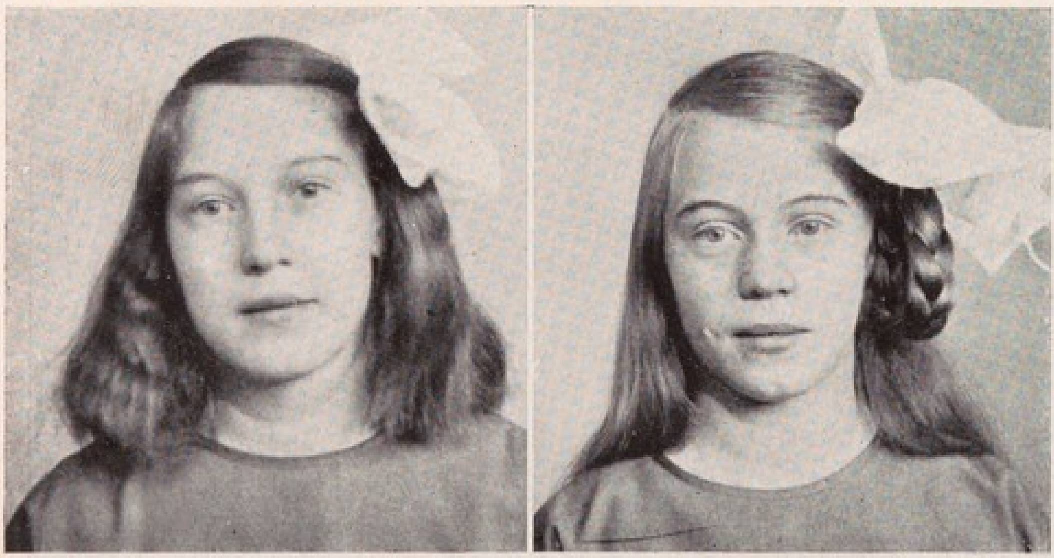
DIZYGOTIC TWINS

All the pairs are taken on the same plate and reproduced on the same scale

104

109



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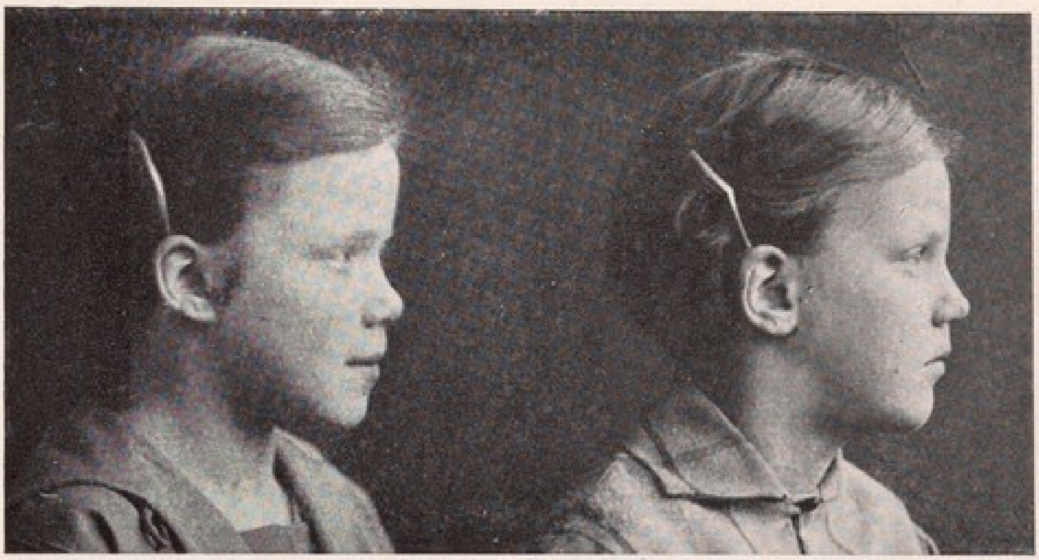

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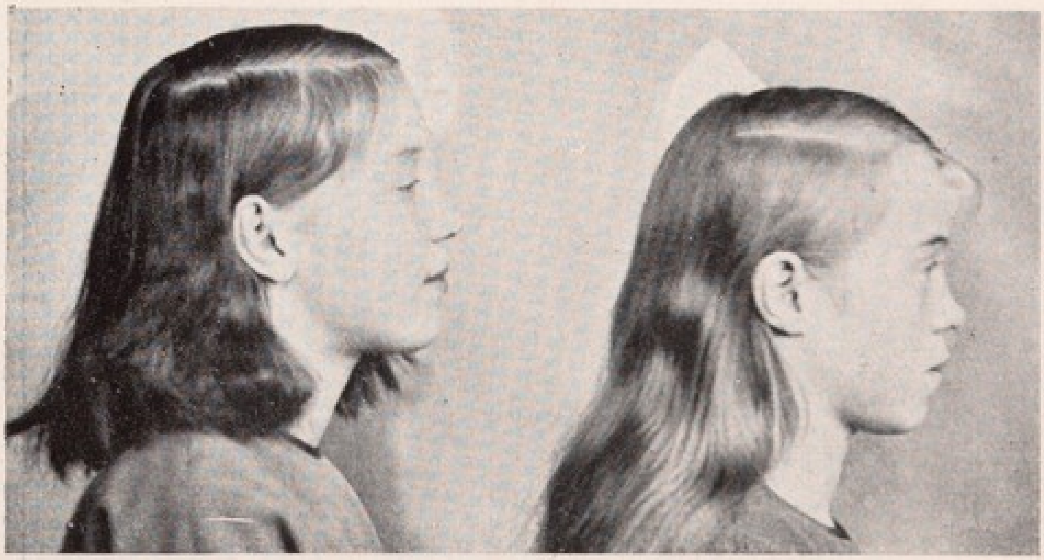

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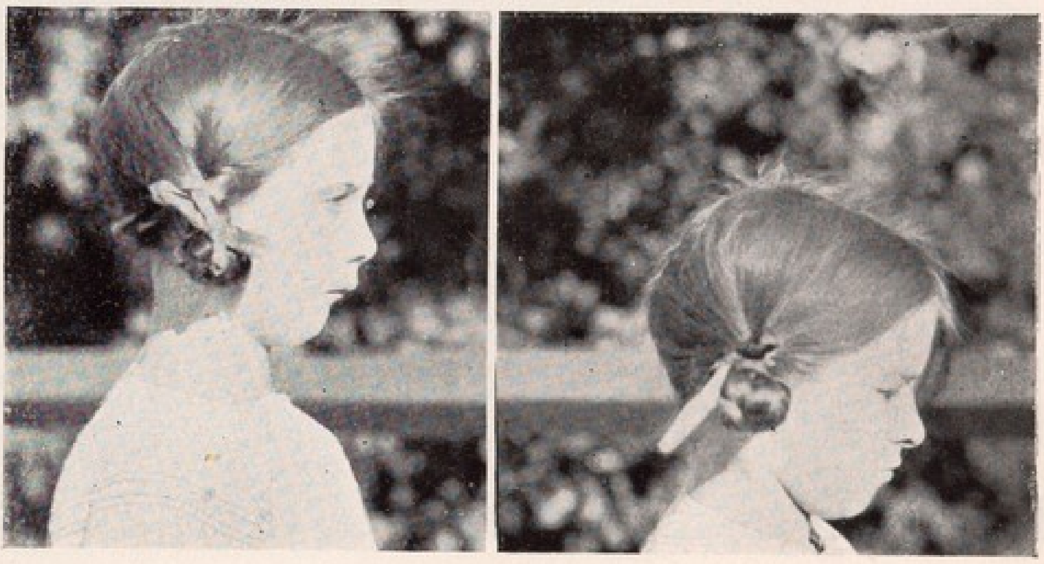

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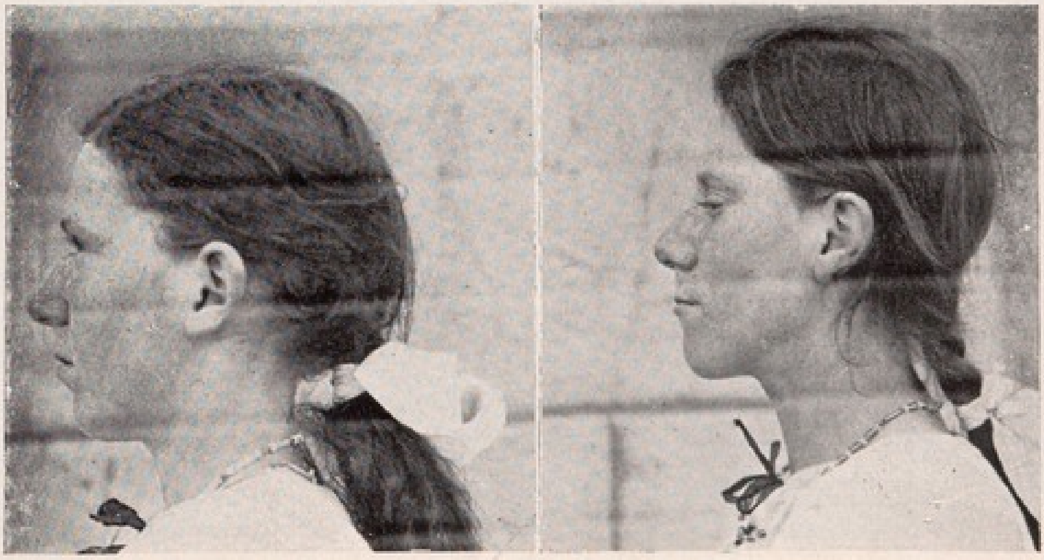

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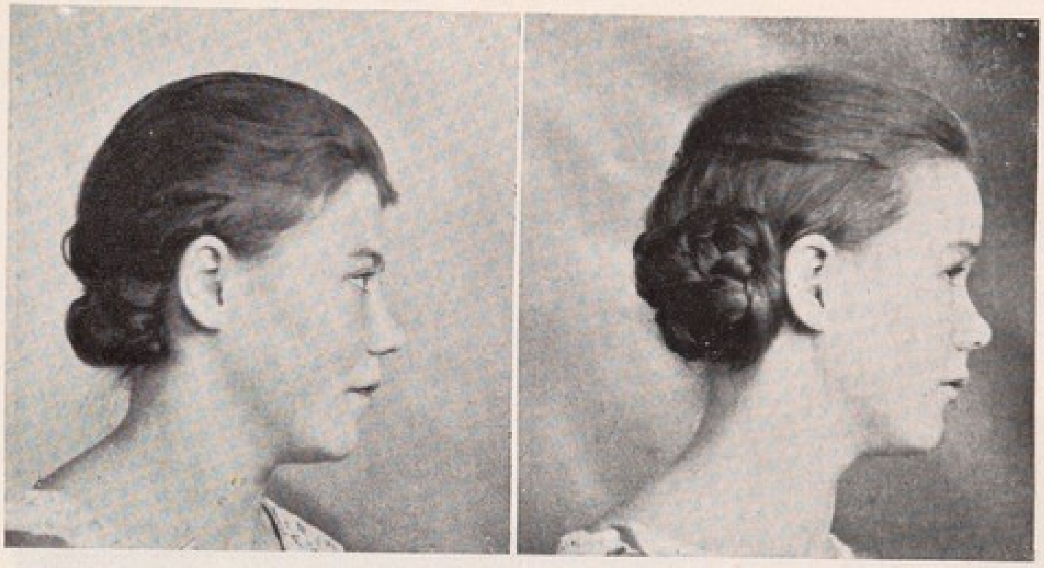

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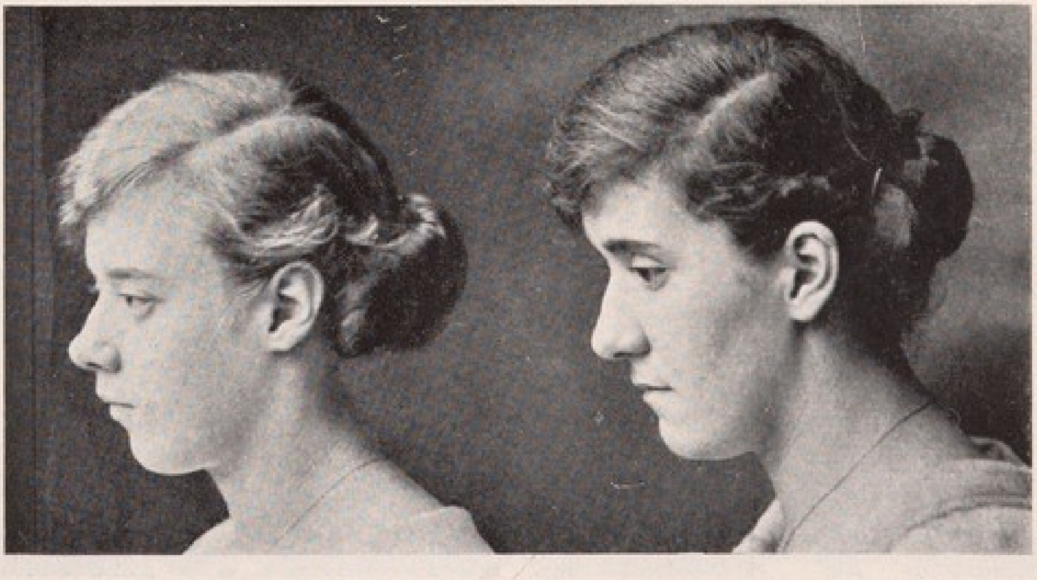

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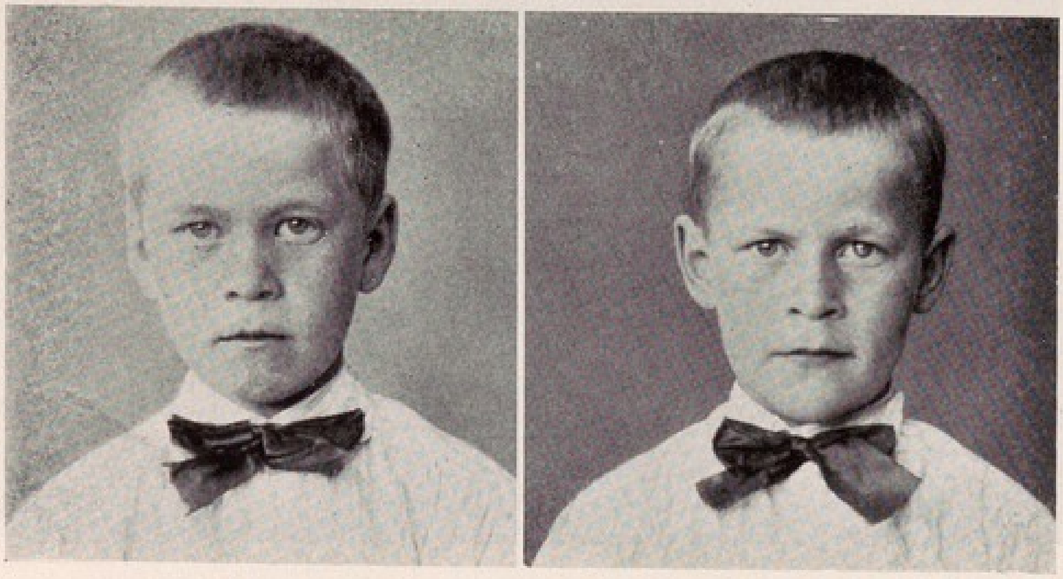

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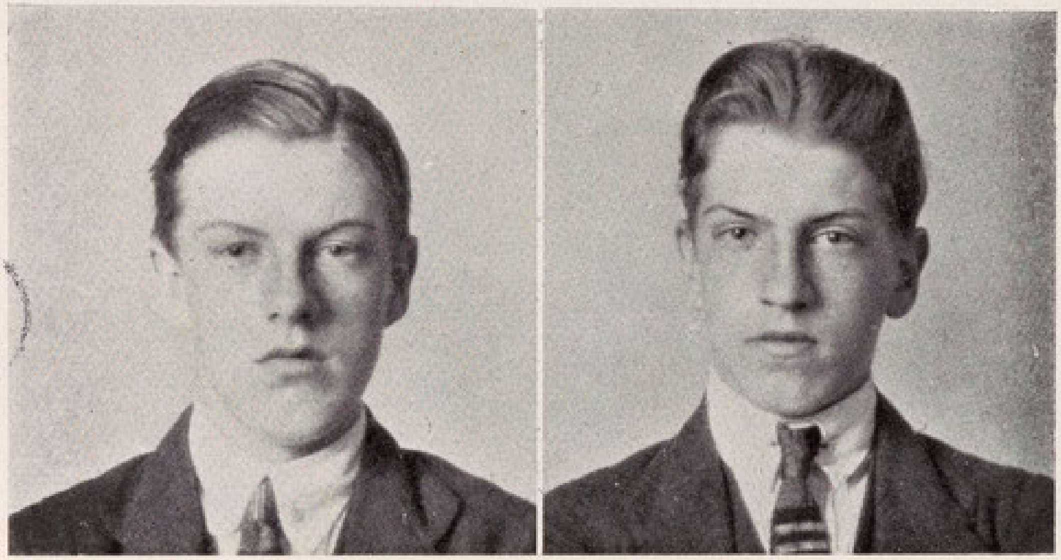

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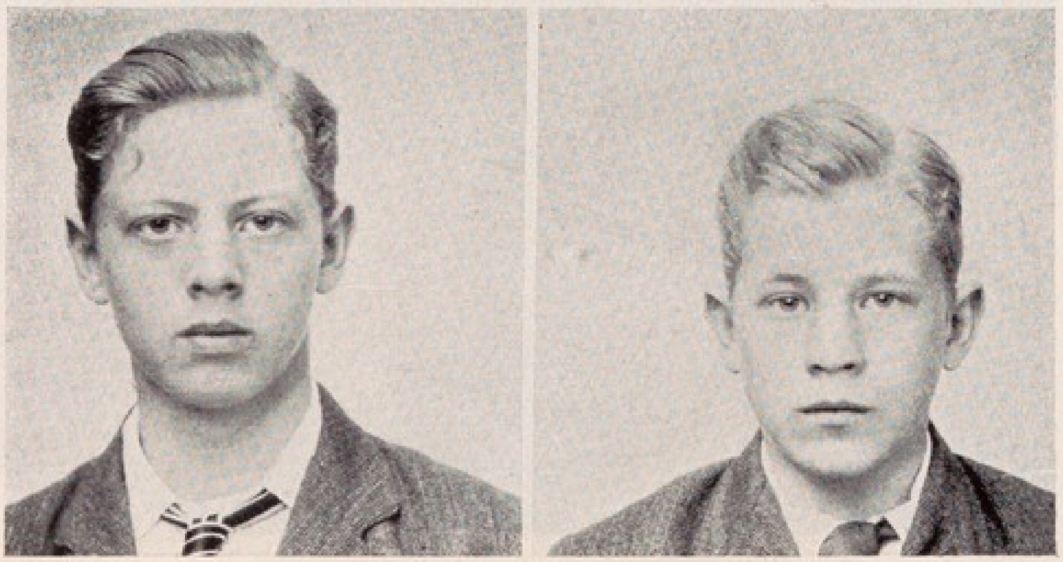

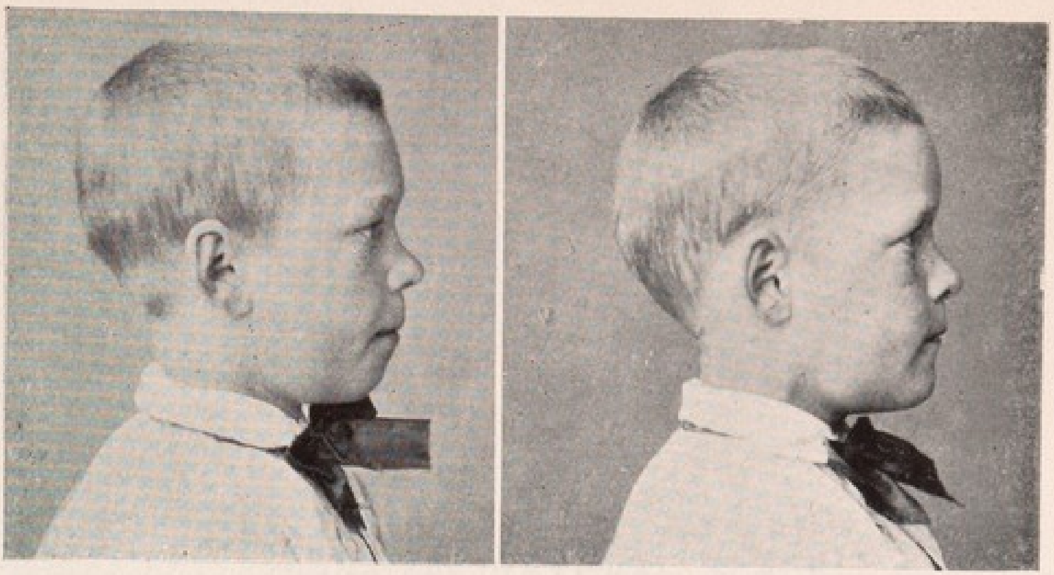

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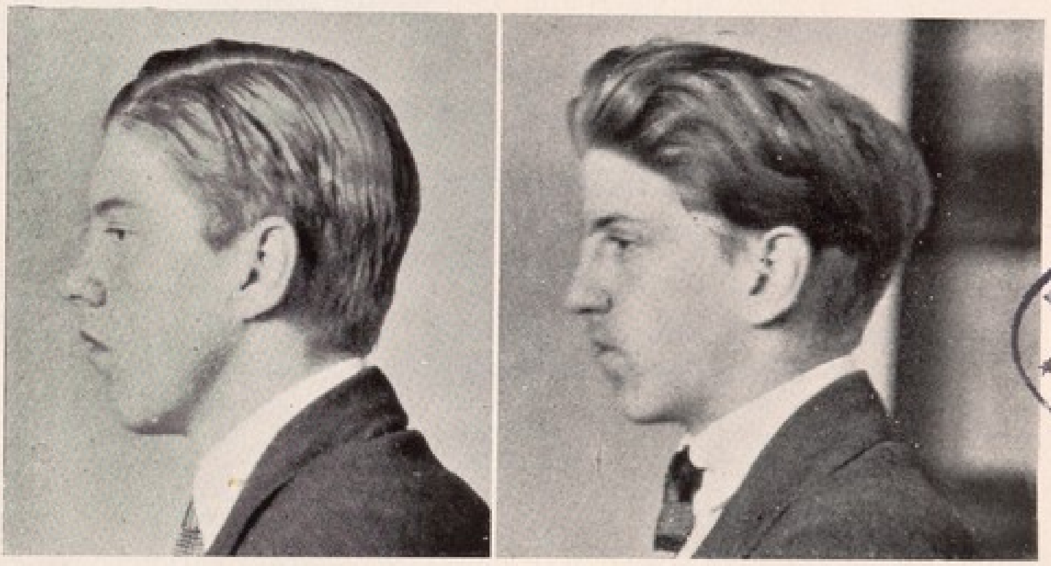


179

180

EARS ON NATURAL SCALE

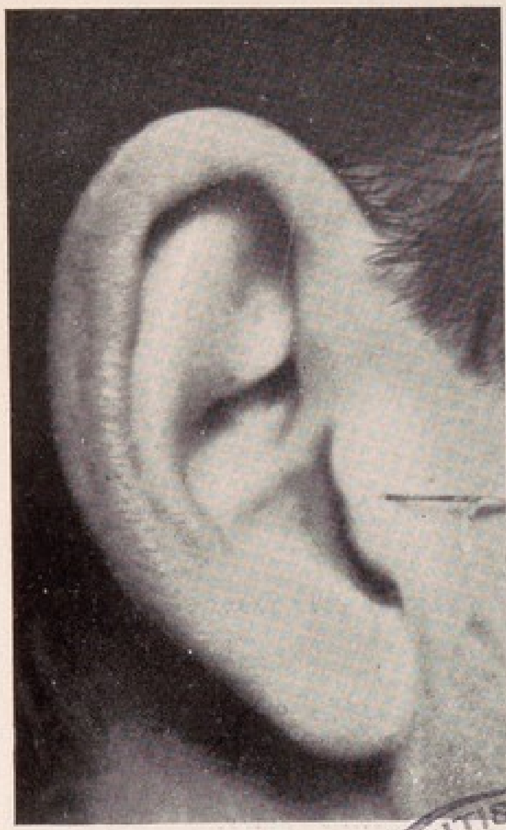
Page 64—68. Especially unlike pairs of ears from the same person.

Page 69—74. Ears from monozygotic twin pairs. The ears of one twin = a, the ears of the other = b.

Page 75—80. Ears from dizygotic twin pairs. (P. 80 of opposite sex). The ears of one twin = A, the ears of the other = B.

Page 81—85. Especially like ears from different persons selected in pairs out of photographs of 100 persons.

8



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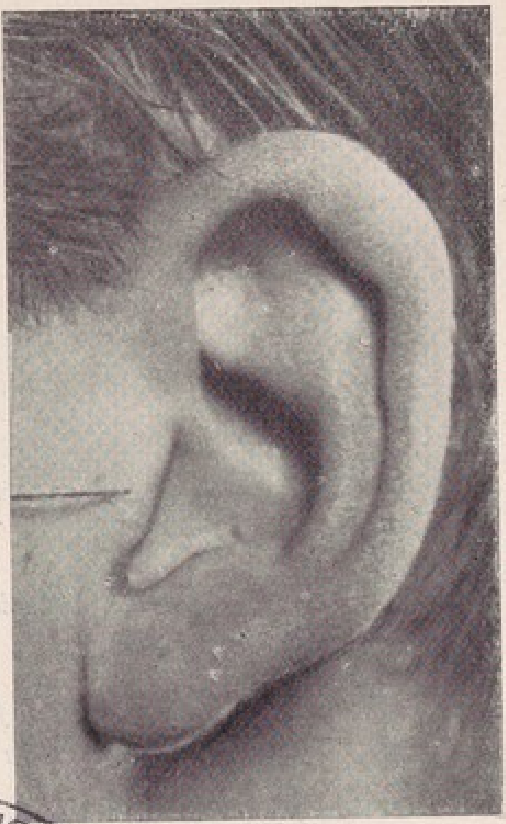

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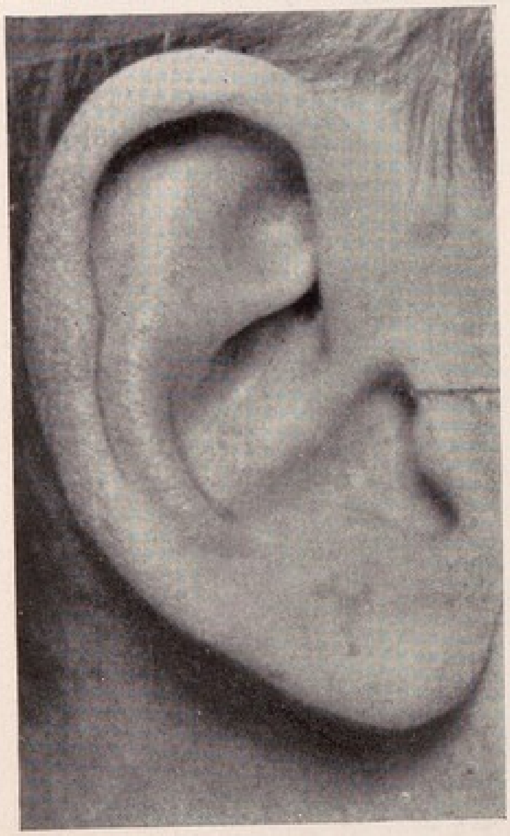

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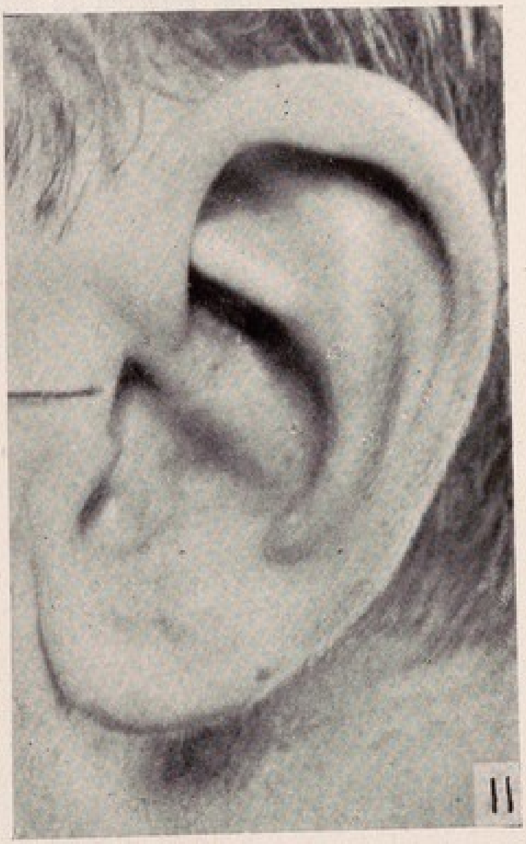

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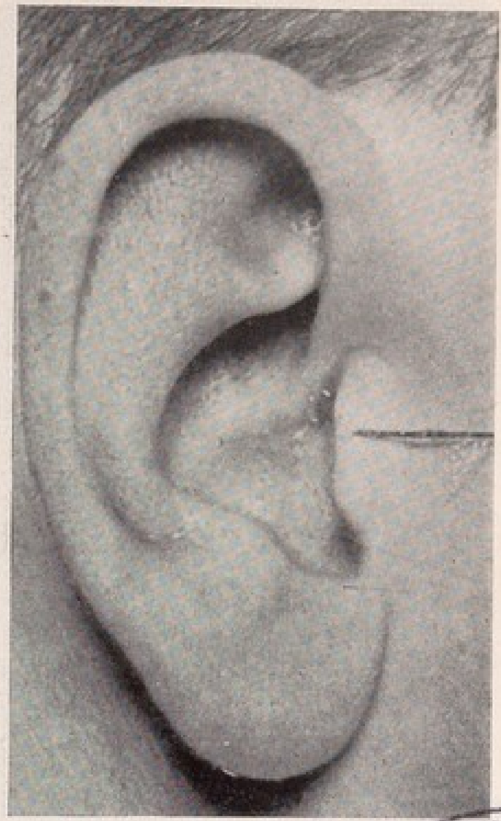

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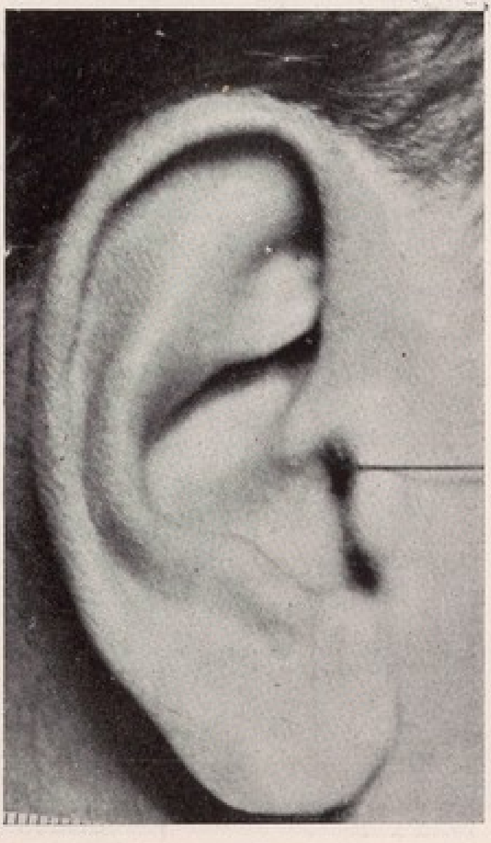

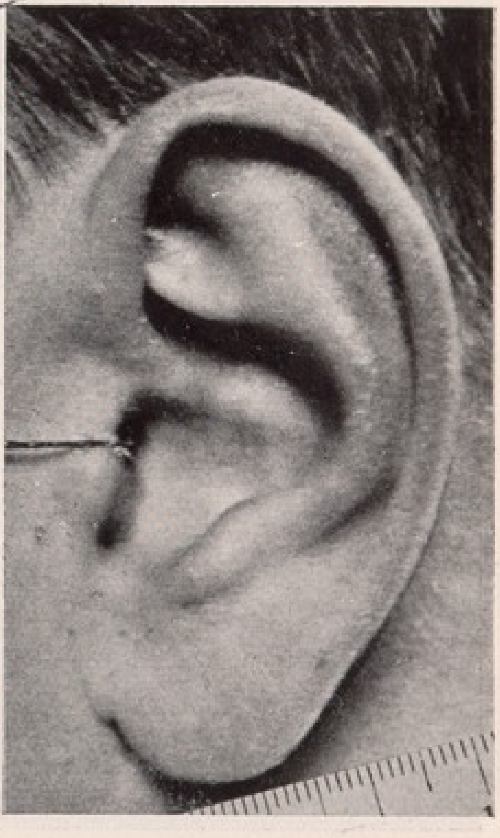

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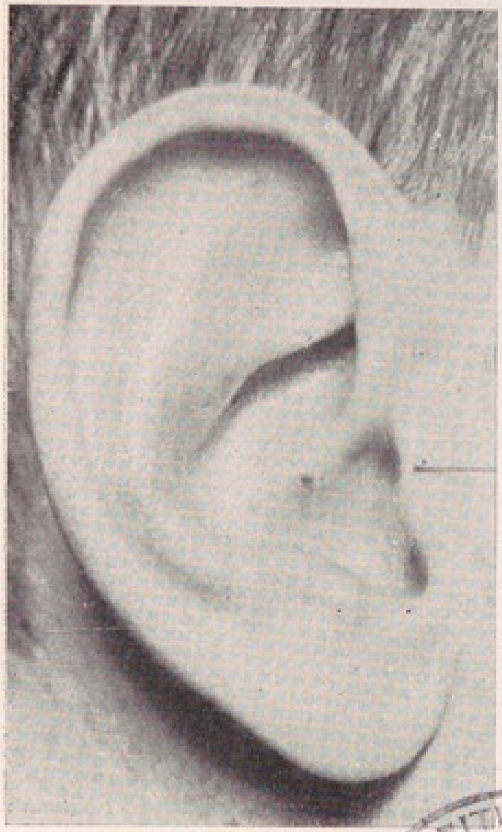

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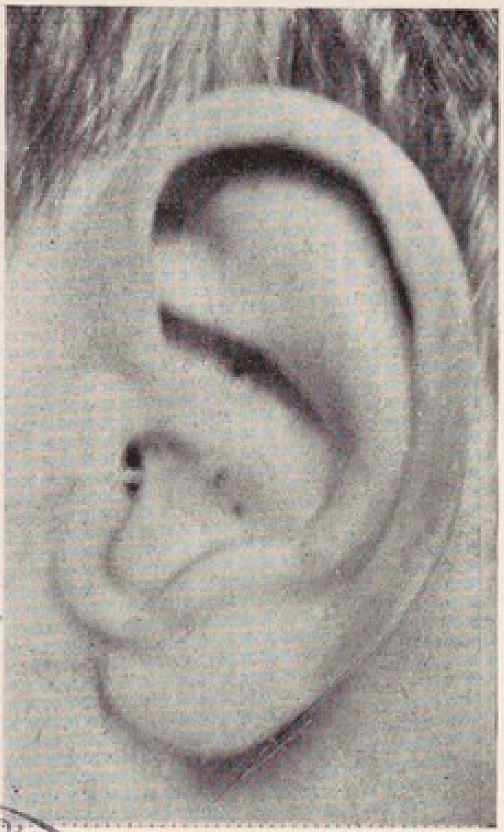

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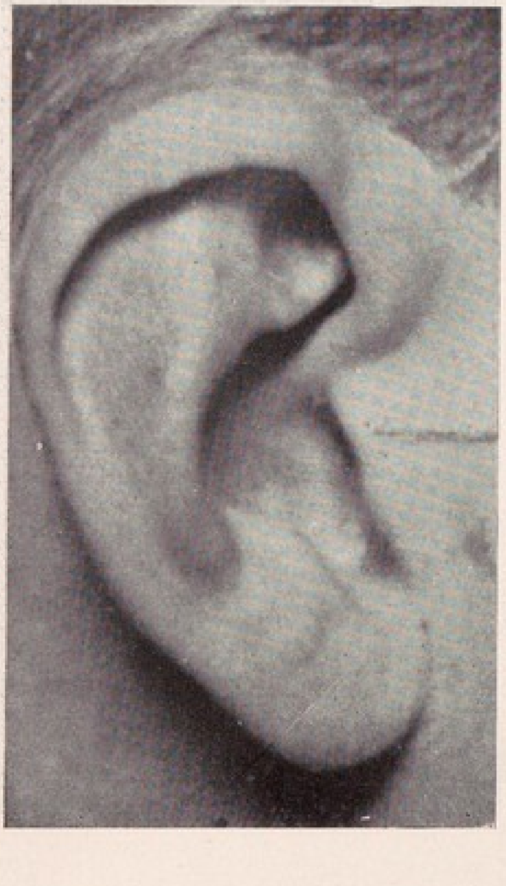

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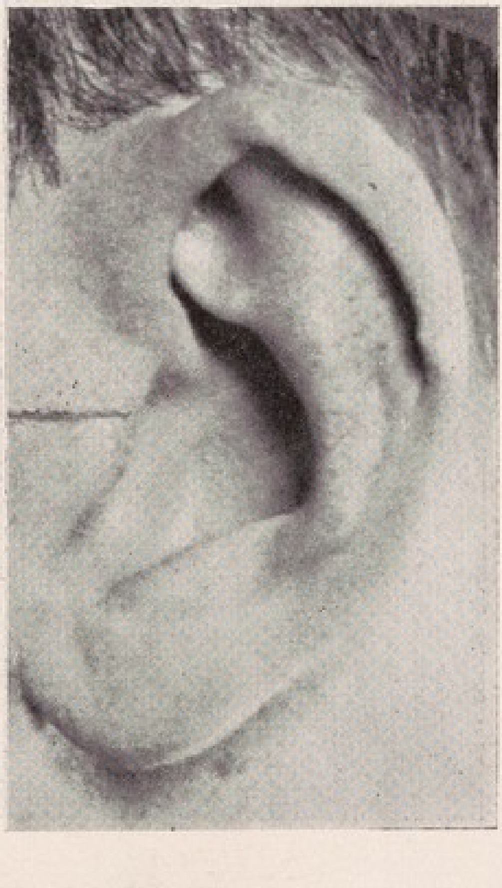

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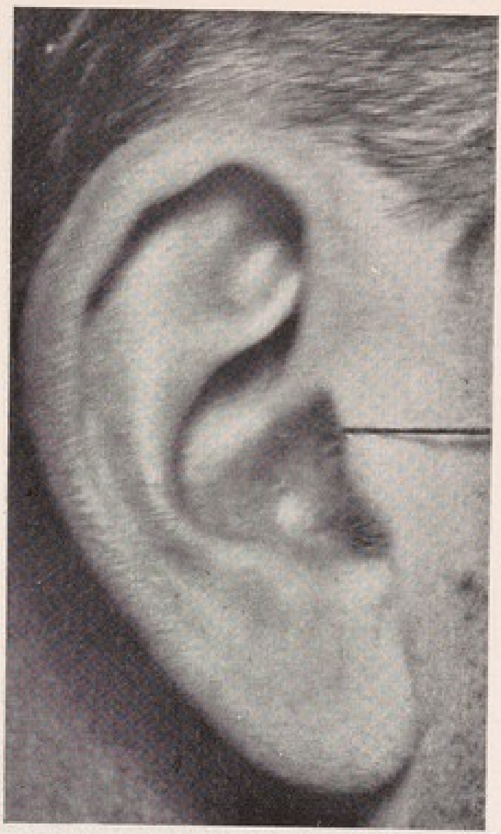

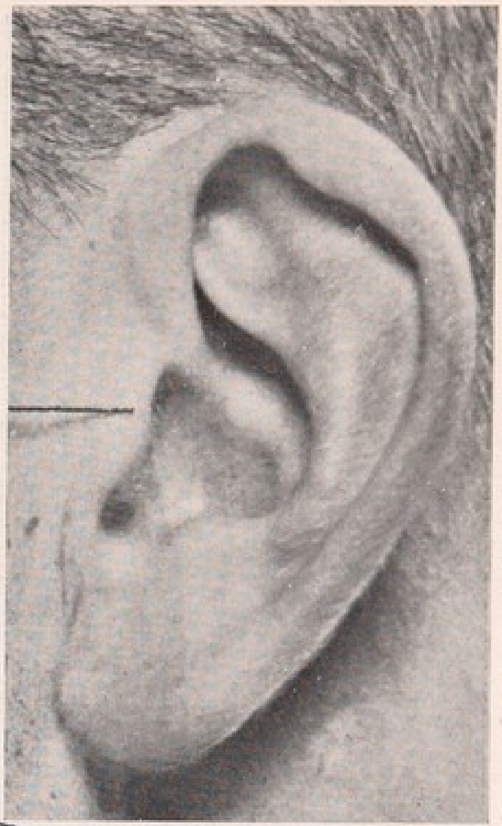

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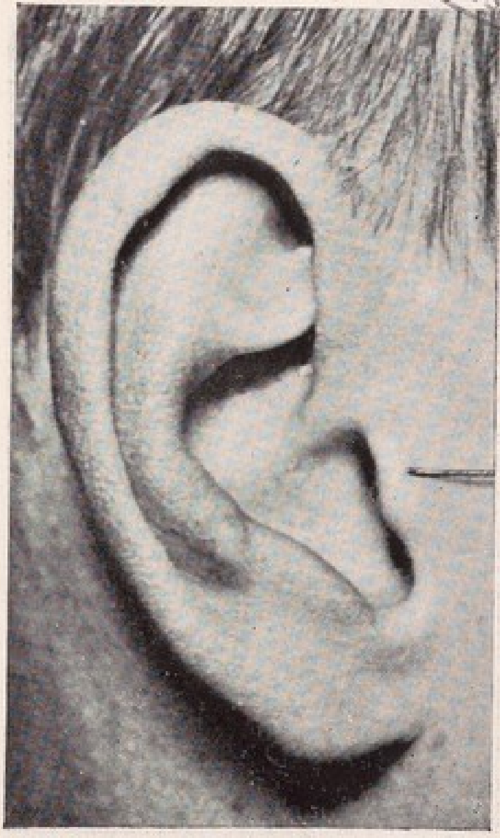

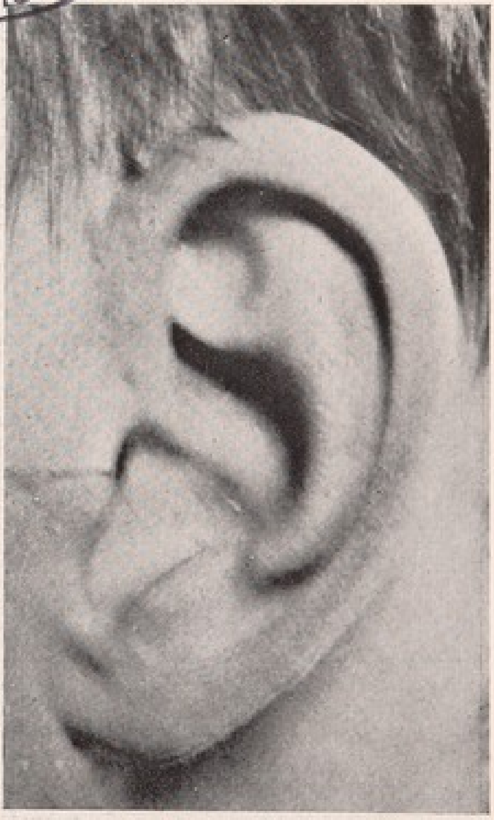

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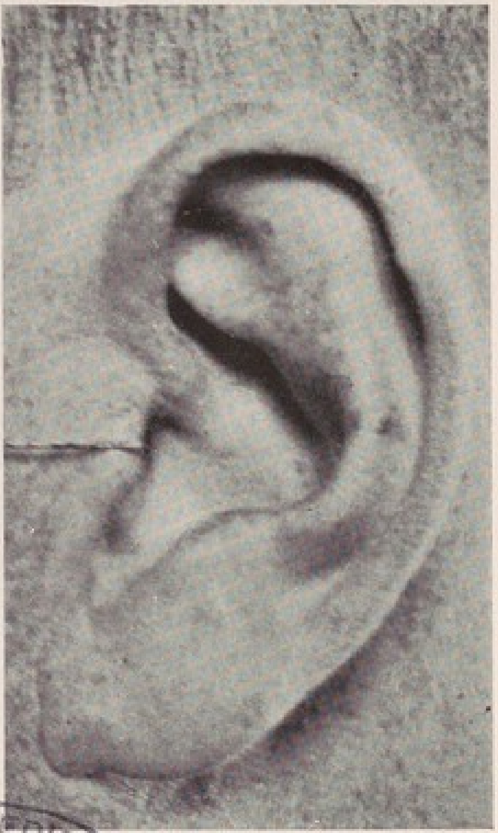

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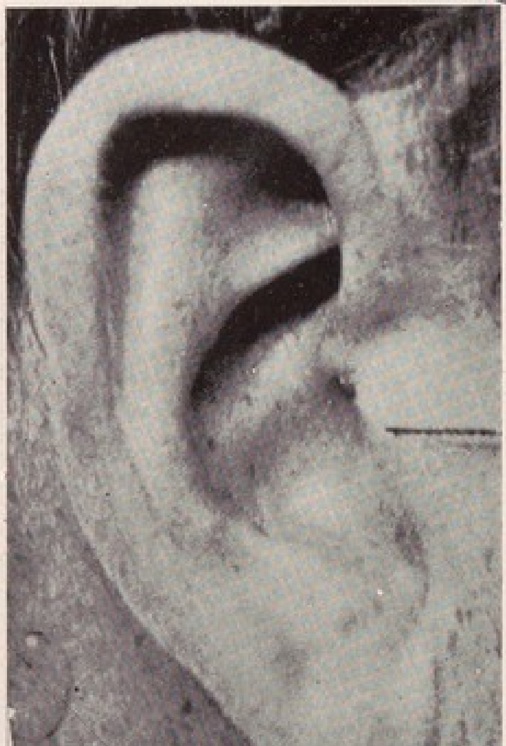

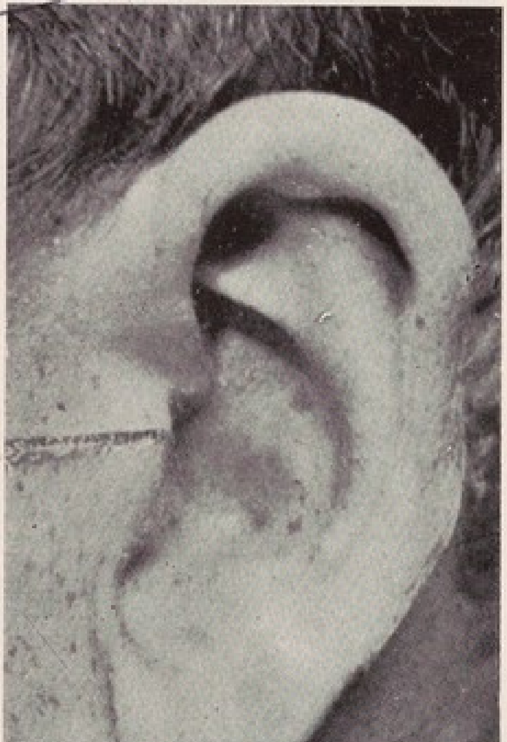

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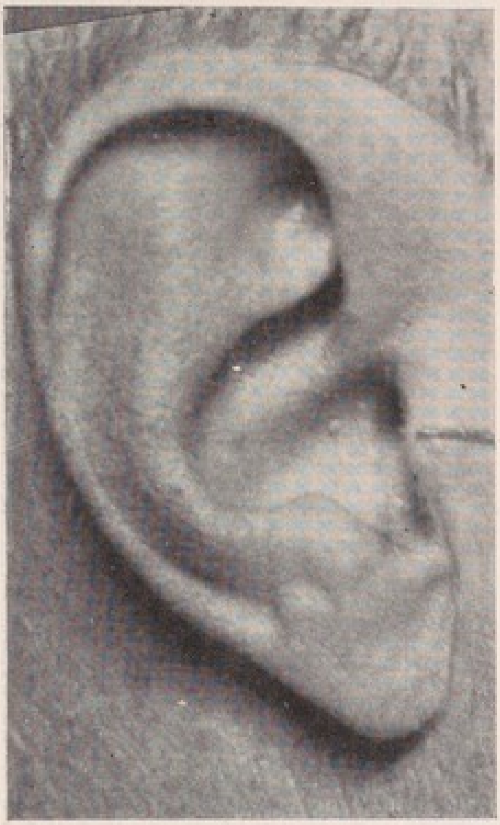

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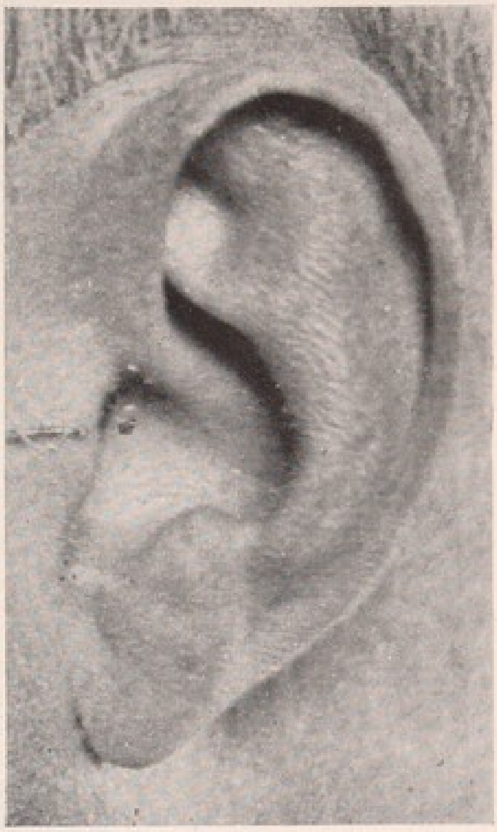
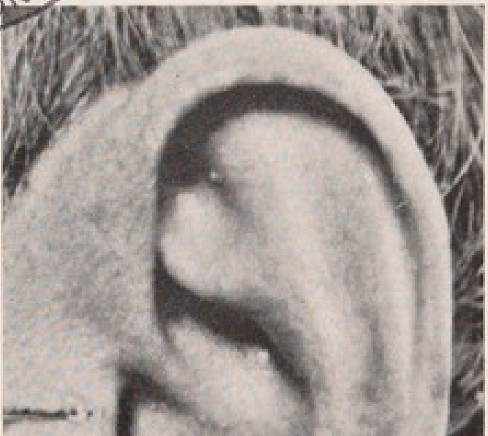


1 b.

1 b.



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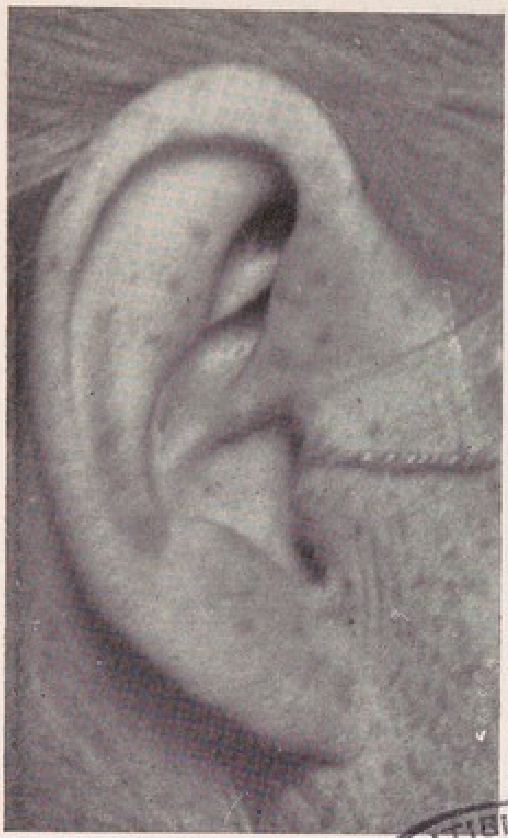

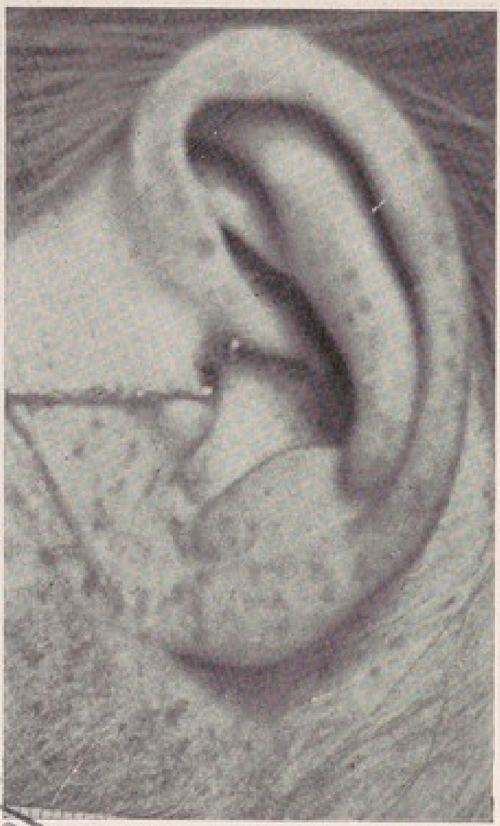

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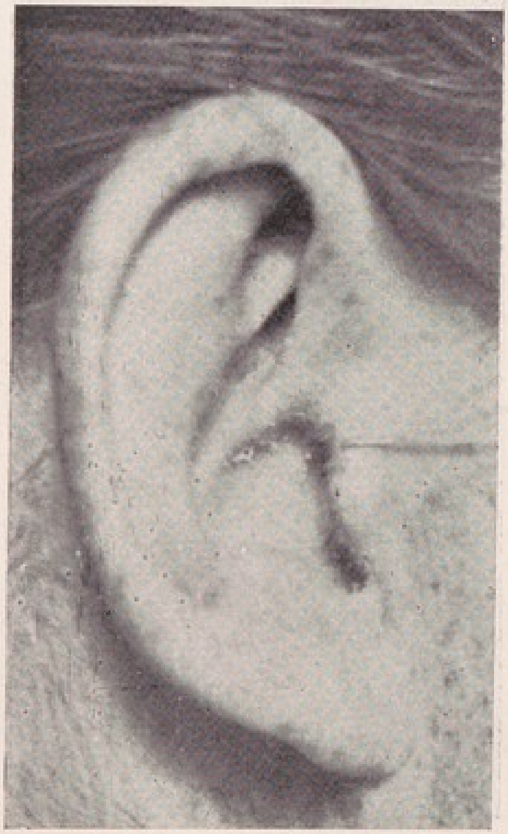

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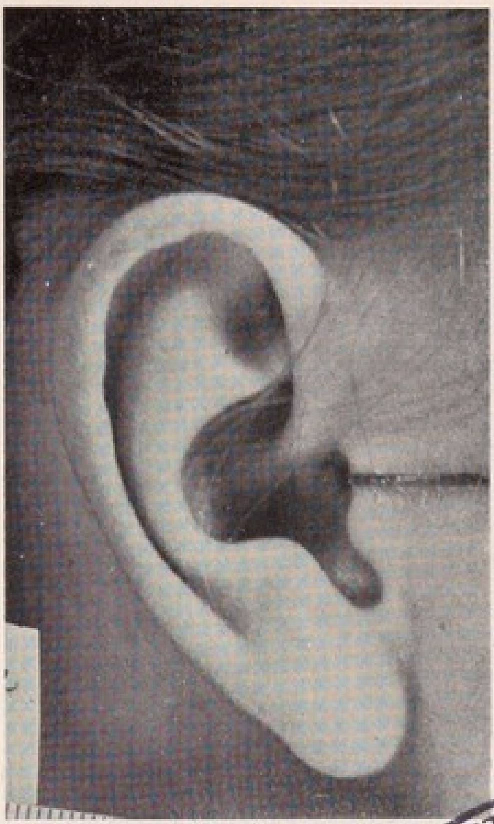

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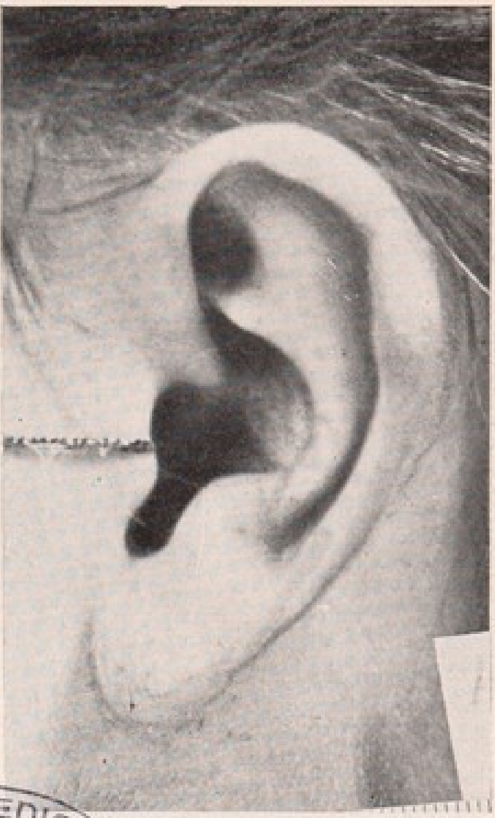

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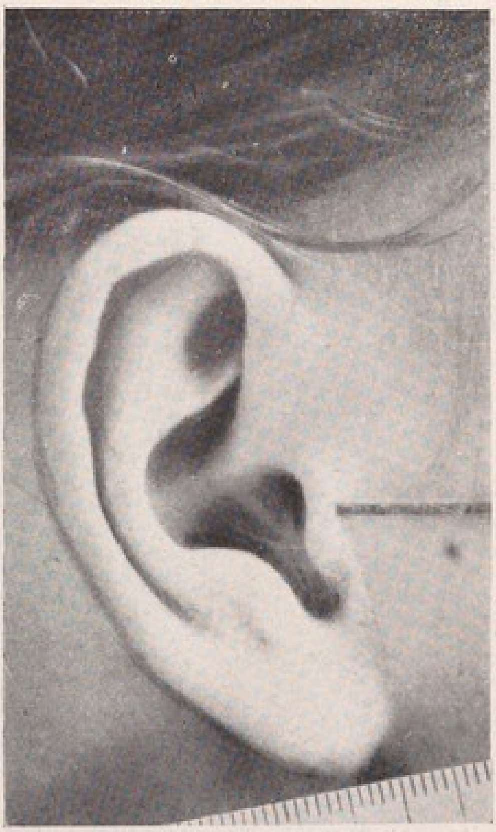

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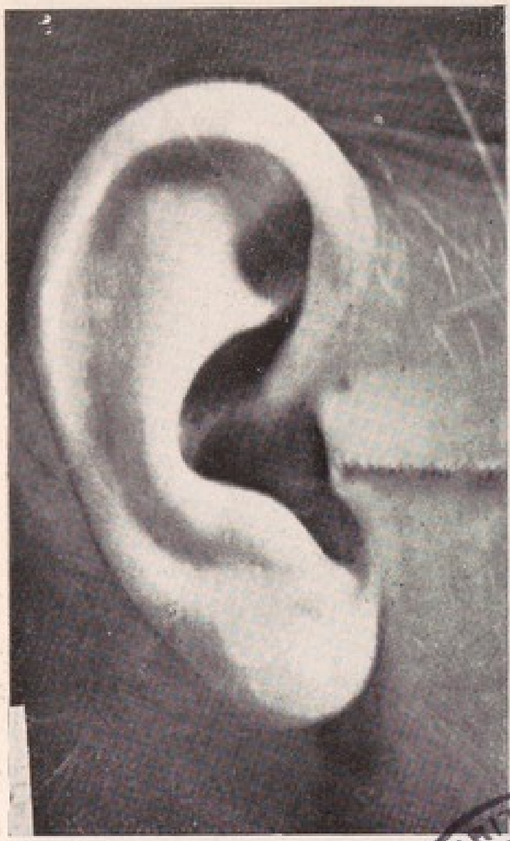

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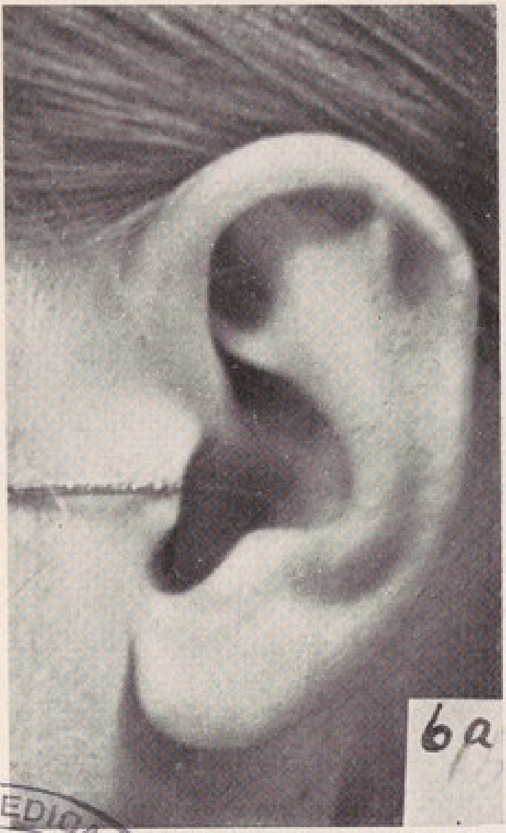

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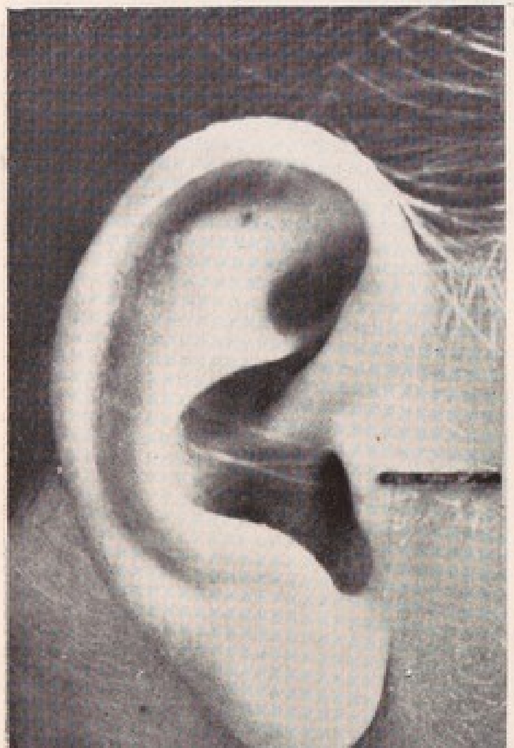

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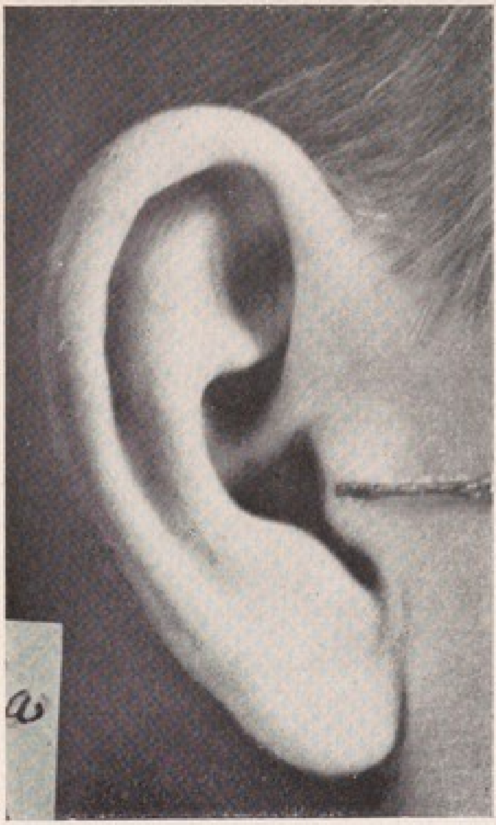

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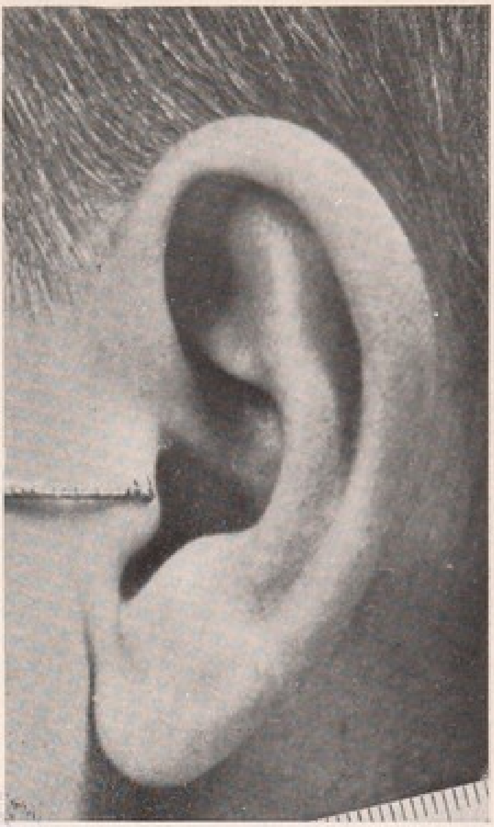

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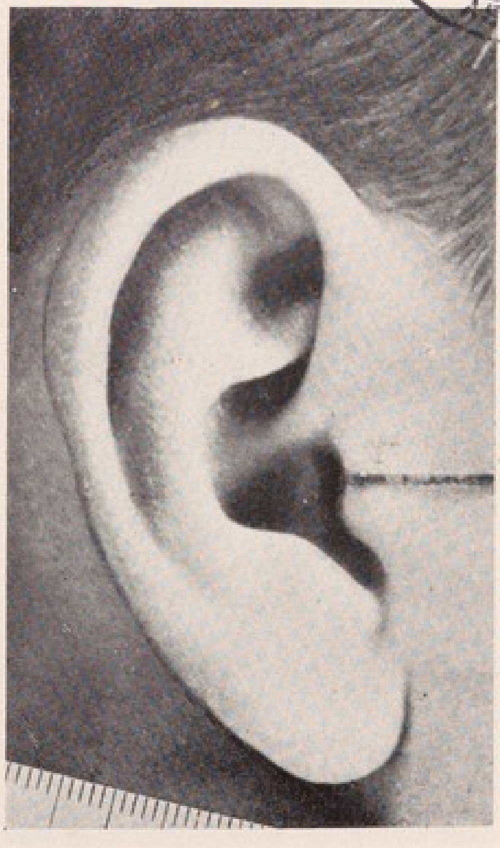

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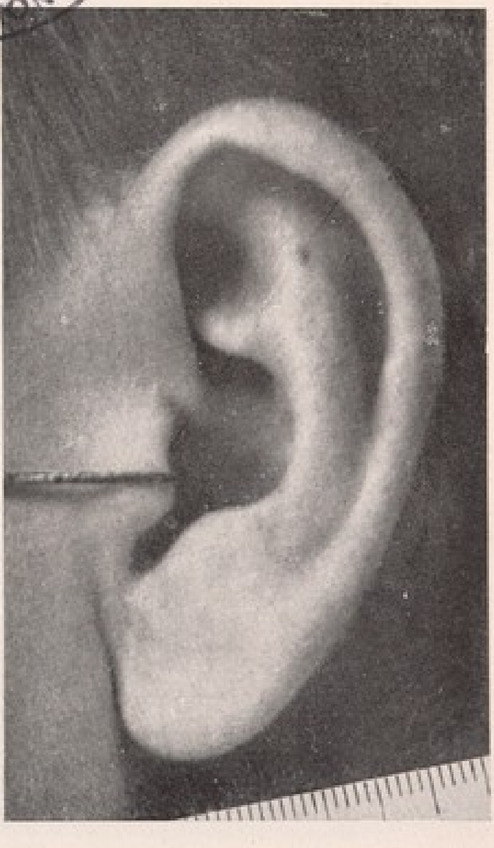

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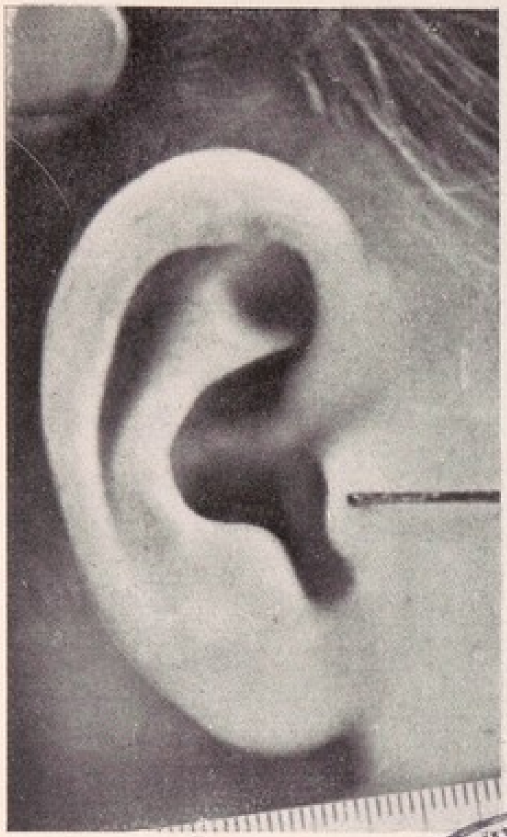

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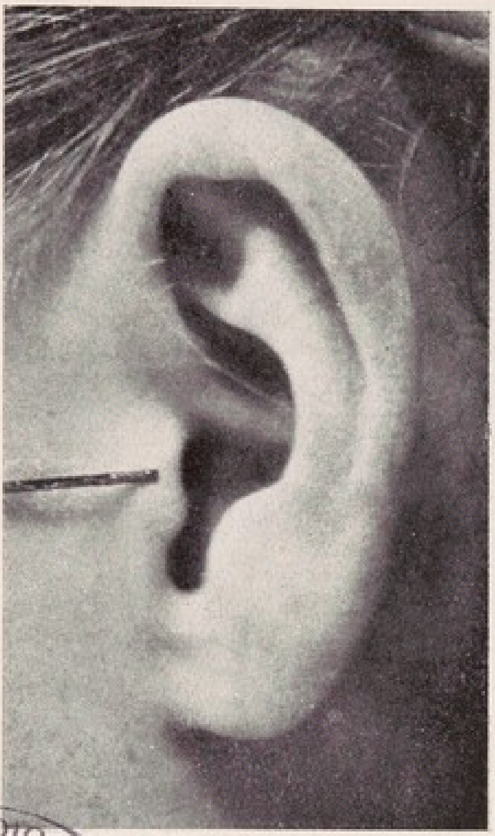

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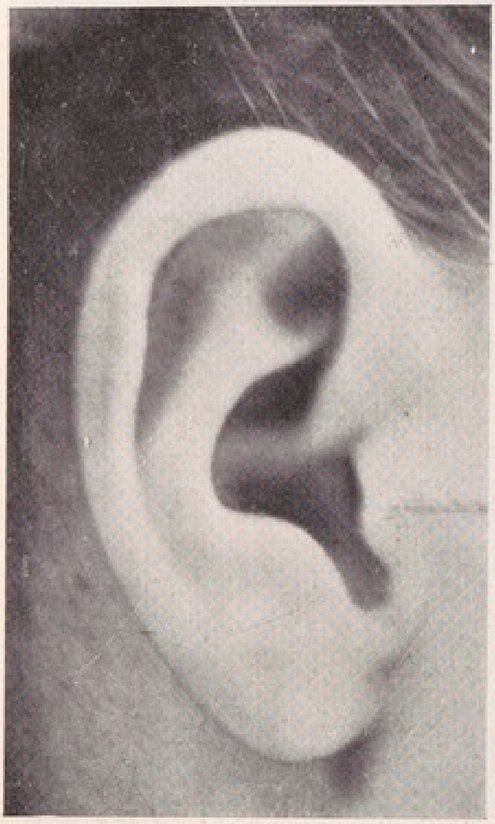

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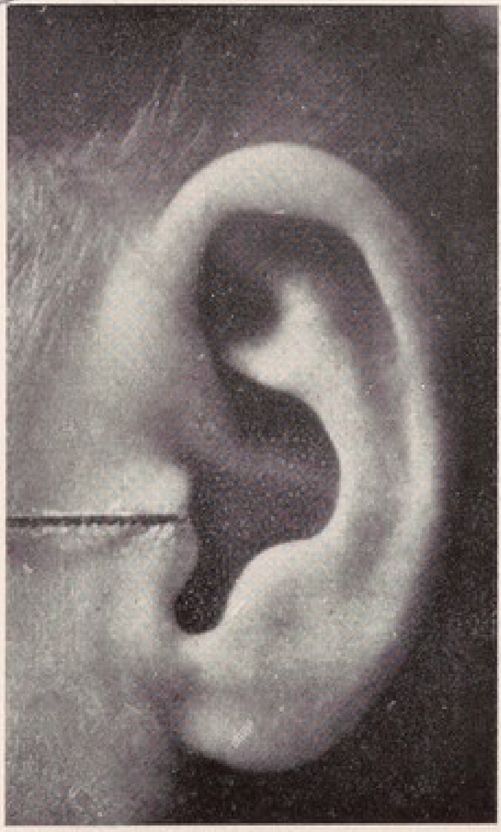

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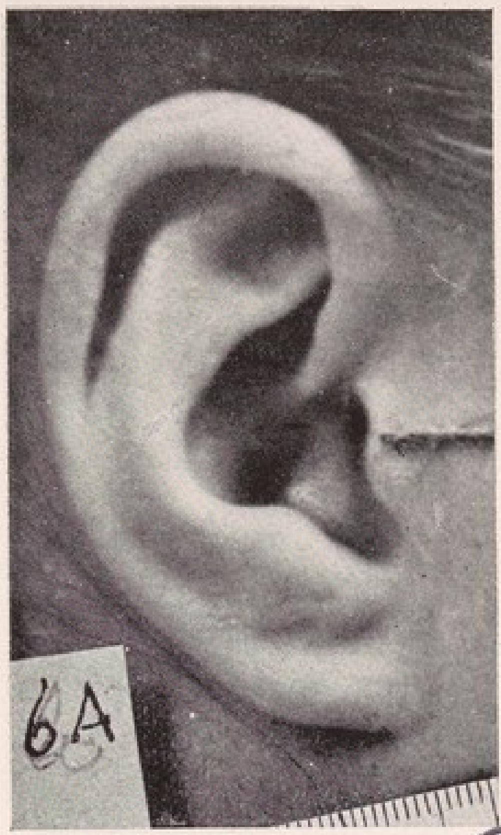

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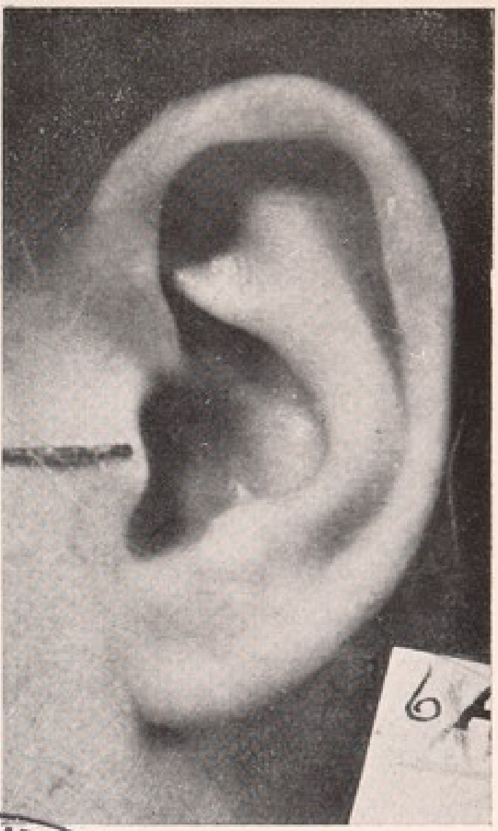

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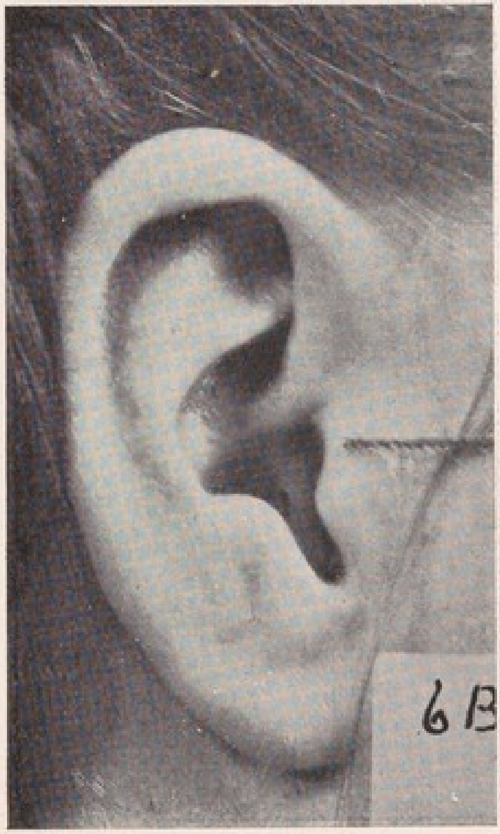

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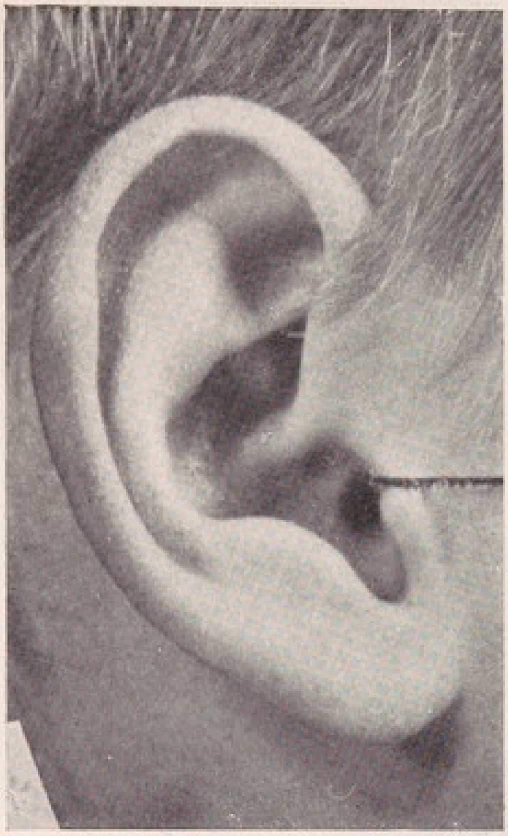

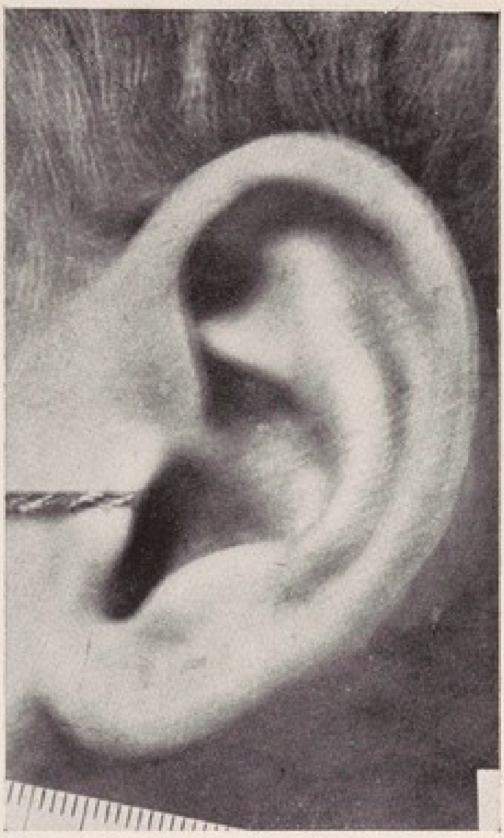

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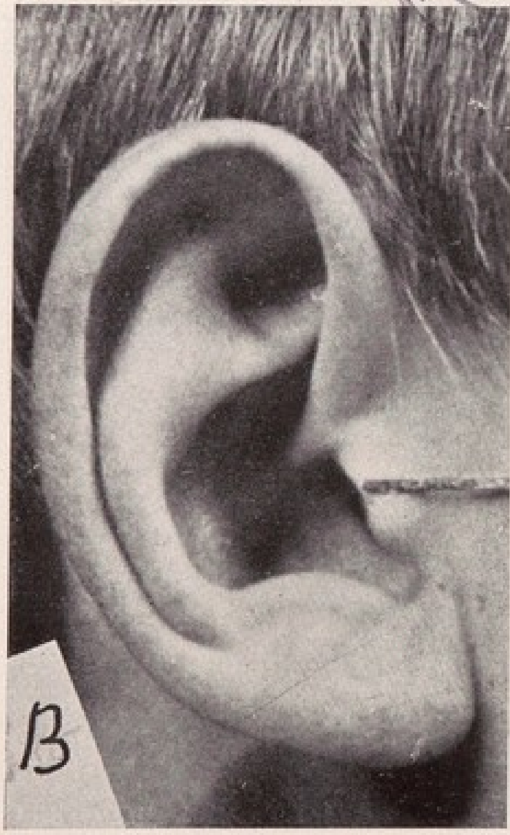

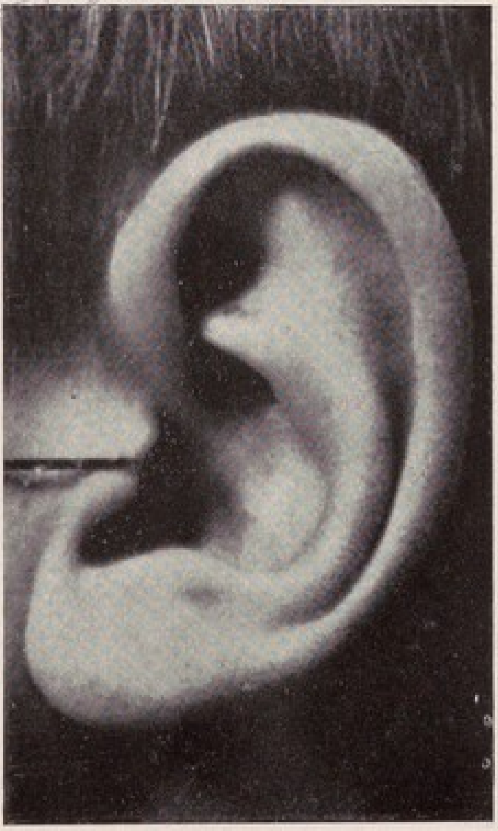

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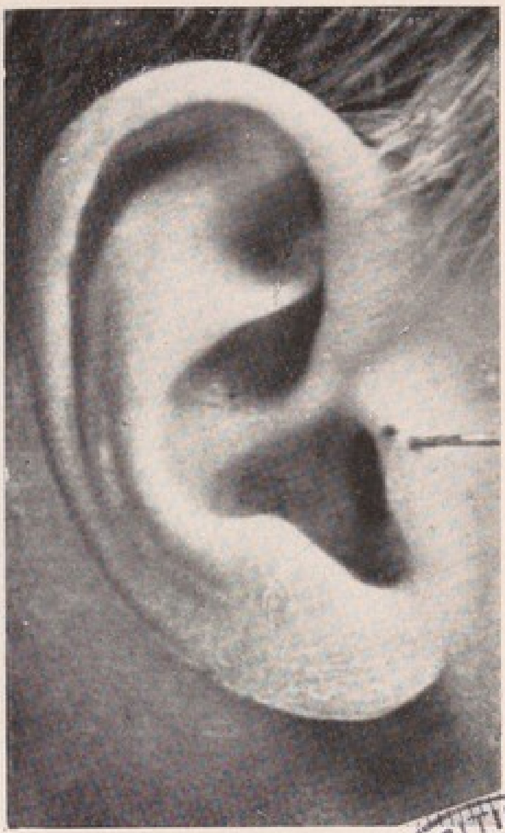

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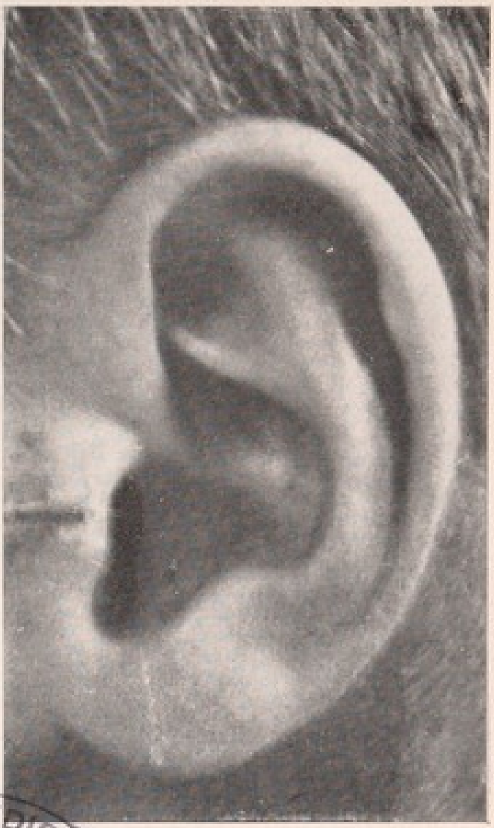

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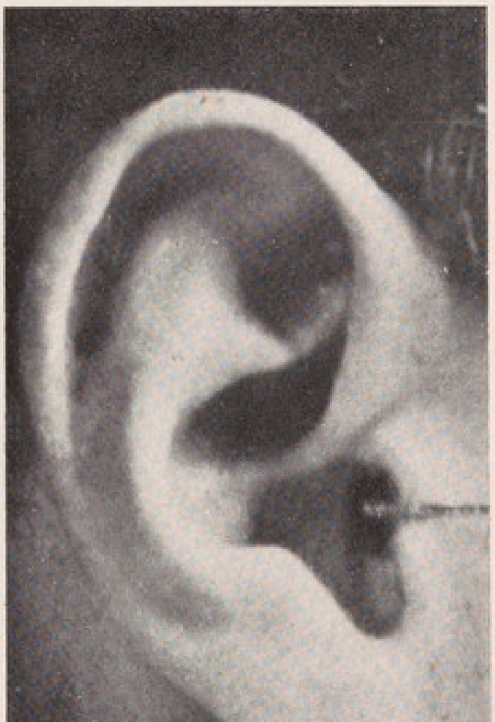
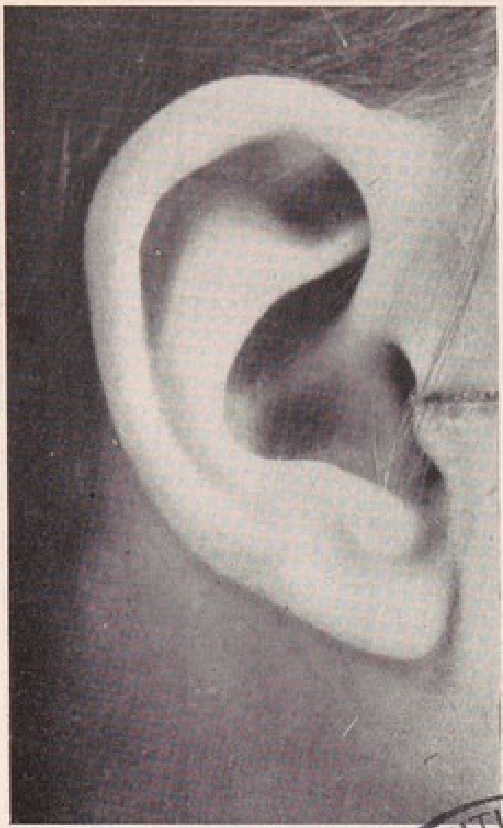


9 B.

10 A.



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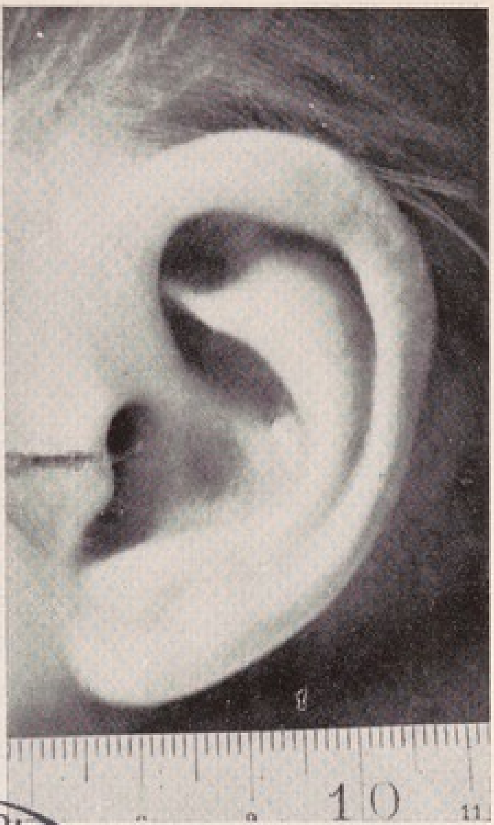

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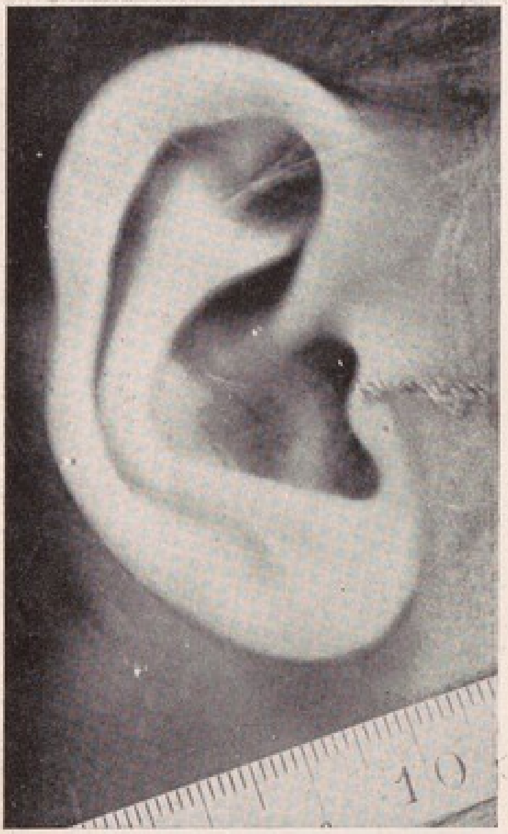

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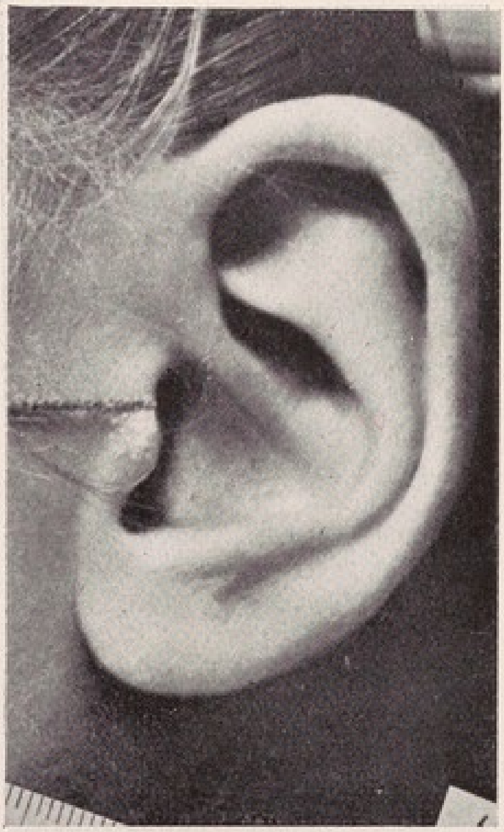

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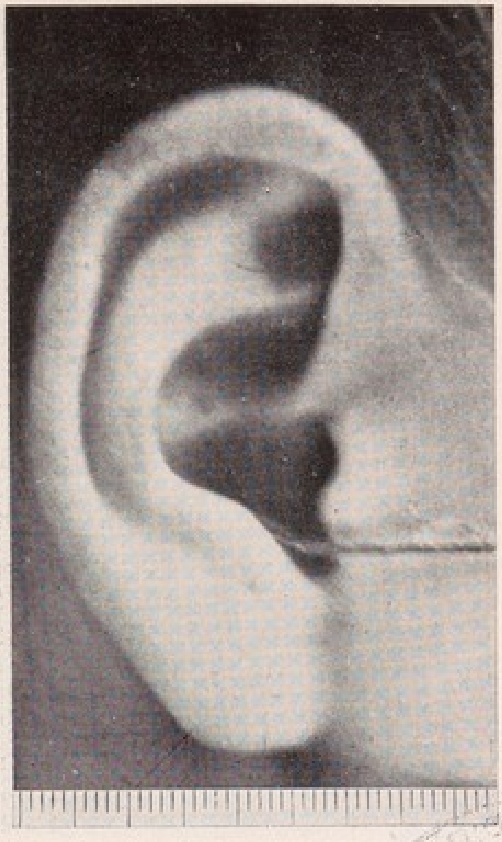

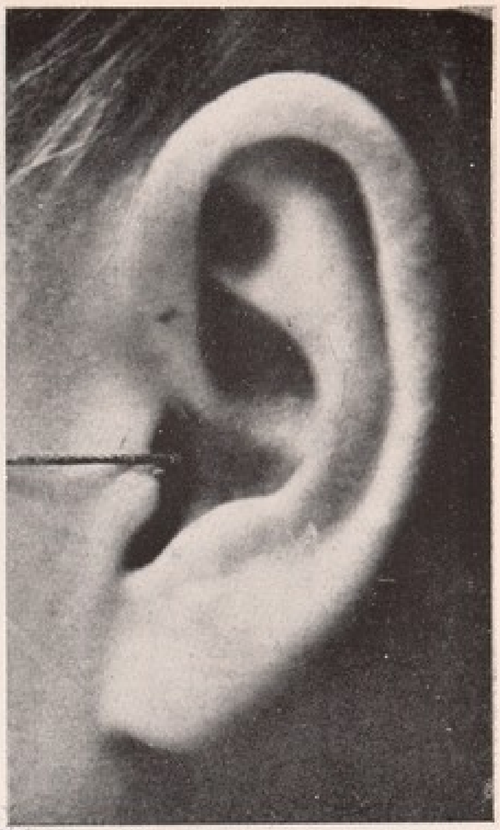

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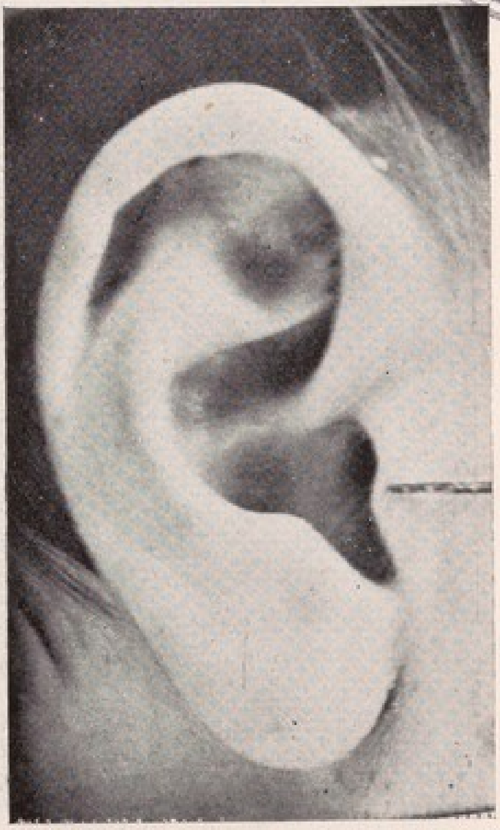

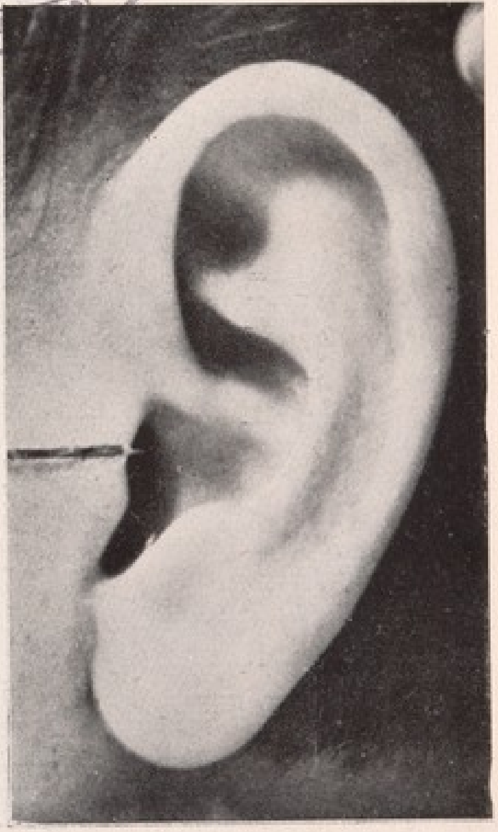

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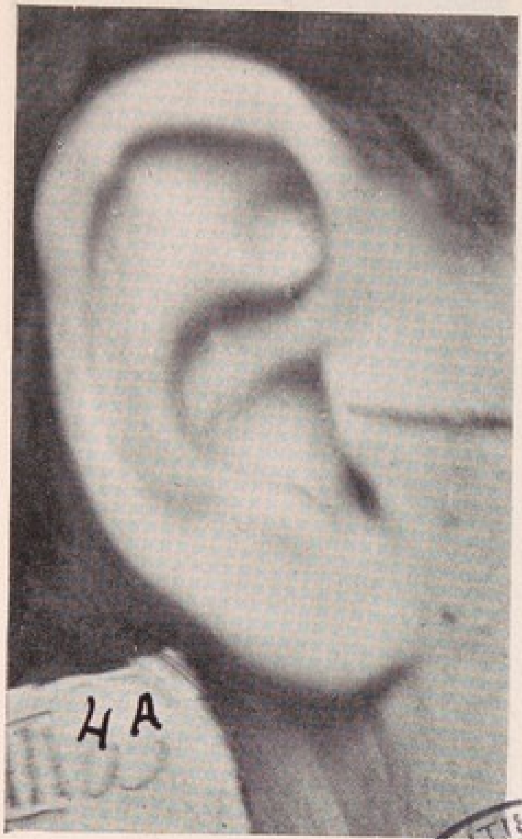

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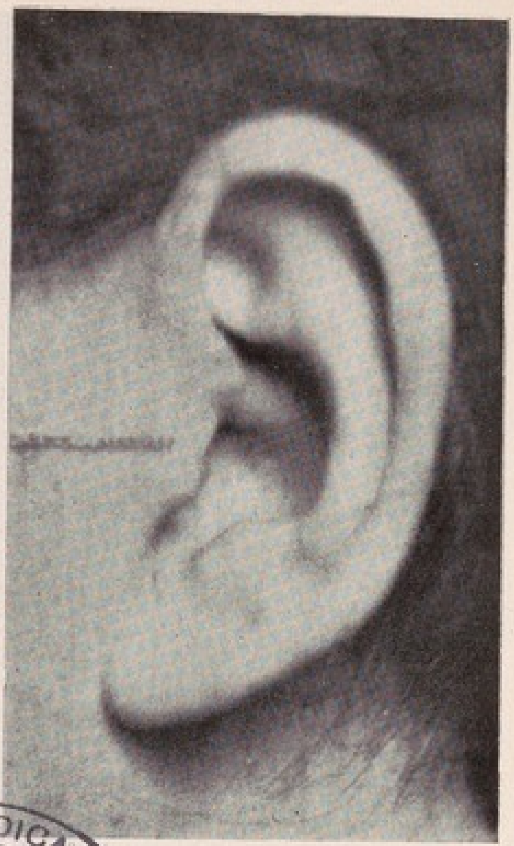

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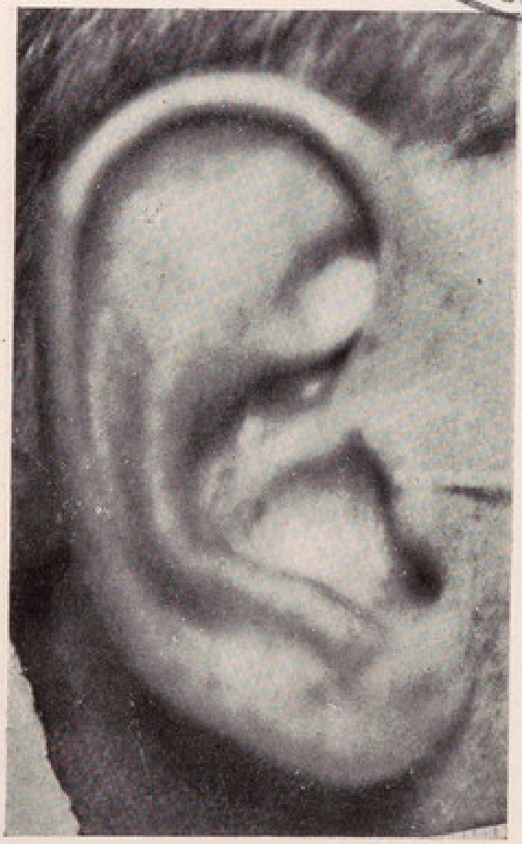

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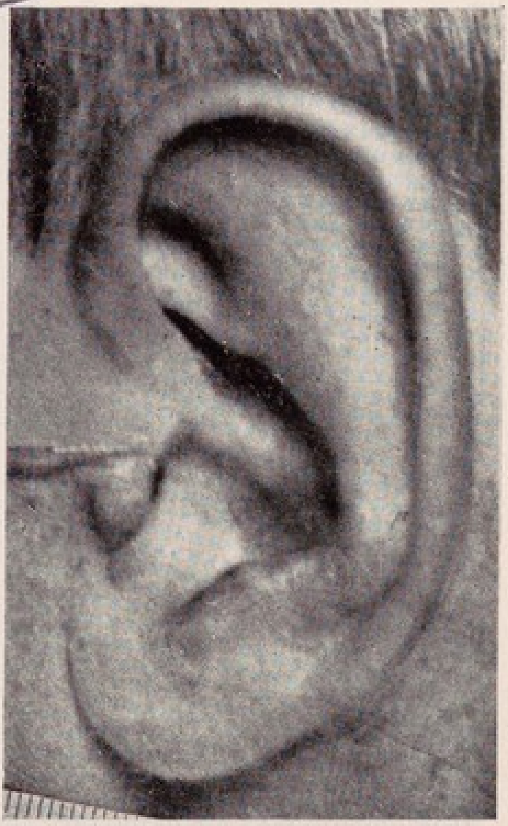

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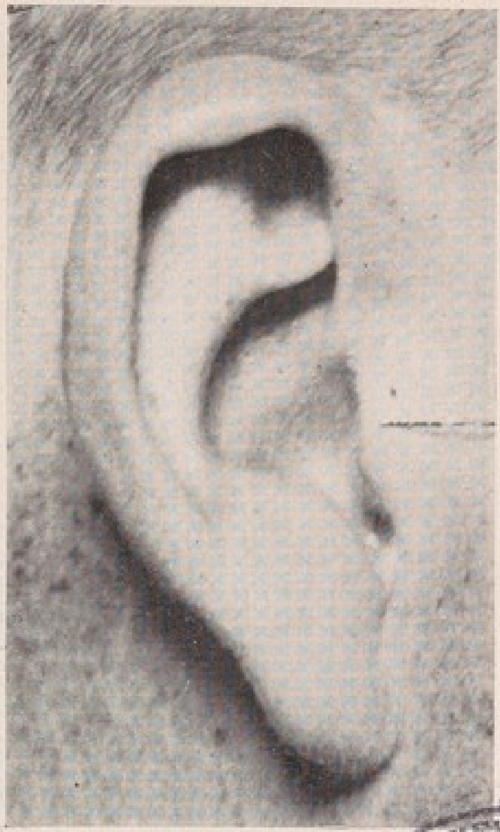

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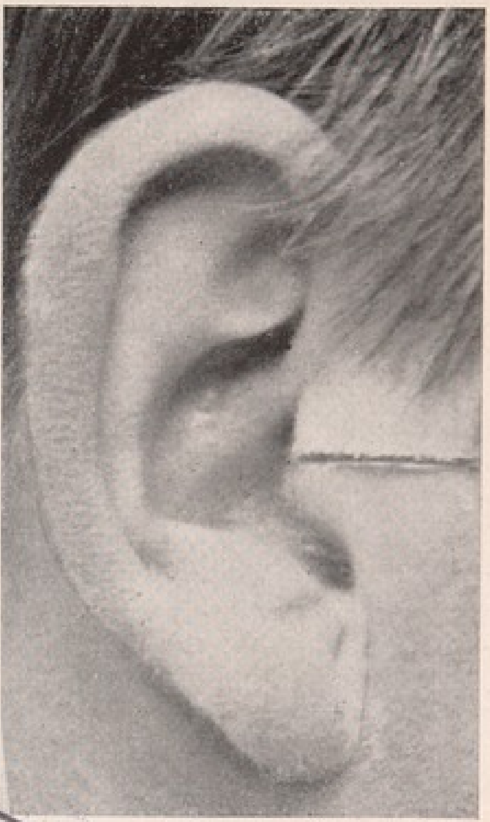

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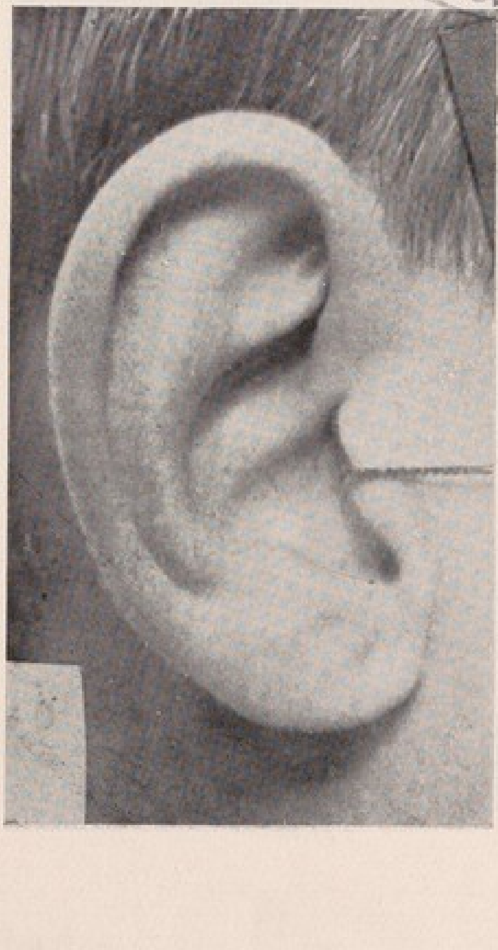

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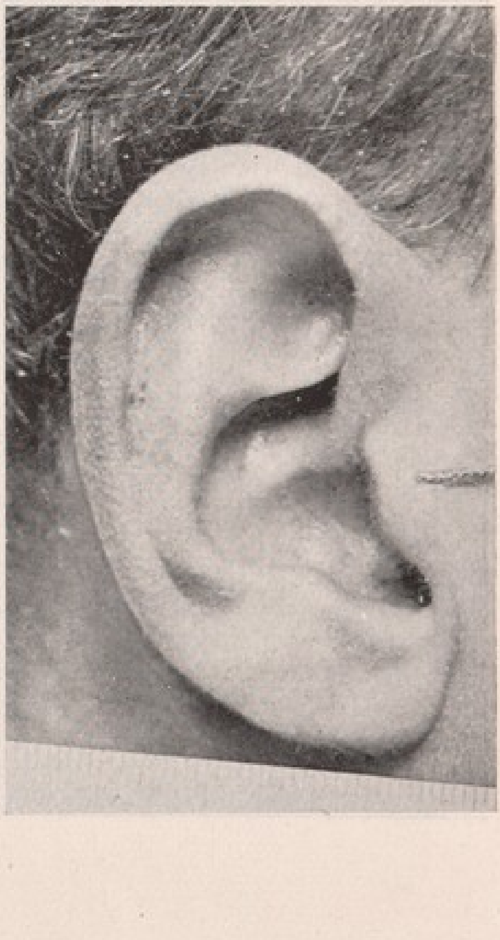

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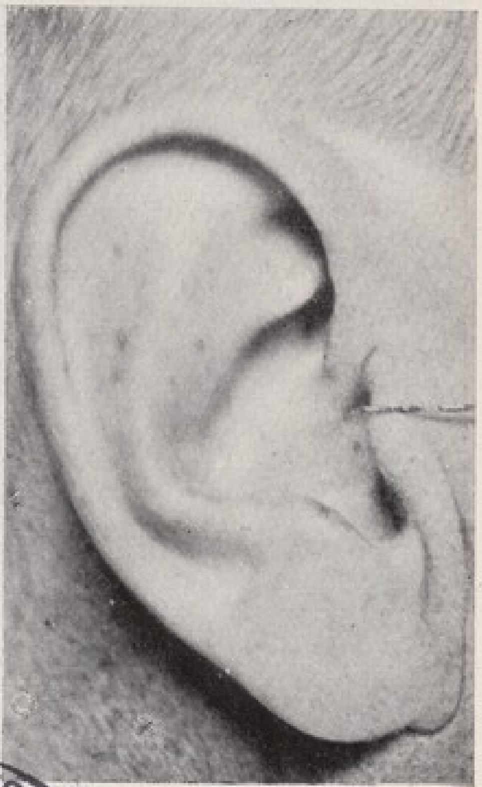

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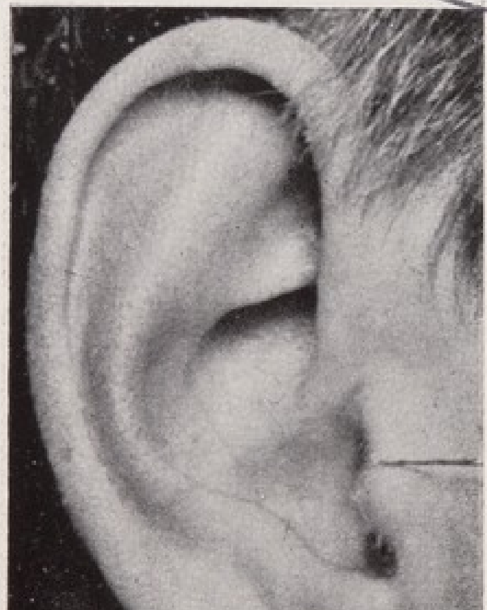

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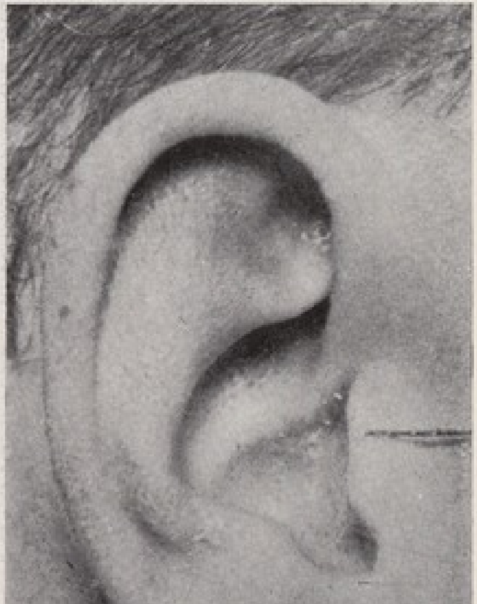

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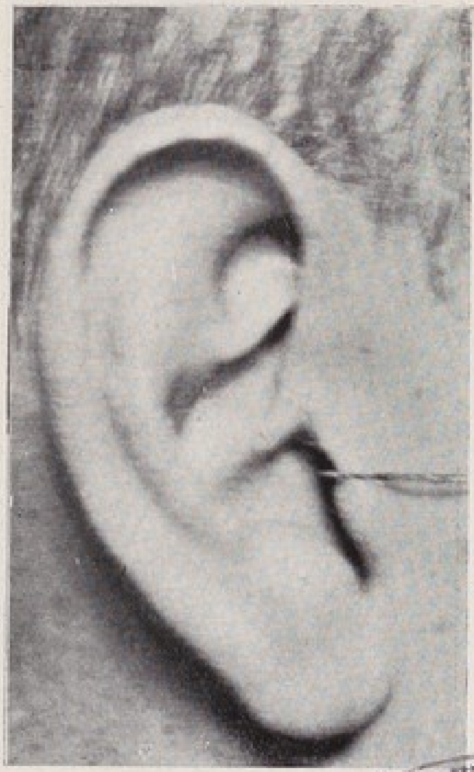

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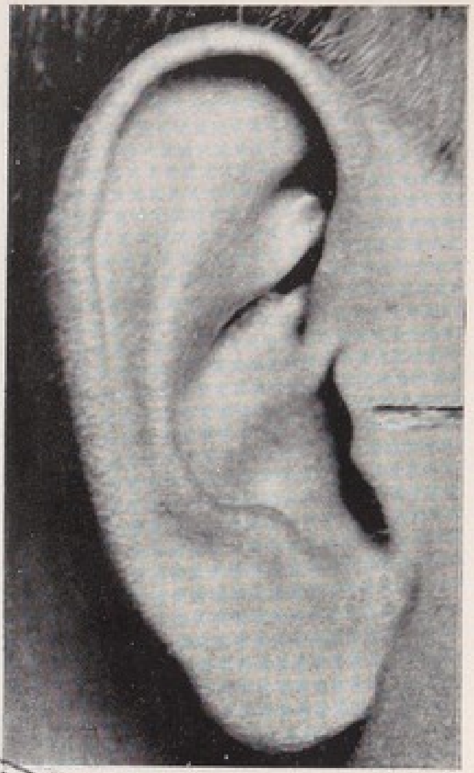

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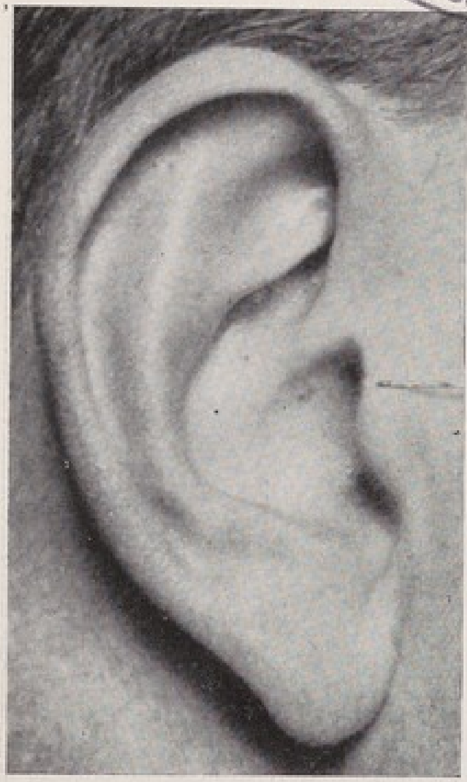

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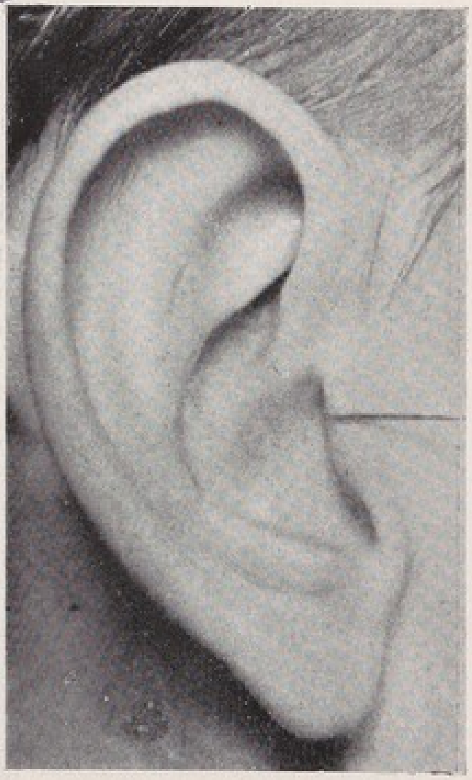

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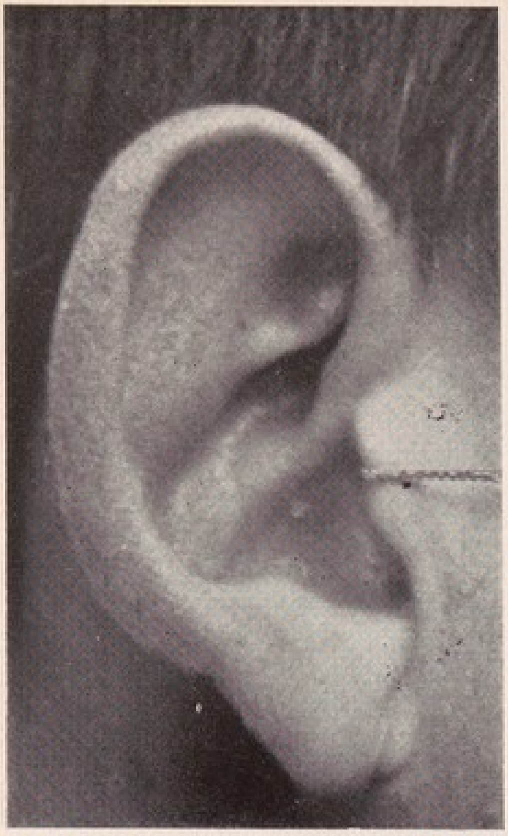

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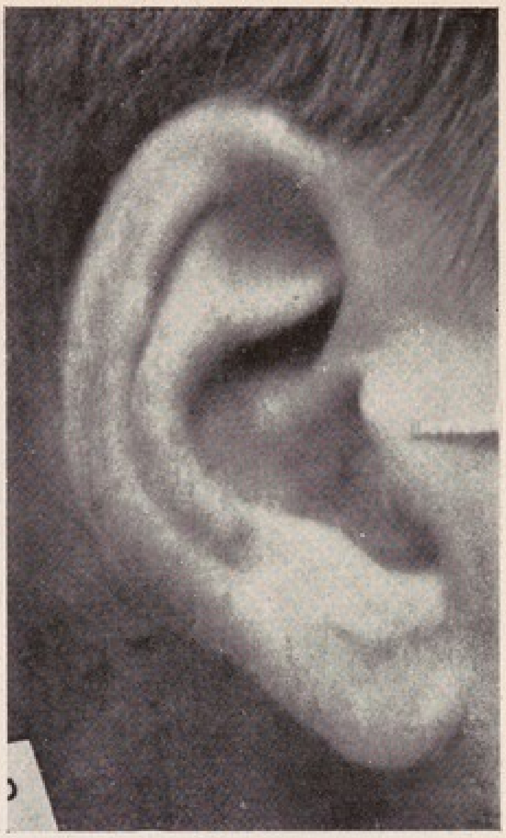

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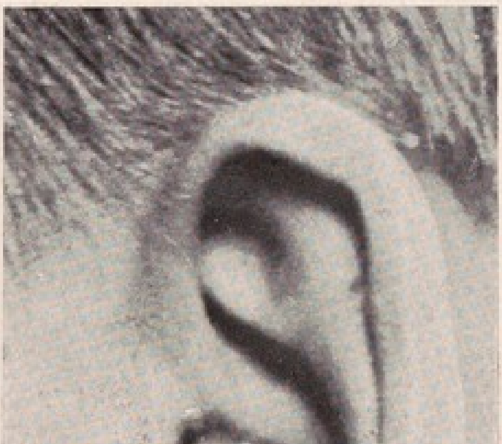

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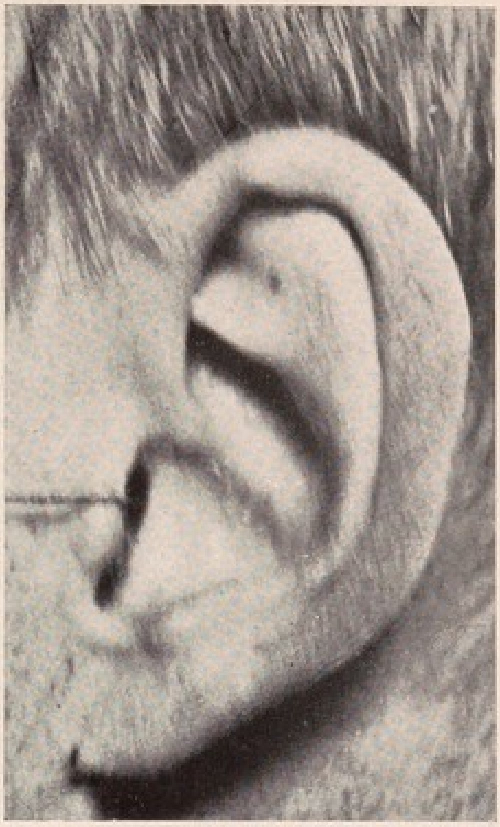

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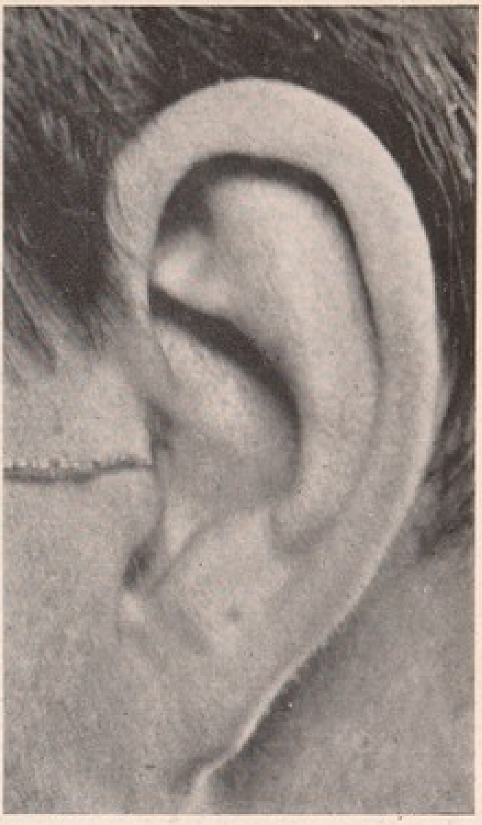

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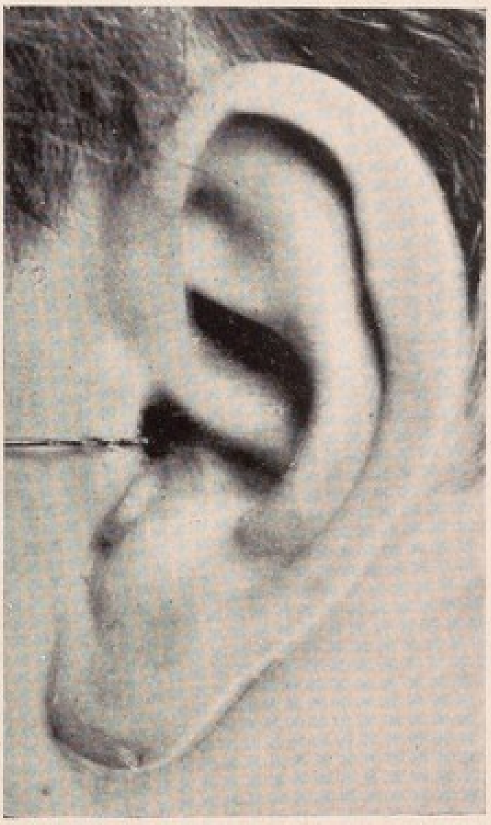

70