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Anatomy. — *"On the position and displacement of the Foramen magnum in the Primates."* By Prof. L. Bolk.

(Communicated in the meeting of June 26, 1909).

In the Primates the Foramen magnum is very differently situated in the cranial base. Sometimes, as with Mycetes, it lies very near the occipital pole of the skull, so that the condition is found which is the rule with other mammals, sometimes, as in man, it lies about the middle of the cranial base. This latter circumstance has occasionally led to the assumption of a causal relation between the shifting of the Foramen magnum in a facial direction and the acquiring of an errect gait. But Huxley already pointed out that the amount of the shifting does not depend on the position which the genus occupies in the Primate system and it will be shown in the present communication that the relation between the two phenomena is certainly not such that the acquisition of an erect gait has been the cause of the displacement of the Foramen magnum.

Together with the variations in position also the inclination of the plane of the Foramen magnum generally changes. This latter point, however, will not be dealt with in this communication, which will only treat of the shifting. The main points of this phenomenon have been known for a long time. In a certain sense the history of comparative craniology was even inaugurated by the study of this displacement. As early as the year 1764, namely, a paper on this subject was published by Daubenton [1]), in which he proved the shifting more especially by measuring an angle which has since been known as Daubenton's occipital angle, but which has the disadvantage that its two legs do not lie in the median plane. This angle has later been replaced by Broca's occipital angle which at any rate has the advantage that the two legs are both in the median plane. Yet it seems to me that Broca's method as well as that which the following investigators (Huxley, Virchow, Welcker) applied in order to express the displacement of the Foramen magnum numerically, may be replaced by a more exact one. They constructed a certain angle which they used as a measure for the displacement. But an analysis of their methods shows that the value of their angle is not only determined by the position of the Foramen magnum but also by different other factors (inclination of the plane of the Foramen magnum,

[1]) Différences de la situation du trou occipital dans l' homme et dans les animaux. Mém. Acad. d. Sciences.

degree of bending of the cranial base, shifting of the anatomical points towards which the legs of the angle diverge). Hence in this communication a different method will be followed which will be presently explained [1]).

This paper contains the first results of an investigation on the anatomy of the Primate skull, especially based on the study of the median plane. In order to prevent repetitions in subsequent communications I shall begin with an enumeration of the materials used. In following papers reference may then be made to this enumeration. All skulls were cut in two along the median plane which was then drawn in natural size by means of the MARTIN pantograph, except the small skulls of Hapale, which were drawn at twice their natural size. The mediagrams of the foetal human skulls were made differently. All measures, ratio numbers, etc. which will be given now and later, have been derived from the mediagrams, unless the contrary is expressly stated.

Human skulls.

20	foetal skulls				
10	skulls	from	the	first year	
5	,,	,,	,,	1st — 2nd	year
7	,,	,,	,,	2nd — 3rd	,,
4	,,	,,	,,	3rd — 4th	,,
5	,,	,,	,,	4th — 5th	,,
7	,,	,,	,,	5th — 7th	,,
6	,,	,,	,,	7th — 8th	,,
4	,,	,,	,,	8th — 10th	,,
6	,,	,,	,,	10th — 12th	,,

10	dolichocephalic skulls	(Frisians)	Ind.	ceph.	average	75.7
10	,, ,,	(Papouas)	,,	,,	,,	67.5
10	,, ,,	(Negroes)	,,	,,	,,	71.2
10	brachycephalic skulls	(Zeelandians)	,,	,,	,,	84.8
10	,, ,,	(Javanese)	,,	,,	,,	82.7

Besides median sections were made through 10 other dolichocephalic skulls with an average index of 74,8, the origin of which was not accurately known, however.

[1]) The best work on comparative craniometry of the Primates (that of AEBY) differs from other works also in this respect, that in it ratio numbers are used as much as possible and angular values as little as possible. C. AEBY. Die Schädelformen der Menschen und der Affen. Leipzig 1867.

Skulls of monkeys.

Hapale sp.	6
Cebus fatuellus ♂	5
Cebus fatuellus ♀	5
Chrysothrix sciurea.	10
Mycetes seniculus	5
Pithecia nocturna	4
Ateles sp	7
Inuus nemestrinus	5
Cynocephalus sp	3
Macacus cynomolgus ♂	5
Macacus cynomolgus ♀	5
Cercopithecus sp	4
Colobus guereza.	2
Semnopithecus maurus	5
Siamanga (ad.)	10
Siamanga (juv.)	2
Hylobates sp	5
Simia satyrus (ad.)	10
Simia satyrus (juv.)	3
Troglodytes niger (ad.)	2
Troglodytes niger (juv.)	2
Troglodytes gorilla (ad.)	8
Troglodytes gorilla (juv.)	2

For Ateles, Cynocephalus and Cercopithecus the data were derived from individuals of different species. The species of the two former genera are not accurately known to me, of Cercopithecus the skulls belonged to the species: albogularis, patas, talapoin and Campbelli. The small skulls of Hapale belonged to individuals from the environs of Paramaribo; it would be difficult to assert whether they all belong to one species. Also of Hylobates I did not know the exact species; two of them originated from the south-western part of Borneo (probably H. concolor), the three remaining ones from Deli on Sumatra (probably H. agilis). But it must be borne in mind that SCHLEGEL, THOMAS, and MAX WEBER are of opinion that these are no distinct species, but regional varities.

The skulls, mentioned here as Frisians, are old "mound" skulls from the first centuries of our aera and hence may be looked upon as representatives of the Germanic skull which may be indicated as skulls of the Homo europaeus, frisius. The above mentioned skulls of Zeelandians were obtained from the drowned land of S. Beveland, I have shown elsewhere and it had been remarked already formerly by others that in the old inhabitants of S. Beveland we have an almost unmixed round-headed population which must be classed among the short, brown-eyed, brachycephalic race of Europe, now generally known as Homo alpinus. So the skulls may be indicated as skulls of the Homo alpinus zeelandicus [1]).

Before dealing with the Foramen magnum itself I will briefly explain the method followed in this comparative craniological investigation. At the outset the necessity was at once felt of having a base line in the median plane of the skull, to which the different ratios to be calculated and compared, could be referred. This base line must satisfy certain conditions. Firstly it must join in all skulls two easily determined corresponding points. These points must be determined by the shape of the skull itself. Hence they may not be relief points, since a shifting of these would modify the direction of the base line, while moreover its length would become dependent on the more or less vigorous development of the relief. For the same reason I could not choose a line, the length or course of which could depend on the local thickness of the cranial wall, so that the two terminal points must lie on the interior surface of that wall. Nor did it seem advisable, where skulls of such different form as those of the Primates were concerned, to choose as fixed points the crossing point of one of the sutures intersecting the median plane. For the position of the sutures on the cranial surface depends too much on the development of the adjacent cranial bones themselves. The point where a suture intersects the median plane may be a homologous point with all skulls, but the base line of a comparative craniometric system must lie, if possible, between two homotopic points. [2])

[1]) By giving this definition I comply with the wish, formulated by FRIZZI: Es ist zu wünschen dass alle Länder und deren einzelne Bezirke, welche auf den Alpinus Anspruch erheben werden dürfen, fernerhin dem Oberbegriff Homo alpinus als Unterbegriff den seines näheren Bestimmungsortes beifügen mögen. E. FRIZZI. Ein Beitrag zur Anthropologie des "Homo alpinus tirolensis". Mith. Anthrop. Gesellsch. Wien Bnd XXXIX.

[2]) For this reason KLAATSCH wrongly asserts that the glabella-lambdaline, proposed by him, is to be preferred to the "glabella-inion" line of SCHWALBE. Although the position of the inion may be variable, since it lies in a muscular frame, the lambda is no less variable, being dependent on the surface growth of the squama occipitis. Now when we remember how very variable is the part, played by the ossa interparietalia in the formation of the squama, this would seem a reason why the course of the lambda suture might be even more fortuitous than of any other cranial suture. That moreover KLAATSCH's line has no advantage over SCHWALBE's became evident to me from what follows. KLAATSCH asserts that his Glabella-lambda line in man always forms about a right angle with the Basion Bregma

The base line of my system, to which all further ratios will b referred, and with respect to which the values of angles will b determined, is indicated in Fig. 1 in the mediagram of a Cebu skull. As frontal point I chose the lowest point of the fronta wall of the skull where the interior surface of the skull bend inwardly in a more or less sharp curve to be continued in the roo of the nasal cavity. The determination of this point presents n difficulties, as a rule, since in the median plane the interior surfac of all Primate skulls possesses a distinct frontal wall which may b more or less inclined and may pass more or less gradually into th cranial roof, but which is still always present. I might express thi fact as follows: in the median section all Primate skulls posses internally a front. On both sides of the median plane this fronta wall disappears, since the roof of the orbitae approaches very closel under the cranial roof, so that the cranial plane and the orbital roo join under an often very acute angle. It will be shown in a followin communication that the human front has its origin not exclusively i a higher vaulting of the frontal bone but also to no small extent i a downward displacement of the eye-sockets. Also in AEBY's work I find this idea already expressed and it seems to me that the inves tigations of recent years on this part of the skull would have take a different course if more attention had been paid to the facts i AEBY's work.

The transition of the cerebral into the nasal plane, i. e. in genera the foremost lowest point of the anterior surface of the skull, can i most cases be determined at once. Only in a few cases I met wit some difficulty in this respect, namely with the skulls of Javanese since here I found, except in a single case, a frontal crist projecting very far into the cranial space. For the sake of brevity I shal henceforth call this anterior point of the base line the "Fronton" The second point I determined by means of compasses from the first. I namely sought on the posterior wall the point which is a

line. Now I have measured in the mediagrams of my adult human skulls the angle which the Basion-Bregma line forms with the line of KLAATSCH and with that o SCHWALBE and found the following results. In 70 human skulls the angle whic the Basion-Bregma line forms with the glabella-lambda line (KLAATSCH), varie between 84 and 98 degrees and the angle which this same line forms with the glabella-inion line (SCHWALBE) between 104 and 117 degrees. According to the method of KLAATSCH the top of the variation curve lies at 90° (in 17 out of 70 cases), according to the method of SCHWALBE at 112° (in 14 out of 70 cases) From this comparison it is obvious that the proper displacement of the inion i no larger than that of the lambda and that consequently on this account neithe of the two lines is to be preferred to the other.

the greatest distance from the fronton. With the lower Primates this point can as a rule be determined at once, in man, however, and especially with juvenile skulls, this is not the case. For it was not unfrequently found that a fairly large part of the interior surface of the skull in the median plane describes a circular arc with the fronton at the centre. Where this was the case the middle of this circular arc was always chosen as the posterior point. In what follows this point will be referred to as the "Occipiton".

The base line extending between fronton and occipiton may at the same time be the line of maximum length within the cranial cavity and is so in the majority of cases, although not always, especially with juvenile skulls. For in man as well as with the Anthropoids the frontal wall of skulls where the milk-teeth are still present, shows a more or less distinctly developed concavity. With such skulls the line of maximum length consequently lies in a slanting direction through the cranial cavity starting about the middle of the frontal bone and ending about the middle of the squama of the occipitale.

Now I shall first point out how in the different skulls I studied the Foramen was placed with respect to the base line, after which I shall compare its position in juvenile and adult skulls of the same species.

It was remarked above that this cannot be done by constructing a certain angle and determining its value and variations. In general it seems to me that in comparative craniology any phenomenon must be studied as little as possible by variations of angular values and that the construction of angles has to be restricted. For any angle requires three points, the two terminals of the legs and the apex. Now a variation in the value of an angle can only then be a true criterion of the course of any phenomenon, when one is convinced that two of these three points have not changed their relative position. And this is hardly to be expected in most cases. The position of every point in the skull varies on its own account, since on every point a large number of factors have a localising influence. Now two points may have a number of these factors in common, but besides several others which are different. Hence if in two skulls the angle between three points is found to vary, we are not justified to explain the difference by the shifting of one of these points only. The inaccuracy inherent in such a method is not entirely avoided, but greatly diminished by constructing projections on a base line instead of making angular determinations and by expressing the course of a phenomenon by the different values of ratio numbers. The degree of accuracy depends with this method chiefly on the question whether the points, joined by the base line, are really homotopic.

In the present paper this method, which was also followed by AEBY, although his base line was in my opinion wrongly chosen [1]), will be first applied for determining the position of the Foramen magnum. This can be done in a very simple manner. If namely from the anterior edge of the foramen magnum — the basion — a perpendicular is raised on the base line, this latter is divided into an anterior and a posterior part (See fig. 1). The anterior part will in future be indicated by A, the posterior by B. In my gradually to be developed craniometrical system these letters will always have the same meaning.

The base line itself will be indicated by G, so that A is the part of G, situated before the projection point of the basion, while B is the part of G behind it. Now A becomes greater the further the basion and hence the foramen magnum lies backward. If now we

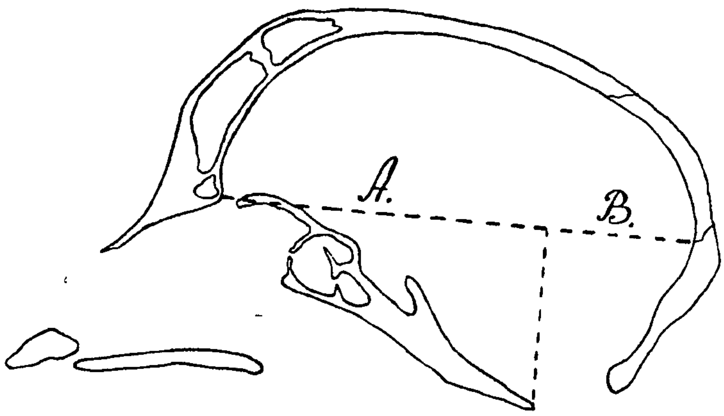

Fig. 1.

put G 100, in order to become independent from absolute measures and to be able to make direct comparisons, then by determining A and G in absolute measure in the mediagram, the ratio of A and G may be directly expressed by a number which will be larger as A itself becomes larger. This ratio number will in future be called the "basal index" of the skull. It is found by the formula

$$\frac{100\,A}{G} = \text{Index basalis.}$$

1) The chief error in AEBY's base line is that he placed it between two "anatomical" points; he derived it from the "structure" of the skull, whereas the base line I have chosen, is determined by its "form".

This index becomes larger as the foramen magnum lies more occipitally.

I shall now first give the basal indices found with the skulls of the different apes, those of man will be given later.

Index basalis of skulls of monkeys.

Hapale 77, 72, 71, 70, 70, 68. Average **71**.
Chrysothrix 62, 61, 60, 60, 60, 59, 58, 58, 57, 56. Average **59**
Cebus 71, 70, 70, 69, 68, 68, 67, 65, 64, 64. Average **67**.
Ateles 67, 66, 65, 64, 61, 58. Average **64**.
Pithecia 76, 75, 74, 70. Average **74**.
Mycetes 95, 91, 86, 84, 78. Average **86**.
Inuus 67, 65, 65, 64, 63. Average **65**.
Cynocephalus 69, 66, 60. Average **65**.
Macacus 69, 69, 66, 65, 65, 63, 62, 60, 60, 60. Average **64**
Cercopithecus 60, 60, 57, 54. Average **57**.
Semnopithecus 76, 76, 74, 71, 70. Average **74**.
Colobus 76, 74. Average **75**.
Siamanga (adult) 78, 77, 76, 76, 76, 75, 75, 75, 73. Average **76**.
Siamanga (juv.) 70, 62.
Hylobates 66, 67, 71, 72, 80.
Chimpanse (adult) 65, 63. Average **64**.
Chimpanse (juv.) 53, 50.
Gorilla (adult) 67, 66, 65, 62, 59, 58, 58, 56. Average **61**.
Gorilla (juv.) 54, 50.
Orang (adult) 69, 65, 60, 60, 58, 58. Average **61**.
Orang (juv.) 55, 53, 51, 51, 50. Average **52**.

Leaving aside for the present the infantile skulls, the basal index appears strongly to vary with the different simian genera, while moreover no inconsiderable individual variations exist. The highest average was found with Mycetes, the lowest with Cercopithecus. At the same time the correctness appears of what had already been asserted by Huxley, that the position of the foramen magnum in the cranial base, does not depend on the place occupied by the genus in the system. This is shown most clearly, if the genera are arranged according to the average value, found for their basal index, beginning with the genus with the highest index, where the foramen magnum lies hindmost. The following series is obtained: Mycetes, Siamanga, Colobus, Pithecia, Semnopithecus, Hapale, (Hylobates), Cebus, Inuus, Cynocephalus, Macacus, Ateles, Chimpanse, Gorilla, Orang, Chrysothrix, Cercopithecus.

From this series may also be inferred that there is no direct causal relation between the position of the foramen magnum and the development of the biped gait. Although it will presently appear that the basal index in man is lower than in the other Primates, the given enumeration shows that we must be cautious in attributing this only to the acquisition of an erect gait. If this were the case, Siamanga would certainly not be at the top with the highest basal index but one.

And as to the genus with the highest index value — Mycetes — it is not unlikely that here we have a secondary occipital shifting of the Foramen magnum as the result of the extraordinary development of the hyoid apparatus. The place, occupied by Mycetes, is an exceptional one on account of peculiar developmental phenomena. Taking this into account, Siamanga, the animal which is perhaps more skilled in biped walking than any other Primate, mentioned in this paper, stands at the top as to the value of its basal index and approaches most closely the half-apes of which e.g. Lemur albifrons had an index 87 and Propithecus diadema 80. But one must be careful not to place Siamanga on this ground only lower in the system than the Primates with a smaller basal index and especially not to look upon this phenomenon itself in Siamanga as the preservation of an original condition. Of this I am not convinced. For, as will be shown in a following paper, the position of the foramen magnum is largely determined by the position of the facial skull with respect to the cerebral skull. And in the Primates an evolutional line in this respect may certainly be recognised, being in short that the facial skull, first situated before the cerebral skull, is displaced under it, after which it is shortened. Now this occipital displacement of the facial skull has a great influence on the position of the foramen magnum.

At the bottom of the series stands with the lowest index Chrysothrix as the representative of the platyrhine monkeys and Cercopithecus of the catarrhine. For these latter an examination of more individuals, specially of the same species, seems desirable to me, in order to settle whether indeed in the genus Cercopithecus the foramen magnum is in general placed so much to the front. The Anthropoids do not, as far as their basal index is concerned, occupy a conspicuously favoured position among the apes and certainly do not form a direct link between the lower apes and man.

The basal index of man is given in the following list, in which the different groups, mentioned above, are kept separate. For the sake of completeness I also mention the cephalic index.

Skulls of Zeelandians (Homo alpinus var. Zeelandicus) Index cephalicus: lowest 81.6, highest 88, average 84.8.

Index basalis: 50, 49, 48, 48, 48, 48, 45, 44, 43, 43, aver. **45.7**.

Skulls of Javanese. Index cephalicus: lowest 78.3 highest 87.9.

Index basalis: 52, 51, 50, 50, 49, 48, 46, 45, 42, 42, aver. **47.9**.

Skulls of Papuas. Index cephalicus: lowest 63.4, highest 69.6 average 67.5.

Index basalis; 46, 45, 45, 45, 44, 44, 44, 44, 43, 42, aver. **44.6**.

Skulls of Frisians (Homo europaeus var. Frisius). Index cephalicus: lowest 71.5 highest 79.1 average 75.7.

Index basalis 48, 47, 46, 46, 46, 44, 44, 44, 42, 40, average **44.7**.

Skulls of Negroes. Index cephalicus: lowest 68.2 highest 76.4, average 71.2.

Index basalis: 50, 49, 48, 47, 47, 47, 45, 44, 43, 42, average **46.6**.

If we compare the index values of man with those of the adult apes, there appears to exist a considerable difference between them, the average of all the human skulls being fifteen units smaller than that of all Anthropoid skulls. By this considerable forward displacement of the foramen magnum the human skull has obtained a characteristic which it shares with none of the other Primates. For if the basal index is greater than 50, this means that the projection of the basion on G. lies behind the middle of this line. Now this was the case without exception with all the adult ape skulls; in man, however, the projection point of the basion lies nearly always before the middle of G and only in exceptional cases it coincides with or lies a little behind it. The individual place occupied by man as to the position of the foramen magnum appears also from the fact that the lowest value I found for the basal index with an adult ape skull, namely 54 with Cercopithecus patas, is higher than the highest value which I found in man: 52 in a Javanese. Whereas with apes A is always larger than B, the opposite is the case with man.

The question whether in man the foramen magnum in the brachycephalic and dolichocephalic skull occupies different positions, corresponding to the difference in shape, must be answered negatively on account of the above figures. To be sure, the two brachycephalic groups, — the Zeelandians and the Javanese — have a slightly higher basal index than the dolichocephalic Papuas and Frisians, but on the other hand the group of the strongly dolichocephalic negroes with their average cephalic index of 71,2 has a basal index which is higher than that of the very short-headed Zeelandians. [1]) So my results do not indicate that in man there exists a relation between the position of the foramen magnum and the shape of the skull, neither on account of the averages, nor of the range of variation, for with the brachycephalic skulls the basal index varied from 52 to 42 and with the dolichocephalic ones from 50 tot 40·

The independence of cephalic and basal index also appears from the following table in which the two indices are placed side by side for ten long-headed skulls. These skulls do not belong to any of the above-mentioned groups.

Index cephalicus	Index basalis
68.9	46.7
71.5	43.8
72.3	48.—
72.5	41.7
72.9	44.5
73.1	48.7
74.7	50.—
74.8	50.6
75.9	45.5
76.4	44.6

Also in these ten skulls we have again the same range of variation of about 10 units in the basal index as with the five groups above.

The main conclusion from what precedes is that in man the projection of the basion on G regularly falls a little before the middle of this line. Now if we bear in mind that the line of support of the skull, which joins the middle of the two condylae, lies regularly a little behind the basion, the conclusion is arrived at that the projection point of the line of support of the human skull on the base line I assumed, coincides with the middle of this line. It may be taken for granted that in regard to the erect gait of man this relation is a favourable one from a statical point of view.

An unexpected result was obtained by comparing the basal indices of juveniles and adult skulls of the same species. In all cases in which it was possible to make this comparison the basal index of the infantile and juvenile skull proved to be lower than of the adult, in other

[1]) In AEBY's monograph I find the following remark as to the Foramen magnum in negroes: Einige Beobachter glauben die Wahrnemung gemacht zu haben dass die Stellung dieser Oeffnung insofern veränderlich sei, als sie bei gewissen Völkerschaften und zwar speziell den Negern, weiter hinten liege, als bei andern. (Die Schädelformen der Menschen und der Affen. Leipzig 1867 p. 16).

words: *during the postfoetal development of the skull the foramen magnum is shifted occipitally.* I had not expected this result. A priori I should have expected the opposite, namely that the individual development would reflect the phylogenetic. I shall first show the stated for the ape skulls, and then for human skulls.

The direct proof of this shifting is obtained by comparing the basal indices. But also in another manner I will give a striking proof, namely by superposing the mediagrams of youthful and adult skulls.

Of the Siamanga I made sections of two juvenile skulls, the youngest of which possessed all the milk teeth, while no permanent tooth had yet appeared. The basal index of this skull was 62, i. e. eleven units less than the lowest basal index of an adult siamanga skull. The second possessed a mixed set of teeth, the permanent canines, the first premolars and the third molar had not yet come through. Of this skull the basal index was 70. Hence a considerable backward shifting of the Foramen magnum had taken place already, which evidently had not been completed yet.

The difference of position of the Foramen magnum which is indicated by these different values of the basal index, is very clearly shown in fig. 2.

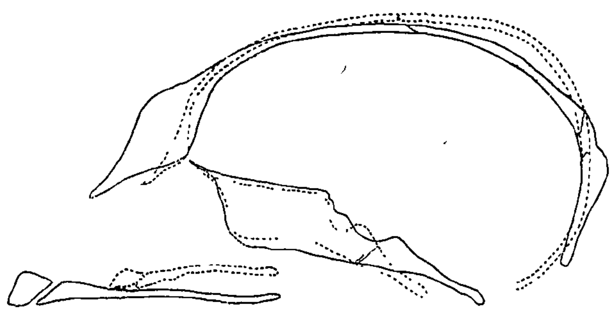

Fig. 2. Mediagrams of an adult and an infantile Siamanga skull.

In this figure the full line is the mediagram through an adult Siamanga skull with a basal index of 76, the dotted one is the mediagram of the young Siamanga with the milk teeth and a basal index of 62. The absolute length of G was in the adult skull 80 mm., i: the young one 72 mm. The mediagram of the juvenile skull has accordingly been enlarged in the ratio 80 to 72. If now the base lines are made to coincide, so that the fronton and occipiton of the two skulls are the same, a figure is obtained from which it may be seen at a glance what deformations the skull undergoes when developing from the juvenile to the adult form. In my communications on this subject I shall repeatedly use such figures; here the method is applied in order to show the difference in position of the Foramen magnum in juvenile and adult skulls.

In fig. 2 this difference is clearly shown for the skull of Siamanga; in the adult skull the Foramen magnum lies considerably more backward than in the juvenile one. At the same time this shifting appears to be chiefly caused by lengthening of the basisphenoid and the basi-occipitale, the base-length of the Fossa anterior appears in youthful individuals to differ little from that in adults.

The backward shifting of the Foramen magnum causes the sqama of the occipital to lose its vaulting for the greater part and to stand more vertically.

After this I may be brief concerning the Anthropoids. Of Chimpanse I examined two adult and two juvenile skulls, both with the complete milk teeth. The basal index of the two former amounted to 65 and 63, of the two latter to 53 and 50. Also here the the Foramen magnum consequently appears to lie fairly considerably more frontally in the juvenile skulls. This is moreover shown by fig. 3 in which

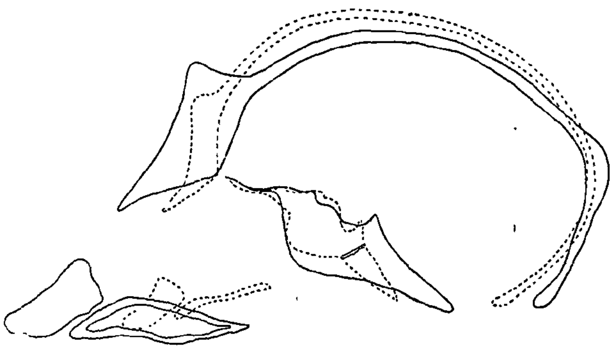

Fig 3. Mediagrams of an adult and an infantile skull of Chimpanse.

again the mediagram of a juvenile skull has been superposed on that of an adult one [1]. For the knowledge of the development of the skull it is important to point out that here also the shifting is caused by lengthening of the basi-sphenoid and basi-occipital, together with an increased steepness of the squama of the occipital.

That also with Orang the Foramen magnum is displaced occipitally is sufficiently proved by comparing the two series of basal indices

1) I draw attention to the curious section of the palate of the adult chimpanse which is thickened and inflated by the right and left sinus maxillaris coalescing through the palate, a phenomenon which I also observed in other monkeys (Mycetes),

for adult and juvenile skulls. The proof is here more stringent because of the larger number of juvenile skulls of which the basal index was determined. For the adult skulls I obtained the following figures: 69, 65, 60, 60, 58, 58 and for the juvenile ones 55, 53, 51, 51, 50.

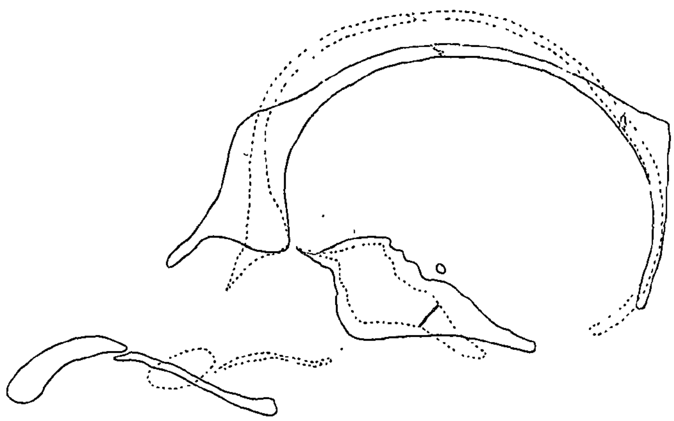

Fig. 4.
Mediagrams of an adult and a juvenile infantile skull of Orang.

In fig. 4 the mediagrams of a juvenile and an adult skull have again been superposed. The former had still all its milk teeth.

For Gorilla finally I refer fo Fig. 5 in which the mediagram of an infantile gorilla skull with complete milk teeth has been drawn on that of an adult skull. We state the same phenomena as with the

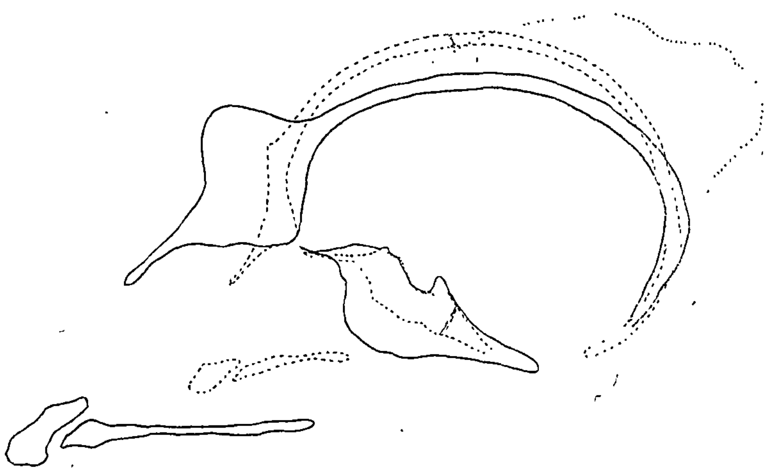

Fig. 5.
Mediagrams of an adult and an infantile skull of Gorilla.

remaining Anthropoids: lengthening of the cranial base and diminished vaulting of the occipital are here also met with. As to the basal index it was found, that in the adult skulls it varied between 67 and 56, while the index value of the juvenile skulls amounted to 50 and 54. With the latter of these two the first molar had already appeared, while the medial incisor had been changed.

By what precedes it is sufficiently proved that in all Anthropoids the foramen magnum during the juvenile period is shifted in a backward direction. At what moment this shifting begins and whether it does so immediately after birth I cannot decide, having no skulls at my disposal in which the milk teeth are not already fully developed.

Several investigators have of late years pointed out that the infantile skull of the Anthropoids stands morphologically nearer the human skull than that of the adult Anthropoids. This phenomenon has especially been discussed in regard to the frontal vaulting. As I have the intention systematically to investigate the whole skull this point will also in due time be dealt with; the remark may here suffice that also in regard to the foramen magnum, this greater agreement is confirmed. For since the basal index of the infantile skull is without exception lower than that of the adult one, it comes nearer the index of the human skull. This approach is so close that the lowest index of the infantile skull of the Anthropoids, namely 50 with Chimpanse, Gorilla and Orang, is equal to the highest I found with Zeelandians and negroes, while with Javanese even a higher index was found. Very important and instructive is a superposition of the mediagrams of the young Gorilla skull with basal index 50 and a Zeelandian skull of the same index, which will be given in a following communication.

There remains to be shown that the same phenomenon which was stated for the skull of the anthropoid apes obtains in man and that here also the basal index of the child is lower than that of adults. The foetal skulls will be left out of account here and only the results obtained with infantile skulls will be given. They will be given as averages for the groups mentioned in the enumeration of materials.

Basal index of the skulls of children.

10	skulls	of	0— 1	year:	average	**41.99**
5	„	„	1— 2	„	„	**40.4**
7	„	„	2— 3	„	„	**40.4**
4	„	„	3— 4	„	„	**41.5**
5	„	„	4— 5	„	„	**40.—**
7	„	„	5— 7	„	„	**40.7**
6	„	„	7— 8	„	„	**40.9**
4	„	„	8—10	„	„	**44.—**
6	„	„	10—12	„	„	**43.5**

When interpreting these figures we must take into account that the average I found for five groups of adult skulls was: 44.6, 44.7, 45.7, 46.6 and 47.9. If we compare with these figures the values found for the skulls of children, it is seen at once that in man as well as in the anthropoid apes the foramen magnum is shifted occipitally during development. If the number in each group of infantile skulls were more numerous one would sooner feel inclined to draw the conclusion from the averages found that this shifting begins with the eighth year, about simultaneously with the changing of teeth.

Having learnt how to express numerically the position and displacement of the foramen magnum in the Primates, we may now continue our investigation with the determination of the variations of the inclination of the plane of this aperture. This will form the subject of the following communication.

Physiology. — *"On the changes in the blood serum of sharks after bleeding."* By Mr. F. J. J. BUIJTENDIJK. (Communicated by Prof. H. ZWAARDEMAKER).

(Communicated in the meeting of September 25, 1909).

The blood serum of sharks has an osmotic pressure about equal to that of the salt water in which they live and which varies as the concentration of the salts of the sea or aquarium is changed (RODIER [1]) BOTAZZI [2])).

This osmotic pressure, measured by the lowering of the freezing point of the serum, is partly caused by the salts, dissolved in the blood liquid and for the rest by the urea which is present in high concentration in the body liquids of these Selachians. SCHROEDER [3]) found in the blood of Scyllium with large freshly caught animals 2—3 °/₀ urea, which figures have been confirmed by other investigators (BAGLIONI) [4]).

In relation with my investigations on the diuresis of sharks I put myself the question whether perhaps the blood serum would after

1) RODIER, Travaux de la Station Zoölog. Arcachon 1899 p. 103.

2) BOTAZZI, Ergebnisse de Physiologie 1908.

3) v. SCHROEDER, Zeitschr. f. physiol. Chemie 14 p. 5 75, 1890.

4) BAGLIONI, Hofmeisters Beiträge 9 p. 50.