IX.—A Contribution to the Study of the Scottish Skull. By **Matthew Young**,
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cated by Professor **THOMAS H. BRYCE**. (With Three Plates.)

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The present communication is based principally on the results of a series of investigations into the form, dimensions, and characters of the skulls that comprise the unique collection which has been located in the Anatomy Department at the University of Glasgow for a number of years, and of which no account has yet been published. We owe the collection and preservation of this large and valuable series of crania—comprising over 700 specimens—to the zeal of Mr W. K. HUTTON, Lecturer in Anatomy, Queen Margaret College, University of Glasgow, to whom I am much indebted for permission to continue the work begun, but given up, by him.* I am very grateful to Professor BRYCE for assistance and much encouragement during the progress of the research.

* Mr HUTTON intended to carry out a research, not dissimilar to my own, and to that end obtained a grant from the Carnegie Trust for the purchase of craniological apparatus. Unfortunately, from circumstances over which he had no control, he was unable to continue the work, and I have made use of the instruments obtained by him. The present paper formed part of a Thesis presented for the degree of Doctor of Medicine to the University of Glasgow. I have gratefully to acknowledge a liberal grant from the Carnegie Trustees in aid of its publication.

The skulls were obtained in a Glasgow burial-ground, during the course of excavations preparatory to the erection of a building on the site, but beyond that little is known as to the exact period of time to which the skulls belong. In one of the graves a token was found bearing the date 1840, but such evidence does not carry us far, and probably many of the skulls belong to a period antecedent to that date.

The skulls are undoubtedly, in the great majority of cases, Scottish skulls, and the remarkable uniformity of the series, which is evident even to the untrained eye, points to the fact that they, for the most part, belong to one type. Proof of this uniformity will be supplied afterwards when we consider the variability exhibited by the series. No doubt there may be a few "foreign" skulls present in the collection, but the number is certainly small, and in my calculations in this paper I think that in most cases I work with a series sufficiently large to prevent a few aberrant specimen influencing at all, or at most to a trifling degree, the final results.

In order to pursue my investigations in connection with this subject I have found it necessary to subdivide the series into the following subsidiary groups:—

- (A) A group of 405 presumably male skulls.
- (B) „ „ 100 female skulls.
- (C) „ „ 90 skulls of doubtful sex.
- (D) „ „ 45 male metopic skulls.
- (E) „ „ 20 female metopic skulls.
- (F) „ „ 45 juvenile skulls of various ages.
- (G) „ „ 100 taken from group (A) for the application of KLAATSCH's and SCHWALBE's methods of examination, and afterwards for median sagittal section. (Series K in Appendix.)

It will be seen that, in arranging these skulls in the above sub-groups, I have endeavoured to arrange them according to their sex. This is not a difficult task when one is confronted with typical male and female specimens presenting well-marked distinguishing features peculiar to the two sexes (Plates I, II, and III), but in a series of the magnitude of the present one, as in other collections, there are many skulls which present no very definite distinguishing sexual features, which lie on the border-line between the two sexes as it were, and which might reasonably be placed in either division. These I have placed, for the present, under the heading of "doubtful sex." The problem of allocating skulls to the proper sex when there are no other skeletal remains to assist one, has presented difficulties to most craniologists who have attempted the task.*

The 405 skulls put down in the subsidiary group as males have what are usually regarded as the distinguishing male features pretty well marked, and I have little hesitation in affirming that the great majority of those are the skulls of males,

* TURNER (1 and 2), BARTEL (3), AEBY, VIRCHOW (4), KLAATSCH (5), WARREN (6), PARSONS (7), PEARSON (8), ROBERTSON (9), and BRYCE (10) all agree that it is sometimes difficult, if not impossible, to ascribe certain skulls to their proper sex.

although it is quite possible I have ascribed a few to the wrong sex. A similar statement may be made regarding those classed as females. The 90 of doubtful sex I have decided to leave aside in dealing with the sexed skulls, instead of following the method advocated by some craniologists, namely, to ascribe them to the sex to which they showed a preponderance of characters. In the present work I have merely recorded for future use their principal measurements, and have calculated some of the mean values and variations of their dimensions.

With such a large collection of material, moreover, I can afford to set aside the "doubtfuls," as the numbers left to represent the two sexes, 400 and 100 respectively, are sufficiently great to make the probable error reasonably small and practically to negative the influence of the inclusion of a few specimens of the wrong sex on the final results. Besides, 400 is as large a number as is convenient to work with when calculating the correlation coefficients by the most reliable method.

In the Appendix I have also recorded the detailed measurements of the metopic and juvenile skulls, but shall not further deal with them in the present publication.

1. (A) THE MEAN VALUES OF DIMENSIONS AND INDICES OF MALE SKULLS.

Table I shows in four parallel columns the mean values of the dimensions of the principal cranial characters given by Sir WILLIAM TURNER (1) for his complete Scottish series and his Renfrewshire group as regards the male sex, and the corresponding values in the two male groups (400 and 100) of the series of Scottish skulls under examination.

Table II, which follows, gives in three parallel columns the mean values for TURNER's complete female group, his female group derived from Renfrewshire, and a group of 100 female skulls from our collection. The "K" series is the group of 100 presumably male skulls which became separated from the remainder in the following way:—

As a preliminary to a complete investigation into the characters of the skulls comprising the collection, I began with a group of 100 skulls taken from the whole series which, having the characters usually ascribed to the male sex fairly well marked, I presumed to be, in most cases, the skulls of males. Unconsciously, in making this selection, but as might have been expected, I have included in the group selected an unusually large proportion of the larger skulls. This influences to a marked extent, as will be seen later, the mean capacity and, to a less extent, the other measurements. This group of 100 may be accepted, notwithstanding, as fairly representative of the relative proportions of the male skulls, although the respective mean values may be a little higher. It is to this group of 100 that I have applied KLAATSCH's "craniotrigonometrical" method of examination and SCHWALBE's measurements, and thereafter I had them all bisected in the median sagittal plane to study several features only measurable after this has been done.

Comparing the measurements of the present series with TURNER's series and beginning with the capacity of the male skulls, we find that, in the large male group, the mean capacity is 1459·5 c.c., while for TURNER's male series the mean capacity is 1478 c.c., a difference of about 20 c.c. In estimating the capacity I have followed carefully the directions of TURNER both as to material, *i.e.* shot, and technique, as furnished in his "*Challenger*" Reports and in his memoir on the Scottish skull, but, as is well known, the "personal equation" is an important factor in estimating capacity of skulls even by similar methods.

Comparing the lengths in the two series of Scottish skulls, *i.e.* the glabello-occipital lengths or greatest lengths, we find that there is a difference of about 1 mm. in the mean values, with the advantage on the side of the present series, the values being 186·6 mm. and 187·52 mm. respectively. For the "K" series the mean glabello-occipital length is 189·2 mm.

TABLE I.
Mean Values of Dimensions of Male Skulls.

Character.	Present Series.	TURNER'S Series.	Renfrew Group.	"K" Series.
Cubic capacity	1459·5 ± 4·11	1478	1526	1511·3 ± 8·60
Glabello-occipital length	187·52 ± 20	186·6	190	189·18 ± 39
Basi-bregmatic height	132·72 ± 17	132·4	133·5	133·71 ± 37
Vertical index	70·81 ± 09	70·9	70·3	70·7 ± 20
Maximum breadth	139·56 ± 16	144·3	142·8	140·7 ± 29
Cephalic index	74·36 ± 08	77·4	75·1	74·41 ± 16
Horizontal circumference	526·60 ± 47	531	531	529·69
Vert. trans. circumference	426·23	434	429·9	428·03
Basi-nasal length	100·37 ± 13	101·4	101·4	100·96 ± 27
Basi-alveolar length	95·08 ± 16	96	94·5	94·87 ± 32
Gnathic index	94·68	94·5	93·3	
Total long. circumference	513·13	513·2	523	517·43
Interzygomatic breadth	127·16 ± 18	132·2	127·5	128·14
Nasi-alveolar length	70·96 ± 16	71·6	73·5	72·35
Maxillo-facial index	55·81	54·3	58·1	
Nasal height	51·72 ± 11	53·5	52·2	53·32
„ width	23·47 ± 06	23·1	23·3	23·18
„ index	45·58 ± 15	38·9	45·2	
Orbital width	38·67 ± 05	39	39·3	39·24
„ height	33·05 ± 07	34	35	33·76
„ index	85·51 ± 17	87·2	89·08	
Palato-alveolar length	52·94	55·6	54·5	50·84
„ breadth	59·59	60·9	60·7	57·91
„ index	112·76	113	111·4	

The mean values of the basi-bregmatic heights are practically equal, *viz.* 132·4 mm. for TURNER's series and 132·72 mm. for that under examination. In the "K" series the mean value is about 1 mm. greater, *i.e.* 133·71 mm.

With regard to the greatest breadth or parieto-squamous breadth we find a notable difference in the two series of Scottish skulls; the mean value given in

TURNER's memoir is 149·3 mm. (which in MACDONNELL's paper in *Biometrika* (iii) is given as 144·3 mm.), while the mean value for the group of 405 is 139·56 mm.—sensibly different from 144·3 mm. For the group of 100—the “K” group—the mean value is 140·7 mm.: still much smaller than TURNER's value. Herein lies the most notable difference between the two series of Scottish skulls, TURNER's and the present one. While there is comparatively little difference between the respective mean lengths and heights, there is a distinct difference between the mean breadths, amounting to 10 mm. if we accept TURNER's figures, or 5 mm. if we accept MACDONNELL's correction. Almost wholly due to this difference in breadth, but minimised to a slight extent by the difference in the greatest lengths, we have the higher value of the cephalic index in TURNER's series, namely 77·4, *i.e.* mesaticephalic, while the mean cephalic index for the present series is 74·36, *i.e.* dolichocephalic. For the “K” series the mean value of the cephalic index is 74·4, while for the group of 11 male skulls derived from Renfrewshire and included in TURNER's series the mean cephalic index is 75·1, distinctly below that for the whole series. The details are given in Table II.

TABLE II.*

Class.	TURNER'S Series.		West Scottish Series.		“K” Series of 100.
	No.	Per cent.	No.	Per cent.	No. and per cent.
Dolichocephalic, —75	49	28	232	57·3	58
Mesaticephalic, { 75–77·4	45	26	129	31·8	34
{ 77·5–79·9	45	26	35	8·6	7
Brachycephalic, +80	35	20	9	2·2	1

Following TURNER's method of subdividing the mesaticephalic group into two subsidiary sections, one with the index from 75 to 77·4, the other from 77·5 to 79·9, as those in the lower section approach more closely to the dolichocephalic type and those in the higher section to the brachycephalic type, it was found that, in the “K” series, in the higher division of the mesaticephalic group and the brachycephalic group were contained only 8 per cent. of the skulls examined, the remainder either being dolichocephalic (58 per cent.) or in the lower section of the mesaticephalic group (34 per cent.), whereas in TURNER's series 46 per cent. were either brachycephalic or showed a tendency towards that type, while the remaining 54 per cent. were dolichocephalic (28 per cent.) or approached that type (26 per cent.).

* In making up this and the succeeding tables the measurements recorded in the Appendix were all first reduced to the “arithmetical mean.” In Tables II and XI, however, in subdividing the mesaticephalic skulls into TURNER's two classes, this was not done for the indices between 77 and 78, but all the skulls with indices from 77 to 77·4 were placed in the lower group and those with indices from 77·6 to 78 in the higher group, while of the skulls with indices of exactly 77·5 half were placed in the lower, half in the higher, group.

In the complete male series of 405 skulls the proportions in the different groups were as follows:—

Dolichocephalic, 57·3 per cent., or, with a tendency to dolichocephaly, 31·8 per cent.; in all, 89 per cent. Brachycephalic, 2·2 per cent., or, with a tendency to brachycephaly, 8·6 per cent.; in all, 10·8 per cent. Although less well marked than in the “K” series, this large group shows well the remarkably small proportion of skulls contained in it which show a brachycephalic tendency.

In the Renfrewshire group in TURNER’S series, which comprised 21 skulls, of which 11 were male, 8 skulls were dolichocephalic and 7 had an index between 75 and 76·7, which is a much higher proportion of skulls showing a tendency towards dolichocephaly than is seen in the generalised results in TURNER’S memoir. They belong to the same type as the group “K.” The measurements of the latter furnish additional evidence of the fact, which has been demonstrated by several authorities, including RIPLEY (14), that while the cephalic index throughout Scotland—in fact, throughout Britain—is remarkably uniform, it has a lower value over some parts of the west and south-west of the former country than over the remainder, especially the east, where it has a distinctly higher value. I shall return to this subject later.

The conclusion that one would draw from an examination of this male series is that the type of skull prevalent in Glasgow and the surrounding district is the dolichocephalic type, and that it exists almost to the complete exclusion of the brachycephalic type. There is little, if any, evidence in this series of “that strong brachycephalic strain which pervades the population of Scotland,” according to TURNER (1).

On comparing the height indices or vertical indices of the two series there was found to exist a close similarity between them, as we could expect, knowing that the mean lengths and heights were approximately equal in value. In TURNER’S series of 98 male skulls (part of his group of 150) the mean value of the index was 70·9, in the Renfrewshire group of 11 the mean value is 70·3; in the subsidiary group of “K” of this series the mean value of the index is 70·7, while in the complete male group the mean value is 70·81.

TABLE III.

Class.	TURNER’S Series.		“K” Series.	Complete West Scottish Series.	
	No.	Per cent.	No. and per cent.	No.	Per cent.
Below 70 : Chamæcephalic . .	65	43	40	156	38·5
Between 70·1–75 : Metriocephalic . .	68	45	56	220	54·3
Above 75·1 : Hypsicephalic . .	17	11	4	29	7·1

A comparison of the results in the above series shows that the percentages found

in the various classes are very similar to those found in the subsidiary series "K," while about 5 per cent. of those in TURNER's chamæcephalic group and 4 per cent. of those in his hypsicephalic group are transferred in this series to the metriocephalic group. A feature of Scottish skulls, as pointed out by TURNER (1), is the fact that the breadth is greater than the height, except in rare instances. In his series of 150 skulls the height was greater than the breadth in two instances only (1·3 per cent.), the height was equal to the breadth in four instances (2·6 per cent.), while the height was less than the breadth in the other specimens, *i.e.* the Scottish skull is platychamæcephalic.

In the complete male series now under examination, associated doubtless to a large extent with the smaller value of the maximum breadth, the height was equal to, or greater than, the breadth in 67 specimens, *i.e.* 16 per cent. compared with 4 per cent. in the former series. In the "K" subsidiary male series the height was greater than the breadth in 12 per cent. and equal to the breadth in 8 per cent.—in all, 20 per cent.

With regard to the circumferences in the two series, we see that while the mean values of the total longitudinal circumferences are practically equal, as regards the horizontal and vertical transverse circumferences, TURNER's series shows a slight excess in value over the present series.

The longitudinal circumference comprises the complete sagittal arc, with its frontal, parietal, and occipital segments, and the opisthio-nasal length or CLELAND's base line.

With regard to the segments of the sagittal arc, I quote the following figures from TURNER: and these may be compared with the corresponding measurements in the "K" subsidiary series in the following table:—

TABLE IV.

	TURNER.	"K" Series.
Longest frontal arc	148	152
Shortest " "	111	120
Longest parietal arc	148	143
Shortest " "	102	112
Longest occipital arc	139	141
Shortest " "	94	107

TURNER says that the occipital arc was greater than the frontal arc in 13 cases out of 144, and less than it in 131 cases.

In the "K" series of 100 the occipital arc was greater than the frontal in 3 cases and equal to it in 2 cases. In TURNER's series of 138 the occipital arc was greater than the parietal in 26 cases, *i.e.* less in 112 cases. In the "K" series the occipital arc was greater than the parietal in 23 cases and equal to it in 2. In TURNER's

group of 158 the parietal arc was greater than the frontal in 55 cases and equal to it in 7. In the "K" series the parietal arc was greater than the frontal in 25 cases and equal to it in 8. As TURNER writes: "It is the rule, therefore, for the parietal and frontal longitudinal arcs to exceed the occipital, though exceptions to the rule occur in recognisable numbers." And further: "It is obvious, therefore, that so much variation occurs in the relative length of the longitudinal arcs, they have no appreciable value as race characters in the Scottish skulls, and the variation occurred in both the brachycephalic and dolichocephalic types." Evidence which may have an influence in modifying the last statement will be supplied later when we come to consider the correlation that exists between the total arc and its various segments, frontal, parietal, and occipital, and between these segments and the glabello-occipital length in the present series of Scottish skulls. As has been noted by several observers, including HUSCHKE, WEISBACH, and CLELAND (15), the relative proportions of the various segments not only differ in the two sexes, but undergo a change during the course of development, and evidence in support of this is supplied by the values in the series of juvenile skulls.

With regard to the other measurements in the two series of Scottish skulls, we find that the mean basi-alveolar lengths are approximately equal, and the same relationship holds with regard to the nasi-alveolar lengths. As a consequence, the gnathic index which is obtained from these measurements is practically the same in the two groups.

The mean value of the basi-nasal length is only about 1 mm. less in the West Scottish male series of 405 than it is in TURNER's group. Table V shows the skulls classified according to the gnathic index:—

TABLE V.

Class.	West Scottish Series.		TURNER'S Series.	
	No.	Per cent.	No.	Per cent.
Orthognathous (below 98)	308	77·2	72	74·22
Mesognathous (98-103)	84	21	24	24·74
Prognathous (103 and upwards)	7	1·7	1	1·03

The near approach to equality between these proportions in the different classes and those in the series under examination is notable, and confirms TURNER's conclusion that the Scottish skulls are characterised by an almost complete absence of prognathism.

Skulls are classified into three groups according to the value of their orbital index as follows. Table VI shows the two series classified according to the value of the index.

TABLE VI.

Class.	West Scottish Series.		TURNER'S Series.
	No.	Per cent.	Per cent.
Microseme (below 84)	132	33	26·4
Mesoseme (84-89)	149	37·3	26·4
Megaseme (89 and upwards)	118	29·5	45·6

It will be observed that in the series of 399 male skulls we find that 132 are microsemic, 149 are mesosemic, and the remainder are megasemic. The percentages in the microsemic and megasemic classes are seen to be approximately equal, while the mesosemic group has a slight excess. In TURNER'S series, which included both male and female skulls, it is evident that there is a much larger proportion in the megasemic class. There is evidently not the same tendency for the orbit to be high relatively to the breadth in the present group, as is manifestly the case in TURNER'S series. TURNER expresses the opinion that the orbital index is very variable, and that it only possesses "a secondary value as a race character."

We shall refer to the variability of the orbital index later when treating of the variability of the Scottish skull and also to MACDONNELL'S comments on TURNER'S view.

With regard to the nasal index the following table expresses the relationship between the two series :—

TABLE VII.

Class.	West Scottish.		TURNER'S Series.	
	No.	Per cent.	No.	Per cent.
Leptorhine (below 48)	271	67·9	93	75·6
Mesorhine (between 48-53)	103	25·8	26	21·1
Platyrrhine (53 and upwards)	25	6·2	4	3·2

The percentage number in the mesorhine group in the two series of Scottish skulls is not vastly different, as it is only about 4 per cent. The leptorhine group in TURNER'S series contains about 8 per cent. more than the leptorhine group of the West Scottish series of males contains of the whole number; while there is about half the proportion of skulls in TURNER'S platyrrhine group than obtains in this other series of Scottish skulls. The presence of this relatively small platyrrhine group in both series is possibly due to the explanation given by TURNER, *i.e.* "accidental, and

due perhaps to intermixture, through an ancestor of a strain of some race in which a platyrrhine nose was an ethnic character."

Owing to the fact that the mandibles have not been preserved, it is impossible to obtain a complete or nasio-mental facial index for the present series. The maxillo-facial index or upper facial index of KOLLMANN, *i.e.* $\frac{\text{nasi-alveolar length} \times 100}{\text{interzygomatic breadth}}$, has been calculated, however, for both the male and female groups, and in the former the skulls may be arranged in the following way, adopting TURNER's modification of KOLLMANN's mode of arrangement :—

TABLE VIII.

Class.	West Scottish Series.		TURNER's Series.	
	No.	Per cent.	No.	Per cent.
Leptoprosopic (50·1 and upwards) . . .	380	95·2	72	91·1
Mesoprosopic (45-50)	18	4·5	7	8·8
Chamæprosopic (below 45)	1	·2	0	0

While in TURNER's series a relatively small proportion has been transferred from the leptoprosopic to the mesoprosopic group, there is a remarkably close similarity between the proportions contained in the respective groups in the two series of skulls. The general type of face in the series under examination is even more notably leptoprosopic than in TURNER's series.

As regards the palato-alveolar or palato-maxillary index, I have adopted the classification devised by TURNER, and the grouping for the 399 male skulls is as follows :—

TABLE IX.

Class.	West Scottish Series.		TURNER's Series (82).	
	No.	Per cent.	No.	Per cent.
Hyperdolichuranic (below 105) . . .	55	13·8	11	13·4
Dolichuranic (105-110)	96	24	20	24·4
Mesuranic (110-115)	85	21·3	15	18·3
Brachyuranic (115-120)	81	20·3	17	20·7
Hyperbrachyuranic (above 120) . . .	82	20·5	19	23·1

A comparison of the percentages in the corresponding groups requires no comment; the close similarity is obvious. In the series of 400 male skulls the

palato-alveolar breadth was less than the length in 12 cases only, *i.e.* 3 per cent., whereas in TURNER's series this occurred in 3 specimens or 3.6 per cent.

There are a few other measurements in this series which we can compare with the corresponding dimensions in TURNER's series.

E.g. Minimum frontal diameter with a mean value of 96.42 mm.

Interstephanic diameter	„	„	117.93	„
Asterionic diameter	„	„	109.68	„
Intermalar diameter	„	„	90.12	„
Transverse base	„	„	115.13	„
Transverse arc	„	„	311.10	„

With regard to some of these measurements in his Scottish series of skulls TURNER (1) makes the following statement: "As a general rule the frontal stephanic diameter materially exceeded the minimum frontal; the asterionic diameter, except in one skull, was greater than the minimum frontal, but as a rule it was less than the stephanic, although there were several exceptions." The results in the present series are in accord with TURNER's results, as will be evident from an analysis of the above mean values.

Material for comparison with the present series is supplied by TURNER's memoir for other two dimensions of the undivided skull, namely, the length of the base of CLELAND, *i.e.* the opistho-nasal length, that of the sagittal arc, and their relationship to one another. The mean length of the base line in the group of male skulls (22 in number) examined by TURNER was 134.3 mm., and that of the sagittal arc was 376.5 mm. The average base line in the series "K" was 135.3 mm. (for the 405 male skulls it was 134.5 mm.), and the sagittal arc in the same series was 382.3 mm. In the series of 100 the mean relation of the base line to the arc was 1 to 2.819. This is slightly greater than the figure given for Scottish skulls by CLELAND, which was 1 to 2.72; the latter also gives 1 to 2.67 for French skulls, 1 to 2.80 for German, and 1 to 2.89 for Irish. In a series of 5 male skulls measured by TURNER the relation of the base line to the arc was as 1 to 2.78. In a larger series of 15 the relation was as 1 to 2.8. In a series of 20 male Australian aboriginals, dolichocephalic in type, the mean base line was 139.8 mm. and that of the arc 380.4 mm.; the proportion of base line to arc being as 1 to 2.72. We observe that the mean arcs in the dolichocephalic West Scottish series and in the Australian aboriginal group are approximately equal, while the difference in the relative proportions of base line to arc is mainly due to the longer base line in the lower type, the Australian, and not so much to the slight degree of mean difference in the arc. It was long ago pointed out by CLELAND (15) in his well-known memoir on the skull that "uncivilised or lower forms are in general characterised by the possession of a relatively longer base line, while the length of the arc is very variable."

(B) THE MEAN VALUES OF DIMENSIONS AND INDICES OF FEMALE SKULLS.

Table X demonstrates the mean values of the principal measurements of the female skulls in TURNER'S series in apposition to those of the 100 female skulls contained in the collection at present under examination, and a brief review and comparison of these values shows on the whole a nearer approach to equality between the two groups of female skulls than between the two male groups already examined.

TABLE X.

Mean Values of Dimensions of Female Skulls.

Character.	Present Series.	TURNER'S Series.	Renfrewshire Group.
Cubic capacity	1314.5±6.30	1322	1300.5
Glabello-occipital length	177.97±.32	178.7	177
Basi-bregmatic height	125.01±.31	126	127
Vertical index	70.31±.20	70.5	71.3
Maximum breadth	135.16±.29	138	135.7
Cephalic index	76.03±.19	77.2	76.3
Horizontal circumference	503.61±.71	506	501.6
Vertical transverse circumference	408.10	409.6	406
Basi-nasal length	93.82±.20	95.3	95.2
Basi-alveolar length	88.61±.31	91	91.3
Gnathic index	94.45	94.8	95.8
Total longitudinal circumference	490.13	488.8	489.9
Interzygomatic breadth	118.16±.26	121.5	119.7
Nasi-alveolar length	65.83±.24	67	68.5
Maxillo-facial index	55.71	55.1	56.9
Nasal height	48.41±.20	49.9	50.6
„ width	22.56±.11	22.1	21.3
„ index	46.77±.30	44.4	42.2
Orbital width	37.24±.09	37.4	36.8
„ height	32.95±.13	33.0	33.3
„ index	88.53±.35	84.6	90.4
Palato-alveolar length	49.23	51	52.1
„ breadth	56.08	58.3	59.5
„ index	114.16	109.8	114.6

As regards cubic capacity, the difference of the mean values is only between 7 and 8 cubic centimetres, with the excess in favour of TURNER'S group; and this difference, as already explained, may easily be accounted for by the fact that the cubage in the two series has been estimated in a similar fashion by different individuals. The glabello-occipital length and the basi-bregmatic height in the two groups differ in their mean values by less than 1 mm., with the advantage in favour of TURNER'S group. The vertical index, obtained from the above two measurements, is practically equal in the two groups.

As regards maximum breadth, the dimension which was notably different in the two male groups, there is a difference in the two mean values, but it is less than 3 mm., and, as in the male series, TURNER'S value is the greater. TURNER in his

memoir gives measurements for 11 female Scottish skulls, derived from Renfrewshire, which give a mean value for maximum breadth of 135.7 mm.—practically equal to that of the group under consideration. Although the number of skulls is so small and there is necessarily a large probable error, it is interesting that there should be such an approach to equality.

The cephalic index mean value derived from glabello-occipital length and maximum breadth is about one point less than that of TURNER's female group, and nearly equal to that of his Renfrewshire subsidiary group. We see that the female groups are more nearly equal as regards this value than the two male groups. In TURNER's series the values for the male and female groups were nearly equal; in this series the mean value for the female cephalic index is nearly two points higher than that of the male, so that, while the mean male skull is dolichocephalic, the mean female skull is mesaticephalic. With regard to the respective circumferences there is little difference in their mean values. The horizontal and vertical transverse circumferences of TURNER's series are slightly greater than in the present one, while the total longitudinal circumference in the latter series is greater than in the former one; but in none of the three did the mean measurement of one series exceed the corresponding measurement in the other by more than $2\frac{1}{2}$ mm. The mean values of the basi-nasal and basi-alveolar lengths were slightly lower in the present series than in TURNER's, but the mean gnathic index derived from the above measurements was practically equal in the two groups and almost the same as the approximately equal values for the two male groups. As regards nasi-alveolar length and interzygomatic breadth the mean values in the present series are slightly less than in TURNER's, while the mean maxillo-facial index, derived from the above two measurements, is practically the same in the two groups, and almost exactly equal to that in the Scottish male group of 405.

From Table X we see that, while the mean nasal widths in the two series are nearly equal, the mean nasal height is slightly greater in TURNER's series than in the other, and, consequently, the nasal index is slightly lower in value in TURNER's series than in the one with which it is being compared—the difference amounting to fully two units; a still greater divarication occurred in the male groups, with the excess in favour of the present series. The mean orbital heights are approximately equal in the two series, as are also the mean orbital widths. In TURNER's series the mean orbital index is distinctly less, however (to the extent of four units), than the orbital index in the other group—a reversal of the magnitudes of the mean values of the indices in the male groups. It is interesting to note that the Renfrewshire group of 11 skulls has a mean index still further removed from that of TURNER's complete series than the present group. The values for palato-alveolar breadth and palato-alveolar length are appreciably smaller for the present series of 100 than for TURNER's series. The palato-alveolar index, on the other hand, has a mean value for the 100 distinctly greater than that for TURNER's series, the difference being

equal to fully four units, although the index derived by dividing the mean breadth by the mean length gives a value approximately equal to that given by the present series. Of course, such a value is only an approximation to the mean, as it differs from the true mean by a quantity dependent upon the variation and correlation coefficients of the absolute measurements (PEARSON). It is interesting to note that the mean value of the index in the Renfrewshire group of 11 females is practically the same as in the present series of 100.

TURNER gives no figures for females alone in the various groupings according to the value of the respective indices, but takes the male and female together in arriving at his results. We must therefore combine the male and female groups to get figures comparable with those given by TURNER.

TABLE XI.

Cephalic Index.	West Scottish Series.			TURNER'S Series.
Class.	F. (100).	M. (405).	M. & F. (505).	M. & F.
	per cent.	per cent.	per cent.	per cent.
Dolichocephalic	36	57.3	53	28
	(a) 34	31.8	32.2	...
Mesaticephalic	54	40.5	43.1	52
	(b) 20	8.6	10.8	...
Brachycephalic	10	2.2	3.7	20

We observe from the above table the distinctly greater tendency towards brachycephaly in the female than in the male skull, and how that grouping the male and female crania together brings the proportions in the various groups slightly, but not to a marked extent, nearer to those obtaining in TURNER'S series.

As regards the vertical index we may examine the following table :—

TABLE XII.

Class.	West Scottish Series.			TURNER'S Series.
	F. (100).	M. (405).	M. & F. (505).	M. & F.
	per cent.	per cent.	per cent.	per cent.
Chamæcephalic	46	38.5	40	43
Metriocephalic	49	54.3	53.2	45
Hypsicephalic	5	7.1	6.7	11

It will be seen that the proportions in the three groups in the case of the female series are not greatly different from those in the male series. In the female we have $7\frac{1}{2}$ per cent. more in the chamæcephalic group, 5 per cent. less in the metrio-

cephalic group, and 2 per cent. less in the hypsiccephalic group than in the corresponding groups in the male. The grouping of the male and female does not sensibly alter the percentage in the hypsiccephalic group compared with the male group.

As regards the breadth-height index we have the grouping as follows :—

TABLE XIII.

Class.	West Scottish Series.			TURNER'S Series.
	F.	M.	M. & F.	M. & F.
	per cent.	per cent.	per cent.	per cent.
Hypsistenocephalic	4	16·5	14	4
Platyhamæcephalic	96	83·5	85·9	96

In TURNER'S series of 150 the percentages in the two groups were exactly the same as those found in the present female series of 100. By associating the male and female percentages together we find that the numbers in the two groups for male and female together are sensibly altered, owing to there being a relatively high proportion of hypsistenocephalic skulls in the male group.

Passing now to the indices that are derived from the dimensions of the facial skeleton and beginning with the gnathic index, we find in the female series the following grouping, and a comparison with the other series gives the following table :—

TABLE XIV.

Class.	West Scottish Series.			TURNER'S Series.
	F. (100).	M. (399).	M. & F. (499).	M. & F.
	per cent.	per cent.	per cent.	per cent.
Orthognathic	82	77·2	78·1	74·2
Mesognathic	15	21	19·8	24·7
Prognathic	3	1·7	2·2	1

The proportions in the different classes, taking male and female together, are not very different in the two series of Scottish skulls. Grouping the female skulls into the three classes according to the magnitude of the nasal index, we get the following results :—

TABLE XV.

Class.	West Scottish Series.			TURNER'S Series.
	F. (100).	M. (399).	M. & F. (499).	M. & F.
	per cent.	per cent.	per cent.	per cent.
Leptorhine	60	67·9	66·3	75·6
Mesorhine	34	25·8	27·4	21·1
Platyrrhine	6	6·2	6·2	3·2

Analysing the above table, we find that, comparing the percentages in the male and female groups, those in the platyrrhine group are equal, while there is about 8 per cent. less in the female leptorrhine group than in the corresponding male group. Combining the female and male groups, we get figures comparable with those supplied by TURNER, and we observe that there is 9·3 per cent. less in the leptorrhine group in the present collection than in TURNER'S series, and of this 6·3 per cent. is found in the mesorrhine group and 3 per cent. in the platyrrhine group.

With regard to the orbital index, we have for the female the same three groupings as for the male :—

TABLE XVI.

Class.	West Scottish Series.			TURNER'S Series.
	F. (100).	M. (399).	M. & F. (499).	M. & F.
	per cent.	per cent.	per cent.	per cent.
Microsemic	18	33	30	27·1
Mesosemic	36	37·3	37	27·1
Megasemic	46	29·5	32·8	45·6

Comparing the male with the female groups, we find that, while the percentages in the mesosemic groups are approximately equal, about 15 per cent. less are found in the female microsemic group than in the corresponding male group, which is compensated for by an excess of 15 per cent. in the female megasemic group over the corresponding male group. Comparing the present series, taking male and female together, with TURNER'S series, where male and female results are aggregated, we find 3 per cent. less in TURNER'S microsemic group ; 10 per cent. less in his mesosemic group than in the corresponding groups of our series, while 13 per cent. is added to the megasemic group. The tendency for the orbit to be relatively high compared with its breadth is thus better marked in TURNER'S series than in the present one.

As regards the maxillo-facial index we can analyse the following table :—

TABLE XVII.

Class.	West Scottish Series.			TURNER'S Series.
	F. (100).	M. (399).	M. & F. (499).	M. & F.
	per cent.	per cent.	per cent.	per cent.
Leptoprosopic	97	95·2	95·6	91·1
Mesoprosopic	3	4·5	4·2	8·8
Chamæprosopic	...	·25	·20	...

Even more markedly than TURNER'S series does the present series, including male

and female skulls, show the great uniformity in the relatively long and narrow character of the Scottish face.

For the series of 100 female Scottish skulls we can construct the following table, according to the magnitude of the palato-alveolar index, subdividing them into three groups as in the male :—

TABLE XVIII.

Class.	West Scottish Series.			TURNER'S Series.
	F. (100).	M. (400).	M. & F. (500).	M. & F.
	per cent.	per cent.	per cent.	per cent.
Hyperdolichuranc	15	13·8	14	13·4
Dolichuranc	19	24·0	23	24·4
Mesuranc	18	21·3	20·6	18·3
Brachyuranc	22	20·3	20·6	20·7
Hyperbrachyuranc	26	20·5	21·6	23·1

What strikes one on surveying the above table is the near approach to equality in the numbers of the different groups contained in the various classes. The hyperdolichuranc class contains a smaller proportion than is contained in the other classes, but the latter are remarkably similar, only slight variations occurring from group to group.

In the series of 100 female skulls the mean value of the opisthio-nasal length, or CLELAND'S base line, is 126·98 mm., which is considerably shorter than the mean length of the base line of 100 male skulls. In the female series the mean length of the sagittal arc is 363·15 mm., and the mean value for the proportion of base to arch in the 100 skulls is as 1 to 2·859, which proportion of base to arch is slightly less in the female than in the male, where the proportion for 100 is as 1 to 2·819. This larger proportion of the arch to the base in the female skull is held to be the rule by WELCKER (16) and ECKER (17). I shall return to this subject when considering the variability of the skull.

In the 100 female skulls I have measured the lengths of the frontal, parietal, and occipital segments of the total sagittal arc, and find the following mean values :—

Frontal segment, mean value	126·96 mm.
Parietal segment „ „	121·4 „
Occipital segment „ „	114·76 „
Total arc „ „	363·15 „

In the series of 100 the occipital arc is greater than the frontal in 8 per cent. of the cases and equal in 1 per cent.; the occipital is greater than the parietal in 20 per cent. and equal in 4 per cent.; the frontal is greater than the parietal in 70 per cent. and equal in 5 per cent.

This relationship may be expressed in the form of a table as follows :—

TABLE XIX.

Group.	Occip. > Frontal.	Occip. > Parietal.	Frontal > Parietal.
Female (100)	8 per cent. (= 1 per cent.)	20 per cent. (= 4 per cent.)	70 per cent. (= 5 per cent.)
TURNER	9 " (= 1 ")	18·8 " (= 3·7 ")	61 " (= 4·4 ")
"K" series (100).	3 " (= 2 ")	23 " (= 4·6 ")	67 " (= 8 ")

From an analysis of the above table it is easily seen that, comparing the male series of 100 with the female series, the numbers expressing the frequency of a definite relationship of the arcs in length to one another are closely similar, whereas the percentages for the three classes in TURNER'S series (including both male and female) are not markedly different from the male and female groups of the series under examination. The individual variation in the proportional length of the different regions is very considerable, as will be shown when we consider the variability of the segments of the sagittal arc; and the above table seems to be confirmatory of CLELAND'S view that it would be "unsafe to deduce any definite relationship between the variation in relative lengths of the arcs and the sex of the skull." CLELAND (15) also says with regard to the relative values of these segments of the sagittal arc that national variation is slight, while SCHWERZ (18) says that "studies on the proportions of the different bones of the vault to one another have shown that we possess in these characteristics a useful means of help for the pursuit of racial research"—a view somewhat different from that of CLELAND.

It has been asserted that the proportion which the parietal segment bears to the occipital and frontal segments of the sagittal arc varies, not only during development, but also to a marked degree in the two sexes. It is stated that the examination of a large number of female skulls goes to show that there exists a lower proportion of both occipital and frontal arcs compared with the parietal in the female skull than in the male. HUSCHKE, quoted by CLELAND, states that "in the female, the capacity of both the frontal and the occipital segment is smaller in proportion to the parietal than in the male," while WEISBACH speaks of the small forehead of the German female.

For 100 male and 100 female skulls of this series we get the following mean values :—

	Frontal Arc.	Parietal Arc.	Occipital Arc.
Males . . .	133·49 mm.	127·91 mm.	120·78 mm.
Females . . .	126·9 "	121·4 "	114·76 "
In the male . . .	$\frac{\text{frontal arc}}{\text{parietal arc}} = 1·043$		$\frac{\text{occipital arc}}{\text{parietal arc}} = ·94$
In the female . . .	$\frac{\text{frontal arc}}{\text{parietal arc}} = 1·045$		$\frac{\text{occipital arc}}{\text{parietal arc}} = ·94$

I am quite well aware that the index obtained from the mean values of the absolute measurements is not exactly equal to the mean index, as the latter depends to some extent on the coefficients of correlation and variation of the absolute measurements. The above approximate results, however, for female and male, which are practically equal, would seem to show that there is no marked sexual difference in the proportions obtaining between the parietal and the occipital and frontal arcs.

I have instituted, in considerable detail, a comparison between the principal mean values of the various dimensions of the male and female groups in TURNER'S series and the corresponding groups in the series at present under investigation, because it is only in that important memoir that I can obtain material for comparison. While there are many slight differences in the mean values of the dimensions in the two series—differences by no means negligible, but probably partly due to the "personal equation,"—the feature that stands out pre-eminently, and in a sense overshadows the minor differences, is the divergence in value in the greatest parieto-squamous or maximum breadth, which is distinct and definite in the female groups, but exceptionally well marked in the male groups. To this, and not to a difference in the greatest length, is due the difference in the cephalic index. There is a marked tendency to dolichocephaly in the series under investigation, whereas, in the series examined by TURNER, there is a distinct tendency towards brachycephaly. The diminution in cubic capacity in the present series compared with TURNER'S series is undoubtedly a real difference, not entirely due to the personal element but dependent largely upon the smaller maximum breadth.

In the following table I have arranged the mean indices according to their classes for both male and female groups :—

TABLE XX.

Index.	Class.		Remarks.
	M.	F.	
Cephalic index .	Dolichocephalic	Mesaticephalic (lower division)	F. show distinctly greater tendency to brachycephaly
Height index .	Metriocephalic	Metriocephalic	Both sexes practically similar
Height-breadth index	Platyhamæcephalic	Platyhamæcephalic	Male nearer hypsistenocephaly
Maxillo-facial index .	Leptoprosopic	Leptoprosopic	Sexes practically alike
Orbital index .	Mesosemic	Mesosemic	F. index greater (on border of megaseme class)
Nasal index .	Mesorhine	Mesorhine	F. higher index value
Gnathic index .	Orthognathic	Orthognathic	Sexes nearly alike. M. slightly higher mean index
Palato-alveolar index	Mesuranic	Mesuranic	F. higher index than M.

(See Plates I, II, and III for examples of typical male and female skulls from the series.)

2. EXAMINATION OF THE SCOTTISH SKULL BY BIOMETRIC METHODS.

Within recent years much attention has been directed to the application of modern biometric methods to investigations into the characters of various collections of crania, and what is described as the "rational" method of treating craniometric statistics has been evolved. Two of the pioneers in this movement have been PEARSON (19) and GALTON (20), who, while not devising this method of treating statistical facts (which is due, I believe, to QUETELET (21) as far back as 1846), have revived and extended the method devised by the latter. FAWCETT and LEE (22), according to ROBERTSON (9), were the first "to apply modern statistical methods to any series of skull measurements," though STIEDA (24) published "the first scientific determination of the variabilities of the skull." Others who have taken a notable part in this movement are MACDONNELL (12), BOAS (26), TSCHÉPOURKOWSKY (27), and BERRY (28). FAWCETT (22) in her paper on the Naquada crania states "that craniometry cannot in future content itself with either the raw measurements, tables of mere averages, or graphical exhibition of correlation results, but must adopt the methods of modern statistical investigation, tabulating means, variabilities, correlations, and their probable errors in order to draw safe inferences and make racial comparisons"; and further, that "the correlation of the mean values of the chief craniological characters in 50 or 100 races would be a most valuable investigation, breaking practically untrodden ground": while MACDONNELL (12) says, "I venture to think that the chief aim of craniologists at present should be to table means, standard deviations, and correlations of further long series of skulls"; and again, "Only when that collection is far more complete will it be possible to state general conclusions applying to the whole range of craniology, and when such tables are formed for 40 or 50 long series we shall have more light not only on intraracial but on interracial problems." It is impossible to estimate at its proper value how much we are indebted to PEARSON not only for the numerous and important, in fact, invaluable papers he has contributed himself on the subject, but for the way he has influenced, controlled, and advised various other investigators, in addition to supplying formulæ which have in many cases made comparatively easy what seemed formerly interminable calculations.

Having made a full and complete comparison of the values of the characters of the male and female groups of our series of skulls with the values in the corresponding groups in TURNER's series, adopting TURNER's measurements and methods of examination, which the supporters of the new school are pleased to call the "empirical" method of treating cranial statistics, although none the less valuable on that account, I shall proceed to apply the modern biometric methods to the present series of Scottish skulls. I feel I cannot do better than follow the scheme adopted by FAWCETT in her study of the Naquada crania, and also by MACDONNELL in his study of the Whitechapel English crania and other series of English skulls. It will be necessary in the first place for comparative purposes to construct a table with

the mean measurements of the present series in apposition with the mean measurements of various other series to which these methods have been applied.

The measurements and nomenclature made use of by these investigators are principally those of the *Frankfurter Verständigung*, and a very full account of the measurements taken and the precautions necessary to ensure accuracy and exactly comparable figures are given in the two papers above alluded to. If further information is required, that can be obtained in the *Correspondenz-Blatt Deutsch. Anthropol. Gesellsch.*, Bd. xiv, S. 1. The principle underlying the adoption of the German system as expressed in the above volume is, as pointed out by FAWCETT, to bring any unrecorded series of skulls into relationship with, and into a suitable form for comparison with, as many measured series as possible. I shall content myself therefore in the present paper with merely enumerating the various measurements, only adding a few words of explanation when the method of obtaining the measurement differed from that of the above investigators. It is convenient to be able to refer to certain measurements by a reference letter (C, F, L, etc.), as pointed out by the above authors, and I follow their lead also in that respect. The measurements made in the groups of male and female skulls were as follows:—

1. Capacity (C). In obtaining this measurement I made use of the method advocated by TURNER, using shot as a medium and exercising due precautions.* I have performed the measurements with great care, so that though the mean may be altered by the personal equation the relative capacities of the various skulls have the proper proportions.
2. FLOWER's ophryo-occipital length (F).
3. Greatest length from glabella to occiput (L).
4. Horizontal length. This measurement was not taken, as both MACDONNELL and FAWCETT agree that little importance is attached to it when the other two measurements of length are given.
5. Greatest horizontal breadth of skull (B).
6. Least breadth of forehead (B¹). This measurement was taken from one temporal crest to the other across the frontal bone.
7. Height of skull (H). Basi-bregmatic height (405 male and 100 female). Frankfurt method (100 male).
8. Auricular height (OH). 100 male measured on sagittal outline of skull traced by diopetrograph.
9. Basi-nasal length (LB).
10. Horizontal circumference (U₁). Measured directly above the superciliary ridges and round the most projecting part of the occiput (FLOWER).
Ditto. Circumference measured over the superciliary ridges as adopted by TURNER (U₂).
11. Sagittal arc (S). From nasion over top of head to opisthion.
12. Cross circumference of transverse arc (Q). From upper rim of one auricular passage to the other over the bregma.
13. Complete face height. This measurement could not be taken, as no skulls were preserved with mandibles attached.
14. Upper face height (GH). From nasion to alveolar point.

* Both MACDONNELL and FAWCETT have devoted prolonged research to the various methods, some of them complicated, of estimating the cubage by using various materials and also by formulæ. MACDONNELL's conclusion is that different observers using different methods may have an average difference of 20 c.c., and if they use the same method an average difference of 10 c.c. The "personal equation" is thus not a negligible quantity, and is a factor that will always influence the result. MACDONNELL says that we must be content with the degree of agreement above described at the present stage.

15. Face breadth (GB). From the lower end of one zygomatic-maxillary suture to that of the other.
16. Zygomatic breadth (J). From outermost point of one zygomatic arch to that of the other.
17. Nasal height (NH).
18. Nasal breadth (NB).
19. Breadth of orbit for right and left eyes (O^1).
20. Greatest height of orbit for right and left eyes (O^2).
21. Length of palate (G_1). From point of spina-mentalis-posterior to an imaginary surface tangential to the inner alveolar surfaces of the middle incisors.
22. Breadth of palate (G_2). Between the alveolar walls at the second molars MACDONNELL says "that owing to great unevenness of the alveolar walls I have frequently found this a difficult and unsatisfactory measurement."
23. Profile length (GL). From the basion to the alveolar point.
24. Profile angle (P). Measured in the case of the series "K" on the sagittal outline projected by the dioptrograph; in the case of the female by the same method and by the goniometer.
25. Alveolar angle (A). Between GL and GH.
26. Nasial angle (N). Between GH and LB.
27. Basilar angle (B). Between LB and GL.
28. Basio-nasal-horizontal angle ($180^\circ - <N - <P$).
29. Basio-alveolar-horizontal angle ($<P - <A$).

} Determined in 100 male by measuring angles on projection outline, in female by completing the triangles with appropriate length for sides and measuring the angle.

The following indices were also calculated :—

1. Cephalic index.
2. Vertical index.
3. Breadth-height index.
4. Upper face index.
5. Orbital index (right eye).
6. Nasal index.
7. Palatal index.

(A) *Comparison of the Mean Values of the West Scottish Skull with those of Various Other Types of Skull or Skulls of Other Races.*

In the two tables (Tables XXI and XXII) are compiled the data for the mean values of the principal characters in the series of skulls under examination and the mean values of the same characters in the skulls of the following series :—

- (a) English crania, Whitechapel series, MACDONNELL (12), M. and F. groups.
- (b) Bavarian crania (Altbayerisch crania), measured by RANKE, and published in his *Beiträge zur physischen anthropol. der Bayern*, Bd. i (M. and F.).
- (c) Würtemberg crania from *Die anthropol. Sammlung. Deutsch.*, xvi Tub. (M. and F.).
- (d) French crania, the skulls of French soldiers who died in Munich during the Franco-Prussian War, 56 in number. Measurements from *Die anthropol. Sammlung. Deutsch.*, x Mun. (M. and F.).
- (e) Naquada crania from C. D. FAWCETT's memoir (M. and F.).
- (f) Modern Negro skulls from north of Africa, extracted from the German Anthropol. Catalogue. (Taken from C. D. FAWCETT's paper.) M. only.
- (g) Aino skulls, KOGANEI's measurements, "Beiträge zur phys. anthropol. der Aino," *Mittheil. aus der Medicin Facultät der k. j. Universität Tokyo*, 1894, Bd. ii (M. and F.).
- (h) Tasmanian skulls from BERRY and ROBERTSON's compiled results in a "Biometrical Study of the Relative Purity of Race of the Tasmanian, Australian, and Papuan" (M. and F.), and from TURNER's memoir on the Craniology of the Tasmanian.
- (i) Australian skulls from ROBERTSON's compiled results (9), (M. and F.), and from the Catalogue of the Royal College of Surgeons of England, compiled by FLOWER.
- (j) TURNER's Scottish series of skulls.

TABLE XXI.—*Male.*

Character and Reference Letter.	West Scottish Series. (405.)	"K" Series. (100.)	TURNER.	English. (W.)	German. Albäy-ersch.	German. (W.)	French. (56.)	Naquadra.	Modern Negroes.	Aino.	Tasmanian.	Australian.
C.	1459.43±4.11	1511.3 ±8.6	1478	1476.94 ±9.73	1503.5	1493.77	1473	1381.0	1347.7	1462	1235 (T.)	1298
F.	185.77±.20	187.97	..	187.35 ±.35	..	..	..	183.96	182.85	185.8	183.44±.54	183.56±.56
L.	187.52±.20	189.18 ±.39	186.8	189.06 ±.36	180.58	179.96	179.96	185.13	133.15	141.2	136.69±.44	130.60±.36
B.	139.56±.16	140.7 ±.29	149.?	140.67 ±.31	150.47	147.88	143.411	134.87	95.91	96.2	132.11±.44	131.13±.42
B'	96.42±.15	97.48	..	98.02 ±.25	103.70	97.19	96.21	91.06	135.31	139.5	..	..
H	132.72±.17	133.71 ±.37	132.4	132.04 ±.34	133.78	130.94	130.68	135.21	115.04	119.3	..	..
OH	..	118.11 ±.33	..	114.59 ±.25	120.75	115	112.86	115.59	102.96	105.4	..	..
LB	100.37±.13	100.96 ±.27	101.4	101.60 ±.25	100.30	98.60	99.70	99.34	..	..	..	..
U ₁	526.60±.47	529.69	..	524.25 ±.88	524.35	517.82	518.20	511.02	508.47	522.5	..	..
U ₂	522.53±.47	526.39	531.2	377.11 ±.81	365.10	367.20	365.96	373.02	367.72	372.8	..	..
S.	378.60±.43	382.13	..	307.93 ±.72	329.70	323.97	312.20	304.22	306.85	328.5	..	..
Q.	311.10±.36	312.23	..	70.17 ±.30	70.80	71.46	68.39	67.59	68.00	69.8	..	..
G'H	70.96±.16	72.35	..	90.87 ±.45	95.10	92.46	92.46	95.85	96.63	102.1	..	..
GB	90.12±.16	90.82	..	130.05 ±.57	135.00	133.33	130.70	125.63	129.47	137.3	..	..
J.	127.16±.18	128.14	..	51.22 ±.20	50.90	51.45	51.23	48.94	49.52	50.5	..	..
NH	51.72±.11	51.83	52.4	24.29 ±.17	24.80	23.91	23.13	25.12	27.29	25.6	..	..
NB	23.47±.06	23.18	23.2	43.06 ±.15	39.90	39.78	38.21	43.11	39.56	40.9	..	..
O ₁ L*	38.31±.05	39.15	39.1	42.99 ±.16	..	..	..	42.60	..	..	..	..
O ₁ R	38.67±.05	39.24	..	33.46 ±.15	33.72	34.10	33.32	32.67	34.19	34.9	..	..
O ₂ L*	33.05±.07	33.71	34.1	33.42 ±.18	..	..	..	31.87	..	..	..	..
O ₂ R	33.05±.07	33.76	..	48.27 ±.22	44.30	51.68	46.57	55.80	49.42	53.0	..	..
G ₁	50.54±.11	..	..	36.78 ±.24	33.20	38.12	37.20	40.33	39.73	38.2	..	..
G ₂	37.14±.08	..	..	95.93 ±.35	..	..	..	94.72	105.33	104.9	..	..
GL	95.08±.16	94.87 ±.32	96.1	86.09 ±.35	89.10°	86.42°	86.46°	84.41°	82.00°	82°	..	..
<P	..	87.12° ±.20	..	73.38° ±.28	..	..	..	72.82°	..	..	..	..
<A	..	73.25° ±.19	..	65.19° ±.29	..	..	..	66.60°	..	..	..	..
<N	..	64.36° ±.22	..	41.43° ±.20	..	..	..	40.73°	..	..	..	..
<B	..	42.39° ±.18	..	28.71° ±.22	..	..	..	28.29°	..	..	..	..
<θ ₁	..	28.54° ±.20	..	12.92° ±.29	..	..	..	11.30°	..	..	..	..
<θ ₂	..	13.87° ±.20	..	74.34 ±.19	83.20	82.45	79.79	72.99	72.87	76.5	74.7 (M. & F.)	71.29±.24
100B/L	74.36±.08	74.41 ±.16	77.3	69.97 ±.20	74.20	73.02	72.57	73.30	74.15	75.6	71.1 "	71.50±.25
100H/L	70.81±.09	70.7 ±.20	70.9	94.31 ±.29	89.10	88.50	..	100.47	101.75	..	95.8 (T.)	100.50±.35
100H/B	95.14±.14	..	..	76.52 ±.50	74.50	78.10	74.19	70.63	70.37	68.4	..	..
100GH/GB	78.86±.19	..	..	47.55 ±.37	48.70	46.59	45.26	51.08	55.43	50.7	58.8 (T.)	56.9 (F.)
100NB/NH	45.58±.15	..	44.5	77.69 ±.38	84.5	85.85	87.27	74.87	87.20	85.3	77.8 "	80.9 "
100 O ₂ O ₁ R	85.51±.17	..	87.3	76.26 ±.55	74.4	74.21	80.14	71.94	81.52	72.1	..	..
100 G ₂ G ₁	73.69±.21	..	..	..	..	..	..	..	..	..	..	..

* When only one figure is given it represents the measurement on one orbit, which not stated.

TABLE XXII.—*Female.*

Character and Reference Letter.	Scottish Series. (100.)	Scottish (TURNER.)	Whitechapel English.	Altbayerisch. (German Modern.)	German. (Württemberg.)	Naquadra.	Aino.	Tasmanian.	Australian.
C . . .	1314.5 ± 6.30	1323	1299. ± 8.51	1335.50	1336.83	1287.9	1308	1175 (F.)	
F . . .	177.97 ± .32	178.9	180.14 ± .36	173.45	172.74	177.41	177.2	175.00 ± .70	175.59 ± .68
L . . .	135.16 ± .29	137.8	134.68 ± .27	143.98	142.90	131.50	136.8	132.43 ± .44	128.73 ± .55
B . . .	92.66 ± .25	..	93.12 ± .23	96.30	93.90	88.23	92.4		
B' . . .	125.01 ± .31	..	124.56 ± .30	128.01	126.26	129.47	135.1	126.97 ± .66	124.50 ± .87
H . . .	..	..	109.21 ± .25	114.17	112.68	113.11	115.0		
OH . . .	93.82 ± .20	95.3	95.34 ± .24	95.80	93.63	94.86	100.3		
LB . . .	503.61 ± .71	506.7	503.84 ± .85	501.40	500.58	493.74	501.7		
U . . .	363.15 ± .68	..	362.76 ± .84	353.40	358.16	363.64	360.7		
S . . .	299.21 ± .60	..	293.97 ± .71	319.70	314.95	296.46	317.1		
Q . . .	65.83 ± .24	66.9	65.93 ± .40	66.80	65.80	65.84	65.5		
G'H . . .	85.09 ± .24	..	84.86 ± .41	89.70	88.50	92.51	96.7		
GB . . .	118.16 ± .26	121.6	120.27 ± .58	126.30	124.44	117.04	129.7		
J . . .	48.41 ± .20	49.9	48.68 ± .22	48.20	45.74	46.73	47.4		
NH . . .	22.56 ± .11	22.0	23.19 ± .14	23.70	23.05	24.31	24.7		
NB . . .	37.13 ± .10	37.4	41.17 ± .13	38.32	37.95	41.70	39.8		
O ₁ L* . . .	37.24 ± .09	..	40.95 ± .14	..	..	41.30	..		
O ₂ L* . . .	32.94 ± .13	33.4	33.59 ± .12	33.18	32.21	32.16	33.9		
O ₂ R . . .	32.95 ± .13	..	33.73 ± .13	..	..	32.87	..		
G ₁ . . .	47.01 ± .19	..	45.13 ± .26	42.20	50.20	53.89	51.4		
G ₂ . . .	36.21 ± .14	..	35.22 ± .24	32.10	37.20	38.87	37.4		
GL . . .	88.61 ± .31	91.2	90.42 ± .40	..	..	91.02	100.1		
<P . . .	88.67° ± .18	..	87.13° ± .27	88.8°	84.93°	84.49°	81°		
<A . . .	72.9° ± .21	..	73.90° ± .29	..	..	72.62°			
<N . . .	64.85° ± .22	..	64.70° ± .23	..	..	66.40°			
<B . . .	42.19° ± .18	..	41.39° ± .27	..	..	40.98°			
<θ ₁ . . .	26.37° ± .19	..	28.11° ± .24	..	..	29.09°			
<θ ₂ . . .	15.92° ± .20	..	13.13° ± .34	..	..	11.82°			
100 B/L . . .	76.03 ± .19	77.1	74.73 ± .18	83.10	82.78	74.19	77.6	Vide male	73.36 ± .43
100 H/L . . .	70.31 ± .20	70.5	69.13 ± .18	73.90	73.17	73.22	76.7	"	70.95 ± .55
100 H/B . . .	92.53 ± .29	..	92.35 ± .24	88.80	88.46	98.66	..	"	96.64 ± .69
100 G'H/GB . . .	77.45 ± .32	..	77.94 ± .57	74.40	74.11	70.36	67.7	"	
100 NB/NH . . .	46.77 ± .30	44.1	47.79 ± .33	49.20	50.33	52.31	50.5	"	
100 O ₂ /O ₁ R . . .	88.53 ± .35	89.4	82.46 ± .37	86.60	85.11	77.32	85.2	"	
100 G ₂ /G ₁ . . .	77.27 ± .41	..	(81.70 ± .57)L	76.00	74.59	72.30	72.8	"	

* When only one figure is given it represents the measurement on one orbit, which not stated.

These tables enable one to see at a glance the differences between the mean values of the principal dimensions of the skull as they are exhibited in the Scottish skull of the present series and in TURNER's Scottish series and modern advanced types, Bavarian, Württemberg, and French skulls and primitive types, including the Negro, Australian, Tasmanian, and Aino, as well as the Naquada, the representative of an ancient civilisation. I include Australian and Tasmanian for comparative purposes at this stage, to show how they differ from the present Scottish series as shown by the application of the ordinary methods of measurement, because at a later stage I shall institute a comparison between these types and the Scottish skull by other methods.

Male Skulls.—Reviewing the above tables of measurements briefly and taking the male groups first, we find that, as regards capacity, the present Scottish series only differs in its mean value from the Whitechapel English series by an amount which may be wholly due to different observers utilising different methods of measurement. As was previously mentioned, this may account for a difference of 20 c.c., which is greater than the difference between the Scottish and English mean capacities. The mean cubic content value of TURNER's Scottish series is practically identical with that of the English Whitechapel group. The mean capacity of the two German series of crania is distinctly greater, but they each consist of a group of about 100 skulls, and one would like to know if, in the case of the Altbayerisch group, which was taken from a much larger group, the same influence has not been operative as has made itself apparent in my selection of 100, and with a like vitiation. In selecting male skulls, did they not select skulls with male characters distinctly marked? If so, these are, in general, skulls with a capacity above the mean value for the whole series, in fact, large skulls, and 1503.5 c.c. may not be the mean capacity if they take an average of all the male skulls. The mean value for 100 male skulls, chosen at random from the whole series, except that male characters were as a rule distinct, gives a mean capacity of 1511.3 c.c., which compares very favourably, as previously mentioned, with that given for the German Altbayerisch group. The mean capacity of the French group is practically equal to that of the Whitechapel series, and differs from the Scottish series by an amount which may be again due to the personal equation of the measurer. The mean capacity of the Scottish skull is distinctly greater than that of the Negro, Naquada, Tasmanian, and Australian, but practically equal to that given for the Aino—a very primitive type.

The absolute lengths of the various types show distinct differences. There are different methods of taking this measurement:

- (a) Glabella-occipital maximum lengths.
- (b) Ophryo-occipital maximum lengths.
- (c) Horizontal length (*i.e.* the distance between vertical blocks in contact with the skull in front and behind when it is oriented in the Frankfurt horizontal plane). As has been pointed out by MACDONNELL and FAWCETT, there is very little advantage to be gained by recording all these measurements.

PARSONS (7) favours the ophryo-occipital length as advocated by FLOWER, as he says that by this means we avoid the projection due to the frontal sinus. He puts the other on record, however, the comparison between the two giving one some idea of the development of that sinus. Still it is remarkable how frequently the frontal sinus extends upwards in a well-marked form beyond the point where the extremity of the one arm of the calipers is usually placed in taking the ophryo-maximum length, as is evident from our series of sectionised skulls. He says that on an average the ophryo-maximum length is about 2 mm. less than the glabello-maximum length in the male Hythe crania and equal in the female, and this is confirmed by the Whitechapel series and the two groups of the present Scottish series. I have not recorded the horizontal length. The glabello-occipital maximum mean length in the whole Scottish male series is somewhat below that of the Whitechapel series, but the subsidiary male group of 100 has a mean practically identical with the latter. The German and French absolute mean lengths are practically equal, but distinctly less than the two means above mentioned, while the Tasmanian, Australian, and modern Negroes are all distinctly longer than the German, and also, but to a less degree, than the Naquada and Aino.

As regards greatest breadth, we find that the Scottish series and the Whitechapel series show practically identical means, while the German and French are notably higher. The mean value for the Aino is slightly greater; then, in a descending series, follow the Tasmanian, which is slightly less in mean value, the Naquada and modern Negroes about equal, and less still and lowest of all, the Australian, which has a mean value of about 10 mm. less than the Scottish skull in this group.

The influence of the relative lengths of these measurements is apparent in the cephalic index, *i.e.* 100B/L. The mean cephalic index in the Whitechapel series is practically identical with that of the West Scottish series of 400, and this relationship is not appreciably altered if we take the mean of the "K" Scottish series of 100 specimens. The cephalic index in the French series is definitely higher than the above, and lies at the upper limit of the mesocephalic class, while the two German series show a mean value well above the lower limit of the brachycephalic class. The Naquada and modern Negroes give a similar mean value, while the Australian gives the lowest value, dependent to some extent upon its well-marked glabello-occipital maximum length but to a larger extent on its extremely small maximum breadth.

MACDONNELL (12), from a comparison of modern English skulls, obtained by reduction of the measurements from large numbers of living individuals, comes to the conclusion that there has been a decided change in the shape of the English skull during the last two or three hundred years—a change from dolichocephaly as exhibited by the Whitechapel series towards a more brachycephalic type; the length has been decreasing and the breadth increasing. This change, he says, is more marked when we compare English with modern Germans. According to FAWCETT

(22), a similar change has been taking place in the development of Egyptian skulls. TURNER in his memoir says that in Scotland there is exhibited at the present time "a distinct brachycephalic tendency"; while PEARSON (8) states, with regard to the cephalic index, that "it appears to be a quantity closely associated with degrees of civilisation and capacity for racial survival in the struggle for existence. It is a measure of round-headedness, and, in a certain rough sort of way, round-headedness gives the maximum of skull capacity for the same amount of material." He is of the opinion that the extra group struggle for existence has gone in favour of the brachycephalic races, and that in most continents we find the mainland occupied by the latter races, while the promontories, outlying borders, and islands are occupied by dolichocephalic races apparently driven out before victorious brachycephaly. His final conclusion, from a table comprising a long list of cephalic indices, is that "the dominating and most highly civilised peoples of the world, together with the races from which they have sprung, fall into the brachycephalic portion of the table." He admits there are exceptions to this general statement, including the Anglo-Saxon and the Whitechapel English. The position of the Anglo-Saxon type he ascribes to the group being mixed with long-barrow British; but "the Whitechapel English will still, however, remain a striking anomaly."

It is interesting to be able to range alongside the Whitechapel English another series of skulls, more extensive and derived from an entirely different source, but almost identical in their mean characters with the above series in support of the position of dolichocephaly.

It is PEARSON's contention that the Whitechapel skulls were those of the poorer classes, and that this accounts for the long-headedness, as he suggests that there is a class distinction to be noted in European countries—the higher classes having a distinctly greater tendency to brachycephaly than the lower classes. Such an explanation would not hold in the case of the present series, as there is no evidence that the skulls are derived from people in the lower walks of life. It has been asserted that town populations are more brachycephalic than country populations, but the evidence adduced by the present series does not support such a view, as the series—manifestly a town series—is, if anything, less brachycephalic as regards its skull form than the country around.

PARSONS (7) writes of his Hythe crania that "they entirely fail to substantiate the theory which Dr MACDONNELL advances, that during the last two or three centuries a marked change has been going on in the shape of English skulls; that their length has been decreasing while their breadth has increased." He reminds Dr MACDONNELL that the latter's Whitechapel series cannot be regarded as representative of the English skull as a whole, but only of the type of the seventeenth-century Londoner and nothing more, and says that "we must realise the fact that we are still in complete ignorance of the skull shapes in other parts of England in the past."

With regard to the alleged dominance of the brachycephalic over the dolichocephalic type, TURNER writes that "so far as quality of type is expressed by the amount of cranial capacity, skulls of Scotland do not sustain this claim, as those with dolichocephalic proportions were of greater mean capacity than the brachycephalic." In 25 dolichocephalic crania the mean capacity was 1516 c.c.; in 13 brachycephalic the mean was 1469 c.c.

Comparing our series "K" of typical male skulls and dolichocephalic with the Altbayerisch German group, distinctly brachycephalic in type, we find that the mean capacity of the dolichocephalic is greater than the mean capacity of the brachycephalic type—a result which supports TURNER's statement. We are reminded by the latter that "many other factors besides volume of cranial capacity have to be taken into consideration in the estimation of the intellectual power either of individuals or of a collection of individuals belonging to the same people or race."

The mean heights of the different types in the present West Scottish series, TURNER's series, the Whitechapel group, and the Tasmanian series are nearly identical—slightly greater than the Würtemberg series, slightly less than the Altbayerisch. The French mean value is approximately equal to the Würtemberg value, with the Australian in close proximity to it. The Naquada and Negro are practically equal, and a little higher than the Altbayerisch, while the Aino shows the highest value of all. It is interesting to find that the mean value for the Scottish subsidiary "K" group of 100 is identical with that of the Altbayerisch group of 100.

The relative values of these mean absolute dimensions of breadth and height as well as length are shown in the height and breadth-height indices. As regards the first of these, the full Scottish male series, the subsidiary Scottish series and TURNER's series are identical, and less than one point above the Whitechapel English series. The Altbayerisch group is practically equal to the Negro in this respect, about four points higher than the Scottish, as in it we find, associated with the occurrence of a nearly equal height, a smaller maximum length, while the Würtemberg and Naquada are nearly equal and slightly less in value. The French value is just under one point less than the last two, the Australian one point under the French, while the Aino, owing principally to its relatively great height, is highest in value of all the groups.

The height-breadth index ($100 H/B$) is hypsistenocephalic, *i.e.* over 100 in three types, viz. Australian, Naquada, and Negro, and of these the Negro shows the highest value, while the other two are practically equal. This depends principally, in the Australian, on the extremely small maximum breadth, associated with a moderate height, while in the other two it seems dependent to a greater extent on the increase of height, which is associated with a breadth less diminished than in the Australian. The height-breadth indices in the Scottish series and in the Whitechapel series corre-

spond very closely, and are separated by a definite and distinct gap from the two German groups which, owing to their marked increase in maximum breadth, have distinctly lower indices.

The auricular height in the subsidiary West Scottish series of 100 has a mean value slightly greater than in the English series, and intermediate in value to the two German series. The relationship of the mean values in the various groups can be readily seen and compared by referring to the table for male skulls described above. The basi-nasal length is very similar in the West Scottish and Altbayerisch groups, slightly greater and practically equal in TURNER's Scottish and the Whitechapel groups, while the relatively great length characteristic of primitive types is evident in the values for the Negro and Aino. While the upper face heights are approximately equal in the Scottish male group, the English group, and the Altbayerisch group—a relationship which also obtains between the breadths in the two former groups,—the breadth in the Altbayerisch group is distinctly greater than the height, and so we find in this group of German skulls a smaller index and a relatively broader face than in the other two groups.

The mean nasal heights are not markedly different in the four groups, Scottish, English, Altbayerisch, and Würtemberg, and the same may be said of the respective breadths. As regards the nasal index, the mean value in the Scottish series more nearly equals the Würtemberg value than it does the Whitechapel one. These are all leptorhine, while the Altbayerisch value is at the lower limit of, but within, the mesorhine group. With regard to the mean value of the orbital width, which for all practical purposes is the same on the two sides, it corresponds more closely with that found in TURNER's series and in both German series than with the English series, which is markedly greater, while the value for orbital height is very similar in the same groups. We see this relationship reflected in the orbital index, which is practically equal in the West Scottish male group and in the Würtemberg group and in the mesoseme class, slightly greater than that in the Altbayerisch series just within the mesoseme group, and distinctly less in the English Whitechapel group, which falls into the microseme class.

As regards palate index the West Scottish group is more nearly equal to the two German groups than to the English group. With regard to the profile angle in the various groups we observe that the angle in the West Scottish series, with the exception of that in the Altbayerisch group, shows the highest value of all. It is on the average about 2° less than in the Altbayerisch group, and about 1° higher in value than the English, Würtemberg, and French group angles, which are approximately equal.

The angles of the triangle formed by the basi-nasal, nasi-alveolar, and basi-alveolar lines (fig. 1) are shown in the table for the "K" group of 100 male Scottish skulls, and are not very different from those in the English and Naquada groups, which are the only two other groups where the values are given. The angle θ_1 is nearly identical in

the three groups above named, while it is slightly less in value in the Naquada than in the other two groups.

Female Skulls.—Fewer groups are available for the comparison of the values of the various dimensions in the female skulls. An analysis of the groups arranged in Table XXII, however, shows that many of the characters in the various series have a similar relationship to one another as they have in the corresponding male groups.

While the maximum breadth dimension is markedly greater in the German groups than in the English and Scottish groups, we find that in the last group the proportional values of length and breadth have altered, and as a result the Scottish skull has moved into the mesaticephalic class, while the index for the English skull

FIG. 1.

F.H. Frankfurt horizontal plane.
A. Alveolar angle.
N. Nasial angle.
B. Basilar angle.

P. Profile angle.
 $\theta_1 = (180^\circ - \angle P - \angle N)$.
 $\theta_2 = (\angle P - \angle A)$.

remains practically the same as the male index. The length in the Scottish series is approximately equal to that in the Naquada and Aino groups, the lengths of the Tasmanian and Australian are practically alike, while the Tasmanian distinctly exceeds the Australian in breadth. In length both are definitely shorter than the Scottish mean value. As regards height, the Scottish, Whitechapel English, Würtemberg, Tasmanian, and Australian have nearly equal values, while the Naquada is distinctly higher in value. There is no hypsistenocephalic group tabulated in the female sex, even the Australian falling below 100 as regards height-breadth index.

The horizontal circumference is approximately equal in the Scottish, Whitechapel, two German and Aino groups, and distinctly less in the Naquada, while the sagittal arc in the two German female groups, as in the male groups, is distinctly less in value than that found in other series which are very similar in value.

The nasal and orbital dimensions show much the same relationship in the female groups as in the male. In the Scottish female group the nasal and orbital indices are higher in value than in the male group, the nasal index is much the same in the English male and female groups, while the orbital index is distinctly higher in value in the female than in the male series. While the nasal index is higher in value in

the two German groups than in the Scottish group, the reverse relationship holds in regard to the orbital index.

The palatal indices in the Scottish and Whitechapel series are practically equal, and are higher in value than those found in the two German groups.

As regards the alveolar, basilar, and nasial angles of the triangle ANB, there is no great difference in their respective values for the English, Scottish, and Naquada groups.

The profile angle was computed in the series of 100 female skulls by the aid of dioptrographic median sagittal tracings. The angle was found in the female to be on an average about 1° greater than in the male, a relationship which was also present in the English group, whereas in the German series the mean angle in the female was slightly smaller than in the male.

The upper facial index is approximately equal in the Scottish and English groups and distinctly smaller in the German groups, which points to the relatively shorter and broader face in the latter race, a condition found also in the male sex.

(B) *The Variability of the Scottish Skull.*

One of TURNER's principal aims in regard to the formation of his collection of Scottish skulls was that it should be thoroughly representative, and should contain specimens not only from many different but from definite places in Scotland. This he has been successful in accomplishing, but diversity is apparent in the high degree of variability exhibited by the skulls when grouped together. He has obtained a representative series, but at the expense of homogeneity. The collection being derived from such varied districts and sources lacks uniformity, although it loses no value on that account, but rather receives an enhanced value, as it gives us a knowledge of the different types in the different parts of Scotland.

There has been, till recently, much difficulty in defining what is exactly implied in the term "homogeneous series," but PEARSON (32) has made a definite statement on the subject which has removed the difficulty. The statement is to the effect that "the heterogeneity of any series the variability of which for skull length exceeds 6.5 (standard deviation), or for skull breadth exceeds about the same amount, should be suspected and the series subjected to close examination. If the variability of skull length be less than 5.5, or of skull breadth less than 3.3, then we must suspect that the series is a rather stringently selected sample. This rule will generally enable us to distinguish between heterogeneity due to a mixture of crania from diverse races, and the homogeneity of a single race which may, indeed, be the product of a number of generations of cross-breeding such as we may assert of modern English, French, and German, but hardly with the same certainty of Ainos or Bengal castes."

TURNER in his summarised results in his memoir gives the minimum, the maximum, and mean values for any measurement taken by him. MACDONNELL has

calculated, from the complete series of results, the standard deviation for maximum length and breadth, and finds that for length the factor is 7·418 for males and 7·151 for females; for breadth 5·94 for males and 5·11 for females. While they apparently satisfy the conditions required for homogeneity as regards breadth, they do not do so in the case of length, and MACDONNELL's conclusion, supported by PEARSON, regarding them is that "they show a much higher variability than is found in fairly contemporary individuals of homogeneous races."

With regard to the series of Scottish skulls at present under examination, which were all obtained at the same time and from the same burial-place, we find that the conditions for uniformity are satisfied both by maximum length and breadth variability. The homogeneity and great size of this series of skulls gives this part of the inquiry a general interest in connection with the general principles of cranial variability.

The variability for length and breadth shown by several different types is exhibited in the following table:—

TABLE XXIII.

Series.	Standard Deviation.	
	Skull Length.	Skull Breadth.
Naquada crania	5·722	4·612
Bavarian „	6·088	5·849
Aino „	5·936	3·897
French „	7·202	6·068
English „	6·446 (Whitechapel, 6·27)	4·976 (Whitechapel, 5·28)
Scottish „ (present series) .	5·94	4·76
„ „ (TURNER)	7·418	5·94

These deviations are small enough in the case of the present series of Scottish skulls to warrant the conclusion that they constitute a homogeneous series. Showing a value well above 5·5 for length and 3·3 for breadth, there seems no reason to suspect that the series is a "stringently selected sample." It is worthy of note that in the subsidiary male series "K" the standard deviation for length is 5·82 and for breadth 4·43, figures well above those values which suggest stringent selection.

TABLE XXIV.
Variability of the West Scottish Skull.

Character.	Male.			Female.		
	Mean.	S. D.	V.	Mean.	S. D.	V.
C	1459.43 $\pm$ 4.11	122.13	8.36	1314.5 $\pm$ 6.30	93.51	7.11
F	185.77 $\pm$.20	6.04	3.25			
L	187.52 $\pm$.20	5.94	3.16	177.97 $\pm$.32	4.75	2.67
B ₁	139.56 $\pm$.16	4.76	3.41	135.16 $\pm$.29	4.40	3.26
B ₂	96.42 $\pm$.15	4.46	4.63	92.66 $\pm$.25	3.76	4.05
H	132.72 $\pm$.17	5.30	3.90	125.01 $\pm$.31	4.61	3.68
OH	118.11 $\pm$.33	4.92	4.16			
LB	100.37 $\pm$.13	4.05	4.03	93.82 $\pm$.20	3.11	3.31
U ₁	522.53 $\pm$.47	14.10	2.69	503.61 $\pm$.71	10.64	2.11
U ₂	526.60 $\pm$.47	14.06	2.67			
S	378.60 $\pm$.43	12.89	3.40	363.15 $\pm$.68	10.16	2.79
Q	311.10 $\pm$.36	10.95	3.52	299.21 $\pm$.60	9.04	3.02
G'H	70.96 $\pm$.16	4.75	6.69	65.83 $\pm$.24	3.67	5.57
GB	90.12 $\pm$.16	4.89	5.42	85.09 $\pm$.24	3.64	4.25
J	127.16 $\pm$.18	5.37	4.22	118.16 $\pm$.26	3.94	3.33
NH	51.72 $\pm$.11	3.51	6.78	48.41 $\pm$.20	3.00	6.19
NB	23.47 $\pm$.06	1.78	7.58	22.56 $\pm$.11	1.71	7.58
O ₁ L	38.31 $\pm$.05	1.79	4.67	37.13 $\pm$.10	1.55	4.17
O ₁ R	38.67 $\pm$.05	1.73	4.47	37.24 $\pm$.09	1.48	3.97
O ₂ L	33.05 $\pm$.07	2.15	6.50	32.94 $\pm$.13	2.05	6.22
O ₂ R	33.05 $\pm$.07	2.11	6.38	32.95 $\pm$.13	2.07	6.28
G ₁	50.54 $\pm$.11	3.27	6.47	47.01 $\pm$.19	2.96	6.29
G ₂	37.14 $\pm$.08	2.54	6.84	36.21 $\pm$.14	2.09	5.77
GL	95.08 $\pm$.16	4.94	5.19	88.61 $\pm$.31	4.62	5.21
<P	87.12° $\pm$.20	3.09	..	88.67° $\pm$.18	2.70	..
<A	73.25° $\pm$.19	2.82	..	72.9° $\pm$.21	3.14	..
<N	64.36° $\pm$.22	3.30	..	64.85° $\pm$.22	3.35	..
<B	42.39° $\pm$.18	2.75	..	42.19° $\pm$.18	2.75	..
θ_1	28.54° $\pm$.20	2.98	..	26.37° $\pm$.19	2.90	..
θ_2	13.87° $\pm$.20	3.05	..	15.92° $\pm$.20	3.02	..
100 B/L	74.36 $\pm$.08	2.53	3.40	76.03 $\pm$.19	2.89	3.80
100 H/L	70.81 $\pm$.09	2.92	4.12	70.31 $\pm$.20	3.00	4.26
100 H/B	95.14 $\pm$.14	4.27	4.48	92.53 $\pm$.29	4.42	4.77
100 G'H/GB	78.86 $\pm$.19	5.91	7.49	77.45 $\pm$.32	4.79	6.18
100 NB/NH	45.58 $\pm$.15	4.62	10.13	46.77 $\pm$.30	4.49	9.60
100 O ₂ /O ₁ R	85.51 $\pm$.17	5.25	6.13	88.53 $\pm$.35	5.21	5.88
100 G ₂ /G ₁	73.69 $\pm$.21	6.33	8.45	77.27 $\pm$.41	6.17	7.98

S. D. = Standard deviation.

V. = Coefficient of variation.

The accompanying table (Table XXIV) gives the mean values of many of the characters of the Scottish skulls for both male and female sexes, with their standard deviations and coefficients of variation for the comparison of their variability with that occurring in the corresponding characters of various other series of crania. I have computed the additional measurements given in Table XXV, for which I give

the standard deviation and the coefficient of variation. I cannot compare their variability with the corresponding measurements in other series of skulls, as these are not available, but it is of interest to compare them with the corresponding values in the female group:—

TABLE XXV.

Character.	Male.			Female.		
	Mean.	S. D.	V.	Mean.	S. D.	V.
Maxillo-facial index (interzygomatic)	55·81	3·58	6·41	55·71	3·20	5·74
Gnathic index	94·68	3·89	4·10	94·45	3·78	4·00
Frontal segment	131·73	6·44	4·88	126·96	5·70	4·48
Parietal „	127·00	7·46	5·87	121·4	6·74	5·55
Occipital „	119·88	5·22	4·35	114·76	6·53	5·69
Transverse base	115·13	4·63	4·02	108·89	3·72	3·41
CLELAND'S base (opisthionic nasal length)	134·53	5·08	3·77	126·98	4·16	3·27
Sagittal arc/base	2·819	·117	4·16	2·859	·1145	4·00
Palato-maxillary index	112·76	7·82	6·93	114·16	8·45	7·40
Asterionic breadth	109·68	4·21	3·83	105·44	4·03	3·82
Interstephanic breadth	117·93	5·33	4·52	114·91	4·53	3·94
Palatal length (T)	52·94	3·03	5·72	49·23	2·72	5·52
„ breadth (T)	59·59	3·67	6·15	56·08	3·38	6·04

From a brief survey of the above tables we observe that in the great majority of the characters or dimensions the male shows a greater variability than the female. The female is more variable than the male in the cephalic index, height index, height-breadth index, palato-maxillary index, occipital segment of sagittal arc, basi-alveolar length, alveolar and nasial angles; or equal variability in the nasal breadth, asterionic breadth, and basilar angle. In all the others, *i.e.* 39 out of 49, the female is less variable than the male, variability being determined by the coefficient of variation in all the instances except the angles when the standard deviation is used.

We are now in a position to compare the variability of the Scottish skull as regards its various dimensions with that shown by other series, and we begin with the capacity. PEARSON in his *Chances of Death*, vol. i, gives the coefficients of variation for this dimension for a number of different races from which I have made a selection; MACDONNELL (12) gives the coefficients for his English series, and FAWCETT supplies the factor for the Naquada crania. From these sources I have compiled the following table:—

TABLE XXVI.

Race or Type.	Capacity. Coefficients of Variation.	
	M.	F.
Scottish	8·36	7·11
English	8·28	8·68
Parisian French	7·36	7·10
Modern Italians	8·34	8·99
„ Germans	7·74	8·19
Naquadas	7·72	6·92
Ainos	6·89	6·82
Negroes	7·07	6·90
Andamanese	5·04	5·59

From an analysis of the above table we see that the variability of the Scottish skull, as regards cubic capacity, is very high in the case of the male group, practically identical with the Italian, slightly greater than in the English series, and markedly greater than the others in the table.

In the case of the female group, however, the variability is distinctly less than in the male group, is practically equal to that exhibited by the Parisian French, and much less than modern Germans and Italians, which show a relatively high degree of variation for the female sex as regards this dimension. We notice that the Scottish female, in being less variable than the male, resembles the French, Naquada, and Aino, while the opposite relationship holds in the English, modern Italians, and Germans.

Comparing the coefficients of variation of length, breadth, height, and auricular height, we find them arranged in the following table for different types :—

TABLE XXVII.

Race.	Length.		Breadth.		Height.		Auricular Height.	
	M.	F.	M.	F.	M.	F.	M.	F.
West Scottish	3·16	2·67	3·41	3·26	3·9	3·68	4·16	
English	3·31	3·45	3·75	3·54	4·21	3·96	3·73	4·12
Bavarian	3·37	3·57	3·89	3·39	...	...	4·47	3·91
French	3·97	3·65	4·21	3·67				
Naquada	3·17	3·14	3·29	3·45	3·98	3·66	3·86	3·54
Aino	3·20	3·08	2·76	2·68	...	...	3·67	3·18
Tasmanian	3·18	3·27	3·49	2·47	3·60	4·21		
Australian	4·04	2·69	3·69	3·00	4·23	4·86		
Scottish (T)	3·97	4·00	4·11	3·71	4·60	3·98		

The Scottish male, as represented in the present series, is the least variable as regards length, with the Naquada and Tasmanian almost equal to it; the English male is distinctly more variable, and the Australian shows the highest variation. In the case of the female, as regards length the Scottish group shows the smallest coefficient of variation, the Australian is next lowest and almost equal to the Scottish, while all the other types are distinctly more variable.

In respect of breadth, the Scottish male is less variable than the English male, which is less than the German; the Tasmanian shows an equal variability with the Scottish skull. In the case of the female, the Scottish skull is less variable than the English and German but distinctly more variable than the Tasmanian and Australian.

As regards height, the English skull is again more variable than the West Scottish, which is practically equal in variability to the Naquada crania and distinctly less so than the Australian. Auricular height I have calculated only for 100 male skulls, and the variability shown for this measurement is greater in the Scottish than in all the other races contained in the table, except the Germans.

For each of these dimensions, as before mentioned, the male is more variable than the female.

For circumferential measurements we can compile a table such as the following from the figures available :—

TABLE XXVIII.

Race.	Horizontal Circumference.		Vertical Circumference.		Sagittal Arc.	
	M.	F.	M.	F.	M.	F.
Scottish	2.69	2.11	3.52	3.02	3.40	2.79
English	2.87	2.92	3.70	3.97	3.63	3.90
Bavarian	2.86	3.09				
Naquada	2.54	2.27	3.32	2.72	3.19	3.51
Row Grave Germans	2.70	2.40				

From an examination of the above table we find that, for the horizontal circumference in the male, the Naquada crania show the least variability, the Scottish and Row Grave Germans practically equal variability and sensibly greater than that of the Naquada, while the English and Bavarian coefficients of variation are equal and distinctly higher than that shown by the Scottish series. In the female, on the other hand, the Scottish group shows the smallest coefficient of variation; then the Naquada, Row Grave Germans, English, and Bavarian in an ascending degree.

With regard to the vertical circumference, we observe that the Scottish groups, both male and female, are more variable than the corresponding Naquada groups but less variable than the English Whitechapel series.

For the variability of the sagittal arc the same relationship obtains in the male sex as for the transverse arc, but in the female the sagittal arc is less variable than in the Naquada crania and the Whitechapel English. No figures are available for the sagittal arc and the transverse arc in the Bavarian series.

Fewer figures are available for the remaining absolute measurements in the various races, but we may compare the following :—

TABLE XXIX.

Profile Angle.

Race.	Standard Deviation.	
	M.	F.
Scottish	3.09	2.70
English	3.92	2.85
Bavarian	2.79	3.59
Naquada	2.87	3.66

The English skull shows the highest variability in respect of this angle in the male sex, the Scottish is next in magnitude, while the coefficients of variation in the Bavarian and Naquada are distinctly less and about equal in value. In the female there is a rearrangement of the groups. The Scottish and English are approximately equal in variability, while the Bavarian and Naquada are sensibly more variable and are also about equally so. In the Scottish and English groups therefore the male is, as regards this dimension, more variable than the female, while the opposite relationship obtains in the Bavarian and Naquada.

Comparing palate lengths and breadths with regard to variability, we have the following table :—

TABLE XXX.

Race.	Length of Palate.		Breadth of Palate.	
	M.	F.	M.	F.
Scottish	6.47	6.29	6.84	5.77
English	5.65	6.53	7.75	7.68
Bavarian	6.42	6.85		
Naquada	6.49	7.41	9.29	8.55

The above table shows the high degree of variability that holds in all the series named in respect of palate length and breadth. For palate length the Scottish

male is more variable than the English male, while the female is less variable than the English female. Exactly the opposite arrangement is shown in the values for the variability of palate breadth in these two series of crania. In both male and female the palate length is more variable than the palate breadth in the Scottish skull, while in the English series, in both male and female, palate breadth is more variable than palate length. The Naquada crania show a very high degree of variability for palate breadth in both sexes. The variability of palate length in the male Bavarian is practically equal to that of the Scottish male, while the variation in the female is greater than the male.

The following table shows the variability of certain absolute measurements in Scottish, English, and Naquada skulls:—

TABLE XXXI.

Reference Letter.	Character.	Scottish.		English.		Naquada.	
		M.	F.	M.	F.	M.	F.
B'	Minimum frontal breadth	4·63	4·05	4·29	4·55	5·29	4·47
LB	Basi-nasal length	4·03	3·31	4·07	4·11	4·88	4·68
G'H	Nasi-alveolar length	6·69	5·57	5·50	7·14	6·08	6·87
GB	Intermalar breadth	5·42	4·25	5·58	5·40	5·18	4·77
J	Interzygomatic breadth	4·22	3·33	4·28	4·13	4·16	4·77
NH	Nasal height	6·78	6·19	5·08	5·55	6·13	6·81
NB	„ breadth	7·58	7·58	8·89	7·06	7·89	7·28
O ₁ L	Orbital breadth (left)	4·67	4·17	4·20	3·53	4·97	5·30
O ₁ R	„ „ (right)	4·47	3·97	4·69	4·00	5·02	5·38
O ₂ L	Orbital height (left)	6·50	6·22	5·61	4·31	7·06	6·58
O ₂ R	„ „ (right)	6·38	6·28	6·65	4·47	7·27	6·85
GL	Basi-alveolar length	5·19	5·21	4·68	4·95	4·84	5·09

The above table at first sight seems rather complex, but it shows a few notable features. First of all, in the Scottish series the variability for the male is greater than that for the female in all the characters except two, viz. nasal breadth and basi-alveolar length. In the former the variabilities shown by the two sexes are equal; in the latter the female is slightly the more variable.

In the English series the female is more variable than the male in several of the characters, namely, minimum frontal breadth, basi-nasal length, nasi-alveolar length, nasal height, and basi-alveolar length.

In the Naquada the female is more variable than the male in the following characters: nasi-alveolar length, interzygomatic breadth, nasal height, orbital breadth (both orbits), and basi-alveolar length.

Examining the male coefficients of variation we find that, for minimum frontal breadth, it is greatest in the Naquada and least in the English; for basi-nasal length it is greatest in the Naquada and smallest in the Scottish; for nasi-alveolar length

the Scottish series shows the highest value, the English the least, and Naquada is intermediate; for intermalar breadth the English has the highest coefficient and Naquada the smallest; for interzygomatic breadth the same relationship holds; for nasal height the Scottish shows the highest value, the English the least; for nasal breadth the English group has the highest value and the Scottish the smallest.

For orbital breadth (left orbit) Naquada is most, and English least, variable; for orbital breadth (right orbit) Naquada is most variable, but now Scottish is least variable; for orbital height (left) the Naquada is most variable and the English group least; for the right orbital height Naquada is still most variable, but now Scottish is least variable; while for basi-alveolar length the Scottish group is most, the English group least, variable. For the female the relationship of the variabilities is equally changeable, and I think we can represent it best in the following way:—

TABLE XXXII.

Character.	Male.		Female.	
	Most Variable.	Least Variable.	Most Variable.	Least Variable.
B'	Naquada	English	English	Scottish
LB	"	Scottish	Naquada	"
GL	Scottish	English	English	"
GB	English	Naquada	"	"
J	"	"	Naquada	"
NH	Scottish	English	"	English
NB	English	Scottish	English	Scottish
O ₁ L	Naquada	English	Naquada	English
O ₁ R	"	Scottish	"	Scottish
O ₂ L	"	English	"	English
O ₂ R	"	Scottish	"	"
GL	Scottish	English	Scottish	"

The English group is most often least variable in the male skulls as regards those dimensions, and the Scottish is least variable of the three most frequently in the female sex.

We have still to compare the variability of the various indices, and material for this purpose is more abundant. The variability is determined in the case of indices by the standard deviation.

TABLE XXXIII.

Cephalic Index.

Series.	Breadth and Length $\left(\frac{B}{L} \times 100\right)$.	
	M.	F.
Scottish	2.53	2.89
English	3.26	2.98
Bavarian	3.50	2.97
French	4.43	4.19
Naquada	2.80	3.12
Row Grave Germans	2.28	2.35
Aino	2.41	2.54
Egyptian mummies	3.35	3.36
Modern Egyptians	5.42	5.10
Negroes	2.77	3.52
Punjabi low caste	2.98	3.75
Australian	3.21	3.05
English (upper classes)	3.03	

Of the various series included in the table the Scottish male is less variable than all the others as regards the cephalic index with the exception of two, namely, Aino and Row Grave Germans. The standard deviation in the Scottish male is sensibly less than in the Bavarian, French, or English, and less than the factor in the female, which is the opposite condition to what is found in the German and English series, the male in the two latter being more variable than the female. The Australian male and female are more variable as regards their index than the corresponding sexes in the West Scottish series.

The following table shows the data for the vertical or altitudinal index :—

TABLE XXXIV.

Race.	$100 \times \frac{H}{L}$	
	M.	F.
Scottish	2.92	3.00
English	3.22	2.83
French	3.53	3.67
Naquada	2.73	2.96
Australian	3.39	3.83

From the above we see that in the male sex, as regards the vertical index, the Scottish crania are less variable than the English, French, and Australian, but more variable than the Naquada crania; whereas in the female sex the English female is

less variable as regards this index, then comes the Naquada, then the Scottish, while the Australian is most variable. The Scottish male is less variable than the female as in the Australian, unlike the relationship which obtains in the English series.

The following table represents the variability of the height-breadth index in the various types :—

TABLE XXXV.

Race.	$100 \times \frac{H}{B}$	
	M.	F.
Scottish . . .	4.27	4.42
English . . .	4.58	3.84
French . . .	4.74	4.31
Naquada . . .	4.73	4.66
Australian . . .	4.59	4.81

In the male groups, as regards the height-breadth index, the Scottish series is the least variable ; then follow the English and Australian, sensibly different and showing equal variability, while the French and Naquada are still more variable and to an equal degree.

In the female groups the least variable is the English series, then comes the French, then the Scottish, and last of all the Australian—most variable, with the Naquada between it and the Scottish.

The Scottish male is less variable, as regards the above index, than the female—a relationship which also obtains in the Australian series, while the opposite relationship holds in the English, French, and Naquada series.

The standard deviations of the remaining indices in the different series are as follows :—

TABLE XXXVI.

Race.	Upper Face Index or Maxillo-Facial Index.		Palatal Index.	
	M.	F.	M.	F.
Scottish . . .	5.91	4.79	6.33	6.17
English . . .	5.39	6.26	8.39	8.52
Bavarian . . .	3.26	3.33		
Naquada . . .	4.52	4.15	10.23	8.20

The Scottish male is more variable, as regards upper facial index and also palatal index, than the female ; and, as so often occurred in the other characters examined, we find again the opposite relationship holding in the English series.

The Scottish palatal index shows a remarkably small standard deviation compared with that shown by the English and Naquada crania.

As regards the maxillo-facial index in the male, the Bavarian shows the least variability, then the Naquada, while the English and Scottish are appreciably more variable. In the female the Bavarian is again the least variable; following this comes the Naquada; then the Scottish, while the English female is the most variable.

We have still to examine the orbital and nasal indices, and the following table contains all the figures available :—

TABLE XXXVII.

Race.	Orbital Index.		Nasal Index.	
	M.	F.	M.	F.
Scottish	5.25 (R.)	5.21 (R.)	4.62	4.49
English	4.66 (R.)	4.33 (R.)	4.58	3.90
Bavarian	6.66	5.22	4.43	4.61
Naquada	5.00	4.78	4.18	4.86

In the Scottish series the orbital index was not calculated for both orbits, as there seemed to be so little difference between the mean values of the respective lengths and breadths. The orbital index in the above table is obtained from the right orbit.

Examining the above table, we observe that the English crania are least variable in both sexes for the orbital index. In the male the Bavarian is highest in variability, the Scottish distinctly less variable, and the Naquada less than the Scottish. In the female sex we find the Naquada next to the English in variability of orbital index, while the Scottish and Bavarian are distinctly more variable than the latter and show an equal degree of variability. The variability for orbital index is practically equal for the male and the female in the Scottish series.

In respect of the nasal index, in the male sex the Naquada shows least, the Scottish most, variability, while the English series is just a slight degree less variable than the Scottish. In the female the English is the least variable, the Scottish comes next, and the Naquada is the most variable. The variability of the nasal index is greater in the male than in the female in both Scottish and English series, while the reverse is the case in the Bavarian and Naquada groups. In this Scottish series, as in TURNER'S, the English, and Naquada series, the nasal index, as measured by the coefficient of variation, is much more variable than the orbital index, although, as MACDONNELL points out, TURNER says that the latter "shows a great range of variation in the same race, and that it possesses only a secondary value as a race

character," while he says of the former "that it constitutes one of the most important anthropological characters of the face.

The results shown in the foregoing tables with reference to the variability of the different characters in different races are so diverse that it is difficult, in fact sometimes impossible, to find evidence therein for two important conclusions of PEARSON:—

- (1) That the male is not more variable than the female.
- (2) That the more highly civilised races are the more variable.

Before PEARSON's essay on "Variation in Man and Woman" appeared, it seemed to be the general belief—a view supported by DARWIN (33)—that the male was more

FIG. 2.—Frequency curve for glabello-occipital length in 100 male and 100 female skulls.

variable than the female. This belief PEARSON ascribed to the use of non-scientific methods to measure the variability, and, in the course of his paper, furnished numerous instances where, in the most diverse characters, the female is as variable as, if not more variable than, the male; so that his conclusion is, with regard to the characters he has examined for both sexes, that there is "no evidence of greater male variability but rather of a slightly greater female variability." In the paper above mentioned the measure of significant variation is the coefficient of variation $\frac{100 \times \text{S.D.}}{\text{M.}}$ when

the sexual means differ considerably, and the standard deviation when the means are practically identical.

As previously mentioned, in the different characters for which the variability has been estimated by these criteria in the present collection, with very few exceptions, the male skull shows greater variability than the female. Respecting the second conclusion, *i.e.* that the more highly civilised races are the more variable, we find

that where measurements for certain characters of the Australian are available for comparison, the coefficients of variation are sensibly greater than in the present Scottish series of skulls in all cases, and than in MACDONNELL'S English series in

FIG. 3.—Frequency curve for maximum breadth in 100 male and 100 female skulls.

FIG. 4.—Frequency curve for basi-bregmatic height in 100 male and 100 female skulls.

most cases. As we shall see later, the same relationship holds in the Tasmanian and Scottish in regard to certain dimensions in KLAATSCH'S scheme for the examination of skulls. The Tasmanian not infrequently shows greater variability than the Scottish skull for the same character. Are we to regard these in the light of "exceptions

that prove the rule," or has there been any special selection of skulls made in our series, especially as regards the female group? Of such a contingency I am not aware, and the only conclusion I can come to is that there is room for further research as to the relative variability exhibited by the two sexes in different races.

The variability of the foregoing dimensions and indices may be graphically represented by constructing frequency polygons; and, from the data given in the tables, it only requires time and patience to calculate the analytical constants of the curves which graphically represent the true nature of the frequency distribution.

I have constructed frequency polygons for several of the dimensions and indices representing the variability of these in both sexes (figs. 2 to 6). One of the pro-

FIG. 5.—Frequency curve for cephalic index in 100 male and 100 female skulls.

minent features of these frequency polygons is the irregularly peaked or multimodal appearance they present, which may appear to point to heterogeneity in the series of crania from which the measurements were taken. Both C. D. FAWCETT and MACDONNELL urge us strongly to be cautious against using this "mountain range" appearance of the curve as an argument in favour of heterogeneity, as the peaks may be due to various other causes, among which the chief are :—

- (a) That we are dealing in most cases with very small random samples.
- (b) That some of the skulls are attributed to, and included in, the results of the wrong sex group.
- (c) That "foreign" skulls are included.
- (d) That the ages of the skulls in the collection are very varied.
- (e) That some of the skulls may have been altered by post-mortem changes.
- (f) That clustering may occur due to family groups included in the collection.

There are other causes that operate against uniformity in the curve of frequency ; and one that is specially noticeable in the curves given at the end of this paper for the indices is the small size of the unit compared with the number of skulls in the series. The indices have been calculated to '5 as well as to whole numbers, which gives '5 as a difference between successive groups. As may be easily seen from the

FIG. 6.—Frequency curve for height index in 100 male and 100 female skulls.

curves, many of the indentations would not have been present had one point been the difference between one index group and the succeeding one. According to FAWCETT, "it would be quite unjustifiable to argue from a series of peaks as to racial mixtures. Even if like peaks occur in the two sexes for several characters, the sources of heterogeneity given above are often ample explanation."

(C) *The Correlation of the Characters of the Scottish Skull.*

Correlated variability is such a relation between the magnitudes of two or more characters that any abmodality of the one is accompanied by a corresponding abmodality of the other or others. The length of this series and the remarkable uniformity of the type of skull represented presents an almost unique opportunity for the study of the correlations of cranial characters.

As the possible combinations of the various measurements I have made of the different skulls, taking two at a time, would amount to a very large number, in fact some thousands, it is necessary to make a selection of the characters for the purposes of correlation. My choice has been regulated largely by those for which I can find comparative figures in other races, and so resembles closely, in so far as it goes, the list given by FAWCETT and MACDONNELL, which includes those characters of special

interest. Although the list at present is not so complete as theirs, lack of time and the labour and calculations involved in determining the coefficients of correlation of the pairs of characters selected by the method which gives the most reliable results, *i.e.* by estimating the sum of the products of the actual pairs of measurement, has made the list smaller than intended. The data for a longer list are provided in the Appendix.

I give tables showing the pairs of characters correlated and their coefficients of correlation, with the probable errors of that criterion, and shall proceed to examine the various coefficients and compare them with those that have been calculated for other races.

In the first place, we may construct a table (XXXVIII) for length, breadth, and height correlations such as the following :—

TABLE XXXVIII.

Race.	Length and Height.				Length and Breadth.				Breadth and Height.			
	No.	M.	No.	F.	No.	M.	No.	F.	No.	M.	No.	F.
Scottish .	405	$\cdot 356 \pm \cdot 029$	100	$\cdot 089 \pm \cdot 066$	405	$\cdot 454 \pm \cdot 026$	100	$\cdot 187 \pm \cdot 064$	405	$\cdot 264 \pm \cdot 031$	100	$\cdot 053 \pm \cdot 066$
English (W.) .	120	$\cdot 255 \pm \cdot 058$	117	$\cdot 425 \pm \cdot 051$	131	$\cdot 240 \pm \cdot 055$	130	$\cdot 350 \pm \cdot 052$	116	$\cdot 233 \pm \cdot 059$	115	$\cdot 340 \pm \cdot 056$
French † .	860	$\cdot 294 \pm \cdot 022$	340	$\cdot 132 \pm \cdot 036$	860	$\cdot 089 \pm \cdot 024$	340	$\cdot 042 \pm \cdot 037$	860	$\cdot 224 \pm \cdot 023$	340	$\cdot 229 \pm \cdot 035$
German ‡	100	$\cdot 097 \pm \cdot 067^*$	99	$\cdot 314 \pm \cdot 061^*$	100	$\cdot 286 \pm \cdot 062$	99	$\cdot 488 \pm \cdot 052$	100	$\cdot 072 \pm \cdot 067^*$	99	$\cdot 276 \pm \cdot 063^*$
English § (criminals) .	..	..	..	..	3000	$\cdot 402 \pm \cdot 010$	..	..	87	$\cdot 345 \pm \cdot 064^*$	63	$\cdot 178 \pm \cdot 082^*$
English § (mid. classes) .	..	..	..	..	1000	$\cdot 345 \pm \cdot 019$	..	..	129	$\cdot 273 \pm \cdot 055$	163	$\cdot 119 \pm \cdot 052$
Aino .	87	$\cdot 501 \pm \cdot 054^*$	63	$\cdot 349 \pm \cdot 075^*$	87	$\cdot 432 \pm \cdot 059$	63	$\cdot 376 \pm \cdot 073$	..	..	..	..
Naquada ¶	134	$\cdot 489 \pm \cdot 044$	163	$\cdot 283 \pm \cdot 048$	139	$\cdot 344 \pm \cdot 050$	183	$\cdot 143 \pm \cdot 049$	..	..	..	..
Australian ††	..	$\cdot 337 \pm \cdot 060$	..	$\cdot 083 \pm \cdot 143$	..	$\cdot 313 \pm \cdot 069$	..	$\cdot 016 \pm \cdot 144$	..	$\cdot 314 \pm \cdot 069$	..	$\cdot 311 \pm \cdot 130$
Tasmanian ††	..	$\cdot 577 \pm \cdot 061$	..	$\cdot 178 \pm \cdot 119$	..	$\cdot 452 \pm \cdot 073$	..	$\cdot 256 \pm \cdot 115$	..	$\cdot 268 \pm \cdot 085$	..	$\cdot 151 \pm \cdot 120$
Sioux Indians §§	..	$\cdot 36 \pm \cdot 08$	..	..	..	$\cdot 24 \pm \cdot 08$	..	..	..	..	..	..

In the above tables the correlations for length and height and breadth and height are marked with an asterisk in the Aino and German to indicate that they are not comparable with the other results, as the auricular and not the basi-bregmatic height has been made use of; whereas in the Naquada crania the height was measured from the basion to the vault vertically above, but perpendicular to, the German horizontal plane, instead of the distance between the basion and the bregma, which was introduced by BROCA and adopted and advocated by TURNER, FLOWER, and many others. From the median sagittal tracing of 100 male skulls I was able, having also traced the opening of the external acoustic meatus and the

† Paris Catacomb Crania.

‡ A. LEE, *Phil. Trans.*, vol. cxcvi, A, p. 23.

§ Measurements on living head.

|| A. LEE, *Phil. Trans.*, vol. cxcvi, A, p. 23.¶ C. D. FAWCETT, *Biometrika*, i, p. 457.†† ROBERTSON, *Proc. Roy. Soc. Edin.*, vol. xxxi, pt. i.‡‡ BERRY, ROBERTSON, and CROSS, *Proc. Roy. Soc. Edin.*, vol. xxxi, pt. i, No. 2.§§ BOAS, *Amer. Anthropol.*, vol. i, p. 453.

lower margin of the orbit, to delineate on the tracing not only the line of the Frankfurt horizontal plane, but also to get the auricular height at right angles to that plane and the distance from the basion to the vault in a plane at right angles to it. In the 100 male skulls I was able to compare the basi-bregmatic height (Broca's) with this other height as used in Germany, and was able to convince myself that the two were practically identical in the group examined. In the great majority of the cases, in fact with the exception of a very few, the two measurements were exactly equal; in some cases there was a difference of a $\frac{1}{2}$ mm., and in only practically a negligible number of cases did the difference in the two heights equal 1 mm. in amount. So far as the present series goes, therefore, I see no reason why we should not regard the correlations of length and height and breadth and height in the Naquada and Scottish crania as truly comparable, the difference produced in the result due to the small difference in the heights being so small as to be of no account. It is worthy of note that HUXLEY (29) pointed out many years ago that the difference between the basi-bregmatic height and a more perpendicular height was not more than $\frac{1}{10}$ th of an inch on the average. Having obtained the auricular height by the method above noted, I was able to correlate this auricular height with the length, breadth, and basi-bregmatic height in 100 male skulls and thus get figures comparable with the Aino and German male results given by PEARSON and LEE (13).

The following table (XXXIX) shows the comparison:—

TABLE XXXIX.

Race.	Length and Auricular Height.	Auricular Height and Breadth.	Auricular Height and Basi-bregmatic Height.
	M.	M.	M.
Scottish (100)	$\cdot 45 \pm \cdot 053$	$\cdot 39 \pm \cdot 056$	$\cdot 69 \pm \cdot 034$
German (100)	$-\cdot 096 \pm \cdot 067$	$\cdot 072 \pm \cdot 067$	..
Aino (87)	$\cdot 501 \pm \cdot 054$	$\cdot 345 \pm \cdot 064$	..

For the same 100 skulls the other correlation coefficients were

Race.	Length and Basi-bregmatic Height.	Breadth and Basi-bregmatic Height.
Scottish	$\cdot 35 \pm \cdot 058$	$\cdot 19 \pm \cdot 064$

We see that, taking 100 male skulls, *i.e.* those with male characters well marked, the correlation coefficient of length and basi-bregmatic height is practically unaltered, while the correlation coefficient of breadth and basi-bregmatic height is slightly diminished in value. Taking the auricular height instead of the basi-bregmatic height to calculate the coefficient of correlation, we find that the auricular shows a distinctly higher correlation, with both the glabello-occipital length and the maximum breadth,

than the basi-bregmatic height does, and the increase is more marked in the case of auricular height and breadth than in the other.

Examining the above table of correlation coefficients, we find great diversity in their value and relationships. The first feature of the Scottish series that attracts our attention is the high correlation for these characters shown by the male compared with that by the female. The above fact is brought into greater prominence owing to the circumstance that, in the English Whitechapel series immediately underneath the Scottish series in the table (XXXVIII), the female is more highly correlated than the male for all these dimensions.

In this relationship of the correlation of the sexes for the above measurements the Scottish skull resembles the Aino, the Naquada, the Tasmanian, and the Australian; the French, in so far as length and breadth and length and height are concerned, also shows higher correlation coefficients in the male than in the female; while, as regards breadth and height, the two correlation coefficients are practically equal. In the German, on the other hand, the coefficients of correlation in the male for length, breadth, and height are very small compared with those in the female—in fact, in the case of the length and height in the male, the coefficient is negative.

Of the three pairs of characters in the Scottish series we observe that length and breadth has the highest coefficient and breadth and height the least, and this holds for both male and female.

In the English series the order of magnitude in the coefficients for both female and male is r_{LH} , r_{LB} , and r_{BH} , the first being greatest, but, as before mentioned, the coefficients for the female are in the case of all the pairs greater than for the male. So far as the results of the Scottish series go they would seem to support one of the conclusions of PEARSON and LEE that "correlation is more nearly equal for the two sexes in uncivilised than in civilised races," when the Aino is regarded as the type of the uncivilised race; but, in the case of length and height in the Tasmanian, and length and breadth in the Australian, the difference between the male and female coefficients is greater than in the corresponding pairs in the Scottish series.

With the second conclusion in PEARSON and LEE'S (13) memoir, "that woman tends with advance in civilisation to gain in correlation on man," the results supplied by the Scottish skulls appear to be in direct contradiction. According to PEARSON and LEE, their conclusions on this subject have been called in question by E. T. BREWSTER (35), but they say that his results are not to be relied upon owing to his series being extremely small and his treatment of them not being quite satisfactory. They find confirmation of the suggestions of their paper "On the Relative Variation and Correlation in Civilised and Uncivilised Races" in a "First Study of the Correlation of the Skull" (13).

PEARSON and LEE'S chosen representative of the civilised race is the German, and their conclusions are largely based on a comparison of other races with that type.

From an examination of the table of correlations of length and breadth, length and height, and breadth and height, we observe that in all cases, with the exception of length and height in the male German and length and breadth in the French female, the coefficients of correlation are positive; that in the case of each of these groups of skulls of different types where one of these dimensions increases, there is a distinct tendency for increase in the other which is correlated with it. In the case of the above two exceptions, moreover, the value of the negative correlation is hardly significant, considering the magnitude of the probable error; whereas in most of the other cases the positive coefficients are scarcely, if at all, significantly altered by the deduction of the probable error.

This series of Scottish skulls affords new proof that there is no scientific foundation for the theory usually defined as the "law of compensation." This was first enunciated by VIRCHOW (36), is firmly upheld by many anatomists, and, according to Professor THOMSON, has an important bearing on the growth of the cranium.

THOMSON (37) writes: "As that distinguished anatomist (VIRCHOW) has shown, among skulls belonging to the same type a breadth above the average is compensated for by a height and length below the average." This, according to THOMSON, "is also associated with a difference in the activity of the growth along the line of the cranial sutures as exemplified in the types of form described as scaphocephalic, thyrsocephalic, and trigonocephalic, where each variety is associated with premature synostosis of the sagittal, coronal, and mid-frontal sutures respectively. But this principle of compensation seems to act independently of these factors, and appears to be associated with the poise of the skull upon the summit of the vertebral column."

The evidence supplied by 405 male skulls and 100 female skulls of the same type is confirmatory of the contention that we do not find between the lengths and breadths of skulls in the same race a relation which is in accordance with the principle spoken of as that of "compensational growth." If one increases the other also increases. It is otherwise if, according to TSCHÉPOURKOWSKY (27), we take dolichocephalic and brachycephalic groups in the same race or such groups from different races, "If we pass from one race to another we find that with a growth of length there is a decrease of breadth, and *vice versa*. This arises from the fact that the most brachycephalic races have the greatest breadths and smallest lengths."

BOAS (26) seems to favour the intraracial "law of compensation" theory. He states that "when capacity is introduced into our consideration of the question a compensatory growth is found to exist between the breadth of the head on the one hand and height and length on the other." He also states: "If one of the diameters differs from the normal in being excessively large, the other will tend to be too small." This view is not supported by the correlation of these characters in series of skulls of the same type.

TABLE XL.
Correlations of Capacity, with Height, Breadth, and Length.

Race.	Capacity and Height.		Capacity and Breadth.		Capacity and Length.	
	M.	F.	M.	F.	M.	F.
Scottish . . .	$\cdot 56 \pm \cdot 024$	$\cdot 39 \pm \cdot 05$	$\cdot 73 \pm \cdot 017$	$\cdot 63 \pm \cdot 04$	$\cdot 69 \pm \cdot 017$	$\cdot 55 \pm \cdot 050$
English . . .	$\cdot 501 \pm \cdot 059$	$\cdot 600 \pm \cdot 049$	$\cdot 631 \pm \cdot 048$	$\cdot 646 \pm \cdot 044$	$\cdot 597 \pm \cdot 051$	$\cdot 691 \pm \cdot 040$
Naquada . . .	$\cdot 642 \pm \cdot 043$	$\cdot 519 \pm \cdot 046$	$\cdot 434 \pm \cdot 058$	$\cdot 532 \pm \cdot 044$	$\cdot 501 \pm \cdot 054$	$\cdot 599 \pm \cdot 039$
Aino . . .	$\cdot 544 \pm \cdot 054$	$\cdot 521 \pm \cdot 068$	$\cdot 561 \pm \cdot 053$	$\cdot 502 \pm \cdot 070$	$\cdot 893 \pm \cdot 016$	$\cdot 663 \pm \cdot 053$
German . . .	$\cdot 243 \pm \cdot 064$	$\cdot 451 \pm \cdot 054$	$\cdot 672 \pm \cdot 037$	$\cdot 706 \pm \cdot 034$	$\cdot 515 \pm \cdot 050$	$\cdot 687 \pm \cdot 037$
Sioux . . .	$\cdot 440 \pm \cdot 070$	..	$\cdot 67 \pm \cdot 05$	..	$\cdot 54 \pm \cdot 06$	..

For the 100 male skulls previously mentioned I calculated the correlation between the capacity and both the basi-bregmatic and auricular heights with the following result :—

Race.	Capacity and Height.	Capacity and Auricular Height.
Scottish (100)	$\cdot 58 \pm \cdot 045$	$\cdot 60 \pm \cdot 043$

From this table it is evident that the coefficient of correlation between capacity and basi-bregmatic height in the 100 male skulls is practically the same as the coefficient for the larger group of 405 male skulls. The coefficient of correlation between the auricular height and capacity is sensibly greater than between basi-bregmatic height and capacity, but only amounts to $\cdot 02$, with a probable error (the square root of the sum of the squares of the probable errors of the coefficients themselves) of $\cdot 06$, which is definitely greater than the difference, so that there is no real difference between the coefficients of correlation of capacity and the respective heights, basi-bregmatic and auricular, in this series of 100 skulls.

Examining the above table, we find that in the Scottish series in both male and female the maximum breadth and glabello-occipital length have each a distinctly higher correlation with capacity than has basi-bregmatic height, which latter dimension has, as stated above, a correlation with capacity practically equal to that of auricular height. Comparing the Scottish series with the English one, we observe that in the former the three correlation coefficients are higher in the male than the corresponding ones in the female, a condition that obtains in the primitive type, the Aino; whereas in the English series the opposite relationship holds, as it also does in the German. In fact, looking carefully at the table, there is seen to be a very close resemblance between the Scottish male coefficient and the corresponding German female coefficient: were we to change in each German pair the coefficients for the sexes, making the male female in all the three, we would be at once struck with the approach to equality exhibited by the corresponding coefficients. Again, there is a greater difference between the male and female coefficients in the Scottish series than

in the Aino series, which, unless my treatment of the series is "not entirely satisfactory," goes to disprove PEARSON and LEE's second conclusion, namely, "that woman tends with advance in civilisation to gain in correlation on man."

The comment of Dr LEE (*Phil. Trans.*, vol. cxcvi, A, 1901) on Dr F. BOAS' (26) statement to the effect that "the relation between capacity and head diameters is found to be of fundamental importance, and among these the relation of transversal diameter and capacity is more significant," is that she thinks it is only true for fairly brachycephalic races. He is dealing with 87 Sioux Indian skulls with a cephalic index of 79. Here we have a series of 405 Scottish skulls, with a cephalic index of 74·4—distinctly dolichocephalic,—and the correlation between capacity and breadth is definitely greater than that between capacity and length or height.

It would be comparatively easy from the data supplied in the above tables to construct a formula from the three absolute dimensions of the skull which would give the capacity in the Scottish type.

Let us now compare circumferences and capacity :—

TABLE XLI.

Race.	C and U.		C and Q.		C and S.	
	M.	F.	M.	F.	M.	F.
Scottish	.78±.013	.73±.032	.76±.041	.72±.032	.714±.039	.811±.026
English	.82±.026	.848±.021	.812±.027	.744±.034		
Naquada	.681±.040	.723±.030	.656±.042	.603±.039		
Theban mummies .	.813±.016	.826±.033	.788±.018	.673±.038		

Examining the above table, we observe that the coefficients of correlation for horizontal circumference and capacity and transverse arc and capacity are in the Scottish series in each case of greater value in the male than in the female, but that the two male coefficients are approximately equal, and that the two female coefficients are even more nearly so. The coefficients are smaller in value than the corresponding coefficients in the English series, except that the coefficient for transverse arc and capacity is approximately equal in both. There is a close resemblance between the correlation in the English series and that obtaining in the Theban mummies, while both show distinctly greater values for correlation coefficients than the Naquada.

In the English series the female is more highly correlated than the male with regard to C and U and C and S, whereas the opposite relationship is evident in regard to C and Q.

I have estimated the correlation coefficients for some absolute measurements for which I can obtain no comparative data. With regard to the correlations of minimum frontal breadth (B'), we have the following table :—

TABLE XLII.

Race.	B' and L.		B' and B.		B' and H.		B' and C.	
	M.	F.	M.	F.	M.	F.	M.	F.
Scottish	$\cdot 37 \pm \cdot 056$	$\cdot 24 \pm \cdot 064$	$\cdot 39 \pm \cdot 056$	$\cdot 26 \pm \cdot 061$	$\cdot 28 \pm \cdot 061$	$\cdot 23 \pm \cdot 064$	$\cdot 42 \pm \cdot 056$	..

Here again we observe that the correlation between the characters in the male is higher than that between the corresponding characters in the female. It is evident that the correlation between minimum frontal breadth and maximum length is approximately equal to that between minimum frontal breadth and maximum breadth, while both are slightly greater than that between minimum frontal breadth and height and slightly less than that between minimum frontal breadth and capacity. In the female the three correlation coefficients are practically identical. I calculated these correlation coefficients in the male skulls in order to compare them with the corresponding coefficients obtaining in the metopic male skulls, in the hope that some light might be thrown on the condition of metopism, but I shall refer to this subject in a later paper.

It was pointed out earlier in the present communication, when comparing the relative lengths of the three components, frontal, parietal, and occipital, of the sagittal arc, that these varied very much, and that, according to TURNER and CLELAND, their relative lengths being so variable they could not be regarded with any degree of certainty as having either a racial or a sexual significance. According to TURNER also, the variability was as great in the brachycephalic type as in the dolichocephalic type.

The question as to whether there was a difference in their relationship to one another has engaged the attention of other anatomists, and the idea occurred to me that the correlation of these dimensions might throw some light on the subject. To that end I calculated the correlation coefficients between each segment and the total arc in 405 male skulls and in 100 female skulls, and the coefficients of each of the segmental arcs with the greatest length, and the results are not without interest. They are included in the table below :—

TABLE XLIII.

Race.	Frontal Arc and Total Arc.		Parietal Arc and Total Arc.		Occipital Arc and Total Arc.	
	M.	F.	M.	F.	M.	F.
Scottish (400 M., 100 F.)	$\cdot 73 \pm \cdot 017$	$\cdot 57 \pm \cdot 048$	$\cdot 53 \pm \cdot 025$	$\cdot 54 \pm \cdot 050$	$\cdot 77 \pm \cdot 013$	$\cdot 50 \pm \cdot 050$

We observe from the table that, in the case of the male, the coefficients for frontal segment and total arc and occipital segment and total arc are greater than the corresponding coefficients in the female; while, in the case of the parietal arc, the coefficients for male and female are practically equal, taking into consideration the greater probable error in the case of the latter. Of these coefficients the greatest of all is that between occipital arc and total arc, this being slightly greater than that for frontal arc and total arc, which implies a slightly greater tendency on the part of the occipital arc to increase corresponding to an increase in the sagittal arc than is shown by the frontal arc. The coefficient of the parietal arc and total arc is distinctly less than that of the other two segments with the total arc.

I then correlated the frontal, parietal, and occipital arcs with the maximum glabello-occipital length in 100 male ("K" group) and in 100 female skulls, and the results show a definite relationship between these measurements to obtain in the Scottish series under examination. The results are included in the following table:—

TABLE XLIV.

Race.	Frontal Arc and Maximum Length.		Parietal Arc and Maximum Length.		Occipital Arc and Maximum Length.	
	M.	F.	M.	F.	M.	F.
Scottish (100 M., 100 F.)	$\cdot 47 \pm \cdot 05$	$\cdot 27 \pm \cdot 06$	$\cdot 36 \pm \cdot 05$	$\cdot 38 \pm \cdot 05$	$\cdot 61 \pm \cdot 04$	$\cdot 46 \pm \cdot 05$

In the first place, the correlation coefficients are in all cases smaller than those between the segments of the arc and the total arc, as was to be expected. In the case of the frontal and occipital correlations with the maximum length the coefficients are distinctly greater in the male than in the female, whereas in the case of parietal arc and maximum length the coefficient for the male is approximately equal to that in the female. As is seen from the table, the correlation coefficients, in the case of the occipital arc for both sexes, are distinctly greater than the corresponding coefficients for the other arcs and greatest length. It would not have been so surprising had the parietal arc shown the highest correlation with the greatest length, but it does seem somewhat anomalous that the occipital, whose whole length does not take part in the formation of that portion of the sagittal arc which forms the arc of the glabello-occipital chord, should show the highest correlation with the aforesaid chord. Unfortunately, there are no comparative figures for other races, but so far as these figures go they seem to show that in the Scottish series, when the greatest length of the skull is increased, there is a definitely greater tendency in the male for the occipital to increase in proportion; and that the parietal shows, of the three segments, the smallest tendency to increase under such circumstances. In the female, with increase of glabello-occipital length the occipital arc again shows the greatest tendency to increase proportionately, while the frontal shows the least tendency to increase. As

before mentioned, the tendency of the parietal to increase when the glabello-occipital length increases is approximately equal in the two sexes.

Amongst other correlations I have calculated for the Scottish series those for cephalic and vertical indices and cephalic index and capacity, and they are embodied in the table below:—

TABLE XLV.

Race.	Capacity and Cephalic Index.				Cephalic Index and Vertical Index.			
	No.	M.	No.	F.	No.	M.	No.	F.
West Scottish . .	405	$\cdot 091 \pm \cdot 033$	97	$\cdot 15 \pm \cdot 065$	405	$\cdot 301 \pm \cdot 03$	100	$\cdot 316 \pm \cdot 061$
" " K . .	100	$- \cdot 013 \pm \cdot 06$	..	..	100	$\cdot 211 \pm \cdot 064$		
German	100	$\cdot 202 \pm \cdot 0647$	97	$- \cdot 0307 \pm \cdot 0677$				
Aino	76	$- \cdot 3069 \pm \cdot 0701$	52	$- \cdot 2466 \pm \cdot 0878$				
Thebans	187	$- \cdot 1480 \pm \cdot 0482$	84	$\cdot 0080 \pm \cdot 0736$				
Modern Egyptians .	56	$- \cdot 1410 \pm \cdot 0883$	23	$- \cdot 4960 \pm \cdot 1060$				
Male French . . .	56	$\cdot 1437 \pm \cdot 0883$						
Male Malays . . .	76	$\cdot 0331 \pm \cdot 0773$						
Etruscans	78	$\cdot 2157 \pm \cdot 0729$	38	$\cdot 1443 \pm \cdot 1071$				

Analysing the above table, there seems to be great diversity in the value of the correlation coefficient, so much so that Dr LEE (13), from whose valuable paper most of them have been derived, applies the term "erratic" to describe its unstable and variable character.

It will be seen that I give in Table XLV two coefficients of correlation for the male skulls, one for a group of 100 and the other for one of 405. First of all, I calculated the coefficient for the 100 whose mean cephalic index was 74·4, and found that it was negative in value, but that the number was so small compared with its probable error as to be practically negligible. I then calculated the coefficient for the whole 405 male skulls with the same cephalic index, and found that a positive coefficient was the result and that the coefficient was sensibly greater than its probable error. The latter coefficient should be more reliable than the former, and we may take it as definitely representing the correlation between the cephalic index and capacity in the West Scottish male series rather than the former, which is derived from a smaller number of skulls.

The conclusion that one may draw from this positive correlation, even though it is small, is that in this Scottish series a tendency to brachycephaly is associated with a tendency to greater capacity.

There would appear to be some doubt, therefore, in regard to Dr LEE's conclusion on this subject, *i.e.* "On the whole, I think, we must conclude that, while there is only a small relationship between cephalic index and capacity, yet that in brachycephalic races greater roundness points to greater capacity and in dolichocephalic

racess less roundness points to greater capacity. In either case the emphasis of the racial character denotes an increase of capacity." Here in the Scottish series we have a dolichocephalic group consisting of at least four times the number of specimens of any series on which Dr LEE's conclusions are based where, if the accuracy of the calculation of the coefficient is to be relied upon, we have a decrease in the emphasis of the racial character accompanying an increase in capacity. Dr LEE gives figures for three fairly brachycephalic races (3 male and 1 female) in which the correlation is positive, denoting increased capacity associated with increase in the magnitude of the index. Dr LEE admits, however, that in three of the cases the correlation is so small that it is hardly sensible considering the size of the probable errors.

There is apparently need, therefore, for revision of the statement that "there appears to be little doubt that in dolichocephalic races those who possess the race character most markedly have the greater skull capacity."

The mean cephalic index for the male Aino, from which Dr LEE's coefficients were calculated, was 76.5, and for the female 77.4. For the female Scottish group of 100 the mean cephalic index was 76.03, practically equal to that of the male Aino and more dolichocephalic than the female Aino; yet we find in the case of the Scottish female a positive correlation between capacity and cephalic index, and in both male and female Aino distinctly negative coefficients. The female German skull, as brachycephalic as the male, shows a negative correlation coefficient which, however, is hardly sensible considering the magnitude of the probable error.

The results certainly are very erratic, and at present, if the Scottish results are reliable, too unstable to warrant conclusions regarding the relation of brachycephaly and dolichocephaly to capacity.

THOMSON (37) claims to have demonstrated in a most forcible way with his "elastic capsule arrangement" the gradual transition from the dolichocephalic to the brachycephalic type which accompanies increased cranial expansion, and states that "it seems absurd after this exhibition of the influence of internal pressure to discuss the independent origin of the dolichocephalic and brachycephalic types." He states further that "the modification in shape consequent on an increase of the bulk of the encephalon will tend towards sphericity: in other words, the cranium will become rounder." This is in direct opposition to PEARSON and LEE's conclusion, which is, as stated above, that an emphasis of the dolichocephaly in a skull of that type is associated with increased capacity.

In our large male series, however, there is a positive correlation, though it is very small, between cephalic index and capacity, which shows that in that series there is a very slight tendency towards brachycephaly, associated with increase in capacity.

Amongst the skulls that comprise our Scottish collection is one specimen of very large size, well formed, and remarkable in appearance only in so far that the facial part seems smaller than it normally does owing to the brain-box being so large. It may have been the seat of a hydrocephalic condition at an earlier stage, but of that

there is no evidence now, and the walls are of average thickness. The norma verticalis presents an elongated elliptical form and the cephalic index is 74·5. I had not enough shot to estimate the capacity in the usual way, as after the introduction of fully 1950 c.c. there was still left a considerable space to be filled, but I was able to calculate the capacity by using LEE'S formula, and found it to be well over 2050 c.c. It thus seems possible for a skull from a dolichocephalic group to attain to the above capacity without in any way "tending towards sphericity." If future stages of evolution therefore should be characterised by an increase in the cranial capacity, it would seem that this end is attainable in a dolichocephalic type of skull without a necessary change in the prevailing form of the latter. There would seem to be some factors exercising an influence over skull form when the capacity is increased which are not demonstrable by the aid of a "mechanical appliance." The shape of this large skull is proof of such an influence, at least till the skull capacity reaches 2000 c.c.

I have also calculated the correlation existing between several of the indices, namely, $100 \frac{B}{L}$ with $100 \frac{H}{L}$; $100 \frac{L}{H}$ with $100 \frac{B}{H}$; and $100 \frac{H}{B}$ with $100 \frac{L}{B}$.

As has been pointed out by PEARSON (23), even though there is no correlation between the absolute measurements taken in pairs, in arranging them in the above manner and correlating two indices with the same denominator a form of correlation exists to which he applies the term "spurious correlation," and suggests that this correlation value should be deducted from the whole value or gross correlation obtained by correlating the indices in the usual way to get the real measure of correlation between those indices or what is called "organic correlation."

Having found it somewhat arduous to calculate the correlation between indices by the method, said to be the most reliable, of multiplying the deviation from the means in pairs and summing the products (which requires to be done over 400 times in each calculation in the male group), and then applying the requisite formula to obtain the coefficient of correlation, I decided to apply the formula which KARL PEARSON has provided for calculating the coefficient of correlation between indices with the same denominator in terms of the coefficients of correlation and coefficients of variation of the three absolute measurements. I had already calculated the coefficient between the cephalic and vertical indices by the previous method, and found, as stated in a former table, that the coefficient had a value in the male of $\cdot301 \pm \cdot030$ and in the female of $\cdot316 \pm \cdot061$. By the formula above mentioned the values obtained were $\cdot302$ and $\cdot317$ respectively, quantities practically identical with those obtained by the other method. I applied the formula to find the correlation existing between the $\frac{B}{H}$ and $\frac{L}{H}$ indices and the $\frac{H}{B}$ and $\frac{L}{B}$ indices, and also calculated the spurious correlation values. The results are arranged in the following table, with corresponding values from other races for comparison.

TABLE XLVI.

Race.	$\frac{B}{L}$ and $\frac{H}{L}$.					
	M.			F.		
	No.	Gross Correlation.	Spurious Correlation.	No.	Gross Correlation.	Spurious Correlation.
Scottish series . . .	405	$\cdot 302 \pm \cdot 030$	$\cdot 428 \pm \cdot 028$	100	$\cdot 317 \pm \cdot 061$	$\cdot 320 \pm \cdot 061$
English „ . . .	114	$\cdot 439 \pm \cdot 051$	$\cdot 419 \pm \cdot 052$	108	$\cdot 391 \pm \cdot 055$	$\cdot 494 \pm \cdot 049$
French „ . . .	860	$\cdot 489 \pm \cdot 018$	$\cdot 464 \pm \cdot 019$	340	$\cdot 576 \pm \cdot 025$	$\cdot 477 \pm \cdot 028$
Naquada „ . . .	130	$\cdot 284 \pm \cdot 054$	$\cdot 432 \pm \cdot 048$	166	$\cdot 371 \pm \cdot 046$	$\cdot 438 \pm \cdot 043$
$\frac{B}{H}$ and $\frac{L}{H}$.						
Scottish series . . .	405	$\cdot 670 \pm \cdot 020$	$\cdot 48 \pm \cdot 025$	100	$\cdot 656 \pm \cdot 043$	$\cdot 607 \pm \cdot 043$
English „ . . .	114	$\cdot 580 \pm \cdot 042$	$\cdot 598 \pm \cdot 041$	108	$\cdot 581 \pm \cdot 043$	$\cdot 559 \pm \cdot 044$
French „ . . .	860	$\cdot 419 \pm \cdot 020$	$\cdot 527 \pm \cdot 017$	340	$\cdot 417 \pm \cdot 030$	$\cdot 541 \pm \cdot 026$
Naquada „ . . .	131	$\cdot 595 \pm \cdot 038$	$\cdot 603 \pm \cdot 037$	163	$\cdot 527 \pm \cdot 039$	$\cdot 552 \pm \cdot 037$
$\frac{H}{B}$ and $\frac{L}{B}$.						
Scottish series . . .	405	$\cdot 49 \pm \cdot 025$	$\cdot 48 \pm \cdot 025$	100	$\cdot 507 \pm \cdot 050$	$\cdot 514 \pm \cdot 050$
English „ . . .	114	$\cdot 478 \pm \cdot 049$	$\cdot 478 \pm \cdot 049$	108	$\cdot 522 \pm \cdot 047$	$\cdot 444 \pm \cdot 052$
French „ . . .	860	$\cdot 586 \pm \cdot 016$	$\cdot 508 \pm \cdot 018$	340	$\cdot 503 \pm \cdot 027$	$\cdot 482 \pm \cdot 028$
Naquada „ . . .	131	$\cdot 601 \pm \cdot 037$	$\cdot 459 \pm \cdot 046$	163	$\cdot 594 \pm \cdot 035$	$\cdot 508 \pm \cdot 040$

It will be observed that the value for spurious correlation has the same sign as that for gross correlation and sometimes equals, sometimes exceeds, the latter in value in the Scottish as in the other series. The coefficient of correlation (gross) between $\frac{B}{L}$ and $\frac{H}{L}$ being positive in the Scottish series shows that in this, as in the English, French, and Naquada groups, a tendency to brachycephaly is associated with a tendency to hypsiccephaly.

It would appear that neither the opisthio-nasal length (CLELAND'S base line) nor the transverse base in a series of skulls is entirely independent of the magnitude of the capacity, as is generally believed. In the female series of 100 I calculated the coefficients of correlation between these two base lengths and the cubage and found that in the former case the value of the coefficient was $\cdot 38 \pm \cdot 056$, and in the latter $\cdot 26 \pm \cdot 061$, showing that there is a tendency, in the female series at least, on the part of both of these diameters to increase when the capacity increases. In the male series of 100 skulls I also found that the coefficient of correlation between the basi-nasal length and the maximum length of the skull was $+ \cdot 60 \pm \cdot 043$, so that there is a distinct tendency shown for the former to increase when the latter increases.

The feature that attracts our attention in a survey of the coefficients of correlation in the foregoing tables, apart from the diversity shown in the values in different races, which is very marked indeed, is the fact that the coefficients between the magnitudes of various skull characters, with a few exceptions, *i.e.* principally when cubic capacity is one of the quantities involved, as has been pointed out by MACDONNELL, are almost invariably of comparatively small value. When we recollect the close approximation to unity shown by the correlation coefficients of the bones of the extremities—for example: right and left femur, '96; femur and humerus, '84; femur and tibia, '81; humerus and ulna, '75-'86,—this fact is brought into greater prominence.

The comparatively low value on the whole of the coefficients in the Scottish series points to the infinite variety of minor differences in, or refinements of, skull form that may exist in such a homogeneous dolichocephalic series as the present one, because it is possible apparently to have an alteration in a certain dimension with only a comparatively slight, though in most cases sensible, tendency to a corresponding increase in another dimension.

The divergence shown in the coefficients of correlation between certain skull characters in different types or races shows to what a small extent it is legitimate, in the present state of our knowledge, to apply conclusions drawn from the evidence supplied by one series of skulls to the building up of suggestions or laying down of laws as to what may have been the original form of certain defective parts of pre-existent or fragmentary skulls, which at the present day forms the basis of most of the schemes for the reconstruction of skulls.

3. KLAATSCH'S "CRANIOTRIGONOMETRICAL METHOD."

Having completed the study of the Scottish skull by the recently introduced biometric methods, in so far as I have been able to do so with the measurements and time available, I have applied the scheme for the examination of skulls devised by KLAATSCH to the "K" series in order to see if any fresh features would be brought to light by its use, and to try to form an estimate as to the value of the method. In this connection I have again found it convenient, in fact necessary, to utilise biometric constants in establishing a contrast between the Scottish skull and other types.

The method introduced and made use of by KLAATSCH is not entirely new, as some of the chords and angles included in the scheme have been utilised by other investigators, including CUNNINGHAM, SCHWALBE, and TURNER, and KLAATSCH himself admits that it is merely a continuation or extension of the pioneer research of VON LISSAUER on the "*norma sagittalis*"; but the complete scheme of examination is distinctly original, and since its introduction has been known as KLAATSCH'S "*craniotrigonometrical method*."

The following is a brief account of the procedure adopted in utilising this scheme:—

A median sagittal outline tracing of the skull, previously centred and oriented in the glabella-lambda horizontal plane, is obtained, and on this outline are marked carefully the positions of the glabella, bregma, lambda, inion, basion, and prosthion. In this method KLAATSCH adopts the glabella-lambda line as his base line, and explains at great length in his paper why he does so. This explanation I will discuss later. Within the outline tracing a quadrilateral figure is devised (fig. 7) with its angles situated at the glabella, bregma, lambda, and basion respectively, and this polygon is divided by the two diagonals being inscribed into four triangles almost invariably right-angled at the centre of the figure according to KLAATSCH; as the latter dis-

FIG. 7.—Median sagittal tracing of skull No. 26, series K, showing the inserted quadrilateral figure on the sides of which triangles are erected. The values of the various dimensions in this skull are approximately equal to the mean values for the complete series. (For lettering see fig. 8.)

covered in his experimental examination of skulls, and as he first explained at the Berlin Anatomical Congress, that the angle which the two lines form with one another is either a right angle or shows a deviation of only a few degrees from that value. The point of intersection he named the central point or zentrum. The triangles so formed are known as the inner triangles, and are numbered I, II, III, and IV in fig. 8. On the four sides of the quadrilateral figure as bases are erected triangles which are named the frontal, the parietal, the chief occipital, and the upper facial; the chief occipital with its vertex at the inion, the upper facial with its vertex at the prosthion, and the frontal and parietal with their vertices on the corresponding arcs at the points on those most distant from the frontal and parietal chords respectively. On the lambda-inion line as base another triangle is erected with its vertex at the point on the lambda-inion arc most distant from the lambda-inion chord. This triangle is named the adjacent occipital triangle. Perpendiculars are dropped from the vertices

of the frontal, parietal, and adjacent occipital triangles to the bases of these triangles, and another perpendicular is dropped from the prosthion on the lambda-glabella line, continued forwards, meeting the latter at the point Pr.

The lengths of the various lines and chords composing the figure so devised and the magnitudes of the various angles are carefully estimated and noted, and an analysis of the whole system of lines and angles comprises what is known as KLAATSCH's "craniotrigonometrical method" for the study of the skull. In applying the method to the group of 100 male skulls I have made use of the dioptrograph to

FIG. 8.—Outline of skull No. 13 of series K. This skull shows the highest value for the angle at the zentrum, *i.e.* 100°. Note the relatively long glabella-bregma and relatively short glabella-basion chord.

G. Glabella.	I, II, III, IV. Inner triangles.	Br.Z.G. Zentral angle.
Br. Bregma.	V. Frontal triangle.	Br.G.Z. Upper glabella angle.
L. Lambda.	VI. Parietal triangle.	Br.G.Ba. Cranial glabella angle.
I. Inion.	VII. Chief occipital triangle.	G.Br.L. Bregma angle.
Ba. Basion.	VIII. Adjacent occipital triangle.	G.Ba.L. Basion angle.
P. Prosthion.	IX. Upper facial triangle.	Br.L.Ba. Lambda angle.
Z. Zentrum.		

obtain the median sagittal tracings necessary, the skulls being previously carefully oriented and centred. The various points required having been marked on the tracings, the quadrilateral figure, the triangles and the various perpendiculars were drawn as above described. The lengths of the various chords and their segments were measured and the values of most of the angles noted. The angles of the polygon were named by KLAATSCH, each from the point where its apex lay, that no confusion could arise—as does happen in SCHWALBE's scheme,—and the position of these angles will be readily understood from fig. 8.

From a superficial examination of the method, one would think that the measurements are so numerous and so varied that one should be able to make a minute and detailed examination of the difference between any two skulls or skulls typical of

different races. Several points of interest, as we shall see later, have been brought to light during the examination of the results.

The only large series of skulls to which the method has been accurately applied, and of which the measurements are available, is, so far as I am aware, that of 52 Tasmanian crania by BÜCHNER (11); of these, about 30 were those of males, and he has selected and recorded 27 different measurements in each skull. It is between the measurements of this group of Tasmanian skulls and those of the series examined by myself that I have instituted a comparison to see how the application of the method will bring out the characteristic features of each type, but I shall also refer to the measurements recorded by KLAATSCH of an Australian, a European, and various other specimens as figured and contrasted by him, and certain measurements of the Tasmanian and Australian given by TURNER in his memoirs, as well as certain other measurements, which I have obtained from FALKENBURGER (41), from BOLK (42), and from BERRY and ROBERTSON's atlases (40 and 40A), of dioptrographic tracings of series of Tasmanian and Australian crania.

It will be observed that the types compared—West Scottish, Tasmanian, and Australian—are all of the dolichocephalic type, and the special interest of the inquiry in this and the next section came to be the answer to the question, What are the morphological differences in the cranial vault of a dolichocephalic skull of high status and one of low status in civilisation?

It will be seen that the general shape of the quadrilateral figure inscribed within the more or less elliptical outline of the sagittal tracing of the skull will be influenced by the altitudinal index; when the minor axis or height of the polygon is diminished in relation to the major axis or length, then the internal angles at its extremities are correspondingly increased, while those near the extremities of the major axis are diminished in magnitude.

Examining first of all the angles of the figure devised within the outline tracing, and beginning with the zentrum angle, or the angle open upwards and forwards and with its apex at the point of intersection of the diagonals of the quadrilateral, we find that in BÜCHNER's series of 25 male Tasmanian crania it varies from 85° to 93.5° , with a mean value of 89.3° . In 9 of these skulls the angle is exactly 90° , 13 of the skulls show a zentrum angle under 90° in value, and only 3 an angle over 90° . The coefficient of variation of the angle is 1.92. KLAATSCH describes the angle as being almost invariably 90° in the Australian skulls examined by him by this method, and figures one with that value in his paper above mentioned, as well as a European skull which shows an angle at the zentrum of the same value. WETZEL (44) did not find the rule invariable in the Australian skulls examined by him. In 2 very typical Australian skulls examined by me the angle was exactly 90° in each case.

I have been enabled recently to estimate the size of the zentrum angle in the larger series of 90 unsexed Australian crania figured in BERRY and ROBERTSON's atlas

of dioptrographic tracings, and find that the angle varies in value from 84° to 94° , with a mean value of 89.45° ; 19 of the specimens have an angle exactly 90° in value, and 27 have an angle greater than 90° . In BÜCHNER's complete series of 40 Tasmanian skulls, including male and female, like the above Australian group, the zentrum angle ranges in value from 85° to 94.5° , with a mean value of 89.6° ; 14 specimens have an angle exactly 90° , and 9 are over 90° in value.

BOLK (42), from an examination of 70 skulls (of which the race is not stated), has found that the angle which the basion-bregma line forms with the glabella-lambda line varies between 84° and 98° . The top of the variation curve lies at 90° (*i.e.* in 17 cases out of 70). He further states, however, that "the angle formed by the basion-bregma and the glabella-inion lines is almost as constantly found at 112° (14 cases out of 70)." In the present series of 100 the angle that occurred most frequently between the last two lines was 107° , and it was found in fifteen instances. The coefficient of variation of the angle was 2.95.

FALKENBURGER (41), from an examination of a series of deformed Peruvian and Mexican skulls, was able to convince himself that this perpendicular relationship of the basion-bregma to the glabella-lambda line was prevalent also in such skulls; the variation of the angle occurring in these skulls was about equal to that found in series of normal skulls.

In the series of 100 Scottish skulls examined I find that the zentrum angle shows a range of variation from 87° to 100° , with a mean angle of 92.5° ; the angle most frequently found is 91° , and it occurs 21 times. The coefficient of variation of the angle is 2.79. The angle is 90° exactly in 11 per cent. of the skulls, 10 per cent. only are under 90° , while the remainder, or 79 per cent., show an angle greater than 90° .

In the Tasmanian and Australian series, therefore, the tendency for the angle to be less than 90° is marked, while in the Scottish series the tendency for the angle to be over 90° is still more evident. A comparison of the coefficients of variation shows that, as regards this angle, the Scottish skull is slightly more variable than the Tasmanian.

From an analysis of the measurements in my series of 100 skulls I find that the magnitude of the angle at the zentrum may be considered to depend on several variable factors:—

1. The length of the glabella-bregma chord.
2. The length of the glabella-basion chord.
3. The size of the upper glabella angle.

There is a very close relationship between the tendency towards increase in size of the upper glabella angle and the tendency towards decrease in the zentrum angle. The relative lengths of the glabella-bregma and glabella-basion chords have also a close relationship with the size of the zentrum angle, a long glabella-bregma chord associated with a short glabella-basion chord tending to increase the angle, and *vice*

SCHWALBE's angle, according to SOLLAS (46), is determined by three factors :—

1. The choice of a base line.
2. The angular position of the bregma.
3. The altitudinal index of the skull.

All three combine to give it a low value in the Australian skull and in the Neanderthal group.

For SCHWALBE's angle or the bregma angle, TURNER gives for Scottish skulls, 6 in number, a variation of 54° – 58° , with a mean of 56° ; for Tasmanian, 7 in number, a variation of 54° – 60° , with a mean value of 57.1° . KLAATSCH gives for Tasmanians, 8 in number, a variation of 54° – 59° , with a mean of 57.3° ; BERRY gives for unsexed Tasmanians, 45 in number, a variation of from 51.5° to 64° , with a mean of 56° . In this Scottish series of 100 there is a variation of from 50° to 63° , with a mean of 56.33° ; for the Australian KLAATSCH gives a variation of from 51° to 62° , with a mean value of 57.5° . The Scottish skull thus shows a lower value than the Tasmanian, according to TURNER's figures, whereas, according to the figures derived from the larger numbers, the Tasmanian and the Scottish show a practically identical mean angle, while the Australian shows the highest value. SOLLAS (46), however, gives for the Australian an angle of 48.3° , which is lower than the Scottish mean angle and is the position one would *a priori* expect the Australian to occupy, and this is confirmed by BERRY's results (59) for a series of 100 Australian crania (unsexed). In this the bregma angle varies from 49° to 60° , with a mean value of 54.7° .

TURNER (47), making use of the nasi-tentorial plane to avoid the variability in the glabella, found in his examination of the angle between the nasi-bregmatic and nasi-tentorial lines that the Australians showed the highest angle, the Tasmanians the smallest, and the Scottish an angle intermediate in value.

BERRY's dioptrographic tracings have permitted me to estimate the upper glabella angle in 90 Australian crania, and its mean value in this long series was practically equal to that shown in BÜCHNER's complete series of Tasmanian skulls, while the mean angle in the Scottish series was lower in value to the extent of 2° . With a more sloping frontal bone we would have expected, as KLAATSCH believed to be the case, that the angle above mentioned would be smaller in the Australian than in the European (as represented by the Scottish skull).

SCHWALBE's view regarding the elevation of the frontal bone, where its upper border is said to move upwards and forwards in modern, as compared with palæolithic, man, the resulting displacement of the bregma and more vertical direction of the frontal bone, has been criticised by CUNNINGHAM (48), who raised several objections to the bregma angle :—

1. Because the glabella was so variable.
2. Because the upper end of the frontal was affected by changes in the other bones of the vault independent of those due to elevation or depression of the frontal bone.

According to CUNNINGHAM (48), different degrees of extension of the parietal and occipital regions, as well as differences in the growth of the frontal area, modify the position of the bregma. The difference in growth of the frontal region, as we shall see later, is brought out in the Scottish series examined by comparing the mean glabella-bregma chord found therein with those found in the Australian and Tasmanian types, and I believe that this difference in growth has an influence on the size of the zentrum angle, while, at the same time, as will be demonstrated later on, growth of the occipital region of the vault is an important factor, not only as affecting the zentrum angle, but also the relative positions of the bregma, and of the lambda, and the size of the upper glabella angle.

The mean value of the upper glabella angle in the Tasmanian is greater than in the Scottish skull, and the glabella-bregma length is considerably shorter on the average in the former than in the latter. The result of these various factors is that the zentrum angle in the Scottish skull is on the average greater than in the Tasmanian skull.

In the Australian skull, as calculated from the series of 90 dioptrographic tracings, the mean glabella-bregma line is relatively shorter than the glabella-basion line, the upper glabella angle is practically equal to that in the Tasmanian, and these factors apparently so balance one another that the mean zentrum angle is approximately equal in the two complete series, namely, 89.45° in the Australian and 89.6° in the Tasmanian.

It is interesting to note in connection with this angle that in the skulls of the anthropoid apes of different ages as figured in median outline by KLAATSCH, with the basion-bregma and glabella-lambda horizontal lines inserted, at an early age in the chimpanzee and orang-utan the zentrum angle is 89° and 90° respectively, thus approaching the angle found in the human subject; the younger the animal the closer is the approximation in the angle, while in the young gorilla it is 84° . With increasing age the basion-bregma line slopes more and the upper end moves forward relatively to the lower end (KLAATSCH), so that the zentrum angle is considerably smaller in the adult than at an earlier stage. The explanation of the alteration in the size of the angle is, without doubt, that it is due largely to the displacement backwards of the foramen magnum and so of the basion, the mid-point of its anterior margin, that takes place in all primates, including man, in their passage from the juvenile to the adult stage, and which is due to the increase in length of the basi-sphenoid and basi-occipital that takes place at that time (BOLK).

Another factor that undoubtedly influences the size of the angle at different ages is the fact that, as pointed out by CLELAND (49), "the base line continues to elongate after the arch has acquired its permanent characters," which is fully confirmed by a comparison of the juvenile and adult skulls in the present collection.

It is found that the chimpanzee shows the largest zentrum angle when it has reached the adult state and is considerably larger than that found in the gorilla and

orang. It is generally agreed that of the members of the anthropoid group the chimpanzee stands nearest to man, *i.e.* is man's nearest relative. It would seem therefore that from the relative size of the zentrum angle we may arrange the groups we have considered in an ascending series as follows:—

1. Adult anthropoids $\left\{ \begin{array}{l} \alpha. \text{ Gorilla and orang-utan.} \\ b. \text{ Chimpanzee.} \end{array} \right.$
2. Juvenile anthropoids.
3. Tasmanians and Australians.
4. Scottish.

The tendency for the zentrum angle to be greater than 90° in the last series is apparently evidence of the higher morphological status of the Scottish skull than that of the Tasmanian and the Australian.

BERRY (50) was at first of the opinion that the Australian stood on the "evolutionary plus" side of the Tasmanian, but has since come to the conclusion (59) that the reverse relationship holds. While there is not a great difference between the mean zentrum angles in the Tasmanian and Australian complete series, it is noteworthy that the angle in the latter is on an average less than in the former.

KLAATSCH refers to the angles at the glabella as the most important angles of the quadrilateral figure, and refers to the different values of the two component parts of the complete or cranial-glabella angle, in the Australian and European specimens figured by him.

In the Tasmanian series the cranial-glabella angle varies from 69° to 80° , with a mean value of 74.7° , S.D. 2.84, V. 3.80. The mean angle in the Australian series of 90 (unsexed) is 74.92° , the range is from 68° to 83° , and the standard deviation is 3.13. In the Scottish series the angle varies from 67° to 80° , with a mean of 74.4° , S.D. 2.72, V. 3.65. The mean values of the angles in the three types are thus approximately equal, while the angle in the Scottish series is less variable than in the Tasmanian, and considerably less variable than in the Australian.

With regard to the components of the cranial-glabella angle, we find that in the Tasmanian series the upper glabella angle varies from 34° to 44° , with a mean of 37.9° , S.D. 2.26, V. 5.9; the lower component varies from 31° to 44° , with a mean value of 36.8° , S.D. 2.86, V. 7.77. In the Scottish series the upper component varies from 32° to 42° , with a mean of 35.9° , S.D. 1.99, V. 5.54; the lower component varies from 31° to 44° , with a mean of 38.5° , S.D. 2.63, V. 6.84.

In the Tasmanian series of skulls the upper glabella angle is thus, on an average, larger than the lower glabella angle, whereas in the Scottish series the reverse is the case; the upper component of the cranial-glabella angle being on an average smaller than the lower, and so approximating to the condition found in the Australian figured by KLAATSCH, and also to that of an Australian measured by myself. It may be shown thus:—

An Australian skull (KLAATSCH)	{	Upper angle, 33.
	{	Lower „ 40.
Another Australian skull	{	Upper angle, 34.
	{	Lower „ 39.

From an examination of a larger series of Australian skulls, however, it has been shown, as was previously mentioned, that the upper glabella angle was approximately equal in the complete Australian and Tasmanian series, and that in the Australian, as in the Tasmanian, the mean upper glabella angle is greater than the mean lower glabella angle (*vide* table).

If we examine the two components of the cranial-glabella angle as regards variability, we find that the upper glabella angle shows for the Tasmanian a S.D. of 2.26 and a V. of 5.9, and for the Scottish a S.D. of 1.99 and a V. of 5.54; while the lower glabella angle gives for the Tasmanian a S.D. of 2.86 and a V. of 7.77, and for the Scottish a S.D. of 2.63 and a V. of 6.84. In both upper and lower glabella angles the variability is greater in the Tasmanian than in the Scottish, and in both Tasmanian and Scottish series as well as the Australian the variability in the lower angle is greater than that in the upper angle, which is exactly contrary to what one would have expected. The Australian is most variable of the three in the upper angle and least variable in the lower angle.

The lambda angle in the Tasmanian series varies from 64° to 75°, with a mean of 69°, S.D. 2.73, V. 3.95; in the Scottish series from 62° to 76°, with a mean of 68.34°, S.D. 2.84, V. 4.15; in the Australian series from 64° to 78°, with a mean value of 70.12°, S.D. 2.98. The variability of the angle is thus slightly greater in the Scottish series than in the Tasmanian series, while the angle is on an average so little less in the former than in the latter that they may be considered practically equal. The angle is slightly greater in the Australian than in the other two types, and shows the greatest variability of the three.

The basion angle in the Tasmanian series varies from 98° to 117°, with a mean of 107.8°, S.D. 4.71, V. 4.37. In the Scottish series the basion angle varies from 95° to 120°, with a mean of 107.4°, S.D. 4.43, V. 4.12. The basion angles are thus shown to be approximately equal in the two series on an average, while that of the Scottish series is slightly less variable than the other. In the Australian series the basion angle has a range in value from 97° to 120° and a mean value of 107.75°, practically equal to the Tasmanian mean, and its standard deviation being 4.43, it is less variable than the latter.

As regards the bregma angle, this, in the Tasmanian series, varies from 100° to 113°, with a mean of 106.8°, S.D. 2.98, V. 2.79. In the Scottish series the angle varies from 103° to 115°, with a mean of 108.96°, S.D. 2.98, V. 2.73.

The above angles in the two series of skulls show equal deviations and nearly equal coefficients of variability, while in the Tasmanian series the mean angle is slightly smaller than the mean angle in the Scottish series.

In the comparison instituted by KLAATSCH between the Australian specimen and a European skull he pointed out as a feature of the former that the bregma angle was greater than the basion angle, while the relationship in the European skull was the reverse. The result of the examination of these angles in the 100 Scottish skulls is that the mean bregma angle is greater than the basion angle, and so the Scottish skull agrees with the Australian (of KLAATSCH) in this respect. The Tasmanian mean basion angle, on the other hand, is slightly greater than the mean bregma angle, and thus shows a relationship which is that figured in the European specimen of KLAATSCH.

In BERRY's series of Australian skulls, 90 in number, I found that the bregma angle varied from 98° to 120° , with a mean value of 106.94° . The standard deviation was 3.69. This angle is thus in a series of Australian skulls lower in value on the average than the basion angle, which showed a mean value of 107.75° , so that the opposite relationship obtains from what is found in the Scottish skull and the reverse of what KLAATSCH demonstrates in his *Kraniomorphologie und Kraniotrigonometrie*.

The size of the bregma compared with the basion angle in any specimen largely depends on the respective distances of the basion and bregma from the glabella-lambda horizontal, a high value for the bregma angle being predicted by a long low vault which is a feature of the Australian skull. Apparently the relationship pointed out by KLAATSCH, in comparing the Australian and European, is by no means constant, as in many of the Scottish skulls the upper segment of the basi-bregmatic line is considerably shorter than the lower segment, and the mean length of the upper segment is also shorter than the mean length of the lower segment (upper, 65.7; lower, 67.8), while in the Tasmanian the mean values of the two segments of this line are approximately equal. To this I shall refer later.

With regard to the frontal, parietal, and inion angles no measurements are given by BÜCHNER for the series of Tasmanian skulls, but BERRY gives for the first in a series of 50 Tasmanians a range in value from 131.5° to 149° , with a mean of 139.5° , and for the second angle a range in value from 125.5° to 141.5° , with a mean of 134.3° . In the Scottish series the frontal angle varies from 127° to 149° , with a mean of 136.9° ; the parietal angle varies from 128° to 146° , with a mean of 135.61° . In the Australian specimen figured by KLAATSCH the frontal angle is comparatively large, namely, 149° , i.e. at the extreme upper limit of, but still within, the range of the variation shown by the Scottish series; the parietal angle in the Australian is 129° , which is within the range of the Scottish series but at its lower limit. BERRY and ROBERTSON (59) find that in a series of 100 Australian skulls the angle of frontal curvature varies from 123.5° to 153° , with a mean value of 139.65° , i.e. distinctly below the value figured in KLAATSCH's specimen; while the angle of parietal curvature varies from 125° to 145° , with a mean value of 135.7° , both of which values are approximately equal to the values for the corresponding angles in the Tasmanian. The size of those angles depends obviously upon the lengths of the frontal and parietal chords and

the heights of the corresponding arcs, and a consideration of these later will bring out more fully the greater similarity between the frontal and parietal arcs in the Scottish series, as evidenced by the close approximation to equality in the size of the two angles, than in the Tasmanian and Australian as shown by a comparison of BERRY's values, and than in the Australian as figured by KLAATSCH. In the European skull described by the latter the frontal angle is 141° and the parietal 129° .

As regards the inion angle, *i.e.* the angle at the vertex of the chief occipital triangle, in the Scottish series the angle varies from 97° to 114° , with a mean of 104.77° . In the Australian as figured by KLAATSCH the angle is 101° , well within the range of variation found in the Scottish series; in another Australian it is 105° ; in the European (according to KLAATSCH) it is 99° ; in a Negro it is 113° ; in a Chinese skull 104° , and in a brachycephalic German 101° . In the series of 90 skulls shown in BERRY's atlas, I have measured the angle and find that it shows in these a mean value of 104.84° and a range of variation from 95° to 114° (S.D. 4.12), values which are practically identical with those given by the above-mentioned Scottish series. The angle thus shows much variation in the Scottish skulls, but the values of the corresponding angle in those different types of skull all fall within its range.

Figures are given by BÜCHNER (60) for the Tasmanian series in a study of the prognathism of the Tasmanian aboriginal for the first of the two angles which KLAATSCH makes use of in his median diagrams as evidence of prognathism, *i.e.* the angle at the prosthion (at the vertex of the upper facial triangle) and the angle included by the glabella-prosthion line and the continuation forwards of the lambda-glabella line; but, as I intend to confine my attention for the present largely to the brain-box, I need not refer to this at greater length than to mention that in the Australian, as evidence of the prognathism present, these angles show a distinct diminution in value from the mean values of the Scottish series.

With regard to the chords, and considering first of all the glabella-lambda length, we find, in the Tasmanian series, that this varies from 167 to 189 mm. in the male skulls, with a mean length for the series of 178.7 mm., S.D. 5.43, V. 3.03. In the Scottish series the range of variation is from 172 to 198 mm., with a mean value of 184.75 mm., S.D. 5.85, V. 3.87.

By a comparison of these measurements the greater absolute length of this chord in the Scottish series is brought out, associated with the greater length of the skull, while in the two series the coefficients of variability show a fairly close correspondence with one another, that of the Scottish series being slightly greater than the other. In the Australian figured by KLAATSCH the length is 182 mm., which is not greatly different from the Scottish mean value, but in the 90 Australian skulls previously mentioned the length varies from 160 to 192 mm., with a mean value of 177.12 mm., S.D. 6.83, V. 4.42, bringing the mean length of the line in the Australian below that in the Tasmanian.

The basi-bregmatic height in the Tasmanian series varies from 118 to 139 mm.,

with a mean value of 130.1 mm., S.D. 5.27, V. 4.05. In the Scottish series the basi-bregmatic height varies from 123 to 147 mm., with a mean of 133.7 mm., S.D. 5.47, V. 4.09. In this dimension also evidence of the difference in size of the skulls in the two series is marked, while the standard deviation and the coefficients of variability are very similar in the two series.

From a comparison of the coefficients of variability, with regard to this measurement and the previous one, it is shown that the basi-bregmatic height is in both series more variable than the glabella-lambda length. The measurement given by KLAATSCH for an Australian specimen is 133 mm., which is greater than the mean value of the Tasmanian, smaller than the Scottish mean value, but within the range of both; while the mean of BERRY's series of 90 Australian skulls is 130 mm., and the range of variation shown is from 116 to 144 mm., S.D. 6.50, V. 5.00.

As regards the two segments of the basi-bregmatic height in the Tasmanian series of male skulls, the upper segment, which is the measure of the elevation of the glabella-lambda arc, varies from 54 to 73 mm., with a mean value of 65.4 mm.; the lower segment varies from 55 to 75 mm., with a mean value of 65 mm. The means of the upper and lower segments are thus in the series examined nearly equal.

In the Scottish series the upper segment varies in length from 56 to 76 mm., with a mean of 65.75 mm.; the lower segment varies from 55 to 82 mm., with a mean of 67.85 mm. The mean value of the lower segment is thus greater than the mean value of the upper segment, and in this respect approximates to the measurements of the Australian skull as figured by KLAATSCH and of another measured by myself. The basi-bregmatic height of this Australian skull is 133 mm., the upper segment is 59 mm., the lower 74 mm. The mean value of the basi-bregmatic height in the Scottish series, as stated above, is 133.7 mm., which is approximately equal to the height of KLAATSCH's Australian skull, so that both the values of the two segments of the Australian fall well within the ranges of variation shown in the corresponding segments in the Scottish series of skulls.

Noting a few measurements of these segments in skulls of the Scottish series, we can compare them with the condition found in KLAATSCH's Australian in the following way:—

TABLE XLVII.

Australian.			Scottish.		
Basi-bregmatic Height.	Upper Segment.	Lower Segment.	Basi-bregmatic Height.	Upper Segment.	Lower Segment.
133	59 mm.	74 mm.	(a) 133 mm.	63 mm.	70 mm.
			(b) 133 "	64 "	69 "
			(c) 133 "	62 "	71 "
			(d) 142 "	63 "	79 "
			(e) 146 "	64 "	82 "
			(f) 140 "	64 "	76 "

The table shows that the difference of the two segments of the basi-bregmatic height can by no means have the value attached to it by KLAATSCH in his comparison of the Australian and European skulls, and, as the size of the basion and bregmatic angles depends largely on the lengths of these respective segments, the relative size of these angles loses also the significance attributed to it by him.

This is confirmed by the examination of the measurements of the larger series of 90 Australian skulls. In this group the upper segment of the basi-bregmatic height varies from 51 to 80 mm., with a mean value of 65.66 mm., S.D. 5.12, V. 7.79; the lower segment ranges in value from 52 to 77 mm., with a mean value of 64.34 mm., which is less than that of the upper segment. The S.D. is 4.94 and the coefficient of variation 7.67, so that the lower segment is slightly less variable than the upper.

The glabella-bregma chord in the Tasmanian series varies from 94 to 118 mm. and has a mean length of 107.6 mm.; S.D. is 5.99, V. is 5.56. In KLAATSCH's Australian the chord is 106 mm., *i.e.* within the range of both series, while in the larger Australian series of 90 skulls (unsexed) the chord has a mean value of 106.32 mm., with a range of variation from 95 to 121 mm., S.D. 5.41, V. 5.08. In the Scottish series the chord varies in length from 101 to 126 mm., with a mean value 111.62 mm., S.D. 5.509, V. 4.935. The mean length of this chord is thus seen to be decidedly greater in the Scottish series than in the Tasmanian and Australian series. The variability of the line in the Scottish series is decidedly less than in the Tasmanian series, while the chord in the Australian lies between the Scottish and Tasmanian crania.

The bregma-lambda chord in the Tasmanian series varies from 99 to 127 mm., with a mean value of 115.3 mm. The S.D. is 6.08 and V. is 5.27. In the Scottish series the chord varies in length from 104 to 126 mm., with a mean value of 115.15 mm. The S.D. is 5.446 and V. is 4.729.

The mean length of the corresponding chords in the two series is approximately equal, but the variability shown by that in the Tasmanian series is decidedly greater than that in the Scottish series, as in the case of the previous chord. KLAATSCH's Australian specimen gives a value of 111 mm., *i.e.* well within the range of both the Tasmanian and the Scottish series, but BERRY's series of dioptrographic tracings of 90 Australian skulls shows a range of variation from 100 mm. to 137 mm., and a mean value of 114.18 mm. The S.D. is 6.49 and the coefficient of variation 5.68.

The lambda-basion chord in the Tasmanian series varies from 103 to 123 mm., with a mean value of 114.3 mm. The S.D. is 4.58 and V. is 4.00. In the Scottish series the chord varies in length from 111 to 135 mm., with a mean value of 120.58 mm. The S.D. is 4.675 and V. is 3.87. The mean value of the chord is thus decidedly greater in the latter than in the former, while the variability shown by it is slightly less. In the Australian series of 90 the chord varies in length from 100 to 124 mm., with a mean value of 112.01 mm. The standard deviation is 5.31, and the

coefficient of variation 4·74. While the Australian shows the smallest mean value of the three types, it is the most variable.

With regard to the basion-glabella chord, this in the Tasmanian series varies from 100 to 119 mm., with a mean value of 108·6 mm. The S.D. is 4·84 and V. is 4·45. In the Scottish series the chord varies in length from 98 to 119 mm., with a mean of 107·57 mm. The S.D. is 4·183 and V. is 3·88. The mean absolute length of this chord is thus seen to be greater in the Tasmanian series than in the Scottish series, while the variability of the latter is decidedly less than that of the former. In the Australian series the glabella-basion chord varies from 97 to 119 mm., with a mean value of 107·03 mm., the standard deviation 5·67, and the coefficient of variation 5·29. The mean value of the chord is thus approximately equal to that of the Scottish series, but the chord in the former is distinctly more variable than the latter. Comparing the chords as regards their variability, we find the following coefficients of variation :—

TABLE XLVIII.

	Glabella-bregma Chord.	Bregma-lambda Chord.	Lambda-basion Chord.	Basion-glabella Chord.
Tasmanian . . .	V. 5·56	V. 5·27	V. 4·0	V. 4·45
Australian . . .	V. 5·08	V. 5·68	V. 4·74	V. 5·29
Scottish . . .	V. 4·93	V. 4·73	V. 3·87	V. 3·88

In the Tasmanian the variability of the glabella-bregma and bregma-lambda chords is greater than that of the lambda-basion and basion-glabella chords, while the least variable of all is the lambda-basion. In the Australian series of 90 the bregma-lambda chord is most variable, the lambda-basion the least, while the basion-glabella chord is more variable than the glabella-bregma chord. In the Scottish series we find that, as in the Tasmanian, the glabella-bregma and bregma-lambda chords are decidedly more variable than the lower two, and the least variable, as before, is the lambda-basion, although this is less marked than in the case of the Tasmanian series. The fact that the glabella-basion chord is more variable than the lambda-basion in the Scottish series may at first sight be thought to be due to the variability in the glabella. We find, however, on comparing the basi-nasal length and the basi-glabella length that, in a series like the present one, though the standard deviation of the former is less than that of the latter, the coefficient of variation of the latter is less than that of the former; and as this quantity is the true measure of variability when the means of two quantities are unequal, we must come to the conclusion that, in this series, the basi-nasal length is more variable than the basi-glabella length. This may be brought forward as an argument against the use of the basi-nasion line, which is the nearest approach that can be obtained in a non-sectionised skull to HUXLEY'S basi-cranial axis, as a base line.

This introduces the question of a reliable base line and HUXLEY's (51) well-known dictum on the subject: "No comparison of crania is worth much that is not founded upon the establishment of a relatively fixed base line to which the measurements in all cases must be referred." He chose the basi-cranial axis as his base line because he thought it showed least variability, but apparently in a uniform series of skulls like the present one under examination the basion-glabella line would be preferable to the basi-nasion line.

I have been able to obtain the value of the basi-occipito-sphenoid axis in 98 of the same skulls from which the above results were obtained after median section, and, anomalous as it may appear but indubitably proved by the figures, the basi-occipito-sphenoid length, or HUXLEY's basi-cranial axis, is more variable than the basiglabella line.

Perhaps I should explain that by "more variable" I mean that in the series examined it departs more from its mean value than does the basiglabella line from its mean value. As PEARSON (8) explains, we cannot compare the respective variabilities of an elephant and a man without making allowances for their difference in size; or, to state the matter in a different way, it is very evident that a variation of 2 inches above or below the mean is very much greater when the mean is equal to 10 inches than when it is equal to 40 inches. The magnitude of the coefficient of variation is the true criterion for relative variability, and, according to the evidence supplied by this factor, HUXLEY's basi-cranial axis is not the least variable length in a homogeneous series of skulls. Of all the chords measurable, the least variable is the greatest length or glabello-occipital length, and I put forward on this account the plea that it should be adopted as a base line if the least variable line is wanted for such a purpose. This length has the disadvantage, however, that its posterior extremity does not come to any definite point on the cranial vault such as the lambda or inion.

It will be noticed that in his craniotrigonometrical method KLAATSCH abandons the glabella-inion base line utilised by SCHWALBE and others, and also adopted by himself in some of his earlier research work, and makes use of the glabella-lambda line and plane. He advances various reasons why this line should be universally adopted as a rational base line. There are many arguments against the adoption of the above line as a base line. One of these is the fact that it includes the glabella, which varies considerably in development in different types of crania, but considerable variation has also been found to occur in the position of the inion, *i.e.* the posterior extremity of the glabella-inion line. The chief objection from the point of view of morphological analysis of the cranial vault is that it does not correspond, as the glabella-inion line roughly does, to the sub-cerebral plane.

According to BOLK (42), the position of the lambda is as variable as that of the inion, but my figures from the present series show me that the glabella-lambda is less variable than the glabella-inion line. Apparently objections may be raised to

the use of any base line adopted, and the present state of opinion as regards this may be summed in the words of CLELAND regarding the choice of a base line, "All planes are arbitrary; if any be true, they have not been proved to be so."

One of KLAATSCH's reasons for the adoption of the glabella-lambda line as a base was that it corresponded with the natural position of the head during life, but CLELAND (15) came to the conclusion that "it is quite likely that it will always remain impossible to determine from the characters of a skull what was its precise position in the erect posture of the body." The respective variability shown by the various lines drawn from the basion to the nasion, glabella, and prosphenion show that in a uniform series like the present one the variability of development of the glabella is practically negligible.

TURNER (47) adopted the nasi-tentorial line as a base line, as he believed the nasion was a more suitable point than the glabella to be the anterior extremity of a line drawn to estimate the length of the cerebral portion of the cranial cavity. KEITH (25) takes a somewhat similar plane, which he names the "sub-cerebral." BOLK (42), dissatisfied with all other base lines, adopted still another, called the "Fronton-Occipiton" line, which is drawn from the "Fronton," a point on the inner surface of the anterior cranial wall in the middle line where this becomes continuous with the floor of the anterior cranial fossa to the "Occipiton," the point on the inner aspect of the posterior cranial wall furthest removed from the "Fronton." If there was an arc equidistant from the "Fronton," the centre point of the arc was taken as the "Occipiton."

In my study of the sectionised skull I have made use of BOLK's line, and have also drawn in the nasi-tentorial line to give me the nasi-tentorial plane. I have calculated the coefficients of variation of these two lines, and find that of the two the nasi-tentorial line is slightly the more variable, while both are distinctly more variable than the glabella-occipital and even than the glabella-lambda length, but slightly less variable than the glabella-inion line (the magnitude of the coefficient of variation being taken as the index of variability).

In a uniform series of skulls like the present one, therefore, the variability of the prominence of the glabella may be considered as practically negligible in regard to any influence on the length of a line drawn from it to another point on the skull, but of course in a heterogeneous collection of skulls, or in comparing skulls of different races, the influence of its variable development would probably be more marked. It is an interesting fact, however, that even in such a homogeneous series of skulls the basion-lambda line should show the smallest coefficient of variability.

With regard to the lambda-inion chord, this is the most variable of all the chords measured so far. In the Tasmanian series the length varies from 47 to 73 mm., with a mean length of 56.7 mm.; the S.D. is 7.04 and V. is 12.4. In TURNER's Tasmanian series of 6 the mean value is 56 mm., while in the Scottish series the corresponding

chord varies in length from 46 mm. to 88 mm., with a mean length of 65.19 mm.; the S.D. is 7.730 and V. equals 11.85. This chord is, to a certain extent, a measurement of the length of the corresponding arc, and illustrates its variability.

In the Australian skull figured by KLAATSCH the length of the chord is 64 mm., which is approximately equal to the mean length in the Scottish series; but in the Australian series of 90 the chord shows a range of variation from 41 to 69 mm., with a mean value of 52.43 mm., which is slightly less than the mean value of the Tasmanian and more than 13 units less than the Scottish mean value. As the standard deviation is 5.65, and the coefficient of variation 10.77, the chord is not so variable in the Australian as in the Tasmanian and Scottish series.

The inion-basion length varies in the Tasmanian series from 77 to 96 mm., with a mean of 86 mm.; in the Scottish series from 68 to 97 mm., with a mean of 86.44 mm.; in the series of 90 Australian skulls from 68 to 101 mm., with a mean value of 86.48 mm. The mean is thus practically equal in the three series.

In the Tasmanian the basion-prosthion chord varies from 88 to 111 mm., with a mean of 99.6 mm.; in the Scottish series the chord varies from 81 to 107 mm., with a mean of 94.87 mm. The mean value of this chord is thus considerably less in the Scottish skulls than in the Tasmanian, while the value of this measurement in 90 Australian skulls ranged from 84 to 120 mm., with a mean value of 99.86 mm., *i.e.* practically equal to that of the Tasmanian.

The prosthion-glabella length in the Tasmanian series varies from 62 to 88 mm., with a mean value of 73.5; in the Scottish series the length varies from 71 to 93 mm., with a mean value of 80.87 mm. The mean length in the Scottish skull is thus considerably greater than in the Tasmanian, while the mean length of 90 Australian specimens was 74.72 mm., just a little greater than the value in the Tasmanian.

With regard to the respective heights of the frontal, parietal, and occipital arcs, the following values have been obtained in the present Scottish series:—The frontal varies from 15 to 30 mm., with a mean height of 21.69 mm.; the parietal varies from 16 to 30 mm., with a mean height of 23.49 mm.; and the occipital varies from 3 to 19 mm., with a mean height of 9.76 mm. Of these heights the occipital is much the most variable, and the frontal is slightly more variable than the parietal, as will be seen by comparing their coefficients of variation in the table that follows.

Measurements for the above dimensions are given for the Tasmanian series of skulls, 50 in number, in BÜCHNER's paper (61) "On Curvatures of the Tasmanian Aboriginal Crania." The frontal arc height varies from 10 to 25 mm., with a mean value of 18.9 mm.; the parietal arc height from 19 to 28 mm., with a mean value of 23.3 mm.; and the occipital arc height from 2 to 12 mm., with a mean value of 6.1 mm.

TURNER (47) gives values for the heights of the bregma-glabella arc perpendicular in series of Tasmanian, Scottish, and Australian skulls. In 7 Tasmanian the per-

pendicular varied from 16 to 21 mm., with a mean of 18.5 mm.; in 17 Australians the perpendicular varied from 11 to 25 mm., with a mean of 18 mm.; in 16 Scottish the perpendicular varied from 16 to 24 mm., with a mean of 19.8 mm. The frontal projection in the Australian showed the smallest mean, then with a slightly larger mean came the Tasmanian, while the mean value was distinctly larger in the Scottish series.

He also pointed out that a very much greater portion of the perpendicular was taken up by the thickness of the bone in the Australian than in the European. The mean height shown by those results for the Scottish series is about 2 mm. less than that shown by the mean of my series, and it shows that the height of the Australian figured by KLAATSCH as 13 mm. can by no means be taken to represent the average height of the frontal arc in that type of skull. This is confirmed by the measurements in a series of 90 Australian skulls, where the frontal arc height varied from 13 to 28 mm., with a mean value of 19.30 mm. On the whole, however, the height of the frontal arc appears to be decidedly less in the Australian than in the Scottish.

TURNER gives for the parietal arc height in the Tasmanian a mean value of 24.1 mm., the range being 21 to 26 mm., which, he says, closely corresponded with the value for the frontal arc height as measured from the nasi-bregmatic line, and showed that in their entirety these bones had almost similar curvatures. The same relationship holds between the corresponding heights in the Scottish series, and confirms the belief that these bones have almost similar curvatures in the Scottish skull, which was shown previously by the near approach to equality exhibited by the size of the frontal and parietal angles. For a larger series of 90 Australian skulls the height of the parietal arc varied from 16 to 30 mm., with a mean value of 22.91 mm., *i.e.* distinctly greater than the mean frontal arc height.

TURNER (47) gives for the occipital arc height of the Tasmanian a range of 3 to 10 mm., with a mean value of 7.1 mm. The mean value for the occipital arc height in 90 Australian crania was 5.78 mm., with a range from 3 to 12 mm. In our series the lambda-inion chord was very variable, and the above height varied from 3 to 19 mm., which is a marked illustration of TURNER's statement "that it would be possible to arrange a series of British skulls in which variations from a well-marked occipital bulging to a form closely approaching that of the Neanderthal could be seen." This would seem even possible in such a homogeneous series as the present one.

The index devised by KLAATSCH for the arcs, *i.e.* $\frac{\text{height of arc} \times 100}{\text{length of chord}}$, has been calculated for Tasmanian and Australian series of skulls by BÜCHNER (61). We can compare their values with those found in the Scottish series in a table such as the following;—

TABLE XLIX.

Mean frontal arc index in Scottish is 19.57 (100 specimens)				
"	"	Australian is 18.1	(51	")
"	"	Tasmanian is 18.7	(51	")
Mean parietal arc index in Scottish is 20.36 (100 specimens)				
"	"	Australian is 20.2	(51	")
"	"	Tasmanian is 20.5	(51	")
Mean occipital arc index in Scottish is 14.81 (100 specimens)				
"	"	Australian is 10.9	(51	")
"	"	Tasmanian is 11.1	(51	")

By this means the flattening of the curve of the frontal bone as compared with that of the parietal is shown to be strongly marked in the Australian, while in the Scottish skull the tendency is for the two arcs to show more equal curvatures. The mean parietal arc index is not greatly different in the three types, the Australian showing the lowest value, the Tasmanian the highest, and the Scottish an intermediate value. The mean occipital arc index is distinctly greater in the Scottish skull than in the other two races, which show a nearly equal degree of curvature. These differences in curvature of the arcs, although somewhat obscured by the difference in absolute size of the types, are brought out fairly well in the superimposed tracings (figs. 10, 11, 12, 13).

Leaving out of account for the present the upper facial triangle, which in the Australian shows considerable variation from that in the Scottish skull owing to prognathism being so well marked, and concentrating our attention on the brain-box, it is evident, from a consideration of many of the measurements given above, that some of the features on which KLAATSCH laid stress in establishing a contrast between the Australian and European specimens figured by him in his paper are by no means constant, and that, within a homogeneous series of skulls such as the Scottish one under examination, and also I believe in that of the Tasmanian, it is possible to get specimens which closely approach the Australian type in these characters; in fact, the range of the values in the Scottish series includes in most cases the respective values shown by the Australian; such cases include the size of many of the angles, the segments of the basi-bregmatic height, and the lengths of the various chords.

The retreating forehead of the Australian and the flattening of the frontal arc, as compared with the parietal, are shown by the small mean height of the frontal arc as compared with that of the parietal, the large size of the frontal angle as compared with the parietal angle, and the well-marked difference in the two indices. In the Scottish skull, as previously mentioned, the mean heights of the arcs are more nearly equal, so also the mean values of the two angles, and the indices given by comparing the heights of the arcs and the lengths of the corresponding chords show only a small difference in their mean value.

Many of the typical characters of the Tasmanian and Australian calvariae, *e.g.* the

longitudinal depressions in the vault of the former and the relatively narrow keeled shape of the latter, are not brought out in median sagittal tracings, and considerable value would be added to the method by taking horizontal tracings at the glabella-lambda plane and vertical transverse tracings at right angles to the above-mentioned plane passing up from the basion.

I have done this in a few specimens, making use of the apparatus devised by Professor BRYCE, which enables one to take a tracing of any desired contour in any horizontal or vertical plane. By this means the other characters of the brain-box in the Australian, Scottish, and Tasmanian are well shown, *e.g.* the character and slope of the vault, etc., as well as the relations of breadth and height. By associating or

FIG. 10.—Diagram showing sagittal cranial contours and quadrilateral figures of mean Tasmanian skull and mean West Scottish skull superimposed. Glabella-lambda line as base.
West Scottish—continuous line. Tasmanian—interrupted line.

combining the measurements derived from the sagittal tracing with those obtained from the vertical and horizontal tracings, one can obtain a complete picture or model of the cranial box or calvaria, and so from the values obtained derive more assistance in reconstructing the facial part of a skull when the calvaria is alone available, and thus be able to come to more definite conclusions and with a greater likelihood of accuracy than if the figures in the sagittal plane are alone made use of.

This method of KLAATSCH is fitted for the study and comparison of median sagittal contours of different skulls or types of skull by superposition on a common base, in this case the glabella-lambda line. I have constructed four quadrilateral figures, giving to the various chords lengths equal to the mean values shown by the Scottish series of skulls, and with the zentrum angle 92.5° —the mean value of the angle for the 100 Scottish skulls. By the addition to each quadrilateral figure of the other triangles in KLAATSCH's scheme, making their respective heights equal to the mean heights of the Scottish series, I have obtained a sufficient number of points to

complete a curve which may be considered in each case a close approximation to that of a "mean Scottish skull."

I have done the same with the Tasmanian measurements, making the angle at the

FIG. 11.—Diagram showing sagittal cranial contours and quadrilateral figures of KLAATSCH's Australian skull and mean West Scottish skull superimposed. Glabella-lambda line as base.

West Scottish—continuous line.

Australian—interrupted line.

FIG. 12.—Diagram showing sagittal cranial contours and quadrilateral figures of mean Australian skull and mean West Scottish skull superimposed. Glabella-lambda line as base.

West Scottish skull—continuous line.

Australian—interrupted line.

zentrum $89^{\circ}3'$, and have obtained a sagittal tracing of the mean male Tasmanian skull. This I have superimposed on the mean Scottish contour, making the "zentral" points exactly coincident and the glabella-lambda lines in large part so (fig. 10).

In a second case (fig. 11) I have superimposed on the mean Scottish skull tracing the Australian, with the measurements figured by KLAATSCH, and the principal

differences referred to by him are well brought out in so far as they can be revealed in a sagittal tracing, *i.e.* (a) the relatively low character of the portion of the calvaria above the glabella-lambda plane, and (b) the flatness of the frontal arc compared with the parietal. Fig. 12 shows the mean Scottish skull and the mean Australian skull superimposed, the measurements for the latter being obtained from BERRY and ROBERTSON'S series of dioptrographic tracings. The exceptional character of KLAATSCH'S Australian and the near approximation of the Tasmanian and Australian means are

FIG. 13.—Diagram showing sagittal cranial contour and quadrilateral figure of skull No. 20 of the series superimposed on the contour and figure of KLAATSCH'S Australian skull. Glabella-lambda line as base.

West Scottish—continuous line.

Australian—interrupted line.

demonstrated by these figures. The most striking difference, apart from the value of the zentrum angle, in the figure of the West Scottish skull and that of the Tasmanian or Australian is seen in the occipital region. It will be observed that the height of the glabella-lambda arc is the same in all three.

Fig. 13 shows a sagittal tracing for the Australian, as described by KLAATSCH, superimposed on a Scottish skull (No. 20) from the series of 100. In this case the sagittal tracings, as regards the calvaria only, show a very close resemblance to one another. It is in instances like the present one that coronal tracings would be of great value in bringing out the other points of difference in the vault characteristic of the Australian, because, if the above Scottish skull consisted only of the calvaria—it being similar to the Australian in the various values of the polygon, and the angle at the zentrum being 90° —it might seem quite reasonable to affix an Australian facial portion.

The method may be of value in attempts at the reconstruction of incomplete skulls, as the zentrum angle seems to be in most cases not removed more than several degrees from a right angle; but the study of the correlation of the cranial characters in the Scottish skull, and their comparison with those in other races, confirms me in

the belief that it is very doubtful at present how far it is permissible, if it be so at all, to build up conclusions as to what form a deficient part of a skull should take from evidence supplied by a skull of another type.

The above essay on KLAATSCH'S method has been experimental. As the reader will perceive, I have been rather seeking my way through the somewhat elusive detail, but some important points have emerged, and I have left the matter as it stands for the sake of possible future inquirers. The significance of some of the chief points will be considered again in the section 4 dealing with SCHWALBE'S data.

TABLE L.

Character.	Scottish Male Series (100).			Tasmanian Series (50).				Australian (90).		
	Mean Value.	S.D.	V.	Mean Value.	Mean Value.	S.D.	V.	Mean Value.	S.D.	V.
				M. (30).	M. & F.	M.	M.			
Zentrum angle . . .	92.54°	2.58	2.79	89.3°	89.6°	1.72	1.92	89.45°	2.05	
Cran.-glab. " . . .	74.40°	2.72	3.65	74.7°	75.3°	2.84	3.80	74.92°	3.13	
Upper glab. " . . .	35.96°	1.99	5.54	37.92°	38.2°	2.26	5.9	38.07°	2.40	6.30
Lower " " . . .	38.45°	2.63	6.84	36.8°	37.0°	2.86	7.77	36.83°	2.51	6.82
Glab.-breg.-lamb. or breg. angle	108.96°	2.98	2.73	106.8°	106.7°	2.98	2.79	106.94°	3.69	
Breg.-lamb.-bas. or lamb. angle	68.34°	2.84	4.15	69.0°	69.2°	2.73	3.95	70.12°	2.98	
Lamb.-bas.-glab. or basion angle	107.44°	4.43	4.12	107.8°	108.9°	4.71	4.37	107.75°	4.43	
Glab.-lambda length . .	184.75	5.857	3.17	178.7	175.2	5.43	3.03	177.12	6.83	4.42
Glab.-zentrum " . . .	87.24	3.75	4.30	84.8	83	77-93		84.63	77-97	
Zentrum-lamb. " . . .	97.41	3.956	4.06	94.3	94.8	87-99		92.37	79-103	
Basi-breg. height . . .	133.71	5.478	4.09	130.1	128.0	5.27 4.05		130.00	6.50	5.00
Breg.-zentrum height . .	65.75	4.072	6.19	65.4	64.8	54-73		65.66	5.12	7.79
Zentrum basion " . . .	67.85	5.177	7.63	65.0	63.8	55-75		64.34	4.94	7.67
Glab.-breg. chord . . .	111.62	5.509	4.93	107.6	105.2	5.99	5.56	106.32	5.41	5.08
Breg.-lamb. " . . .	115.15	5.446	4.73	115.3	113.4	6.08	5.27	114.18	6.49	5.68
Lamb.-basion " . . .	120.58	4.675	3.87	114.3	112.3	4.58	4.007	112.01	5.31	4.74
Basion-glab. " . . .	107.57	4.26	3.96	108.6	105.7	4.84	4.46	107.03	5.67	5.29
Lamb.-inion " . . .	65.19	7.73	11.85	56.7	55.5	7.04	12.4	52.43	5.65	10.77
Basi-nasal length . . .	100.96	4.113	4.07	96.60	...	6.02	6.24			
Maximum " . . .	189.18	5.82	3.076							
Basion-prosth. length . .	94.87	4.76	5.01	99.6	97.0	88-111		99.86	84-120	
Front. arc height . . .	21.79	2.67	12.25	19.16	18.9	15-23		19.30	13-28	
Pariet. arc " . . .	23.39	2.72	11.62	24.3	23.3	20-28		22.91	16-30	
Occipit. arc " . . .	9.76	3.11	31.86	6.53	6.1	4-11		5.78	3-12	
Glab.-breg.-bas. angle . .	51.31°	47°-57°		52.4°	51.9°	49°-56°				
Lamb.-breg.-bas. " . . .	57.75°	52°-63°		54.8°	54.8°	50°-58°				
Breg.-lamb.-glab. " . . .	34.61°	29°-41°		34.0°	35.1°	31°-38°				
Bas.-lamb.-glab. " . . .	33.73°	29°-41°		34.6°	35.0°	30.5°-39°				
Lamb.-basi-breg. " . . .	53.42°	46°-61°		55.8°	57.7°	48°-62°				
Glab.-basi-breg. " . . .	54.57°	48°-63°		52.0°	52.3°	47°-58°				
Inion-basion length . . .	86.44	68-97		86.0	...	77-96		86.48	68-101	
Prosth.-glab. " . . .	80.87	71-93		73.5	72.5	62-88		74.72	65-87	
Frontal angle " . . .	136.98°	127°-149°		...	139.5°	131.5°-149°		139.65°	123.5°-153°	
Parietal " . . .	135.61°	128°-146°		...	134.3°	125.5°-141.5°		135.7°	125°-145°	
Inion " . . .	104.77°	97°-114°		...	...	...		104.84°	95°-114°	

Note.—The S.D. and V. have not been calculated for all the measurements. The range of variation is given for these measurements.

The second column of Tasmanian mean values and the column of Australian mean values are obtained from both male and female skulls or unsexed crania, so that the results are not exactly comparable as regards absolute dimensions and degree of variability with those of the Scottish male series.

I have compiled the foregoing table (L) showing the principal mean values for the Scottish skull, with their standard deviations and coefficients of variation, alongside the corresponding quantities for the male Tasmanian, which I have calculated in many cases from the results in BÜCHNER'S (11) paper, as well as the results for 50 unsexed Tasmanian* skulls (BÜCHNER) and the values for 90 Australian crania (unsexed) calculated from the dioptrographic tracings shown in BERRY and ROBERTSON'S atlas (40 and 40A).

We observe that, while the Scottish skull is slightly more variable than the Tasmanian in glabella-lambda length and in basi-bregmatic height in many of the other chords, it is decidedly less variable—a result which is not in agreement with our preconceived notions and with PEARSON'S statement that we get increased variability as we pass from primitive or uncivilised to the civilised type. This was alluded to before in speaking of the mean values of other cranial measurements and their variation in primitive types and their comparison with this Scottish series.

FALKENBÜRGER'S EXTENSION OF KLAATSCH'S METHOD.

FALKENBÜRGER (41), while pursuing an investigation into the application of KLAATSCH'S craniotrigonometrical method to a series of deformed Peruvian and Mexican skulls, discovered another relationship of certain lines that seemed to him to occur very constantly, and he has pursued his investigations regarding this latter point in skulls of individuals belonging to twelve different races, including the Negro, Australian, and European, and the skulls of various anthropoids as well. He asserts that the bregma-prosthion line stands at right angles to the basi-nasal line, and that the greatest variation from this relationship is about 5° . There seems to hold, consequently, he says, "almost a firmly fixed relationship in human skulls." He states further that "the nasion-basion line is parallel to the bregma-lambda line," which implies that the latter line is also perpendicular to the bregma-prosthion line. Prognathism appeared to be without influence on the relationship.

In the anthropoids the angle is always over 100° , *i.e.* falls outside the latitude of human variation. In the chimpanzee the mean was 104° , in the orang-utan 108° , in the gorilla 114° , and in one juvenile gorilla the angle was 99° . He is convinced that these very constant geometrical relations of the isolated points will be of great importance in, and in fact will make easy, the reconstruction of ancient and probably fragmentary or defective skulls.

The point seems so interesting that, having median sagittal tracings of 100 male skulls forming a homogeneous series, it seemed worth while to investigate what relationship held between the lines stated in such a group. This I have done, and the lines and figures are included in the series of 100 diagrams in which I have applied KLAATSCH'S and SCHWALBE'S methods to the median sagittal tracings of Scottish skulls. We can represent the lines alluded to by a rough sketch (fig. 14).

FALKENBÜRGER states that in the human subject in most cases the angle NOBr is a right angle and BL is parallel to BN.

In the examination of our series of 100 Scottish skulls I shall refer to the angle LBrO as the angle "A" and the angle NOBr as the angle "B." In the case of the angle "A" it was found that the mean value was 89.78° and that the range of variation was from 82° to 99° ; the S.D. was 3.25 and the V. 3.62. The angle "B" had a mean value of 89.62° and showed a range of variation from 82° to 95° , the S.D. was 2.59 and the V. 2.89; the latter angle was thus less variable than the former one.

The angle "A" was exactly equal to 90° in 12 per cent. of the skulls, while the angle "B" was equal to 90° exactly in 22 per cent. The two angles were equal,

FIG. 14.—Diagram to illustrate Falkenburger's method.

N. Nasion.	Pr. Prosthion.
Br. Bregma.	L. Br. O. = angle "A."
L. Lambda.	Br. O. N. = angle "B."

and consequently the two lines, bregma lambda (BrL) and basion nasion (BaN), were parallel in 10 per cent. only of the skulls examined.

There is thus a tendency to parallelism of the two above lines, and we may express this in another way by saying that the coefficient of correlation between the two angles is .33, which indicates that there is a certain tendency for the one angle to depart from its mean value in a certain direction when the other departs from its mean value in that direction, *i.e.* either in the direction of increase or decrease. It is not legitimate to correlate the angles of one triangle by the usual formula owing to the influence of what is called spurious correlation, but, in the case of the above two angles, we may regard them as quantities which apparently need not be dependent on one another, and, as such, can have their relationship expressed in the above way.

In a South German skull which I have traced in the sagittal plane the angle "A" is 84° and the angle "B" 88° , while in a Negro skull the angle "A" is a 100° and the angle "B" 97° . We can arrange in two parallel columns the values shown for the two angles in a short series of skulls taken from the group of 100.

Where the angle "A" is 83° , angle "B" is 94° .

"	"	95°	"	89°
"	"	97°	"	91°
"	"	87°	"	93°
"	"	89°	"	94°
"	"	83°	"	88°
"	"	82°	"	84°
"	"	82°	"	89°
"	"	88°	"	82°

While the angle "B" is less variable than the angle "A," it may have as low a value as 82° , and values of 84° , 85° , and 86° also occur; 84° twice, 85° five times, and 86° three times. The highest value of the angle in the 100 skulls, however, is 95° , which occurs only on a single occasion. In the case of the angle "A" we find that the angle of 82° occurs in 3 per cent., 83° in 2 per cent., while the highest value is 99° , which occurs in one specimen, though the angle 97° occurs twice.

It would seem, therefore, that even in such a homogeneous series as the present one the lambda-bregma line need not necessarily be parallel to the basion-nasion line, while the angle formed by the bregma-prosthion line may vary considerably from a right angle. The angle "B" never attains to the value of 100° , however, which would bring it within the range of anthropoid measurement. In spite of the circumstance that the angle "B" shows considerable variation, it is an interesting fact that the mean angle is practically 90° (89.78°).

The relationship as shown to exist between these respective lines should undoubtedly be of value as an aid to reconstruction; but its value is restricted for the same reason as is the relationship, pointed out by KLAATSCH, between the basion-bregma and glabella-lambda line, viz. it involves the assumption that the relationship which exists between certain dimensions in one type of skull will hold in another type, an assumption for which there is no authority in the present state of our knowledge.

4. SCHWALBE'S METHOD OF MEASUREMENT OF THE CRANIAL VAULT.

Having completed my examination of the series of male Scottish skulls by KLAATSCH's method, it was suggested to me by Professor BRYCE that I should apply the methods of SCHWALBE to the same series. The measurements introduced by SCHWALBE have the object of expressing certain morphological features of the vault, more especially of the frontal bone, and were used primarily to elucidate the characters of the fossil skulls of *Homo primigenius* (52 and 53). In recent years Professor BERRY of Melbourne and his collaborators have used this method of measurements in their studies of native Tasmanian and Australian crania, and have added certain biometrical methods of their own in an endeavour to place these crania in their proper morphological horizon. In my selection of measurements and indices

I have limited myself to those given by BERRY and ROBERTSON in their papers on the Tasmanian skull, as they provide the only data available for comparison.

Having compared the Tasmanian and Australian and West Scottish series of skulls by KLAATSCH's method, I thought it would be of interest to see if SCHWALBE's measurements brought to light any new features. While objections have been raised to the value to be attached to some of the measurements in the subjoined scheme, to which I shall refer later, it is generally agreed that they provide a valuable analysis of the characters of the cranial vault. Although morphological in their nature and of value in a general way in establishing a comparison between the anthropoid group, primitive man, and man as he exists at the present day, it is doubtful as to how far these data can serve to define the relative morphological positions of types of recent man, when the skull forms are different.

The special interest in my inquiry, confined as it has been largely to the brain case, was the comparison, in respect of the vault, of a skull of dolichocephalic type and of high status with that of the same type and of a low status in civilisation.

In the series of 100 West Scottish skulls I have recorded the same 27 observations as BERRY and ROBERTSON in their papers on the Tasmanian skull, and all these except the maximum breadth I obtained from the dioptrographic median sagittal tracings.

The following are the observations :—

1. The glabella-inion length.
2. The calvarial height.
3. The calvarial height index, *i.e.* $\frac{\text{calvarial height} \times 100}{\text{glabella-inion length}}$.
4. The maximum breadth.
5. The calvarial height-breadth index, *i.e.* $\frac{\text{calvarial height} \times 100}{\text{maximum breadth}}$.
6. Half of sum of the glabella-inion length and breadth added together.
7. The calvarial height half sum glabella-inion length, *i.e.* $\frac{\text{calvarial height} \times 100}{\text{half sum glabella-inion length and breadth}}$.
8. Distance of foot point of calvarial height from glabella.
9. The calvarial height foot-point positional index.
10. The frontal angle.
11. The bregma angle.
12. The distance of the foot point of the bregma from the glabella.
13. The bregma foot-point positional index.
14. Length of frontal arc.
15. Length of frontal chord.
16. Curvature index of os frontal, *i.e.* $\frac{\text{frontal chord length} \times 100}{\text{frontal arc length}}$.
17. The angle of frontal curvature.
18. The length of the chord of pars glabellaris of os frontale.
19. The length of the chord of pars cerebralis of os frontale.
20. The glabella cerebral chord index, *i.e.* $\frac{\text{length of glabellar chord} \times 100}{\text{length of cerebral chord}}$.
21. The length of the parietal arc.
22. The length of the parietal chord.
23. The curvature index of the os parietale.

24. The angle of parietal curvature.

25. The parietal frontal arc index, i.e. $\frac{\text{parietal arc} \times 100}{\text{frontal arc}}$.

26. The lambda angle.

27. The opisthionic angle.

BERRY in his researches on the Tasmanian and Australian skulls takes male and female results together as unsexed skulls, and as the Scottish series under investigation consists of male skulls only, I have calculated the mean values for the above observations in the male Tasmanian and Australian skulls in BERRY's series so that the results may be truly comparable. The mean values obtained for the absolute measurements of the male skull are slightly greater than those for the unsexed skull, as one would expect, whereas the values for the indices are little if at all altered.

The mean values for the observations may be arranged in the form of a table to compare them with the Tasmanian and Australian, as is shown in Table LI. In this BERRY's results for the unsexed skulls are placed alongside the corresponding male values, and the close correspondence on the whole between the two sets of values will be very apparent.

TABLE LI.

Character.	Scottish Series.				Tasmanian Series.			Australian Series.		
	Mean.	Range of V.	S.D.	V.	Mean.		Range of V.	Mean.		Range of V.
					M.	M. & F.		M.	M. & F.	
G.I.L. (1)	182.37	167-196	6.57	3.60	176.16	173.1	165-188	181.34	179.51	162-196
Cal.H. (2)	103.37	94-117	5.30	5.12	98.63	97	92-108	94.85	95.09	79-108
C.H.I. (3)	56.68	50-67.5	3.36	...	55.98	56.1	48.3-62.7	52.85	53.00	44.91-60.67
Max.B. (4)	140.7	131-152	4.43	3.14	136.13	134.7	120-145	131.17	130.71	120-143
C.H.B.I. (5)	73.46	65-83	3.48	...	72.64	72.2	64.4-79.2	73.12	72.70	61.85-85.41
1/2 S.G.B.L. (6)	161.53	151.5-174	4.55	...	156.15	154	146-164.5	155.94	155.05	143-166
C.H.1/2 S.I. (7)	63.90	57-74.5	3.25	...	63.11	63	55.2-69.5	61.60	61.32	52.30-69.95
F.P.C.G. (8)	105.73	91-123	6.18	5.84	103.88	101.9	92-115.5	101.40	101.11	88-123
C.H.P.I. (9)	57.93	50-66	2.79	...	58.97	59	53.2-63.9	55.88	56.36	44.89-65.31
Front.A. (10)	90.91	78-103	5.27	...	84.81	86	72-92.5	83.63	85.21	71-100
Breg.A. (11)	56.33	50-63	2.63	...	55.88	56	51.5-60	54.74	54.77	49-60
D.B.G. (12)	61.96	51-78	5.86	9.49	59.73	58.7	49-71.5	61.84	61.26	53-74
B.P.I. (13)	33.89	27.5-42	2.76	...	33.88	34	29.8-38.2	34.17	34.12	29.67-38.85
F.A.L. (14)	133.54	120-152	6.87	5.14	128.13	126	114-143	127.55	126.84	118-143
F.C.L. (15)	116.49	105-132	5.36	4.60	111.48	109.5	99-120	111.65	110.87	100-124
C.I.O.F. (16)	87.25	80.5-93	1.86	...	87.38	87.1	81.4-97.5	88.93	87.43	81.30-90.83
F.C.A. (17)	136.98	127-149	3.69	...	140.43	139.5	133-146	140.52	139.65	131-153
P.G.C. (18)	28.35	20-39	3.60	12.69	24.13	23.8	18-29	22.58	22.36	15-29
P.C.C. (19)	96.4	86-110	5.60	5.80	95.84	93.7	80.5-106.5	96.55	95.98	85-112
G.C.C.I. (20)	29.52	19.5-43	4.51	...	25.26	25.5	17.6-35.4	23.68	23.60	15.62-33.52
P.A.L. (21)	127.83	112-143	6.83	5.34	127.93	125.8	114-145	127.15	125.91	109-147
P.C.L. (22)	115.15	104-126	5.24	4.55	115.3	113	99-127	115.68	114.60	99-137
C.I.O.P. (23)	90.05	81.5-94.5	2.20	...	90.04	90	83.8-97.6	91.11	91.06	83.80-96.06
A.P.C. (24)	135.61	128-146	3.44	...	133.88	134.3	128-140	135.84	135.77	125-145
P.F.A.I. (25)	95.97	80-101.5	7.2	...	99.9	99.7	90.7-121	99.75	99.32	88.63-113.95
L.A. (26)	81.95	70-88	3.46	...	79.68	80.5	74.88	79.34	79.56	70-87
Op.A. (27)	35.13	22-41	3.95	...	40.60	40.6	34.5-47	39.97	40.06	31-51

I do not propose to analyse these measurements at length, as I did in the case of the less-known method of KLAATSCH, but shall merely endeavour to develop the conclusions to which they point when taken along with the data already established. It has already been seen (Table XXI) that while the selected series of 100 West Scottish skulls has the same mean cephalic index as the Tasmanian and a rather higher index than the Australian, the mean altitudinal index in the first is slightly lower than in both the others because, while the Scottish skull is slightly higher than the other two, its relative increase in length is more marked.

Showing as it does a greater mean value for the three principal dimensions, the West Scottish skull has a considerably greater capacity than the other two types.

As tested by SCHWALBE'S measurements, the West Scottish skull has a considerably greater calvarial height and the vault above the glabella-inion line is longer, broader, and higher than in the Tasmanian and Australian. Coincidentally with this the frontal bone is on the average longer, more curved, and steeper, as is shown by a comparison of the length of the frontal chord, the curvature index of the os frontale, the size of the bregma angle, and the angle of frontal curvature in the three types; the parietal bone is on the average approximately equal in length in the three races, and presents the same proportionate degree of curvature in all, as was also demonstrated by the equality shown for the three types by KLAATSCH'S parietal-arc-height index. The occipital bone in the Scottish skull is less acutely inclined to the glabella-inion line (the lambda angle being larger) and is flatter below, as the opisthion angle is distinctly smaller than in the Australian and Tasmanian. Now by KLAATSCH'S method it was shown that in the West Scottish skull the lower part of the basi-bregmatic height was on the average longer than the upper segment, the two segments were equal in the Tasmanian, while in the Australian the upper segment was greater than the lower. The mean value for the upper segment was, however, practically identical in the three types. Again, the lambda-inion chord was considerably longer in the Scottish than in the two lower types. This last point tends to explain the greater length of the lower part of the basi-bregmatic height, and also why SCHWALBE'S calvarial height is greater in the West Scottish skull (fig. 15).

The greater development of the supra-inial portion of the occipital bone in the mean Scottish than in the mean Australian skull also explains the fact that while the mean upper glabella angle is smaller in the former than in the latter, the bregma angle is smaller in the latter than in the former. The frontal bone is more inclined in the Australian than in the Scottish skull when the glabella-inion plane is taken as the horizontal, but *apparently* less inclined when the glabella-lambda line is taken as the horizontal. The vault in the Scottish skull is, in short, deeper posteriorly; the lambda is more elevated above the glabella-inion plane; the glabella-lambda line does not lie in the same relative plane as the Australian (fig. 15).

If therefore supposing, for the moment, the West Scottish brain case to represent the evolved or terminal phase of a brain box of the Tasmanian or Australian type,

we find that increased capacity is associated, first, with a certain increase in maximum length, the hinder part of the skull being chiefly affected; second, with marked increase in breadth, affecting frontal, parietal, and occipital regions, so that the vault retains its ellipsoidal or long oval shape; third, with increase in height, affecting more especially the hinder part of the vault. The distinction is well brought out in fig. 15, in which the mean Scottish and mean Australian contours are superimposed and oriented on the glabella-inion line instead of the glabella-lambda line as in fig. 10. The part taken by the occipital segment in the lengthening of the sagittal arc was also proved in the section on correlation, and the facts may possibly be of interest in connection with the feature in brain evolution which has been pointed out by ELLIOT SMITH, viz.

FIG. 15.—Diagram showing sagittal cranial contours and quadrilateral figures of mean West Scottish and mean Australian skulls superimposed—the glabella-inion line as base.

G., glabella; Br., bregma; C.H., calvarial height; L., lambda; I., inion; Ba., basion.
West Scottish—continuous line. Australian—interrupted line.

the increase in the higher type of brain of the great association area between the sensory, the auditory, and visual areas, by which the regions on the lateral aspect of the occipital lobe have been pushed backwards and finally over on to the mesial surface.

As pointed out in the section on KLAATSCH's method, individual skulls may be found in the Scottish series showing characters which approach the lower type; one such skull, number 20, may be referred to in this connection. It has a cubic capacity of 1520 c.c., it is very long, moderately broad, but coincidentally very low, being only, as regards calvarial height, 1 mm. higher than the Australian mean and 1 mm. lower than the Tasmanian. In the *norma lateralis* it has quite a strong resemblance to an Australian skull, and though it has not the great frontal torus it has a very projecting inion and distinct occipital torus. Its breadth, however, is outside the highest range of the Australian in this direction. By the peculiar combination of the three dimensions the measurements fall, in all but five of the tables published by

BERRY and ROBERTSON, on the minus side of the Tasmanian, and in all but eight on the minus side of the Australian.

BERRY and ROBERTSON (50) assert that, taking the individual observations or measurements, it is possible to construct a number of tables, one for each observation, in which is shown arranged in an ascending series, according to the increase or decrease of the corresponding value shown by different types compared with that shown by the anthropoid ape, a progression of all the different types of skull from the anthropoid ape to the modern European, and that the sequence they show in each table is more or less in accordance with our accepted views at the present day on the position they hold in the evolutionary scale, views which are largely due to SCHWALBE's researches and conclusions. They are, of course, slight variations in the order exhibited by the series in the various tables. It is then possible to combine the different tables and obtain the mean position of any type from the whole series of observations, and the above authors insist that it is possible to obtain in this way a very good idea of what position any type holds in the evolutionary scale.

The object of their special research was the Tasmanian skull, and naming this the zero point, they placed other types of skull in their approximate positions relative to the former type by giving them minus values if they were between the anthropoid and the Tasmanian and equal in amount to their distance from the Tasmanian; on the other hand, if the type in any table lay on the side of the Tasmanian from the anthropoid, it received a plus value, and this was of an amount in accordance with its distance above the Tasmanian. The plus values and the minus values for the 27 observations were added together, and the total that resulted, which was either plus or minus, showed whether the type in question was on the plus or minus side of the Tasmanian in the scale of evolution. This, as BERRY admits, only gave them a rough approximation to the relative positions in the above scale "by the adaptation of modern biometrical methods." Dissatisfied with the above approximate result, they have obtained a true mathematical conception of the problem worked out by K. STUART CROSS (38) and based on their data.

The latter has produced an interesting paper which has "resolved itself into a numerical calculation of the approximate relative positions of types (*i.e.* racial types extinct and existent) in the evolutionary scale, together with a determination of the relative values of various cranial measurements and indices employed by SCHWALBE as criteria in assigning these positions."

Taking the mean values of the Scottish series examined by me, I have gone through the necessary calculations shown in CROSS's paper and find that as a result of the consideration of the values of all the 27 observations, with the exception of the glabella-inion length, the glabella chord, the cerebral chord of the frontal bone, the glabella-cerebral chord index, and the angle of parietal curvature, the mean Scottish skull takes up a position in the scale between the Cro-magnon skull and the European, the last being '845 and the first '806, while the Tasmanian is distinctly lower, *i.e.*

753 for the same values. The difference in the Scottish result from that in the Europeans of BERRY and ROBERTSON's papers may be due to the fact that the values of the latter were sometimes obtained from one specimen, and that the type compared was brachycephalic, not dolichocephalic.

I do not purpose here to follow BERRY and ROBERTSON's biometrical methods further. I am prepared to admit that, taking the mean value in a sufficiently large series of skulls of the same form and type as, for instance, the Australian, Tasmanian, and West Scottish, the summation of all these characters of the vault in the manner suggested may result in a reasonable order.

The difficulty is that there are two types *both* on the highest evolutionary plane—one long and narrow, the other short and broad; and even though the calvarial height remain the same, many of the characters of the vault may be different.

Before a proper comparison can be instituted between different types it is essential that large series should be available to get representative mean values.

5. MEDIAN SAGITTAL SECTION OF SKULL.

There is universal agreement amongst craniologists as to the value to be attached to the study of the skull after it has been sectionised in the median sagittal plane; not only that such a view shows us essential differences between the human skull and that of lower forms, but enables us to utilise certain important characters in the comparison of skulls of different races which cannot be made use of by the ordinary methods of measurement, as they only become obvious in the sectional diagram.

Amongst those who have recognised the importance of this method of comparing skulls are HUXLEY (51), and we recall his well-known "dictum" on the subject; TURNER in his "*Challenger*" Reports and various memoirs; CLELAND; and BOLK (42).

The skulls having been sawn, the difficulty was to get the exact outline of their mesial section quickly transferred to paper.

I placed a thick layer of blotting paper on the surface of a slightly yielding pad and placed the sheet of paper with the carbon paper on its upper surface on the blotting paper. The skull cut surface was then applied to the carbon paper and firm pressure exerted from above, with the result that an accurate impression of the cut surface of the skull was left on the paper underneath. This was then outlined in ink.

One skull was not bisected, as the spheno-ethmoidal region was seen to be defective; in another, after being sawn, the same region was found to be deficient, and the values for these skulls are not included in the results. This left me 98 skulls for investigation, and the following results are based on the measurements obtained from these.

I decided first of all to measure and examine the mean value and variability of certain angles measurable on the mesial section which are regarded as of morpho-

logical importance. For the present I shall confine my attention to three of these: two, the speno-maxillary and speno-ethmoidal associated with the name of HUXLEY, and one, the foramino-basilar, with which the name of TURNER is associated, although there have been many others described of less importance.

The speno-ethmoidal angle is open downwards and forwards and is formed by two lines which may be named the basi-occipito-sphenoid axis (TURNER) or basi-cranial axis (HUXLEY) and the cribriform axis, the former extending from the basion, the middle point of the anterior margin of the foramen magnum, to the "prospenion" or foremost part of the speno-ethmoidal junction in the median plane;

FIG. 16. — Impression of median sagittal section of skull 83, series K.

Maximum length, 203 mm.
Basi-nasal length, 110 mm.
Spheno-ethmoidal angle, 170° .
Spheno-maxillary angle, 95° .
Foramino-basilar angle, 166° .

Dotted line represents Frankfurt horizontal plane.

FIG. 17. — Impression of median sagittal section of skull 14, series K.

Maximum length, 200 mm.
Basi-nasal length, 105 mm.
Spheno-ethmoidal angle, 136° .
Spheno-maxillary angle, 75° .
Foramino-basilar angle, 146° .

Dotted line represents Frankfurt horizontal plane.

the latter, the cribriform axis so called, may be continued forwards from the prospenion, more or less in the plane of the cribriform axis, to the uppermost point of the ethmo-frontal suture in or near the median plane, or may be drawn to the nasion—a more definite point. Investigators differ in their conclusions as to where the second line should terminate in front. If the cribriform plate were always horizontal, so that one could have the line in its plane going through its uppermost point of contact with the frontal, in or near the median plane, that should undoubtedly be chosen, but I found that the cribriform plate was often very much curved downwards in the series, and that it was impossible to get the line in all cases in the plane of that plate and at the same time to pass through the uppermost part of the ethmo-frontal suture, *i.e.* at the foramen cæcum. Part of the difficulty in following TURNER's directions may be due to the fact that the skulls were sawn as nearly as possible in the middle line and not slightly to one side of it, as in the case of his

specimens. The foramen cæcum, which might be chosen, has been found also to be very variable, and so I have followed the method advocated by DUCKWORTH (54), *i.e.* to draw the line from the prosthion to the nasion or middle point of the naso-frontal suture, which, although not without disadvantages owing to the fact that the nasal bones vary much in the degree to which they extend upon the surface of the skull, is usually easily identified as a definite point.

For the value of the angle so measured there are many figures available for comparison. To get figures exactly comparable with those of TURNER, however, where it was possible in the present series of skulls I drew the anterior line according to his directions contained in the "*Challenger*" Reports, and will give the mean

FIG. 18.—Impression of median sagittal section of skull 17, series K.

Maximum length, 189 mm.
Basi-nasal length, 101 mm.
Spheno-ethmoidal angle, 164°.
Spheno-maxillary angle, 89°.
Foramino-basilar angle, 156°.

FIG. 19.—Impression of median sagittal section of skull 13, series K.

Maximum length, 187 mm.
Basi-nasal length, 98 mm.
Spheno-ethmoidal angle, 142°.
Spheno-maxillary angle, 75°.
Foramino-basilar angle, 136°.

value for this method from a smaller number of skulls in the series. CLELAND (15), instead of the spheno-ethmoidal junction, took as the apex of this spheno-ethmoidal angle the mid-point between the two optic foramina, and his results do not exactly correspond to those given above; but there is only a slight difference, and we may consider the spheno-ethmoidal angle, as obtained above, to be formed by the "middle base" and the "anterior base" of CLELAND.

The spheno-maxillary angle is the angle enclosed between two lines, the basi-occipito-sphenoid axis as described above, and a line drawn from the spheno-ethmoidal junction to the prosthion. This second line in HUXLEY'S (51) original description passed not through the prosthion but through the akanthion, a point less fixed morphologically than the former. The spheno-maxillary angle is the most important angle for measuring the degree of prognathism, and to it I shall refer later.

The foramino-basilar angle is that enclosed by two lines, one the basi-occipito-

sphenoid axis as above described, the other a line drawn from the basion to the opisthion and lying in the plane of the foramen magnum; in other words, the angle lies between CLELAND'S "middle base" and "posterior base." To some extent the alteration in the magnitude of this angle may be considered as indicative of changes in the slope of the plane of the foramen magnum.

A. Spheno-Ethmoidal Angle.

In the present series of 98 male skulls under examination it was found that this angle had a range of variation from 136° to 170° , and that the mean value was $152^{\circ}35'$; the S.D. was 6.58 and V. was 4.32. For 75 skulls measured according to TURNER'S direction the angle ranged in value from 133° to 162° , with a mean value of $147^{\circ}72'$; the S.D. was 6.14 and the V. was 4.15. TURNER'S mean for 5 skulls in his series was 140° ; so that if my results are truly comparable with those of TURNER, the anterior base of the former series is not on the average so much flexed on the middle base as that of the latter.

For the spheno-ethmoidal angle DUCKWORTH (54) gives the following values:—

	Dog	231°
	Cercopithecus monkey	172°
Simiidae	{ Simia	202°
	{ Gorilla	158°
	{ Chimpanzee	168°
Hominidae	{ Aboriginal Australians (average of 2)	153°
	{ Europeans (average of 2)	138°

The number of individuals in the above table is, of course, quite insufficient, but so far as the data go it would appear that, while the mean angle for the Scottish series is less than a degree below that of the Australian aboriginal, the range of variation of the angle is so great that it includes values higher than those given for the gorilla and chimpanzee, and even attains a value less than 2° below that given for the cercopithecus monkey, which is very expressive of the great degree of variability in the extent of flexion in the cranio-facial axis even in a homogeneous series.

A reasonable explanation for the well-marked variation in the above angle is somewhat difficult to find even with the evidence supplied by such a long series of skulls.

At first sight it seemed probable that a long basi-nasal chord would be associated with a wide angle, and specimens are obtainable from the series, *e.g.* fig. 16, illustrating this. On the other hand, fig. 17 shows that it is possible to have another specimen with a basi-nasal length little diminished from that shown in the former figure, but with the angle diminished to the extent of 34° . Figs. 18 and 19 show two skulls with approximately equal basi-nasal and glabello-occipital lengths, but with spheno-ethmoidal angles differing by more than 20° .

If we regard the size of the angle as a quantity which either increases or decreases throughout the series, and correlate it with the basi-nasal length, we find that the coefficient of correlation is $+0.16 \pm 0.065$, *i.e.* it is positive and sensible but not of great magnitude, so that while there is a tendency for the spheno-ethmoidal angle to increase when the basi-nasal length increases, such a tendency is not at all marked. Correlating the greatest length of the skull with the spheno-ethmoidal angle gives a coefficient of correlation $+0.53 \pm 0.067$ positive but practically negligible considering the size of the probable error, so that the size of the angle in the series seems to be independent of the length of the skull, although the latter, as has been previously stated, shows a high correlation with the basi-nasal length. Both the middle base

FIG. 20.—Impression of median sagittal section of skull, N. B. series F; cubic capacity 2060 c.c.
Spheno-ethmoidal angle, 156° ; spheno-maxillary angle, 88° ; foramino-basilar angle, 153° .

and the anterior base, *i.e.* the boundary lines of the angle above mentioned, vary considerably in their degree of inclination to the Frankfurt horizontal plane, and the angle which the anterior base forms with this plane is more variable than that formed by the middle base.

Apparently there is some doubt as to the value to be attached to the above angle, as has been stated by DUCKWORTH in regard to the foramino-basal angle, and that the former should be used like the latter in comparisons of the Hominidæ with the Simiidæ and lower forms rather than for the comparative study of members of different races in the human family.

B. Spheno-Maxillary Angle (α).

This angle in the series of 98 varied from 67° to 101° , with a mean value of 84.29° ; the S.D. was 5.43 and the V. was 6.44. In TURNER's group of 5 the mean value was 86.4° , slightly greater than the mean value shown by our series. DUCKWORTH gives

for aborigines of Australia (average of 7) an angle of $92^{\circ} 20'$, and for Europeans (average of 2) an angle of $75^{\circ} 30'$; but it is obvious that the latter value cannot be accepted as an approximate mean value for European skulls.

The speno-maxillary angle, as defined by HUXLEY, and slightly different from the above angle, was utilised by him to classify crania into orthognathous if the angle was less than 95° , and prognathous if it was more than 95° . The size of the angle is, to a certain extent, an index to the degree of prognathism; but, as TURNER points out, it is influenced, as is also the speno-ethmoidal angle, by the variation in the slope of the basi-occipito-sphenoid axis.

In the series of 98 sagittal tracings under examination I marked in the Frankfurt horizontal line, and, this being intersected by the basi-occipito-sphenoid axis, I

FIG. 21.—Impression of median sagittal section of skull No. 26, series F; cubic capacity, 1040 c.c.
Spheno-ethmoidal angle, 167° .
Spheno-maxillary angle, 90° .
Foramino-basilar angle, 143° .

FIG. 22.—Impression of median sagittal section of skull No. 21, series F; cubic capacity, 1000 c.c.
Spheno-ethmoidal angle, 156° .
Spheno-maxillary angle, 88° .
Foramino-basilar angle, 153° .

measured the angle between the two, which gave me the change of slope of the above axis to the Frankfurt horizontal plane. This angle I have named the " γ " angle in my tracings. It was found to vary in the series from 29° to 52° ; the S.D. was 4.14 and the V. was 10.29.

From the above range of variation, *i.e.* 23° in the slope of the occipito-sphenoid axis in a uniform series, it is quite evident that this factor cannot be neglected in the general statement that the magnitude of the speno-maxillary angle may be used unreservedly as a criterion for the degree of prognathism.

From the supposed constancy of the somewhat similar angle between the basinasal line and the Frankfurt horizontal plane, THOMSON and M'IVER (55), who found that in 38 skulls it varied from 22° to 34° , with a mean value of 27° , made use of it in a scheme for the measurement of prognathism. FÜRST (56), however, found that the angle possesses such a degree of variation that a constant size cannot be accepted for it.

C. The Foramino-Basilar Angle (θ).

This angle may be taken to a certain extent as an index to the degree of slope in the plane of the foramen magnum, not forgetting, however, that the variation of the inclination of the basi-cranial axis will also exert an important influence in modifying the size of the angle as well as variation in the slope of the above plane.

The angle in the series of 98 skulls was found to have a range from 135° to 168° , with a mean value of $147^{\circ}68'$; the S.D. was 6.36 and the V. was 4.30. The following values are given for the above angle in DUCKWORTH (54):—

Dog	108°
Cercopithecus monkey	147°
Simia	142°
Gorilla	120°
Chimpanzee	133°
Aboriginals of Australia (average of 2)	146° 30'
Europeans (average of 2)	149° 30'

According to DUCKWORTH there is some doubt as to the importance to be attached to the angle, and that it is to be used "in comparisons of the Hominidæ and Simiidæ with other families and other orders rather than for the comparative study of various members within the limits of these families."

While the mean value of the angle in the series of 98 skulls is just one degree greater than the mean angle of two Australian specimens, the latter are too few in number to warrant a conclusion as to its importance, and the same applies to the European value derived from two skulls. The angle in the Scottish series includes in its range the values given for the Cercopithecus monkey and for Simia.

According to TURNER (2) the angle presents considerable variations in different crania. In a Fuegian he found it lowest in value, *i.e.* 138° ; it reached its maximum in an Australian, 157° ; while in three Australians it ranged from 139° to 157° . These values are all included in the range of variation exhibited by the Scottish series.

If we consider the spheno-ethmoidal angle as described above as comparable with the orbito-basilar angle defined by CLELAND, then, the mean spheno-ethmoidal angle being greater than the mean foramino-basilar angle to the extent of about 5° , the mean cranial curve in the Scottish series would be less than 180° by that amount, and would approach the lowest value found for adult Europeans, according to this author. It would seem, however, that the angles above mentioned can hardly be regarded as strictly comparable.

If we accept the value of the spheno-ethmoidal angle obtained by following TURNER's directions as comparable with the above angle of CLELAND, then the two mean angles, foramino-basilar and spheno-ethmoidal, would be equal, the anterior base would be parallel to the posterior base, and the cranial curve would be 180° .

It seems somewhat anomalous that, while the cranial flexure of a skull which has

a capacity of over 2000 c.c. shown in median sagittal section (fig. 20) should fall short of a value of 180° by about 3° , another specimen (fig. 21) with a cubic capacity of about 1100 c.c. should show a cranial curve of only 156° , while a third specimen (fig. 22), very similar to the last, and of an equal capacity, should show a cranial curve of about 190° . One would have expected that the effect of the increased cranial expansion in the very large skull would have been to bring the anterior part of the cranio-facial axis more into the horizontal than in the case of the smaller skulls, but this is not the case, as is shown by the specimens. The influence of the slope of the plane of the foramen magnum on the parallelism of the anterior and posterior

FIG. 23.—Impression of median sagittal section of skull No. 41, series K, illustrating BOLK's method of defining the position and slope of the foramen magnum. Spheno-ethmoidal angle = 151° .

F. Fronton.
O. Occipiton.
B. Basion.
S. Opisthion.

BR = perpendicular dropped on FO from basion.

$\frac{FR}{FO}$ = basal index (BOLK).

$\angle RBS$ = angle by means of which slope of foramen magnum is measured.

base and the resulting size of the cranial curve will be very apparent in the diagrams above mentioned.

Much research has been devoted to the question of the position and the inclination of the plane of the foramen magnum in mammals. Amongst those who have contributed to the subject are DAUBENTON and BROCA, and the angles they utilised are still associated with their names. A more recent investigator of the same problem is BOLK (42), and I have adopted the methods advocated by him in investigating these points in the present series of skulls. BOLK does not favour the use of angles for defining position, but prefers the use of an index to indicate the location of the foramen magnum, and he obtains the index in the following way:—Having obtained a median sagittal section of the skull and an outline of this on paper, he defines a point on the inner surface of the anterior cranial wall where it becomes continuous with the floor in the mesial plane, which point he names the "Fronton" (F in fig. 23).

From this he draws a line to the point on the inner surface of the occipital bone furthest removed from the Fronton, which he names the "Occipiton." If there is an arc equidistant from the Fronton he makes the Occipiton the centre point of the arc. This Fronton-Occipiton line (FO) is his base line, and from the basion, the middle point of the anterior margin of the foramen magnum, he drops a perpendicular on the line FO, meeting it at R, then the length FR divided by the length FO and multiplied by 100 gives him an index which defines the position of the basion and thus of the foramen magnum. To measure the degree of inclination of the plane of the foramen magnum he joins the point B to opisthion S, and the size of the angle at B formed by the lines BR and BS is a measure of the slope of the plane of the foramen magnum.

I have followed the above procedure in regard to the 98 skulls in the series, and find that the index described above or the "basal index" (BOLK) ranges from 39.5 to 51.5, with a mean value of 45.61, which points to the fact that, as a rule, the anterior limit of the foramen magnum is in front of the middle of the Fronton-Occipiton line; in fact, there are in the series only two skulls with an index above 50.

BOLK's important conclusion from the investigation of a large number of specimens is "that in man, as the anthropoids, the foramen magnum is shifted occipitally during development." He gives values for the index of position of the foramen magnum, or index basalis as he names it, and it is interesting to compare these values with those obtained by me in the Scottish series:—

TABLE LII.

Race.	Index.	Type of Skull.
Zeelandians . .	45.7	Brachycephalic
Javanese . . .	47.9	"
Papuans . . .	44.6	Dolichocephalic
Frisians . . .	44.7	Mesaticephalic
Negroes . . .	46.6	Dolichocephalic
Scottish . . .	45.61	"

The Scottish mean index is thus seen to be about equal to that shown by the Zeelandian specimens, slightly greater than that shown by the Papuans and Frisians, and less than that shown by the Negro and Javanese skulls. In the case of the Negro group the range of the index is from 42 to 50; in the Scottish it is from 39.5 to 51.5; so that specimens may be found in the Scottish series with the foramen relatively further back than in the Negro, although on the average the opening lies relatively further forward in the former than in the latter.

According to BOLK there is "no definite relation between the position of the foramen magnum and the shape of the skull," *i.e.* the cephalic and basal indices are independent of one another.

There is a distinct interval between the index shown by the human skull in its various types and that of the various anthropoids, which have always an index well above 50, usually at least 60, although in their juvenile forms they may reach as low a value as 52.

With regard to the inclination of the plane of the foramen magnum, BOLK (42) proves conclusively in his paper that a change in the slope takes place during development both in the human subject and in the anthropoids, but less well marked in the former; the young anthropoid in this, as in many other features, agrees more closely with the human condition than the adult one. Man occupies a distinct position amongst the primates in that the opening is turned towards the front and not towards the back.

In BOLK's method if the angle is equal to 90° the plane of the foramen magnum is parallel to the base line and is considered to be horizontal; if greater than 90° , the foramen looks forwards to a degree which increases as the angle increases. BOLK gives the size of the mean angle for a number of races, and we can compare the angle of the Scottish series with these.

In Papuans the angle is equal to	.	.	.	101·9°
In Negroes	„	„	.	99·2°
In Javanese	„	„	.	99·4°
In Zeelandians	„	„	.	102·3°
In Frisians	„	„	.	96·2°

In the Scottish series the mean angle for the 98 was $94\cdot80^\circ$, but showed a range in value from 84° to 112° , so that the mean inclination of the foramen magnum was not so much forward as in any of the races for which values are quoted by BOLK, although in one case the basal angle was 112° and in a number of others it was over 100° . It is generally believed that in the European the plane of the foramen magnum is directed forwards to a greater degree than in the Negro, but so far as my figures are to be depended upon it would appear that in this Scottish series of skulls the inclination of the opening is directed forwards on the average to a less-marked degree than it is in such a primitive type as the Negro. There is a distinct gap between the values shown by the angle in the human skull and that of the anthropoids, in which the angle varies from 70° to 75° , although in the infantile gorilla an angle of 95° has been found. The smallest angle in the Scottish series was 84° , while two showed an angle of 85° , one an angle of 86° , five were 87° , and four were 88° .

There are certain lines measurable on the mesial sagittal section, and we can compare the mean values of those given by TURNER for the corresponding measurements in his series in the form of a table (LIHI).

TABLE LIII.

Character.	TURNER'S Series.	Present Scottish Series (98).		
	Mean.	Mean.	S.D.	V.
Basi-occipital sphenoid axis	65 mm. (5)	66.21	3.41	5.15
Spheno-maxillary line	74 " (5)	75.39	4.34	5.75
Cribriform axis	29 " (5)	23.74	3.22	13.56
Basi-lambda line	118.6 "	120.58	4.58	4.00
Perpendicular radius	138 "	135.85	5.28	3.88
Basi-bregmatic length	136.2 "	133.7	5.47	4.09
Basi-glabbellar length	111 "	107.57	4.183	3.88
Basi-nasal length	103 " (5)	100.96	4.113	4.073
Basi-alveolar length	95.4 " (5)	94.87	4.76	5.01
Anterior pole distance from perpendicular radius	88 " (5)	84.88	6.91	8.14
Posterior " " "	81 " (5)	84.61	5.32	6.28

Sir WILLIAM TURNER, in his investigation into the characters exhibited on the median sagittal section of some specimens from his series of Scottish skulls, pointed out that in them the distance from the perpendicular radius to the anterior pole of the cranial cavity was greater than that from the corresponding radius to the posterior pole of the cavity in all the skulls examined. He points out further that the two distances were more nearly equal in the brachycephalic than in the dolichocephalic specimens, and that he found the posterior pole distance greater than the anterior pole distance in the dolichocephalic Fuegian and other dolichocephalic skulls described in his "*Challenger*" Reports, while in the brachycephalic and mesaticephalic specimens from the same groups the contrary was the case. It would seem, therefore, he says, "as if in the formation of some dolichocephalic skulls the growth takes place backwards behind the plane indicated by the perpendicular radius to a greater extent than in front of the plane."

In the series of 98 Scottish skulls I have examined which are dolichocephalic (C.I., 74.4) the mean value of the posterior distance was practically equal to that of the anterior distance, while the latter length was more variable than the former, as shown by the coefficient of variability.

As regards the individual skulls, we find that the distance from the perpendicular radius to the posterior pole was greater than that to the anterior pole of the cranial cavity in 44 cases and the distances were exactly equal in 4 cases, which, taken together, is just less than half the number of the specimens examined.

There are other features of the skulls which only become obvious after a sagittal section has been made, and these include the extent and great variability in the degree of development of the various sinuses, especially the sphenoidal and frontal. They are seen to vary very much in extent, in the case of the latter from almost or even complete absence to a condition where it extends upwards in a well-marked

form well beyond a third of the length of the frontal bone, and this not in the skull of an aged person.

We also observe, in such a section, the great variability in the degree of distinctness which the impressions corresponding to the various convolutions exhibit, being sometimes quite evident, at other times practically invisible.

Another feature brought to light and shown well in the sagittal tracings is the variation in the thickness of the skull. As is well known, the skull may become much thicker in old age, but the great variations shown in the series examined is remarkable, even excluding specimens that might have become secondarily thickened owing to advanced years.

I estimated the thickness with the calipers at six places, viz. :—

1. At the glabella.
2. At the inion.
3. At the middle of the frontal (at the cut edge of the sagittal section).
4. At the middle of the parietal (at the cut edge of the sagittal section).
5. In the vicinity of the frontal eminence.
6. In the vicinity of the parietal eminence.

The figures shown in the following table are interesting, as they show that the thickness at the glabella is the least variable, using the coefficient of variation as the criterion of variability, in spite of the variation in the degree of development of the frontal sinus in the series.

TABLE LIV.

Position of Measurement.	Mean Thickness.	S.D.	V.
At glabella	15·88 mm.	2·43	15·30
At inion	14·25 "	3·36	23·58
Middle of frontal (mid line)	7·01 "	1·88	26·81
Middle of the parietal (mid line)	7·24 "	1·42	19·61
At frontal eminence	5·65 "	1·61	28·5
At parietal eminence	6·41 "	1·65	25·74

The greater variability of the thickness at the inion is to be attributed largely to the fact that the external and internal occipital protuberances were frequently at different levels, as has been pointed out by various observers, including SOLLAS (46), ANDERSON (57), and KLAATSCH (43), so that the two eminences did not always come into the measurement of the thickness.

ANDERSON (57) measured the thickness of a large number of skulls, making measurements in twelve different places in each. I have taken his mean measurements given to the places where I estimated the thickness, converted them from inches into millimetres, and the following table shows the mean thicknesses compared :—

TABLE LV.

Measurement.	ANDERSON'S Series.	Scottish Series.
Thickness at inion	9·10 mm.	14·25 mm.
About middle of frontal (mid line)	6·59 "	7·01 "
About middle of parietal (mid line)	5·93 "	7·24 "
At frontal eminence	5·78 "	5·65 "
At parietal eminence	5·66 "	6·41 "

There is considerable divergence in the mean thickness shown by the two series at the site of the external occipital protuberance or inion; but whether the other measurements may be taken as indicative of a greater mean thickness in the Scottish than in the Irish skull, as the figures given would lead one to believe, would require further investigation.

Both TURNER (47) and SOLLAS (46) refer to the relatively great thickness of the cranial wall in the Australian skull.

6. ORIGIN OF THE WEST SCOTTISH SKULL TYPE.

In the course of my investigations into the characters of this Scottish series of crania, I was impressed by the remarkably close resemblance they presented in their general proportions to those of illustrations I had seen depicting crania obtained from long barrows in various parts of the country, generally referred to as "long-barrow crania," and to Professor BRYCE'S skulls from the chambered cairns of Arran; especially was this the case in the series of plates in *Biometrika*, vol. iv, depicting long-barrow crania from the collection of the University of Oxford, described by SCHUSTER. The present series of Scottish skulls also presented an exceedingly close resemblance in their general form to the series of crania described by MACDONNELL and known as the Whitechapel English crania, which the latter regards as the typical skull of the Londoner of 200 years ago.

MACDONNELL was convinced that the skulls which resembled his series most closely were the long-barrow skulls. SCHUSTER (62) gives some measurements for the principal dimensions of the series of long-barrow crania in the museum of Oxford University, and I have made use of some of his measurements and placed the corresponding values in the Scottish series alongside for comparison. From the table it is quite evident that the present series of male Scottish skulls in their general proportions are not far removed from the long-barrow crania, and are undoubtedly of the same type. Their difference from TURNER'S collection of crania containing specimens from the whole of Scotland—although principally derived from the south,—especially in regard to mean maximum breadth, has been already described at sufficient length.

TABLE LVI.

Reference Letter.	Male.			Female.		
	Scottish (100).	Long Barrow. (SCHUSTER.)	No.	Scottish (100).	Long Barrow. (SCHUSTER.)	No.
L	189·18 mm.	190·6 mm.	16	177·97 mm.	182·6 mm.	13
F	187·97 "	187·1 "	17	...	184 "	12
B	140·7 "	142·4 "	18	135·16 "	138·6 "	12
B'	97·48 "	98·9 "	16	92·66 "	94·1 "	11
H	133·71 "	137·8 "	12	125·01 "	135·1 "	
OH	118·11 "	120·7 "	...	...	118 "	
LB	100·96 "	101·9 "	...	93·82	96·8	
100 B/L	74·4	74·9	...	76·03	76·3	12
100 H/L	70·7	72·7	...	70·31	74·0	8
100 NB/NH	45·58	49·0	...	46·77	49·1	
P	87°	83°				

Are the skulls in this series, then, to be regarded as those of descendants of the primitive people whose skulls have been found in the long barrows and chambered cairns, who have remained isolated, as it were, and practically uninfluenced by the influx of invaders of different races who have had such an influence in producing diversity of cranial form in the Eastern parts of Scotland and England?

I was led to investigate the subject further, and to that end have consulted many contributions of various authorities. We find that, between forty and fifty years ago, THURNAM (63), investigated the characters of the crania of the long-chambered tumuli, or long barrows, and found there a long-headed or dolichocephalic type of skull, whereas in the round tumuli and short cists of Scotland were the remains of another distinct stock, round-headed or brachycephalic; and so constantly was this found, that his phrase "long barrow, long skull; round barrow, round skull" may almost be regarded as an unfailing law. He believed that the dolichocephalic type was the forerunner of the brachycephalic type which, having come from Belgium and France, had conquered the earlier type and had in part displaced, in part mixed with it, as appeared from occasional admixture of the two types of crania in round barrows. The later round-headed type, which, according to THURNAM, was the Celtic, finally became dominant.

It is important to note that the primitive long-headed stock was, and is still, regarded as immigrating from the Iberian Peninsula, and was hence called the Iberian stock. SERGI (58) has examined the skulls from these British long barrows and compared them with ancient and modern Mediterranean skulls, and believes that the primitive Mediterranean stock, having occupied the Iberian Peninsula, invaded France and then Britain, constructing tumuli for its dead wherever it took possession. Osteological remains of this Neolithic people are distributed all over Britain from end to end, but are most numerous in the south-west. As Professor BRYCE has

demonstrated from the distribution of their sepulchral monuments, they seem to have entered Scotland from south and west. The round-headed or Alpine (RIPLEY) race entered Scotland from south and east. The earliest comers buried their dead in short cists, and introduced the beaker type of urn. As has been demonstrated by REID, LOW, and BRYCE, they were short and highly brachycephalic in skull form. The later invaders, according to WRIGHT, founding on his observations on the skulls from the Yorkshire round barrows, were already mixed before their arrival with a long-headed stock.

This round-headed influx is stated to have overrun England and every part of Scotland, but not Ireland. The question arises—Did it reach the west of Scotland, the part furthest removed from the landing-place? Archæological evidence clearly proves that it did, though probably it did not overrun the west to the same degree as the east of the country.

There is another point to consider, however. We must not forget the Teutonic invaders from Denmark, Germany, and Scandinavia in the ninth century, who settled down amongst the natives, and descendants of whom we find all over Britain to-day. The head form of these invaders was dolichocephalic, and quite similar to the prevailing type in the parts of the British Isles, where the Mediterranean substratum had maintained its position previous to their arrival.

Apparently the collection of crania forming the present series of Scottish skulls may either be representatives of the Mediterranean stock or, on the other hand, may represent those of a colony of Teutonic invaders; they are Mediterranean in their dolichocephaly but, unfortunately, just as much Teutonic in that respect.

It must be apparent that it would be very difficult, in fact impossible, to decide such an important question from the evidence supplied by the skulls alone, but the evidence of place-names and physical traits strongly points to the conclusion that in the west the prevailing type owes its origin to the earlier invaders, not to the Teutonic settlers. We therefore conclude that the present series of skulls derived from the Glasgow district are to be regarded as those of descendants of the Mediterranean or Iberian stock, represented in a primitive form in the long-barrow crania, and not as descendants of the more recent Teutonic invaders. They seem to have established themselves in this region at a remote period, and have preserved their skull form practically unaltered.

The present series of skulls, as the comparison with TURNER's series demonstrates, represents only one type of skull prevailing in Scotland. The mean values are not national but local values; but none the less the type represented is probably the great basal national type which has remained rather purer in the west than in the east, where it has been affected to a larger extent by the early intrusive brachycephalic element.

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DESCRIPTION OF PLATES.

Plate I. A typical male skull from five different aspects: norma lateralis, norma facialis, norma occipitalis, norma verticalis, norma basalis.

Plate II. A typical female skull from five different aspects: norma lateralis, norma facialis, norma occipitalis, norma verticalis, norma basalis.

Plate III. A, A typical male skull: norma lateralis and norma verticalis; B, a typical female skull: norma lateralis and norma verticalis.

DR MATTHEW YOUNG: "A Contribution to the Study of the Scottish Skull."—PLATE I.

DR MATTHEW YOUNG: "A Contribution to the Study of the Scottish Skull."—PLATE II.

DR MATTHEW YOUNG: "A Contribution to the Study of the Scottish Skull."—PLATE III.

A

B