Anatomy. — *Structural alterations indicated in the development of the human cranium.* By J. HUIZINGA. (Communicated by Prof. M. W. WOERDEMAN.)

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In craniometrics, measures and their quotients (indices) are employed to analyse size and form.

Hitherto, the question of the mutual position of those measures has not yet been considered.

Without closer investigation it is not certain that this mutual situation should not be of great significance to the description of the form.

In earlier anthropologic literature, as far as we had it within our reach, there occurred no description of structure analysis in the manner it has been accomplished recently by DE FROE (1947).

The results of his investigation concerning the spatial relations of the principal skullmeasures justify in every respect a closer study of the question arising therefrom, and eventually a similar consideration of the classification of other properties.

DE FROE's statement give no clue as to his method of investigation.

After consultation we take this working method into closer examination.

Upon each skull to be examined, small marks are placed, indicating the following spots:

1. glabella;
2. bregma (as far as it is not yet sufficiently recognisable);
3. lambda (also when the sutures indicate this point distinctly, attention should be paid to the possible occurrence of ossa suturata in these sutures, which provide a difficulty in ascertaining the exact position of lambda);
4. opisthocranion (after determination with callipers);
5. opisthion;
6. basion;
7. euryon, *L* as well as *R* (the two points, between which lie the largest skullbreadth, are marked after determination with callipers).

The sagittal circumference of the skull is drawn next, in the supposedly wellknown method by means of the perigraph, upon which the position of the points 1—6 inclusive are indicated (in our investigation we are not concerned with the third point mentioned).

The horizontal section through the line glabella-opisthocranion is also drawn, whereby special notation is made of the position of *L* and *R* euryon as regards this horizontal circumference.

This position can be indicated by:

a. measuring the distance from euryon to the point of the needle of the perigraph (following the skull's circumference), at the moment when both these points are centred on the same vertical line.

b. marking in a diagram of the horizontal circumference, the section-point of both vertical and circumference lines, this being the place where the metal needle point is in a perpendicular position under or above the euryon. So doing, we project *L* and *R* euryon upon the horizontal circumference.

The results are shown by the two representations (*a* and *b*) in fig. 1. Fig. 1*b* also shows how many mms *L* and *R* euryon were found situated above (or under) the place of the horizontal section (10 and 22 mm).

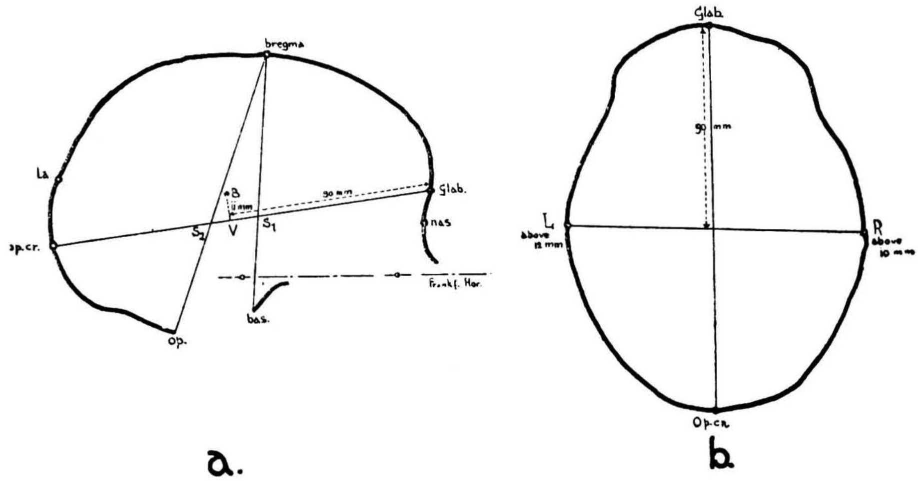

Fig. 1.

Only in exceptional cases one might find this distance *L* and *R* equally large.

Now we assume the mean value of both these *L*—*R* distances to be the distance between the line euryon-euryon and the line glabella-opisthocranion crossing each other.

In fig. 1*b* the position can be located of the intersection point of the projection of euryon-euryon on the plane of the diagram, with the line glabella-opisthocranion (90 mm from glabella).

Now we can say: the skull breadth (euryon-euryon) crosses the skull-length (glabella-opisthocranion) at 90 mm from glabella and 11 mm above the horizontal plane through the line glabella-opisthocranion.

In the concerned publication of DE FROE we find, among other things, a description of point *B* positions in 200 definitely male, and 90 definitely female skulls.

This position may be studied with regard to the length as well as to the height of the skull.

As it was meant to be a preliminary orientation, only the varying positions of B as regards the length (glabella-opisthocranion) has been described.

Naturally the position of B with regard to the length can vary in two ways:

1. point B can: *a.* be lying above the length,
   b. coincide with a point on the length,
   c. be lying under the length.
2. point B can be situated in the course of the length more to the front or more to the rear.

The latter may be studied from the position of the footpoint V of B's projection upon the length.

In this treatise we will occupy ourselves with the position of footpoint V on the length.

As material for research we had at our disposal the sagittal and horizontal sections of:

1. 200 skulls of adult males,
2. 90 skulls of adult females,

as already used in DE FROE's treatise, while in addition we were able to ascertain the circumference diagrams of:

3. 100 skulls of children.

The sex of these 100 skulls was unknown, however we managed to select a great number of these as being of children aging between 12 and 16 years, by examining the teeth among other features.

4. 7 fetal skulls; sex, age, and process of maceration of these being unknown.

At the same time we had a number of skulls available of children whose ages we knew, but not their sex.

Divide in groups in accordance with age we had:

5. 32 skulls of children aging from 0 to 6 years.
6. 20 skulls of children aging from 6 to 11 years.

All these skulls originated from the collection of the Anatomical Embryological Laboratory of Amsterdam.

Studying the sagittal sections it appears that there exists a definite relation between the afore mentioned footpoint V in connection with the two intersectionpoints of the basionbregmaheight and the opisthion-bregmaheight with the length.

The first intersectionpoint (basion-bregma/glabella-opisthocranion) we denote as S_1, the second (bregma-opisthion/glabella-opisthocranion) we call S_2.

A frequently occurring mutual arrangement of these three points (V, S_1 and S_2) has been represented for instance in fig. 1*a*: V lies between the two other points.

Concerning the variability of the position of V with regard to the position of S_1 we can be brief: V is always behind S_1 (reckoned from the glabella).

V's position as regards S_2 varies, however, in three ways:

1. V lies in front of S_2,
2. V coincides with S_2,
3. V lies behind S_2.

We stress the fact that here the points concerned are mathematical constructions.

It is possible that, for instance, the basion-bregmaheight might indeed intersect the length; we doubt however if this would take place in reality.

All used lines have been represented in the following procedure, as actual projections on the medio-sagittal plane (through the length of the skull).

For the achievement of a mathematically exact conception of the structural proportions this method is less fitting; the question is, if such a conception might be gained in any other way.

We realise that an investigation such as this contains the possibility of loosening the connection with its biological object to no small extend; on the other hand, it offers the possibility of indicating as to how the biological object might be approached.

We will return to this question later.

How many times V will coincide with S_2 (see 2 above), is among other things dependent on the accuracy of the measurement.

In our sagittal sections we ascertained the mutual positions correctly to a millimetre.

For example in a diagram in which V is situated either within one millimetre in front or behind S_2, it has been considered to coincide with S_2.

If point V, regarding glabella, is found behind S_2 we refer to it in this treatise as: skulls with Rearlocation or Rearlocators.

In the same manner we can distinguish between skulls with:

Forelocation or Forelocators and Intermediary skulls or Intermediators.

In the above described groups of skulls these three positions are represented as follows:

Group	n	Rearlocators	Forelocators	Intermediators
1. fetal skulls	7	100 %	—	—
2. 0 to 6 years	32	79 %	21 %	—
3. 6 to 11 years	20	65 %	35 %	—
4. 12 to 16 years (±)	100	31 %	61 %	8 %
5. adult women	90	36 %	58 %	6 %
6. adult men.	200	23 %	74 %	3 %

This table shows:

1. the frequency of forelocation increases with advancing age;
2. that, concerning this there is a definite difference between adult women and adult men.

3. that there is no significant difference between adult women and children of about 12 to 16 years of age.

Considering the magnitude of the percentages classification of rearlocation and forelocation, the group "adult women" should be placed between the 6—11, and the 12—16 age groups.

The percentage sequence gives reason to consider the group "adult men", not only regarding fetuses and young children, but also regarding adult women, to be a further developed unit, whereby the development is directed towards an increasing frequency of forelocation.

In an earlier publication (1947) we alluded to the probability, (on grounds totally independent from the present investigation), that adult men compared with adult women might presumably be more individualised, thus in a possible course towards individualisation would represent the more progressive group.

We are inclined to regard the above mentioned as pointing again in this direction.

Rearlocation would be a more primitive, compared with forelocation a less developed condition.

Thus compared with rear-location we find fore-location more frequent in adult skulls.

When beginning with an adult skull, (with already ossified sphenobasilar suture), then the above placed table can serve to obtain an indication for the sex diagnosis of the skull concerned.

Suppose the skull in question is one with rearlocation.

In adult women this type is apparently more frequent (36 %) than in the skulls of adult men (23 %).

Calculating this out at 100 %, the rearlocator appears in the adult female skull in 61 % and in the male skull in 39 % of the cases.

In the same way we calculate as probabilities for forelocation: 44 % chance to have an adult female skull, 56 % chance for an adult male skull.

Fore location (*FL*) is a more masculine, rearlocation (*RL*) a more feminine and juvenile property.

Together with other indications for sex determination this percentage may contribute to a higher probability of the diagnosis.

It is not unlikely that the gradual sex difference mentioned, may be procured in some other way, perhaps less, but equally probable, more convincing.

Further investigation into the correlation of *FL* and *RL* with other phenomena may be able to prove this.

Concerning this we think for instance of certain angular measures, more or less dependent on the position of the points described above. This subject will be referred to later.

Where *RL* resp. *FL* concerns the position of V behind, resp. in front of the intersectionpoint S_2, it is important to consider these two points

(S_2, and eventually S_1) concerning their behaviour, in both situations, regarding the entire line glabella-opisthicranion.

For instance: will V in FL and RL be found on an average in the same place on the said line, and will S_2 be situated more to the front in RL?

As to the study of this and similar questions we may in principle use the following supposition: The original situation of the developing skull is the rearlocation (fig. 2).

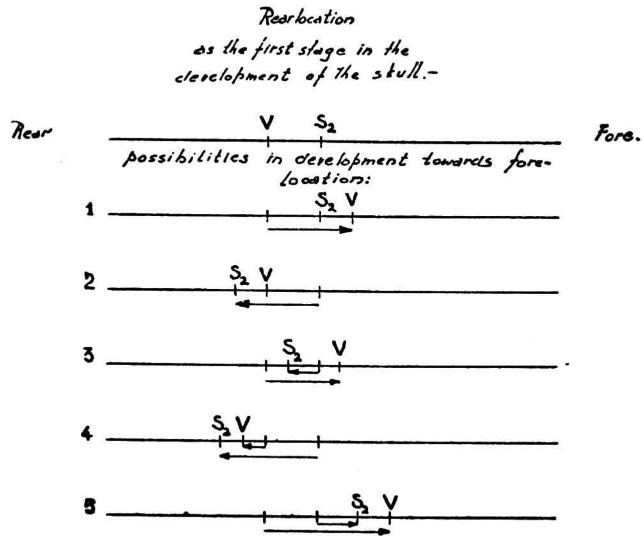

Fig. 2.

The data of the above placed table is pointing in that direction.

In the course of the development the skull type with FL appears.

Logically we expect this to occur via the stage of the intermediary skull (I.) (V and S_2 coincide).

It has been said before that the number of skulls qualified as intermediators depends, among other things, on the accuracy of the calculations.

So it is possible that, if we calculated correctly to within one mm, many cases have been considered FL or RL, which really might have intermediators. In that case we find few instances of intermediary skulls, but those (see table) in their different groups of sex and age in the sequence of magnitude fitting in neatly into our suppositions: from the group of the children, via the group of adult women to the group of the adult men, in a reducing frequency.

When we want to change the original situation (RL) into FL, (via I), then this can be done as follows:

1. V advances, while S_2 remains in its place.
2. S_2 moves to the rear while V keeps its place.
3. V advances while S_2 moves to the rear.

4. both S_2 and V move to the rear, but S_2 covers a larger distance than V.
5. V and S_2 are both advancing, but V covers a larger distance than S_2.
6. Although we do not discuss this point (at least in our publication), it is also possible that RL changes into FL by revolving of the line glabella-opisthocranion (see fig. 1), whereby the projection of B also changes its position.
7. the mentioned factors 1—6 inclusive, are partially co-operating.

It is possible, using the available data, to consider which of the changes mentioned may have taken place.

Of the three largest groups from our material, viz. the 90 female skulls, the 200 male and the 100 juvenile skulls, we ascertained:

1. the distance glabella-V as a percentage of the glabella-opisthocranion length.
2. .... glabella-S_2 ....
3. .... glabella-S_1 ....

(The behaviour of S_1 in the changing process is not unimportant, as S_1 and S_2 will accomplish the same directional movements, as a consequence of their geometrical connection in our biological object.)

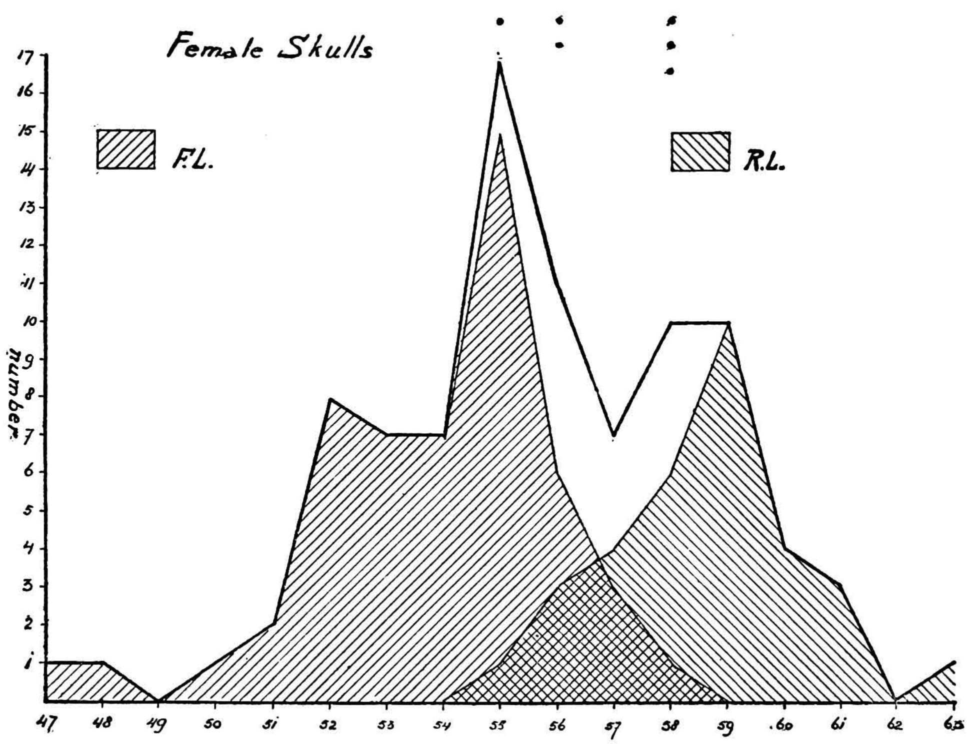

Fig. 3.

Of these three percentage distances the frequency polygons have been made for each of the three groups of skulls.

The particulars to be discussed of a certain frequency distribution (concerning V, S_1 and S_2) are the same in each of the three skullgroups, so we can confine ourselves to represent three frequency polygons instead of nine.

I. The frequency polygon of the positions of point V (a percentage of the distance glabella-opisthocranion) has been represented in fig. 3 for the group of the female skulls ($n = 90$).

Considering the positions of V in skulls of this group with existing *FL* resp. *RL*, it appears that in *RL* the distance between V and the glabella is considerably greater as an average percentage than in forelocators.

The frequency polygons of the percentages expressing the position of V were also drawn in fig. 3 for *RL* and *FL*.

(From these two polygons might be constructed the polygon of the material not yet divided into forelocators and rearlocators, with this restriction, that possible intermediators are not taken into the account. These are missing in the construction of the polygon of the complete number. The number of occurring intermediators at a certain percentage (abscis) has been represented by dotted lines above the polygons.)

The fact that V in the forelocators has moved so much more to the front as an average, is an indication that the possibility mentioned above under 1, 2, and 3, has been applied here, and certainly not the process mentioned under 2 and 4 (further see II).

The position of V in other groups of skulls (men and children) behaves similarly.

II. The frequency polygon of the positions of S_2 (percentages of the distance between glabella and opisthocranion) has been represented in fig. 4 for the juvenile skullgroup ($n = 100$).

Considering the positions of S_2 in skulls (of this group) with *FL*, resp. *RL*, it appears that in opposition to what is said of V, in rearlocators the distance between S_2 and glabella as an average percentage is smaller, than in the forelocators.

In *FL* therefore S_2 as an average percentage lies more to the rear, on the line glabella-opisthocranion, compared with the rearlocator.

As S_2 in other skullgroups (men and women) behaves similarly, we are able to summarize what has been said under I and II among other things, as follows: of skulls with *FL*, point V on an average lies more to the front, while point S_2 on an average lies more to the rear. This also counts, mutatis mutandis, for skulls with *RL*.

If there really is the possibility of "becoming a forelocator", as a progressive process of development, then it is most probable that the points V and S_2 are moving in opposite directions: V to the front, and S_2 to the rear, corresponding with the supposed changing possibilities. (Fig. 2 under 3 and 4.)

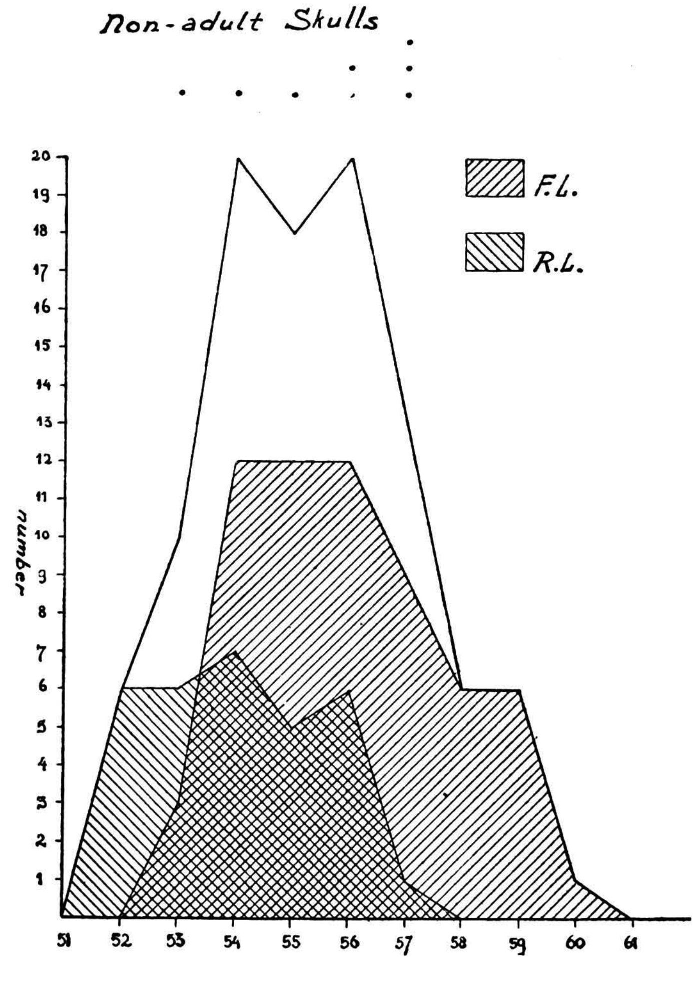

Fig. 4.

From the manner in which forelocator and rearlocator overlap each other, in the figures 3 and 4, it follows, that V's move to the front is striking a higher average than the movement of S_2 to the rear.

S_2 proves to be slightly more stable during the changing process.

III. The frequency polygon of positions of S_1 (in percentages of the distance between glabella and opisthocranion) has been represented in fig. 5 for the male skullgroup ($n = 200$).

The diagram again shows the percentages of forelocators and rearlocators separately.

The same phenomenon occurs here as has been shown by S_2 (see II.): in the rearlocators the distance between S_1 and glabella is smaller as a percentage and as an average than in forelocators.

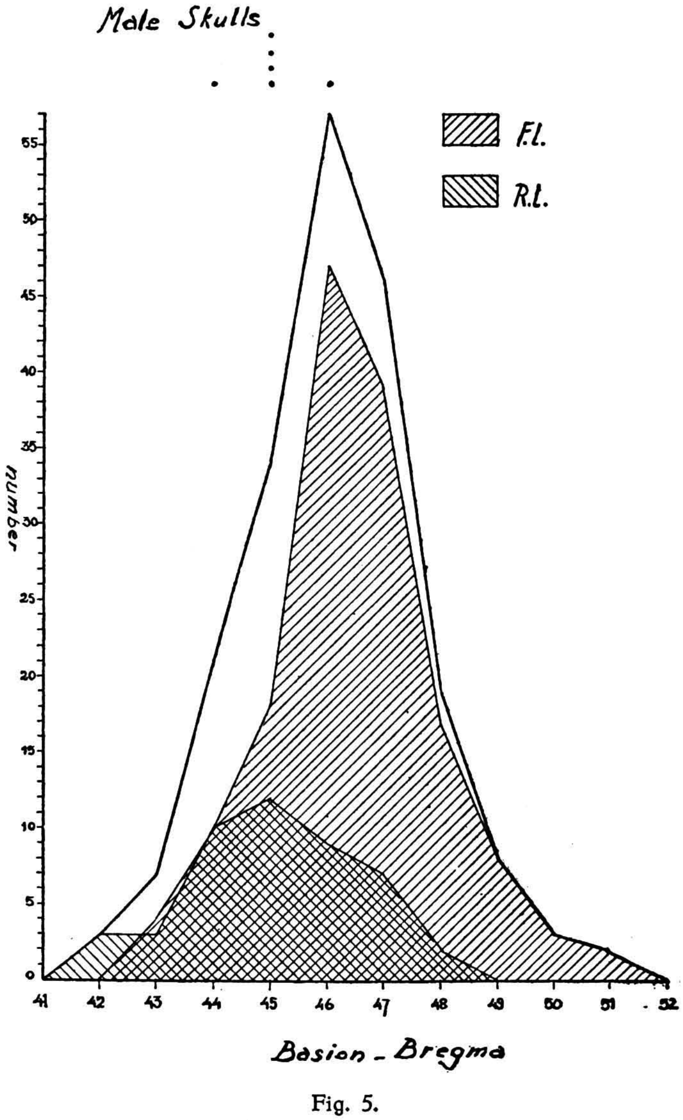

Fig. 5.

Fig. 4, compared with fig. 5 shows that the frequency polygons, indicating the positions of S_1, belonging to RL and FL, overlap each other almost completely (fig. 5), which was not yet the case in S_2.

In our supposed "becoming forelocated", S_1 moves in the same direction as S_2 (meaning: to the rear), but not to the same extent, (meaning: less).

So S_1 shows a greater stability than S_2, while S_2 in its turn is more stable than V during the changing process.

As was written above, concerning the gradual sex differences in the mutual connections between V and S_2, there will certainly exist correlations between forelocation, rearlocation and other phenomena.

Here, for instance, we think of the angle: opisthion-bregma-basion, of which, after what was said of the unproportional movements of S_2 and S_1 in the "becoming forelocator" process, it is most probable, that this angle will undergo variations in magnitude.

We are aware of having placed the biological aspect of this problem in a secondary position, in our geometrical consideration of the mutual arrangement in the sagittal plane.

A more biological treatment of the considered process of change will be possible, however, if the associations with biologically better realized phenomena can be ascertained.

Our further investigation has been based on this conception.

LITERATURE.

1. FROE, A. DE, On spatial relations of the principal skullmeasures. Proc. Kon. Ned. Akad. v. Wetensch., Amsterdam, **50**, 816—820 (1947).
2. HUIZINGA, J., Cephalometrische verwantschap tusschen verwanten van den eersten graad. Thesis, Amsterdam, 107—108 (1947).