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"CUNNINGHAM MEMOIRS."

No. II.

THE
LUMBAR CURVE IN MAN AND THE APES,

WITH AN ACCOUNT OF

THE TOPOGRAPHICAL ANATOMY

OF THE

CHIMPANZEE, ORANG-UTAN, AND GIBBON.

BY

D. J. CUNNINGHAM, M.D. (EDINB. AND DUBL.), M.R.I.A.,

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With Thirteen Plates.



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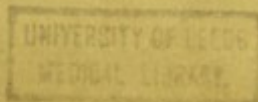
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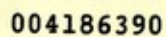


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"CUNNINGHAM MEMOIRS."

The Lumbar Curve in Man and the Apes, with an Account of the Topographical Anatomy of the Chimpanzee and Orang-utan. By D. J. CUNNINGHAM, M.D. (Edin. & Dubl.); M.R.I.A.; Professor of Anatomy and Chirurgery in the University of Dublin. (With PLATES I. to XI.).

[Read, February 8th, 1886.]

THE structural differences between Man and the anthropoid Apes are very largely due to man's assumption of the erect attitude, and to his having dispensed with the use of his upper limbs as a means of locomotion. Thus the upper limbs are shortened, whilst the lower limbs are lengthened and strengthened, and possess the power of being fully extended at the hip and knee-joints. There is not a region of the body in which modifications in structure to suit this characteristic posture may not be found; and it is natural that the vertebral column, in its vertical position, should exhibit peculiarities which are not shared by those animals in which it is oblique or more or less horizontal. A feature which has attracted a considerable amount of attention is the lumbar curve—that bulging or convexity forwards in the region of the loins which constitutes so marked a character of the human spine. By some this curve is regarded as peculiar to man, and this view has recently received the support of Pansch¹ and Aeby.² Other anatomists deny to man the prescriptive

¹ "Anatomische Vorlesungen," von Dr. Ad. Pansch, 1884.

² "Beiträge zur Osteologie des Gorilla." Morph. Jahr. vol. iv.

right to such a distinction, and consider that he shares it with certain of the anthropoid apes. The observations which I have made in this direction tend to minimize the importance of the lumbar curve as a distinctive character of any special group. Not only do the higher apes possess this curve, but so also do the majority of the lower apes; even some of the quadrupeds, under certain conditions, may show traces of it. In man and the Chimpanzee the quality of the curve is identical; the only difference is in the extent of the curvature and in its period of development. But further investigations which I have made upon several of the low races (although necessarily of a very imperfect character from the want of fresh spines) would seem to indicate that the curve is not stamped upon the vertebral column of, say, the Andaman, Australian, or Negro, so firmly as it is stamped upon the column of the European. I do not mean to infer that the degree of curvature is less in these races; but whereas in the European the bodies of the vertebræ are more or less moulded in adaptation to the curve, in the low races there is not a trace of this.

In prosecuting this inquiry into the conditions of the lumbar curve I have approached the question from two different points of view. In the first place I have examined the form-adaptations which are presented by the bodies of the vertebræ concerned; and in the second place I have endeavoured to determine the quality and the degree of the curve in fresh spines. The first part of this Memoir, therefore, is divided into two sections, corresponding to the results obtained in each of these fields.

SECTION I.

ADAPTATION OF THE VERTEBRAL BODIES WITH REFERENCE TO THE LUMBAR CURVE.

This section includes the results obtained by an extended series of measurements of the bodies of the lower five true vertebræ in Europeans, five of the lower races of man, the anthropoid apes, and some of the lower apes of the Old World. European vertebræ have been measured by various anatomists, but always on a very limited scale. Thus in the works of the

brothers Weber,¹ Nühn,² Hirschfeld,³ Horner,⁴ Meyer,⁵ Barwell,⁶ and Aeby,⁷ the adaptation of the vertebral bodies to the different curves is treated with more or less fulness: further, Aeby has compared the measurements of a European spine with those of the vertebral bodies of a gorilla, two gibbons, and some of the lower apes. None of these investigators, however, have extended their observations in this direction to the lower races of man and all the anthropoid apes.

Method adopted in making the Measurements.—The only form-adaptations of the vertebral bodies which could contribute to the formation of the antero-posterior lumbar curve are those which affect the anterior and posterior vertical diameters of the centra, or, in other words, those which produce the wedge-shape or "keilform" condition. Consequently the measurements were strictly confined to the determination of the vertical depth of the body of each of the five lower true vertebræ in front and behind, and to a comparison of the results obtained in each case. The instruments which were employed were Professor Flower's craniometer and the French *compas glissière*. But in several instances it was necessary to measure the bones in the articulated skeleton. This was avoided wherever it was possible to do so, because the determination of the posterior vertical diameters of the vertebral bodies in such cases is a matter of great difficulty; and even with the utmost care errors are apt to occur. A few of the lower races and of the anthropoid apes were measured under these conditions, and to ensure accuracy a special pair of calipers were used. In

¹ "Mechanik der menschlichen Gehwerkzeuge," von den Brüdern Wilhelm und Eduard Weber (1836), p. 92.

² "Untersuchungen und Beobachtungen aus dem Gebiete der Anatomie," &c. Erstes Heft (1849), p. 14.

³ "Nouvel aperçu sur les conditions anatomiques des courbures de la colonne vertébrale chez l'homme." Gaz. Méd. de Paris. 1849.

⁴ "Ueber die Normale Krümmung der Wirbelsäule." Müller's Archiv für Anat. Phys., &c. (1854), p. 478.

⁵ "Lehrbuch der physiologischen Anatomie des Menschen." 1861.

⁶ "The Causes and Treatment of Lateral Curvature of the Spine." 1868.

⁷ "Beiträge zur Osteologie des Gorilla." Morph. Jahr., vol. iv.

these the limbs were of such a size that they could readily be introduced into the spinal canal through the intervertebral foramina, and the extremities of the limbs were bent to the side at a right angle, in such a fashion that they could readily grasp the upper and lower borders of the vertebral body. It is indeed unfortunate, that in the articulation of skeletons of anthropological interest the custom of introducing leather, or cement, or other material to represent the cartilaginous discs, should be so prevalent.

Index of the Vertebral Bodies.—In comparing the results obtained by these measurements, and in striking an average for each race and group examined, it is convenient to construct an index for the separate vertebræ, and also for the sum of the vertebral measurements in a given individual. In calculating such an index I have adopted the anterior vertical diameter of the vertebral body as the standard. The index for an individual vertebra can be determined as follows:—

$$\frac{\text{Posterior vertical diameter} \times 100.}{\text{Anterior vertical diameter.}}$$

Then the combined index, expressive of the condition of the group of vertebræ in a particular individual, may be obtained thus:—

$$\frac{\text{Sum of posterior measurements} \times 100.}{\text{Sum of the anterior measurements.}}$$

The result arrived at by this latter calculation may be termed the *lumbo-vertebral index*.

From the above it must be clear that a vertebra with an index of 100 may be considered to be neutral; it is equally deep in front and behind, and can in no way contribute to the formation of a curve. A vertebra, on the other hand, with an index of 100 +, is moulded in a manner unfavourable to the formation of a curve with the convexity looking forwards; it is deeper behind than in front: whilst a vertebra with an index of 100 – has its body adapted to the lumbar curve; it is deeper in front than behind. The same holds good for the average of the indices of the five lower true vertebræ, which is expressed by the term of lumbo-vertebral index.

Results derived from the Measurements.—The following Table will show the general results of the measurements. In the gorilla, chimpanzee, and orang, which have four lumbar vertebræ, and the lower apes, which have six or seven lumbar vertebræ, the five lower true vertebræ have been considered comparable with the five lumbar vertebræ of man:—

TABLE A.

		M A N.						A P E S.									
		76 Europeans.	17 Australians.	3 Tasmanians.	3 Bushmen.	23 Andamans.	10 Negroes.	5 Gorillas.	9 Chimpanzees.	4 Orangs.	6 Gibbons.	2 Raboons.	3 Macques.	1 Colobus.	1 Sennopithecus.		
Five Lower true Vertebræ.	a	106.1	119.8	115.1	115.9	112.6	113.5	115.3	125.3	113.7	112.8	117.7	109.7	103.8	108.1		
	b	101.4	113.0	109.9	113.4	111.2	111.3	111.7	117.1	118.9	108.8	120.6	107.8	103.8	112.7		
	c	97.2	113.6	110.1	109.9	108.1	105.9	111.3	116.4	119.7	107.5	108.0	103.0	103.8	112.2		
	d	93.5	103.9	109.5	100.8	102.6	105.1	105.3	116.1	111.9	106.4	107.3	103.2	108.3	102.4		
	e	81.6	90.4	92.4	95.3	91.4	92.0	101.9	115.8	103.5	104.1	92.8	96.2	90.4	89.2		
Lumbo-vertebral Index, . . . }		95.8	107.8	107.2	106.6	104.8	105.4	108.1	117.5	112.9	107.1	108.5	103.7	102.4	105.1		

The difference between the European lumbo-vertebral index and the corresponding indices of the lower races is very remarkable. In the former it is 95.8, indicating, therefore, a condition of the vertebral bodies favourable to the formation of a curve in a forward direction. In the lower races the lowest lumbo-vertebral index is that of the Andamans, viz. 104.8. In these races, therefore, the lumbar vertebræ, as a group, show no adaptation in form to the characteristic curve in this region, but are moulded upon an opposite plan.

A comparison of the indices of the individual vertebræ is no less striking. In the European the first lumbar vertebra is the only member of the group with an index (106.1), which shows a decided preponderance of the posterior vertical diameter over the anterior vertical diameter; the second

vertebra exhibits a tendency in the same direction, but to all intents and purposes it is neutral. The lower three vertebræ have all indices well below the standard, and are therefore adapted to the lumbar curve.

Very different is the condition of the separate vertebræ in the low races. In these the only lumbar vertebra, with a centrum possessing an index below the standard, and thus fashioned in a manner favourable to the lumbar curve, is the last member of the series. The upper four show a reverse condition. Whilst this is the case, however, it will be observed that, with the exception of the Tasmanians and Australians, the indices of the lumbar vertebræ diminish regularly from above downwards.

But the Table brings out the relation which the anthropoid apes bear to man in this respect. Between these and the Europeans there is a wide gap. On the other hand, it will be noticed, that in so far as the general lumbo-vertebral index is concerned, there is virtually no distinction between the gorilla and gibbon with their indices of 108·1 and 107·1, and the Australians and Tasmanians, with indices of 107·8 and 107·2. In the chimpanzee and orang the lumbo-vertebral index is very considerably higher. It is interesting to note this difference between the chimpanzee and gorilla—it is a point of some significance in the determination of the curve in the latter.

In another particular the Australians and the Tasmanians show a resemblance to the anthropoid apes. In these the indices of the second and third lumbar vertebræ are very similar, whilst, as we have noted, the indices of the other races diminish regularly from above downwards.

The index of the last lumbar vertebra in the anthropoid ape is widely divergent from that in all the human races, and this must be regarded as a matter of primary importance. In all the anthropoid apes it is well above the standard; in man, the wedge-shaped appearance of the body of the last lumbar vertebra is a matter of everyday knowledge. It is interesting to note that this essential character is not nearly so strongly marked in the low races as in the European.

As this point became developed, in the course of my work, I believed that I had arrived at a feature which might be considered to be a distinctly human characteristic—one which was not shared by any other member of

the order Primates. An examination of the lumbar region of certain of the lower apes proved that in this I was mistaken. In the Baboon, the Macaque, *Semnopithecus*, and in *Colobus* the last lumbar vertebra possesses an index (as will be seen in the Table) in every respect comparable with that of the lower races, although it is not so low as that of the European. Aeby¹ had previously noted this point in *Papio sphinx*, and in *Macacus nemestrinus*, and he ascribes it to the right cause. It has little or nothing to do with the lumbar curve, but is produced by the marked dorsal tilting of the pelvis in these animals. The marked discrepancy between the anterior and posterior vertical diameters of this vertebra is, therefore, chiefly due to a sloping of the inferior surface. In Plates IV. and VI., in which are represented reduced tracings of mesial sections of the frozen *Macacus rhesus* and *Cynocephalus anubis*, this condition will be observed. The oblique position of the pelvis is very evident.

The corresponding condition of the last lumbar vertebra in man is due to the same cause, viz. the great backward sweep of the sacrum; and the fact that in the low races this character is not so prominent might almost lead us to infer that the pelvic inclination is not so marked as in the European. This is a point, however, which could only be determined by the examination of fresh spines, because deficiencies in the body of the last lumbar vertebra may be compensated for by an increased anterior depth of the lumbo-sacral cartilaginous disc.

The relationships which have been stated above can be more easily compared, and more fully appreciated, by referring to Plate I., Chart A, in which the conditions of the vertebral bodies are expressed diagrammatically. The column of figures on each side are the indices; the five main vertical subdivisions are allotted, from left to right, to the five lower true vertebræ, whilst in the sixth is given the average lumbo-vertebral index. Each of these compartments is further subdivided into columns corresponding to the number of animals under examination. A strong horizontal line at the level of the standard index (100) divides the chart into an upper and lower portion, and therefore a single glance is sufficient for the recognition of the

¹ "Beiträge zur Osteologie des Gorilla." *Morph. Jahr.* vol. iv.

manner in which the vertebral bodies are moulded with reference to the lumbar curve. To avoid complexity, only four races of man, and three anthropoid apes, are introduced into this chart. The dotted lines represent the apes; the solid lines refer to man.

The striking manner in which the European stands apart in this respect from his lower brethren, and also from the anthropoid apes, is rendered very evident by this chart. Only two of the European vertebræ are above the standard line, whilst the fourth vertebra occupies a place in the lower portion of the chart almost as low as the last lumbar vertebra of the Australian and Andaman. On the other hand, it will be observed, that the orang and chimpanzee lines stand aloof from the Australian and Andaman, but in an opposite direction. The gorilla line intersects, and is closely associated with, those of the low races. The sudden descent of the latter below the standard constitutes the distinguishing character—the fourth lumbar vertebra of the Australian and Andaman occupying a level very similar to that of the last lumbar vertebra of the gorilla.

SPECIAL POINTS IN CONNEXION WITH EACH RACE.

Europeans.—The foregoing averages were obtained from the measurements of seventy-six European spines, viz. forty-three Irish, twenty-six French, three English, and four German. The detailed indices, resulting from each measurement, are given in the subjoined Tables.

TABLE B.

INDICES OF LUMBAR VERTEBRÆ IN FORTY-THREE IRISH SPINES.

	TWENTY-ONE MALES.																			21 Males. Average Index.
	103.5	104.3	111.0	113.2	106.0	112.0	106.0	105.6	103.7	111.1	109.2	109.0	98.0	96.4	100.0	103.8	120.0	106.3	115.3	
I. Lumbar Vertebra,	103.5	104.3	111.0	113.2	106.0	112.0	106.0	105.6	103.7	111.1	109.2	109.0	98.0	96.4	100.0	103.8	120.0	106.3	115.3	106.9
II. Lumbar Vertebra,	100.0	102.0	93.3	100.0	103.7	103.7	103.7	103.8	101.7	105.3	105.1	93.5	100.0	100.0	94.9	103.8	118.5	100.0	111.1	102.0
III. Lumbar Vertebra,	96.5	96.0	88.5	89.8	96.1	105.8	94.4	98.3	100.0	90.6	101.6	98.3	100.0	91.6	96.6	108.0	103.5	103.4	100.0	97.7
IV. Lumbar Vertebra,	96.5	84.6	87.0	87.7	102.0	100.0	86.2	96.6	93.3	87.5	95.0	90.4	86.6	93.2	86.2	103.8	107.1	101.7	93.1	95.0
V. Lumbar Vertebra,	72.0	74.0	82.4	79.3	83.0	85.7	68.9	80.0	90.0	84.3	83.6	85.7	89.6	91.3	84.6	75.8	90.9	89.2	72.5	82.4
Lumbo-vertebral Index, . .	93.4	91.7	92.0	93.6	97.8	101.1	91.1	96.1	98.2	95.0	98.9	95.0	94.6	94.4	92.5	98.4	107.7	100.0	97.5	96.2

	TWENTY-TWO FEMALES.																			22 Females. Average Index.
	103.7	105.5	105.7	105.8	97.9	103.5	104.0	104.0	104.0	100.0	93.2	104.0	96.6	101.9	110.2	102.1	106.3	101.8	101.8	
I. Lumbar Vertebra,	103.7	105.5	105.7	105.8	97.9	103.5	104.0	104.0	104.0	100.0	93.2	104.0	96.6	101.9	110.2	102.1	106.3	101.8	101.8	102.6
II. Lumbar Vertebra,	100.0	103.4	101.8	100.0	100.0	96.7	96.2	100.0	100.0	100.0	89.2	98.1	91.9	101.8	103.9	96.0	96.0	96.5	100.0	98.1
III. Lumbar Vertebra,	89.3	100.0	100.0	100.0	92.0	103.3	96.2	98.1	91.2	103.4	96.4	90.4	90.4	96.4	92.8	86.7	94.3	89.8	98.0	95.0
IV. Lumbar Vertebra,	84.2	84.7	96.0	96.3	88.4	96.6	98.0	94.2	90.9	83.3	96.4	93.1	98.1	92.5	92.5	86.7	86.7	91.2	103.8	91.8
V. Lumbar Vertebra,	77.4	82.7	86.0	92.3	76.9	70.0	75.4	82.6	80.3	74.1	83.9	65.5	83.0	85.7	78.8	81.4	85.1	81.9	85.7	81.2
Lumbo-vertebral Index, . . . }	90.5	94.7	97.7	94.4	98.8	93.9	93.8	95.7	92.3	88.5	95.5	87.7	96.2	96.6	89.8	92.6	93.9	92.0	98.0	93.5

TABLE C.

INDICES OF LUMBAR VERTEBRÆ IN TWENTY-SIX FRENCH SPINES.—(BOTH SEXES).

Average Index.																											
I. Lumbar Vertebra, }	112.5	108.0	111.0	107.0	113.0	111.5	107.4	113.0	100.0	103.8	108.0	105.7	103.8	108.0	107.4	105.4	111.5	102.0	103.7	112.7	111.1	112.0	103.7	123.8	108.0	112.0	108.6
II. Lumbar Vertebra, }	100.0	96.3	111.5	100.0	108.0	104.0	100.0	108.0	93.0	100.0	98.0	101.8	112.2	110.0	101.7	103.5	109.0	100.0	98.2	104.0	103.4	103.6	101.7	109.6	98.1	103.7	103.0
III. Lumbar Vertebra, }	92.0	96.5	107.7	93.5	96.0	103.5	100.0	96.5	89.6	96.5	96.5	100.0	98.2	92.5	100.0	100.0	109.0	96.2	95.0	100.0	105.2	101.9	93.2	103.7	96.4	107.5	98.7
IV. Lumbar Vertebra, }	89.0	96.5	93.0	84.0	82.7	100.0	100.0	96.6	89.6	96.5	80.7	94.0	101.8	89.0	98.0	96.5	103.7	100.0	95.0	98.1	100.0	100.0	88.3	101.8	96.1	103.7	95.1
V. Lumbar Vertebra, }	72.4	89.3	83.0	76.7	65.5	80.6	79.3	83.3	85.0	89.3	79.3	85.7	77.5	83.6	85.0	84.7	82.1	88.4	82.5	80.7	93.1	75.7	84.7	79.6	77.1	94.5	82.2
Lumbo-vertebral Index, }	92.5	97.0	99.2	92.0	91.5	99.2	97.0	98.5	91.4	97.0	93.8	98.0	99.6	96.2	98.5	97.8	103.0	97.3	94.5	98.8	102.4	98.1	94.0	103.0	94.5	104.1	97.2

TABLE D.

INDICES OF LUMBAR VERTEBRÆ IN THREE ENGLISH SPINES.

	2 MALES.		Average.	1 FEMALE. ²	Average. 2 Males, 1 Female.
I. Lumbar Vertebra,	118.0	101.0 ¹	109.5	101.8	106.9
II. Lumbar Vertebra,	101.7	107.0	104.3	111.0	106.5
III. Lumbar Vertebra,	101.7	101.7	101.7	103.7	102.3
IV. Lumbar Vertebra,	98.2	91.5	94.8	87.2	92.3
V. Lumbar Vertebra,	79.0	81.5	80.2	76.0	78.8
Lumbo-vertebral Index,	99.0	96.5	97.7	96.0	97.1

¹ The male spine in the Cambridge Museum, which was embedded in plaster of Paris, and then cut by Professor Humphry, in the mesial plane.² The female spine in the same Museum, which had been prepared in a similar manner.

TABLE E.

INDICES OF LUMBAR VERTEBRÆ IN FOUR GERMAN SPINES.

	3 MALES.				1 FEMALE.	4 SPINES.
	Braune.	Aeby. ¹	Brothers Weber.	Result.	Braune.	Both Sexes.
I. Lumbar Vertebra, . . .	103.9	103.6	107.6	105.0	100.0	103.8
II. Lumbar Vertebra, . . .	96.5	103.6	107.4	102.5	101.9	102.3
III. Lumbar Vertebra, . . .	88.3	95.0	98.2	93.8	92.3	93.4
IV. Lumbar Vertebra, . . .	93.4	93.2	91.2	92.6	80.3	89.5
V. Lumbar Vertebra, . . .	67.7	83.3	80.0	77.0	81.4	78.1
Lumbo-vertebral Index, . . .	89.3	95.4	96.4	93.7	91.0	93.0

¹ It is hardly right to include this spine with those of the Germans, as in all probability it was taken from a Swiss subject.

The measurements of the Irish spines were made upon fresh spines obtained in the Practical Anatomy Rooms of Trinity College, Dublin. In each case a mesial section was made by means of a saw. The vertical depth of the bodies of the vertebræ in front and behind could then be measured with the greatest accuracy.

The French vertebræ were measured in the dry macerated condition, and chiefly from spines which had been prepared by M. Tramond of Paris. Care was taken to eliminate all those which bore signs of disease, or which were composed of vertebræ which were suspected to have been derived from different individuals.

The measurements of the English spines were obtained in the Anatomical Museum of the Cambridge Museum, and they include the two spines from which Professor Humphry determined the vertebral curves after the manner of the brothers Weber. One of these spines is figured in his admirable work on the Human Skeleton.

The sources from which I derived the results relating to the German spines are indicated in Table E. In the two large Plates by Braune, representing mesial sections of a male and female, the vertebral bodies were carefully measured. As these drawings were built up from tracings taken from the frozen subject, there is every reason to believe that they are thoroughly reliable, even in such small details as those which affect the anterior and posterior vertical depth of the vertebral bodies. In another case the lumbar vertebræ, in the large plate which accompanies the classical work of the brothers Weber,¹ were measured, whilst the indices of the fourth were calculated from measurements given by the late Professor Aeby, in his Paper upon the "Osteology of the Gorilla."²

By the following analysis the individual peculiarities of the lumbar vertebræ in this large number of specimens may be the more easily appreciated:—

TABLE F.
SEVENTY-SIX EUROPEAN SPINES.

	Anterior depth of Centrum greater than posterior depth.	Anterior depth equal to posterior depth.	Posterior depth of Centrum greater than anterior depth.
I. Lumbar Vertebra, .	5	6	65
II. Lumbar Vertebra, .	21	17	38
III. Lumbar Vertebra, .	48	11	17
IV. Lumbar Vertebra, .	57	7	12
V. Lumbar Vertebra, .	76	—	—

But it may be asked, Do any of the European spines show indices which can be compared with the indices of the low races? In only six instances have I met with a European spine with a lumbo-vertebral index above the standard, viz. two Irish and four French—the highest being that of an Irish male, with a lumbo-vertebral index of 107·7. It is further interesting to note that, all through, the French indices are higher than the Irish.

¹ *Antea*, p. 3.

² *Antea*, p. 3.

At this stage it would be well to take note of the observations which have been made in this field by other investigators. In every case the measurements have been confined to Europeans, and the number of individuals examined has been very small. The brothers Weber,¹ who may be said to be the first anatomists to give accurate information upon the normal curves of the human spine, measured the centra of one vertebral column, and from the indices of the lumbar vertebræ of this spine, which are given in Table E, it will be seen that the results which they obtained are very similar to those given in the foregoing Tables. According to Horner² there is no regularity in the vertebral column in this respect, except in the case of the lower lumbar vertebræ. "Whilst everywhere," he says, "there is seen a slightly different height, sometimes in front, and at other times behind, there happens here a constant stronger height in front—a smaller behind;" and he goes on to remark, "that on the average all the loin vertebræ contribute to the curve. Of a surety, therefore, this curve is the most permanent, and the most pronounced." This statement he supports by giving the measurements of the five lumbar centra in five individuals, and his results, in so far as the excess of the anterior depth of the vertebral bodies over the posterior depth is concerned, are somewhat in advance of mine. The average index calculated from his figures is :—

I. Lumbar vertebra,	.	.	.	.	98·5
II. Lumbar vertebra,	.	.	.	.	97·4
III. Lumbar vertebra,	.	.	.	.	93·8
IV. Lumbar vertebra,	.	.	.	.	88·9
V. Lumbar vertebra,	.	.	.	.	81·3
Lumbo-vertebral Index,	.	.	.	.	91·9

The index of the first lumbar vertebra in these measurements is peculiar, in so far as it is below the standard. In only five out of the seventy-six spines I examined did I find this to be the case

Nühn³ arrived at somewhat different results. He divided the vertebral

¹ *Antea*, p. 3.

² *Antea*, p. 3.

³ *Antea*, p. 3.

columns of several well-built male subjects in their whole length, and then measured upon the surface of the section the fore and hinder surfaces of all the vertebral bodies, and he concludes, "that the bodies of the lumbar vertebræ can have no share in the production of the lumbar curve," as the upper four are deeper behind than in front. He only gives the detailed measurements of one specimen, and from his figures I have calculated the following indices :—

I. Lumbar vertebra,	108·4
II. Lumbar vertebra,	100·0
III. Lumbar vertebra,	99·0
IV. Lumbar vertebra,	104·3
V. Lumbar vertebra,	71·0
Lumbo-vertebral Index, . . .	96·5

Whilst, therefore, the general lumbo-vertebral index is very similar to that indicated in Table B., p. 9, yet the index of the fourth lumbar vertebra is exceptionally high. In only one case out of the seventy-six spines that I examined is the index of this vertebra above 104.

Hirschfeld,¹ also, by measurements of the vertebral bodies, denies that in any region these contribute to the production of the curves, and in this he is supported by H. Meyer,² who found no difference whatever in the healthy vertebral column between the fore and hind surfaces of the vertebral bodies, with the exception of the last lumbar and the first sacral vertebræ; and the form of these, he asserts, is determined by the inclination of the sacrum. Barwell gives expression to similar views.

In three different publications the late Professor Aeby of Bern refers to this point, viz. in his text-book, entitled, "*Der Bau des menschlichen Körpers*;" in his Paper upon the "*Osteology of the Gorilla*," which has already been quoted;³ and in his elaborate memoir upon "*Die Altersverschiedenheiten der menschlichen Wirbelsäule*."⁴ In the last article he

¹ *Antea*, p. 3.

² *Antea*, p. 3.

³ *Antea*, p. 3.

⁴ "*Archiv für Anatomie und Entwicklungsgeschichte*," His und Braune (1879).

gives the results he obtained from the measurements of eight spines, classified in a Table constructed on a similar plan to Table F, p. 12. I take the liberty of subjoining this Table for the purposes of comparison :—

EIGHT SPINES MEASURED BY PROFESSOR AEBY.

	Anterior depth greater than posterior depth.	Anterior depth equal to posterior depth.	Anterior depth less than posterior depth.
I. Lumbar Vertebra, .	1	3	4
II. Lumbar Vertebra, .	1	6	1
III. Lumbar Vertebra, .	4	3	1
IV. Lumbar Vertebra, .	7	1	—
V. Lumbar Vertebra, .	8	—	—

His results, therefore, are virtually the same as mine.

Lower Races of Man.—Five of the lower races of man are represented in Table A, p. 5, which I have given to show the general results. In all, fifty-six separate spines were examined, viz. of twenty-three Andamans, seventeen Australians, ten Negroes, three Tasmanians, and three Bushmen. And, in recording the separate indices of these, I must give expression to my sense of the deep obligations under which I lie to Dr. J. G. Garson, Sub-Curator of the Royal College of Surgeons Museum, London; to Professor Macalister of Cambridge; to Mr. More, Curator of the Natural History Department of the Science and Art Museum in Dublin; and to Professor Struthers of Aberdeen. Without their kind aid this part of my investigation could not have been carried out, because in the Museum of Trinity College, Dublin, the number of spines of low races is very limited, and I had necessarily to ask the permission of these gentlemen to examine the specimens under their charge. This was accorded to me in the freest manner possible. More especially, however, I feel indebted to Dr. Garson and Professor Macalister, both of whom gave me very material help in making the measurements, and from whom I received many suggestions, which have proved of the utmost value to me.

TABLE G.

INDICES OF LUMBAR VERTEBRÆ IN SEVENTEEN AUSTRALIAN SPINES.

	10 MALES.										Average.
I. Lumbar Vertebra, .	113·6	119·0	106·8	128·7	110·8	135·1	130·2	153·3	126·0	128·2	125·1
II. Lumbar Vertebra, .	120·0	111·3	111·3	116·3	112·7	125·6	115·2	132·3	113·3	108·7	116·6
III. Lumbar Vertebra, .	114·3	108·7	123·8	104·3	102·0	122·7	120·4	138·7	122·0	108·7	116·5
IV. Lumbar Vertebra, .	95·6	98·0	102·0	102·1	93·8	109·3	106·3	136·3	104·4	97·0	104·4
V. Lumbar Vertebra, .	86·6	91·5	95·6	71·7	81·6	97·6	100·0	103·1	88·8	84·0	90·0
Lumbo-vertebral Index, .	105·4	105·2	107·5	104·0	100·0	117·6	114·2	132·5	110·5	104·3	110·1

	4 FEMALES.					Average.	3 SEX UNKNOWN.			Average. 17. Both Sexes.
I. Lumbar Vertebra, .	107·0	102·0	125·0	111·9	111·4	111·6	108·7	—		119·8
II. Lumbar Vertebra, .	106·6	98·2	104·3	107·3	104·1	113·9	113·0	111·5		113·0
III. Lumbar Vertebra, .	100·0	108·7	109·0	117·5	108·2	113·6	108·7	108·3		113·6
IV. Lumbar Vertebra, .	97·8	89·6	104·5	110·0	100·4	107·1	109·0	—		103·9
V. Lumbar Vertebra, .	92·8	86·0	87·5	102·3	92·1	87·0	91·2	—		90·4
Lumbo-vertebral Index, .	100·9	96·7	105·4	109·7	103·1	106·4	106·0	—		107·8

TABLE H.

INDICES OF LUMBAR VERTEBRÆ IN THREE TASMANIAN SPINES.

	2 MALES.		Average.	1 FEMALE.	Average. 3. Both Sexes.
I. Lumbar Vertebra, .	111·6	124·4	118·0	109·5	115·1
II. Lumbar Vertebra, .	111·3	111·3	111·3	107·1	109·9
III. Lumbar Vertebra, .	108·7	114·6	111·6	107·1	110·1
IV. Lumbar Vertebra, .	108·8	112·2	110·5	107·5	109·5
V. Lumbar Vertebra, .	91·2	93·1	92·1	93·0	92·4
Lumbo-vertebral Index, .	106·2	110·9	108·5	104·7	107·2

TABLE I.

INDICES OF LUMBAR VERTEBRÆ IN TWENTY-THREE ANDAMAN SPINES.

	14 MALES.														Average.
I. Lumbar Vertebra, .	107.5	119.5	116.3	106.8	116.2	127.7	117.3	111.1	113.6	113.3	113.6	113.3	117.2	109.0	114.4
II. Lumbar Vertebra, .	107.1	113.6	113.6	107.0	106.8	144.1	110.2	113.3	115.9	110.8	106.3	118.1	117.2	106.6	113.5
III. Lumbar Vertebra, .	112.8	102.0	113.6	102.2	109.0	128.9	108.3	117.5	111.3	113.0	106.2	104.1	117.0	106.6	110.9
IV. Lumbar Vertebra, .	110.0	95.6	98.0	97.6	98.0	113.5	106.0	107.0	104.1	104.3	102.0	104.3	106.0	106.6	103.7
V. Lumbar Vertebra, .	97.0	80.4	91.6	83.0	95.3	89.5	94.2	95.5	93.6	87.5	88.2	104.5	82.6	88.0	90.7
Lumbo-vertebral Index, .	107.0	101.8	106.1	99.0	105.0	118.8	106.9	108.6	107.4	105.6	102.8	108.8	107.6	103.0	106.2

	9 FEMALES.										Average.	Average. 23 Both Sexes.
I. Lumbar Vertebra, .	116.3	116.6	112.2	108.8	100.0	113.9	111.1	111.6	97.7	109.8		112.6
II. Lumbar Vertebra, .	104.3	116.3	100.0	108.8	101.2	111.1	111.1	114.2	100.0	107.3		111.2
III. Lumbar Vertebra, .	98.3	109.3	100.0	—	96.0	108.7	106.3	111.6	95.9	104.2		108.1
IV. Lumbar Vertebra, .	98.0	113.6	91.3	102.2	98.0	95.9	109.0	102.2	97.9	100.9		102.6
V. Lumbar Vertebra, .	82.0	91.5	85.1	97.6	87.0	93.3	102.3	100.0	94.0	92.5		91.4
Lumbo-vertebral Index, .	99.0	109.1	97.3	—	96.6	104.3	108.0	107.9	97.0	102.4		104.8

TABLE J.

INDICES OF LUMBAR VERTEBRÆ IN TEN NEGRO SPINES.

	7 MALES.							Average.	3 FEMALES.			Average.	Average. 10 Both Sexes.
I. Lumbar Vertebra, .	112.0	116.6	111.9	113.0	125.0	119.0	107.1 ¹	114.9	107.1	110.5	113.6	110.4	113.5
II. Lumbar Vertebra, .	120.0	116.6	113.9	106.1	104.7	117.3	109.0	112.5	115.0	110.5	100.0	108.5	111.3
III. Lumbar Vertebra, .	108.9	118.1	116.6	106.0	91.4	94.2	109.2	106.3	107.0	119.4	88.2	104.8	105.9
IV. Lumbar Vertebra, .	101.7	114.2	107.0	98.0	104.4	100.0	100.0	103.4	104.7	117.6	104.1	108.8	105.1
V. Lumbar Vertebra, .	93.1	97.2	100.0	100.0	97.7	84.6	86.1	94.1	95.4	100.0	65.4	86.9	92.0
Lumbo-vertebral Index, .	106.6	112.6	109.9	104.5	103.7	102.0	102.2	106.0	105.6	111.3	93.4	103.4	105.4

¹ Unusually tall male skeleton (about 6 ft. 3 in.), presented to the Author by Dr. F. Alcock Nixon, of the Ledwich School of Medicine, Dublin.

TABLE K
INDICES OF LUMBAR VERTEBRÆ IN THREE BUSHMEN.

	1 MALE.	2 FEMALES.		Average.	Average. 3 Both Sexes.
I. Lumbar Vertebra, . . .	109·0	115·9	123·0	119·4	115·9
II. Lumbar Vertebra, . . .	120·0	110·8	109·5	110·1	113·4
III. Lumbar Vertebra, . . .	102·0	108·3	119·5	113·9	109·9
IV. Lumbar Vertebra, . . .	93·7	104·1	104·7	104·4	100·8
V. Lumbar Vertebra, . . .	90·4	98·0	97·7	97·8	95·3
Lumbo-vertebral Index, . . .	102·1	107·2	110·5	108·8	106·6

The indices obtained in the case of the Andamans and Negroes exhibit a striking similarity, and this is a point of considerable interest in the light of the view which has recently been so ably advocated by Professor Flower regarding the affinities which exist between these races. He looks upon the Andaman as being the representative of a primitive undeveloped, infantile type, from which both the African and Oceanic Negro have sprung.¹

A similar correspondence between the Australian and Tasmanian indices will be noted; but as only three spines of the latter race were examined, we cannot lay much stress upon this similarity.

The condition of the separate vertebræ, in the five low races under consideration, can be most easily understood and compared with the condition of the European vertebræ by arranging them in the following tabular form:—

¹ Journal of the Anthropological Institute, 1879.

TABLE L.

FIFTY-SIX SPINES OF THE LOWER RACES OF MAN.

	Anterior depth greater than posterior depth.	Anterior depth equal to posterior depth.	Anterior depth less than posterior depth.
I. Lumbar Vertebra, .	1	1	54
II. Lumbar Vertebra, .	1	3	52
III. Lumbar Vertebra, .	6	2	48
IV. Lumbar Vertebra, .	17	2	37
V. Lumbar Vertebra, .	47	5	4

The wide difference between the results brought out by this Table, and that constructed upon a similar plan for the Europeans (Table F, p. 12), is very evident. More particularly does the condition of the last lumbar vertebra attract our attention. In five cases (viz. in one Andaman, one Australian, and three Negroes) it presents an equal depth in front and behind, and in four cases (viz. in two Andamans and two Australians) its posterior depth exceeds its anterior depth. In one instance, indeed, that of a male Andaman, the index of this vertebra was 104.5. In the European spines the highest index observed for the last lumbar vertebra was 94.5, and this was in one of the few examples in which the general lumbo-vertebral index was above the standard (104.1).

In only seven out of the fifty-six low-race spines which were measured was the general lumbo-vertebral index below the standard. These included five Andamans, one Australian, and one Negro; and it is significant to note that, of these exceptions to the general rule, six were the indices of females, and only one the index of a male. Moreover, the latter was very slightly below the standard, viz. 99.

Anthropoid Apes.—The following are the detailed results which have been obtained in the case of the four anthropoid, and also of several of the lower apes:—

[3*]

TABLE M.—INDICES OF LUMBAR VERTEBRÆ IN THE GORILLA.

	3 MALES.			Average.	3 FEMALES.			Average.	Average. 5 Both Sexes.
XIII. Dorsal Vertebra, . . .	131.8	106.1	103.8	113.9	125.0	110.7	115.0	116.9	115.3
I. Lumbar Vertebra, . . .	109.2	106.4	105.4	107.0	114.3	110.0	125.0	116.4	111.7
II. Lumbar Vertebra, . . .	107.2	110.3	105.3	107.6	114.0	109.3	121.9	115.0	111.3
III. Lumbar Vertebra, . . .	101.7	104.8	103.3	103.2	100.0	115.6	106.5	107.3	105.3
IV. Lumbar Vertebra, . . .	94.7	111.5	103.3	103.1	fused to sacrum.	107.9	92.0	99.9	101.9
Lumbo-vertebral Index, . . .	107.7	107.7	104.2	106.5	—	110.0	111.0	110.5	108.1

TABLE N.—INDICES OF LUMBAR VERTEBRÆ IN THE CHIMPANZEE.

	3 MALES.			Average.	5 FEMALES.					Average.	Young. Sex doubtful.	Average. 9 Both Sexes.
XIII. Dorsal Vertebra, . .	125.0	107.0	125.7	119.2	150.0	120.0	110.8	116.6	—	124.3	147.6	125.3
I. Lumbar Vertebra, . .	135.3	113.6	112.5	120.4	105.0	102.2	118.9	119.2	122.2	113.5	125.0	117.1
II. Lumbar Vertebra, . .	130.5	132.5	111.6	124.8	104.3	118.6	112.5	107.7	106.5	109.9	124.0	116.4
III. Lumbar Vertebra, . .	120.0	139.0	111.9	123.6	114.2	102.3	100.0	119.2	111.3	109.6	126.0	116.1
IV. Lumbar Vertebra, . .	125.0	125.6	107.8	119.4	111.6	107.0	120.0 ¹	113.4	121.4	114.6	111.1	115.8
Lumbo-vertebral Index, .	127.1	123.0	113.5	121.2	114.2	109.6	111.9	115.2	—	112.7	125.8	117.5

¹ This vertebra was fused to sacrum, but could readily be measured.

TABLE O.—INDICES OF THE LUMBAR VERTEBRÆ IN THE ORANG.

	3 MALES.			Average.	1 FEMALE.	Average. 4 Both Sexes.
XII. Dorsal Vertebra, . . .	109.3 ¹	111.1 ¹	115.9	112.1	118.5	113.7
I. Lumbar Vertebra, . . .	100.0	129.4	112.0	113.8	134.4	118.9
II. Lumbar Vertebra, . . .	102.0	151.6	105.3	119.6	120.0	119.7
III. Lumbar Vertebra, . . .	86.2	126.3	103.3	105.2	132.1	111.9
IV. Lumbar Vertebra, . . .	96.4	105.0	92.7	98.0	120.0	103.5
Lumbo-vertebral Index, . . .	98.0	123.4	105.3	108.9	125.0	112.9

¹ In these specimens there were five lumbar vertebræ.

TABLE P.

INDICES OF LUMBAR VERTEBRÆ OF THE GIBBON.

	Hylobates lar.	H. lar. (Aeby.) ¹	H. lar.	H. variegatus.	H. leuciscus.	H. syndactylus. (Aeby.) ¹	Average. 6 Both Sexes.
I. Lumbar Vertebra, . . .	107.1	115.3	103.4	121.7	117.3	112.5	112.8
II. Lumbar Vertebra, . . .	113.3	115.3	103.3	107.4	108.0	105.8	108.8
III. Lumbar Vertebra, . . .	112.5	107.1	100.0	111.5	111.5	102.8	107.5
IV. Lumbar Vertebra, . . .	105.8	107.4	106.4	103.8	115.3	100.0	106.4
V. Lumbar Vertebra, . . .	106.6	100.0	96.2	96.0	129.1	97.2	104.1
Lumbo-vertebral Index, . . .	109.0	109.0	102.0	107.8	116.1	103.4	107.1

¹ Indices calculated from measurements given by Professor Aeby in his "Beiträge zur Osteologie des Gorilla." Morph. Jahr., vol. iv.

TABLE Q.

INDICES IN LUMBAR VERTEBRÆ IN SOME OF THE LOWER APES.

		Papio sphinx. (Aeby.) ¹	Cynocephalus anubis.	Cynocephalus anubis.	Macacus nemestrinus. (Aeby.) ¹	Macacus nemestrinus.	Macacus nemestrinus.	Colobus velerosus.	Cercopithecus. (Aeby.) ¹	Semnopithecus entellus.
Lower five true Vertebrae.	$\left\{ \begin{array}{l} a \\ b \\ c \\ d \\ e \end{array} \right.$	103.0	128.9	106.6	117.6	108.1	103.5	103.8	116.6	108.1
		100.0	130.7	110.6	110.5	102.4	110.7	103.8	115.3	112.7
		100.0	116.0	100.0	100.0	102.2	106.8	103.8	115.3	112.2
		95.0	108.5	106.1	100.0	102.3	107.4	108.3	115.3	102.4
		77.7	89.7	96.0	86.3	102.7	100.0	90.4	100.0	89.2
Lumbo-vertebral Index,		95.1	113.4	103.7	101.9	103.4	105.9	102.4	112.5	105.1

¹ Indices calculated from measurements given by Professor Aeby in his "Beiträge zur Osteologie des Gorilla."

The condition of the last lumbar vertebra in the anthropoid apes naturally attracts our attention first. The low index of this vertebra in man has been seen to be a point of primary importance. Is the high average index of the corresponding vertebra of the Anthropoid borne out by the indices of the different individuals? In the chimpanzee it is; in every case the index of this vertebra is above the standard: but in two gorillas, two orangs, and three gibbons it is distinctly below the standard, and therefore approaches the human type. In this respect, therefore, a hard and fast line cannot be drawn between the lower races of man and the anthropoid: a certain amount of overlapping in each case takes place.

A study of the separate indices of the individual anthropoids reveals a striking want of uniformity in the condition of the vertebræ. Whilst the average indices exhibit a regular decrease from above downwards, no such principle can be deduced from the examination of the indices of each individual. This is, in a marked degree, different from the separate indices of the European, and to a less extent, also, it is different from the separate indices of the lower races of man.

Sexual Differences.—It would appear from the observations of Luschka, Balandin, Charpy, and Ravenel, that the lumbar curve is more marked in the human female than in the male. In the second volume of his well-known treatise upon "Human Anatomy," Luschka states that "in the female sex the lumbar column is not only somewhat higher than in the male, but it is also more strongly bent;" and he further remarks that a strong loin-excavation on the posterior aspect of the trunk is a mark of a well-formed female body. He omits, however, to mention by what means he arrived at these conclusions. Balandin,¹ in his investigations into the physiological curves of the human spine, found in his preparations "that the male vertebral columns show a smaller degree of curvature, but a greater stability, than the female." He examined a very

¹ "Beiträge über die Entstehung der physiologischen Krümmung der Wirbelsäule beim Menschen," von Dr. J. Balandin in St. Petersburg. Virchow's Archiv für. Path. Anat. und Phys. 1873.

large number of specimens, but his methods were of such a kind that absolute accuracy could not be expected. He removed from the body that section of the column which is composed of all the true vertebræ, and, leaving the thoracic walls attached, he stripped the specimen of all the soft parts, with the exception of the ligaments. The spine, thus prepared, was then placed on its side upon a table, and the curves determined by means of the profile view. The stability of the column was estimated by the resistance it offered to stretching when grasped by the hands at either end. Dr. Adrien Charpy¹ of Lyons has recently gone more fully into the question. He points out that the degree of lumbar curve is, as a rule, in accordance with the inclination of the sacrum, and that in the two sexes, at a corresponding age, the sacro-vertebral angle is slightly more acute in the female than in the male (viz. 110° in the male, and 107° in the female)—“This same difference is also found in new-born children, which proves that it is a congenital condition, transmissible by heredity.” He has further directly estimated the amount of lumbar curve in twenty-five young well-formed subjects by moulding a strip of lead upon the anterior face of the column. The average results gave a superior curvature to the female.

Ravenel² has approached the question from a different standpoint. By measurements of the anterior and posterior surfaces of the column formed by the vertebral bodies and the intervening cartilaginous discs in eleven males and an equal number of females, he has arrived at the following conclusions:—(1) That the anterior face of the lumbar segment is in a small degree relatively longer in the female than in the male; and (2) that the posterior surface of the same segment is relatively very considerably shorter in the female than in the male. Taking the fore surface of this section of the column as equal to 100 in both sexes, he estimates that the posterior surface in the male is 86.6; whilst in the female it is only 69.6. If this startling difference

¹ “De la Courbure Lombar et de l’inclinaison du bassin. *Journal de l’Anatomie et de la Physiologie.*” (Robin et Pouchet.) Paris, 1885. No. 4.

² “Die Maasverhältnisse der Wirbelsäule und des Rückenmarkes beim Menschen,” von Michel Ravenel. *Zeitschrift für Anatomie und Entwicklungsgeschichte.* 1877.

can be substantiated, it will undoubtedly constitute, as Ravenel claims, "ein spezifischer Geschlechtsunterschied." He includes the intervertebral disc between the last lumbar vertebra and the sacrum in his measurements. This is strongly influenced in its shape by the inclination of the pelvis, and according to Charpy the sacro-vertebral angle is, as a rule, more acute in the female than in the male. Differences resulting from this, however, would be of small moment. Much more likely were inaccuracies and fallacies to creep in from the methods which he adopted in manipulating the vertebral column previous to and during the measurements. He took no precaution towards the fixing of the vertebral bodies in their mutual relationships, but straightway exposed the two faces of the column by the removal of the neural arches and spinal cord from its posterior aspect, and the viscera from its anterior aspect. Hirschfeld¹ rightly insists upon the influence which the powerful elastic ligaments connecting the neural arches exert upon the maintenance of the curves; and everyone who has tried the experiment knows that, when these are removed, the curves of the column diminish in degree, whilst the flexibility increases; indeed, it can now be bent with facility in every direction. But further, in making his measurements upon the spines thus mutilated, Ravenel found it necessary to support the curves by means of props.

The results which I have arrived at from measurements of the entire length of the lumbar region in the two sexes does not agree with those obtained by Ravenel. It is right to bear in mind, however, that although I claim a greater exactitude of method, the number of individuals I have examined is small in comparison with his. I have frozen the spines of five well-formed males, and four well-formed females, and then divided them in the mesial plane by means of a saw. While still in the frozen condition, with each element immovably fixed in proper position, I have taken careful tracings of the cut surface. In a reduced form these are figured in Plate II. (Nos. 1, 3, 4, 5, 6, males, and Nos. 1, 2, 3, 4, females). To this series I

¹ "Nouvel aperçu sur les conditions anatomiques des courbures de la colonne vertébrale chez l'homme." Par M. L. Hirschfeld. *Gaz. Méd. de Paris.* 1849.

have added tracings of Braune's well-known plates of the male and female in mesial section [Nos. 2 (male) and 5 (female)], and of the male spine figured by the Brothers Weber.¹ The accuracy of the last is sufficiently attested by the fact that Parow,² in seeking a means of determining the curves in the living individual, chose it as one of his standards.

Upon the tracings thus obtained, the anterior and posterior face of the lumbar region in each case could be measured with the greatest accuracy. In the first instance I adopted Ravenel's delimitation of the lumbar section, and measured each face from the level of the upper surface of the first lumbar vertebra to the level of the upper surface of the sacrum. In other words the lumbo-sacral intervertebral disc was included in the region. In comparing the results obtained in the two sexes I was surprised to find no essential difference. Taking the fore surface as the standard, and equal to 100, the following were the indices:—

Five females,		85.3
Seven males,		85.6

These indices stand in striking contrast to those given by Ravenel.

I next eliminated the lumbo-sacral intervertebral disc, and measured both aspects of the column from the level of the upper surface of the first lumbar vertebra to the level of the lower surface of the last lumbar vertebra. This gave slightly different results, and showed in the female a greater length of the anterior face, in proportion to the posterior face; in short, it indicated a stronger curve in the female. The average indices were:—

Five females,		88.1
Seven males,		89.1

The results obtained from the two sets of measurements, therefore, turned out to be the very reverse of what I had anticipated, and

¹ *Antea*, p. 3.

² "The Physical Conditions of the Upright Position and Curvatures of the Spine." Virchow's Archiv. Band xxxi., p. 108.

to reconcile the discrepancy it was necessary to determine the sacro-vertebral angle in each case. This can be done in a variety of ways, but the most convenient, and it seems to me the most accurate method, is to prolong the lines joining the central points of the upper and lower

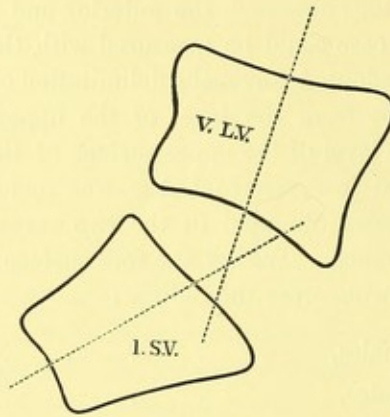


Fig. 1.

surfaces of the last lumbar and first sacral vertebræ respectively (in other words, to prolong the axis-line of each of these vertebræ). These lines intersect in the lumbo-sacral disc of cartilage; and in the twelve spines figured in Plate II., the average angle for the males was $133^{\circ} 6'$, and for the females $137^{\circ} 40'$. The lumbo-sacral angle, therefore, is more acute, and the promontory more marked in the males than in the females; and this accounts for the lower index which was obtained for the males when the lumbo-sacral disc of cartilage was included in the measurements. The following Table gives the detailed results in the case of each spine:—

TABLE R.

SEVEN MALES figured in Plate II.										FIVE FEMALES figured in Plate II.				
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	Weber's	Average.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	Average.
Relative height of fore surface of Lumbar region in comparison with the relative height of back surface: taking the fore surface as 100.	Includes Lumbo-sacral cartilage.	86.7	82.5	88.1	88.6	85.7	82.1	85.4	85.6	87.4	85.7	82.2	83.5	85.3
		Exclusive of Lumbo-sacral cartilage.	91.5	86.3	90.5	91.5	91.0	84.2	89.0	89.1	91.6	88.0	86.9	84.0
Lumbo-sacral angle,		137° 0'	130° 30'	135° 0'	125° 30'	138° 45'	138° 30'	126° 30'	133° 6'	137° 30'	117° 20'	136° 0'	150° 30'	137° 40'
Curve Index,		10.3	10.3	6.9	5.4	8.9	12.9	7.1	8.8	6.0	9.7	12.0	11.7	9.5
Indices of Vertebral bodies.	I. Lumbar Vertebra, . .	113.2	103.9	112.0	105.6	103.7	106.0	107.6	.	104.0	104.0	100.0	100.0	
	II. Lumbar Vertebra, . .	100.0	96.5	103.7	101.7	105.3	103.8	107.4	.	100.0	100.0	100.0	101.9	
	III. Lumbar Vertebra, . .	89.8	88.3	105.8	98.3	100.0	94.4	98.2	.	98.1	96.2	92.0	91.2	92.3
	IV. Lumbar Vertebra, . .	87.7	93.4	100.0	96.6	93.3	86.2	91.2	.	94.2	98.0	88.4	90.9	80.3
	V. Lumbar Vertebra, . .	79.3	67.7	85.7	80.0	90.0	68.9	80.0	.	82.6	75.4	76.9	80.3	81.4
Lumbo-vertebral Index,		93.6	89.3	101.1	96.1	98.0	91.1	96.4	.	95.7	93.8	90.8	92.3	91.0

NOTE.—The fact that the average lumbo-sacral angle in the twelve spines examined by me is more acute in the males than in the females cannot be regarded as in any way militating against the general results obtained by Charpy.¹ In his investigations he determined the angle in the spines of subjects of the same age; in my specimens the sum of the ages of the males was slightly greater than the sum of the ages of the females.

¹ *Annales*, p. 23.

But there is another and more simple method by which the degree of lumbar curvature in the tracings of the different spines may be compared, viz. by drawing a straight line from the anterior border of the lower surface of the last lumbar vertebra to the anterior border of the upper surface of the first lumbar vertebra. By the eye we can readily judge the amount of projection which takes place in front of that line in the different tracings (Plate II.), but for accurate comparison it is well to formulate an index. This can readily be done by taking the length of the lumbar region (measured from the centre of the upper surface of the first lumbar vertebra to the centre of the lower surface of the fifth lumbar vertebra) as the standard, and equivalent to 100, and then comparing it with the distance between the intersecting line and the point of greatest prominence. The most projecting point will generally be found to be the anterior border of the upper surface of the fourth lumbar vertebra in the male, and the anterior border of the lower surface of the third lumbar vertebra in the female. The index may be calculated thus:—

$$\frac{\text{Distance of most prominent point in front of intersecting line} \times 100}{\text{Length of lumbar column.}}$$

A high index will, therefore, indicate a strongly pronounced curve, and a low index a feeble degree of curvature; it may be termed the *index of the lumbar curve*.

In Table R, p. 27, the *curve indices* for each spine, figured in Plate II., is given, and the *average curve index* for the two sexes will be seen to be:—

Seven males,	8.8
Five females,	9.5

In every respect these data bear out the results obtained by measurement of the two faces of the lumbar column after excluding the lumbosacral intervertebral disc.

The evidence, therefore, which is obtained by an examination of the lumbar part of the vertebral column, as a whole, is entirely in favour of

the view that the curvature is more pronounced in the female than in the male; and we may now turn to the individual vertebræ and see what information, bearing upon this point, may be gathered from an examination of their centra in the two sexes. As will be seen from the following Table, the results obtained are of a very important character:—

TABLE S.

	IRISH.		ANDAMANS.		NEGROES.		AUSTRALIANS.		TASMANIANS.		BUSHMEN.	
	21 ♂	22 ♀	14 ♂	9 ♀	7 ♂	3 ♀	10 ♂	4 ♀	2 ♂	1 ♀	1 ♂	2 ♀
I. Lumbar Vertebra, .	106.9	102.6	114.4	109.8	114.9	110.4	125.1	111.4	118.0	109.5	109.0	119.4
II. Lumbar Vertebra, .	102.0	98.1	113.5	107.3	112.5	108.5	116.6	104.1	111.3	107.1	120.0	110.1
III. Lumbar Vertebra, .	97.7	95.0	110.9	104.2	106.3	104.8	116.5	108.2	111.6	107.1	102.0	113.9
IV. Lumbar Vertebra, .	95.0	91.8	103.7	100.9	103.4	108.8	104.4	100.4	110.5	107.5	93.7	104.4
V. Lumbar Vertebra, .	82.4	81.2	90.7	92.5	94.1	86.9	90.0	92.1	92.1	93.0	90.4	97.8
Lumbo-vertebral Index, .	96.2	93.5	106.3	102.4	106.0	103.4	110.1	103.1	108.5	104.7	102.1	108.8

Of the forty-three Irish spines examined, twenty-one were males, and twenty-two females. The *lumbo-vertebral index* of the latter is distinctly lower than that of the former, viz.:—

Females, 93.5
Males, 96.2

The vertebral bodies of the female are thus moulded more in adaptation to the curve than those of the male; and here again, therefore, we have corroborative proof as to the superiority of the female lumbar curve. Aeby¹ was unable to find any difference in this respect between the sexes, but it is evident that his observations were on too limited a scale. It will

¹ "Der Bau des menschlichen Körpers."

be further noticed in Table S, that in the Irish female the only lumbar vertebra with an average index above the standard is the first member of the series.

But this sex distinction is not limited to the European; the same difference between the lumbo-vertebral indices of the male and female is to be noted in every race examined, with the exception of the Bushmen, and of these only three spines were measured. Charts C and D (Plate 1.) will render these several differences more apparent. In chart C all the races (with the exception of the Bushmen) are included; the females are indicated by dotted lines, and the males by solid lines. In chart D the Tasmanians and Negroes are omitted in order to simplify the diagram. Except in the column which is allotted to the last lumbar vertebra, the female lines will all be noticed to occupy a lower level than the corresponding male lines. The European lines proceed together, apart from the others, and throughout they occupy the lowest place on the chart.

In the anthropoid apes we see no such sex distinction, except, perhaps, in the chimpanzee; and in view of the great irregularity exhibited by the lumbo-vertebral index in the individual members of this group, we cannot attach any importance to this discrepancy between the sexes:—

TABLE T.

		GORILLA.		CHIMPANZEE.		ORANG.	
		3 ♂	3 ♀	3 ♂	5 ♀	3 ♂	1 ♀
Lower five true Vertebrae.	a	113·9	116·9	119·2	124·3	112·1	118·5
	b	107·0	116·4	120·4	113·5	113·8	134·4
	c	107·6	115·0	124·8	109·9	119·6	120·0
	d	103·2	107·3	123·6	109·6	105·2	132·1
	e	103·1	99·9	119·4	114·6	98·0	120·0
Lumbo-vertebral Index, .		106·5	110·5	121·2	112·7	108·9	125·0

In the case of the gorilla and orang the lumbo-vertebral index exhibits an opposite condition, but the number of individuals examined has been too small to justify us in formulating any law upon this point.

Dr. Charpy in his Paper upon the lumbar curve, to which we have already had occasion more than once to refer, discusses the influences at work in producing a more prominent curve in the human female than in the male; and the views which he advances are very reasonable. He says:—

“Si la courbure lombaire est normalement, originellement plus forte chez la femme, à plus forte raison cette différence va-t-elle en s'accroissant, dans le cours de la vie, sous l'influence de circonstances en quelque sorte aggravantes et spéciales au sexe féminin. En première ligne se place la grossesse, qui oblige la colonne dorsale à se reporter en arrière et impose aux muscles lombaires extenseurs et incurvateurs un effort proportionnel au poids surajouté du côté de la flexion. Et ce n'est pas seulement pendant quelques mois que cet effet se manifeste; souvent toute la vie persiste un affaiblissement de la paroi abdominale qui laisse prédominer les muscles redresseurs antagonistes. Il est naturel de croire que c'est l'attitude de la grossesse, qui, poursuivie dans une série incalculable de générations a fini par créer un type héréditaire et originel, indiqué vaguement dès le premier âge, nettement accusé à la puberté et recevant tout son développement par les fonctions maternelles de la gestation et du port de l'enfant allaité.”

It seems to me that the carrying of the child either in the arms or upon the back must have a more important influence in determining the greater curvature of the spine than the occurrence of intermittent pregnancies, or the slight disturbance which results in the balance of power between the extensors and flexors of the spine. At all events it is clear that it is a hereditary condition.

Which Vertebra in Man and the Anthropoids shows an Index most nearly approaching the Standard?—In comparing the average indices of the sepa-

rate vertebræ, with a view to determine this question, a somewhat interesting point becomes apparent, as will be seen from the accompanying diagram :—

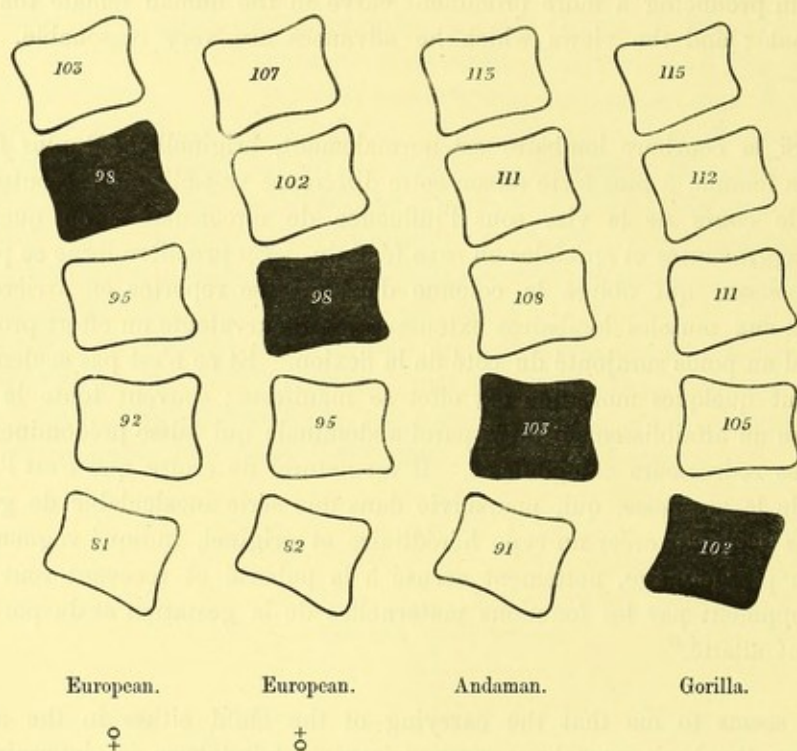


Fig. 2.

The numbers on the different vertebral bodies indicate the average index of that vertebra in the four groups represented in the diagram. The vertebral body in black shading is that member of the lumbar series which possesses an index most nearly approaching the standard; in other words, it is the vertebra of transition.

In the anthropoid ape the vertebra which shows an index most nearly approaching the standard is the last lumbar; in the low races it is the fourth lumbar; in the European male it is the third lumbar;¹ and in the European female it is the second lumbar. It ascends, therefore, step by step, from the anthropoid ape to the European female. But in constructing the accompanying diagram, another curious point became evident, viz. that (with the exception of the two lower lumbar vertebræ) the index of a given vertebra in the European female corresponds closely with the index of the vertebra in the male immediately below it. A similar correspondence will be noted in the case of the Andaman and the gorilla, but not in so marked a degree.

Relation of the form-adaptation of the Vertebral Bodies to the degree of Lumbar Curvature.—An important point must now be discussed: Has the moulding of the vertebral bodies any relation to the degree of lumbar curvature? We have noted that the lumbo-vertebral index, which expresses the amount of this form-adaptation, is very variable in different individuals; the question, therefore, comes to be: Is a low lumbo-vertebral index associated with a high degree of curvature, and *vice versa*? This point can in a measure be determined by comparing in Table R, p. 27, the lumbo-vertebral index of each spine figured in Plate II., with the corresponding index of curve. In so far as the individual spines are concerned, it will be noticed that there is a general correspondence between the two indices. But this can be brought out in a more striking manner if we calculate the average indices for the six spines which exhibit the highest degree of curvature in the lumbar region, and compare these with the

¹ In the European male it is the second lumbar vertebra which, strictly speaking, most nearly approaches the standard index, viz. 102, as against 97·7 for the third lumbar vertebra; but in view of the other relationships mentioned above, I have thought myself justified in overlooking this minute difference, and in giving the preference to the vertebra which possessed an index below the standard. The Andamans were chosen for comparison, because I had examined a greater number of specimens from this race than in the case of the other low races; and the gorilla, on account of the closer correspondence of its indices to those of man, than in the case of the other anthropoids.

average indices obtained from the six spines which exhibit the lowest degree of curvature. The following is the result:—

	Average Index of Lumbar Curvature.	Average Lumbo-vertebral Index.
The six spines in Plate II. which exhibit the lowest degree of curve in the lumbar region, viz., Nos. 3, 4, and 5, males, Nos. 1 and 2, Females, and Weber's figure,	7.0	96.8
The six spines in Plate II. which show the highest degree of lumbar curve, viz., Nos. 1, 2, and 6, Males, and Nos. 3, 4, and 5, Females,	11.1	91.3

It is clear, therefore, that the bodies of the vertebræ in the lumbar region are fashioned in a more or less marked manner in accordance with the degree of the lumbar curvature. In all cases, however, the difference in height between the anterior and posterior surfaces of the lumbar vertebræ (with the exception of the fifth) is so slight that it can have little or no influence in determining the curve. Weber,¹ Nühn,² Meyer,³ Hirschfeld,⁴ &c., have all given expression to a similar opinion. As Meyer,⁵ Horner,⁶ Aeby,⁷ and Pansch⁸ remark, the difference in height between the anterior and posterior surfaces of the lumbar vertebral bodies must be looked upon as *the consequence*, and not as *a cause* of the curve. But whilst this is the case, the condition which produces it is not, as some suppose, the unequal pressure to which the centrum is subjected during the life of the individual. Its cause is not immediate and mechanical. If it were so we would find it equally developed in all races; whereas in the low races the fifth lumbar vertebra alone exhibits the peculiarity—and this in a minor degree. Who, on such scanty evidence, would presume to say that in these races the lumbar curve is less marked than in the European? The condition is a hereditary one, and it has originated from influences operating upon the bodies of the vertebræ, as the lumbar curve has become in successive generations more and more firmly established. At the same time it must

¹ *Antea*, p. 3.² *Antea*, p. 3.³ *Antea*, p. 3.⁴ *Antea*, p. 3.⁵ *Antea*, p. 3.⁶ *Antea*, p. 3.⁷ *Antea*, p. 3.⁸ *Antea*, p. 3.

be admitted that it is very doubtful if the new-born child exhibits a like condition of the bodies of the lumbar vertebræ. At this early age, when only the central parts are ossified, it is a matter of extreme difficulty to measure the vertebral bodies accurately. Bouland¹ found a greater height of the lumbar column in front than behind, and that as a rule the osseous nuclei, the cartilages of ossification, and the intervertebral discs, all concurred to produce this. Horner² and Aeby,³ however, believe that in the first instance the bodies of the lumbar vertebræ are equally deep in front and behind. From a series of careful measurements which I have made myself, I am inclined to think that the difference between the anterior and posterior vertical diameters of the lumbar vertebræ in the new-born child (if indeed there is any) is very slight indeed, and that it is sometimes in favour of the front surface, and sometimes in favour of the back surface of the column.

From what has been said, some might be inclined to argue that the European had assumed the erect attitude at a period antecedent to the low races. Such a deduction would be altogether untenable. The difference in the form-adaptation of the lumbar bodies with reference to the curve, in a European and in a low race, is easily explained when we reflect upon the difference in their habits. The European who leads a life which rarely necessitates his forsaking the erect attitude, except as an intermittent occurrence, and then for short periods, has sacrificed in the lumbar part of the vertebral column *flexibility* for *stability*. It is evident that the deeper the bodies of the vertebræ grow in front, the more permanent, stable, and fixed the lumbar curve will become, and the more restricted will be the power of forward bending at this region of the spine. The savage, in whose daily life agility and suppleness of body are of so great an account, who is frequently called upon to pursue game in a prone position, and climb trees in search of fruit, preserves the pithecoïd condition of vertebræ in the lumbar region; and on account of this a superior flexibility of the spine must result. As we have stated, there is no reason to suppose that this condition is associated with a smaller degree of curvature in this region.

¹ "Journal de l'Anatomie et Physiologie," Paris, 1872.

² *Antea*, p. 3.

³ Der Bau des menschlichen Körpers.

Indeed it is well known that many of the lower races are distinguished by their erect and graceful carriage, and by the depth of the loin excavation on the posterior aspect of the trunk—an appearance which would indicate a strong degree of lumbar curvature.

The following Table gives the indices of the lumbar vertebræ in the Chinese, Esquimaux, and certain natives of India. As the number of spines belonging to each of those races which I had an opportunity of examining was very small, I have not included the results in the foregoing Tables:—

TABLE U.

	3 Esqui- maux (2 males and 1 female)	1 native of Canton (male).	2 Hindu males.	1 native of Bhutan (female).	1 native of Maldivé Islands (male).	2 natives of Punjab (males).	1 Koni native of Orissa (male).	1 native of Cabul (male).	1 Sikh (male).
I. Lumbar Vertebra,	114.0	126.0	117.1	116.2	118.1	112.3	127.9	109.2	116.6
II. Lumbar Vertebra,	103.7	114.0	115.0	112.7	104.0	111.0	116.3	111.3	112.0
III. Lumbar Vertebra,	97.3	112.0	111.3	104.1	106.2	105.1	114.0	111.3	112.2
IV. Lumbar Vertebra,	97.0	115.2	101.0	86.5	94.0	101.1	108.0	105.7	104.0
V. Lumbar Vertebra,	87.5	86.7	93.6	86.9	78.0	93.0	92.0	92.3	93.6
Lumbo-Vertebral Index, . . . }	99.7	110.5	107.6	101.0	100.0	104.3	111.5	105.9	107.5

The data which are given in this Table are of two meagre a kind for us to generalize upon. If it should so happen, however, that they are borne out by subsequent observations, the European will present a form-adaptation of the bodies of the lumbar vertebræ, more suited to the lumbar convexity than that exhibited by any of the other races which have come under our notice.

In bringing the first Section of this part of the memoir to a conclusion, I must express my indebtedness to my assistant, Dr. H. St. John Brooks, Demonstrator of Anatomy in the University of Dublin, for the ready help which he has given me in calculating the formidable rows of vertebral indices.

SECTION II.

The second section of this Memoir deals with the Lumbar Curve as a whole in man and the apes; and at the very outset of the inquiry we are met with a difficulty which has presented itself to every observer who has entered upon this subject. It is this: What standard are we to assume as typical? Is there any condition of vertebral curvature which may be considered normal? This is, indeed, a puzzling question, and we need not wonder, when we reflect upon the many forms which the spine may assume, that certain anatomists consider that there is no one condition which may be regarded as typical. In life¹ there is not a gesture, not a change of attitude, which is not accompanied by some alteration of spinal form. Our very respiratory movements, gentle and unconsciously performed as they are, meet a response in alterations of curvature of the vertebral column. And in the dead, when the spine is removed from the influence of the muscles—those contracting guy-ropes which help to keep it erect—when removed also from the influence of gravity, the changes which it undergoes must be considerable.

But even assuming that in life one of the many postures which may be taken by the human body is the normal one—be it the military attitude, or the easy unrestrained erect posture, it does not matter which—how is it possible for us to determine with accuracy the outline of the column formed by the bodies of the vertebræ? It is a task beyond the power of the anatomist. The only parts of the spine which approach the surface are the tips of the spinous processes, and the distances which remove these from the central points, or the anterior surfaces of the vertebral bodies, are not uniform. Not only are they different in different individuals, but even in dealing with persons of equal stature and development, and of corresponding sex, they cannot be relied upon. Further, in the movements of the spine, the excursions which are performed by the spinous processes are

¹ Henke remarks that the spinal form is variable according to taste and fashion.

much greater, and of a different nature from those of the bodies of the vertebræ.

Had it been possible to determine with precision the curvature of the spinal column in the living, there cannot be a doubt but that Parow¹ would have solved the question. His investigation into the physical conditions of the upright posture, and the normal curves of the spine, is a model of patient and laborious research; but while he has furnished us with many important and interesting facts, the representations which he gives of the curves of the column of vertebral bodies in the living can only be accepted as approximately correct.

The following is the manner in which Parow endeavoured to ascertain the curved outline presented by the anterior face of the vertebral column in the living individual. He tried to obtain the mean distance between the tips of the several spinous processes and the middle points of the front surface of the corresponding vertebral bodies by measurements carried out on a number of male and female columns. In certain of the dorsal vertebræ, on account of the strong slope of the spinous process, it was necessary to take three distinct measurements, viz. to the anterior face of the body of the corresponding vertebra; to the front of the vertebral body next in order below; and to the front of the column immediately opposite. In the cervical region such measurements would have been useless, not only on account of the deep position of the spinous processes, but also on account of their very variable degree of development. In the diagrams, therefore, which he gives, the cervical curve must be considered as being more or less fanciful. In the male spines the differences in the distances between the tips of the spinous processes and the front surface of the column were less than would have been expected. The most striking discrepancy, in the case of the movable vertebræ, was that exhibited by the vertebra prominens, and it amounted to 12 m.m. In the female spines the discrepancies were much greater, and the want of uniformity in different spines very marked.

¹ "Studien über die physikalischen Bedingungen der aufrechten Stellung und der normalen Krümmungen der Wirbelsäule." *Archiv für pathologische Anat. und Phys.* 1864.

But the great problem which presented itself to Parow was the determination of the position of the promontory—a point of the utmost importance in constructing a schema of the curvatures. The variable development of the sacrum renders it impossible to attain a definition of this point by measurements from the spinous process of the first sacral vertebra. In the two males measured by Parow the difference was so great as 27 m.m. He therefore had to devise other means of obtaining information upon this point, and not very successfully, for he says—"Ich habe indess in den dieser Abhandlung beigegebenen Zeichnungen den Versuch einer genauer Bestimmung der Lage des Promontoriums, resp: des Mittelpunktes der oberen Fläche des Kreuzbeins unterlassen, da ich mich überzeugt habe, dass dieselbe nicht die Wichtigkeit hat, die man ihr früher beilegen mochte."

Taking into account, then, the variations in form of the vertebræ, it will readily be understood that the difficulties in the way of obtaining the accurate curvatures of the spine in the living are insuperable. Parow carried out his investigations in this direction by means of an instrument which he terms the "Co-ordinatemesser," and unquestionably his results are of value, in so far as they bring out the transient changes of form which the vertebral column undergoes under the influence of slightly altered conditions. In fig. 3 (A and B) two of his outlines are reproduced. A represents what he considers to be the "Profile-projection of the fore surface of the vertebral column in the unrestrained upright attitude in the nearly empty condition of the alimentary canal." B is the same individual, with "a full condition of the alimentary canal." C and D are outlines of the fore surface of the spines of No. 1, male, and No. 3, female, in Plate II. The latter are tracings of mesial sections of frozen isolated spines, in which, therefore, the different levels can be marked off with the greatest accuracy. It will be seen that in C and D, although they are drawn upon a larger scale than A and B, the distance between D 2 and D 6 (*i.e.* the second and sixth dorsal vertebræ) is virtually the same. This shows that, in so far as these points are concerned, Parow cannot have succeeded in placing them accurately upon his profile outline. And this discrepancy cannot be accounted for by a compression of the

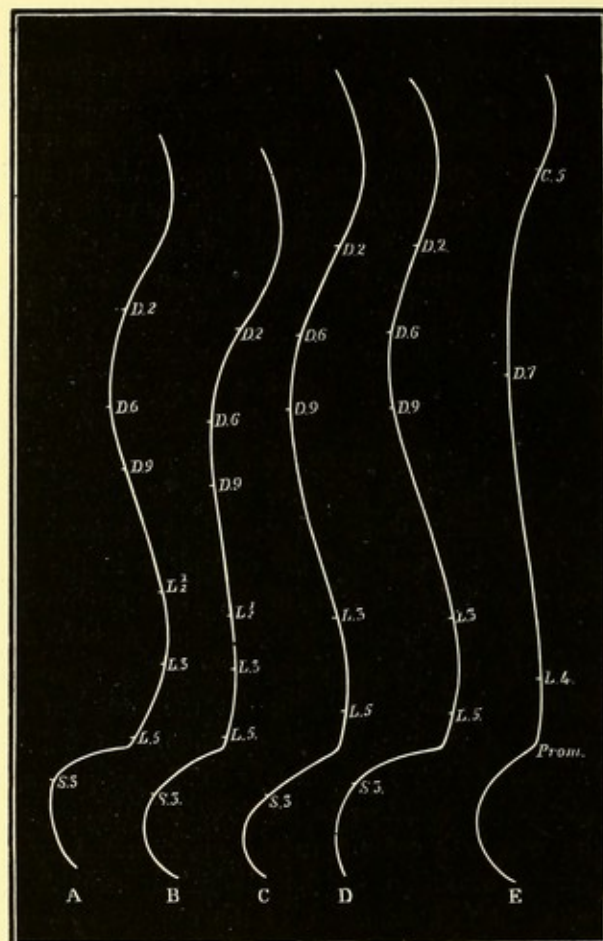


Fig. 8.

A and B (from Parow) :—

- D. 2. Upper border of the second Dorsal Vertebra.
- D. 6. Upper border of the sixth Dorsal Vertebra.
- D. 9. Middle of the ninth Dorsal Vertebra.
- L. $\frac{1}{2}$. Intervertebral disc between the first and second Lumbar Vertebrae.
- L. 3. Upper border of the third Lumbar Vertebra.
- L. 5. Lower border of the fifth Lumbar Vertebra.
- S. 3. Third Sacral Vertebra.

C Anterior curvature of No. 1, male, in Plate II. :—

D Anterior curvature of No. 3, female, in Plate II. :—

- D. 2. Middle point of the second Dorsal Vertebra.
- D. 6. Middle point of the sixth Dorsal Vertebra.
- D. 9. Middle point of the ninth Dorsal Vertebra.
- L. 3. Middle point of the third Lumbar Vertebra.
- L. 5. Middle point in the fifth Lumbar Vertebra.

E (from Parow) :—

- C. 5. Middle point of the fifth Cervical Vertebra.
- D. 7. Middle point of the seventh Dorsal Vertebra.
- L. 4. Middle point of the fourth Lumbar Vertebra.

Prom. Promontory.

four intervening discs by the superincumbent weight from which C and D have been relieved. This would never cause such a marked difference.

But even supposing that by the "Co-ordinatemeser"¹ we were able to obtain the precise curvature of the spine in the living, it would give a standard which could never be applied to comparative anatomical research. We are therefore obliged in this field of work to seek our standard of comparison in the dead.

Various methods have been employed for the purpose of determining the normal spinal curvature in the dead body. The brothers Wilhelm and Eduard Weber, in their classical treatise, "*Ueber die Mechanik der menschlichen Gehwerkzeuge*," published in 1836, were the first to treat the subject in a thoroughly reliable and scientific manner. Having removed the viscera and muscles from the trunk of a male subject, without injuring the ligaments of the spine and thorax, they embedded the preparation in plaster of Paris. When the latter was firm, the vertebral column and the block of enclosing plaster were divided in the mesial plane by means of a saw. By this method the various segments of the spine were held firm in the gypsum, and no displacement of these could take place through the escape of the fluid central parts of the intervertebral discs. The authors give a full-size representation of the cut surface of this spine, and I have taken the liberty of reproducing it in a reduced form in Plate II. There cannot be a doubt that this method will give fairly accurate results, although it is more than possible that in the process of embedding the spine in the plaster a change in the normal curvature may be induced; and some authors consider that the strong dorsal concavity² which is exhibited in the Webers' representation is due to this cause.³ Horner objects to this method as one calculated to give rise to inevitable errors from the manipulation

¹ Pansch, in his lectures to advanced students, remarks, with great truth, that in order to reproduce the spinal curvature of the living we would require to examine the individual first during life, and subsequently after death.—("Anatomische Vorlesungen.") 1884.

² The strong dorsal bend of this spine is certainly remarkable; but it appears to me that it is more reasonable to assume that it represents a pathological condition—perhaps, indeed, a condition resulting from emphysema of the lungs.

³ Vrolik, "*Tijdschr. voor de Natuurk. Wetensch.*" T. iii. 1850.

and the weight of the plaster. Professor Humphry of Cambridge, in his work upon the "Human Skeleton," figures the mesial section of a spine which he had treated in the same way, and Dr. Pierre Bouland¹ likewise adopted this method in his investigations into the development of the spinal curves. But however suitable this plan may be for the adult spine, in which the curves are more or less consolidated, it must be very evident that it is altogether inappropriate for the flexible column of the new-born child.

Dr. Friedrich Horner² approached the question from a totally different point of view. In Weber's method no account whatever is taken of the influence exerted upon the spine by the force of gravity, or the elasticity of the muscles, and Horner endeavours to rectify this. He does not attempt to arrive at an exact result for any one spine, but endeavours to construct an ideal or typical curve of the fore surface of the vertebral column from results obtained by the examination of three specimens. In two of these he left the muscles intact, whilst in the third the ligaments alone were retained. The vertebral columns thus prepared were divided in the mesial plane, and one-half of each placed upon a board. The sacrum was then firmly nailed in position, and the two end-points of the fore surface of the section connected by a straight line. The different regions were investigated separately, and by bending each part backwards and forwards its maximum power of backward and forward movement, as well as its middle position, were determined. Horner further endeavoured to compensate for the absent influence of gravity by pressure upon a given point; and in order to determine this point he employed the law which had been propounded by H. Meyer, viz. that the upright position "is maintained essentially only by conditions which lie in the skeleton and its ligamentous apparatus, and by which only the smallest degree of muscular activity is called into play." Meyer places the point of gravity of the trunk with the head and arms opposite the ninth dorsal vertebra, whilst he considers that the vertical line of gravity passes

¹ "Rech. Anat. sur les courbures du Rachis chez l'homme et chez animaux."—*Journ. de Anat.* Paris, 1872.

² "Ueber die normale Krümmung der Wirbelsäule." *Müller's Archiv.* 1854.

downwards so as to intersect the third sacral vertebra. In Horner's representation, therefore, the anterior face of the ninth dorsal vertebra is brought back until it touches the vertical line of gravity. It is by no means to be regarded as certain that the premises assumed by Horner are correct. The line of gravity is a point of extreme difficulty to determine, and Parow, with a full acquaintance of the work of Meyer and Horner, considers that it is not placed so far back, but cuts the promontory. It is in this neighbourhood also that Weber places the line of gravity.

In a postscript to Horner's Paper, H. Meyer makes a few slight alterations in Horner's schema, and likewise gives a formula by means of which he considers that the curves of an ideal and typical vertebral column may be constructed.

Pansch,¹ in his instructive and interesting lectures to advanced students, remarks: "A single determined form (of the vertebral column), which we might designate a normal one, does not exist. . . . But with Meyer we regard that form, which the powerful and stiff upright body shows, as a typical one. This stiff or 'military' position . . . offers the peculiarity that the two ends lie perpendicularly, the one over the other." If the Horner-Meyer schema represents the military position, then it is a forced attitude, and one which is very largely produced by the influence of muscular contraction. Krause² indeed considers that this posture is only fit for a pregnant woman.

Fr. Merkel³ objects to the preceding methods of investigating the curves of the vertebral column, inasmuch as they only give us information regarding the vertebral bodies, and the intervening cartilaginous discs. We obtain, in other words, the collective curvature without perceiving the part which the several vertebræ play in its construction, because the neural arches, and more especially the articular processes, are concealed from view: and he holds that it is only by a study of the details of the architecture of the separate vertebræ that we are able to tell whether or not a normal curvature exists. His Paper on this subject is an exceedingly ingenious one. By the application of geometrical laws he has been able to construct

¹ "Anatomische Vorlesungen." 1884.

² "Handbuch der menschlichen Anatomie," p. 81.

³ "Ueber den Bau der Lendenwirbelsäule." Archiv für Anat. und Phys. (His und Braune). 1877.

drawings of the lumbar region of twelve different individuals from the macerated and separate vertebræ. He endeavours, therefore, to rebuild the lumbar section of the column from a study of the manner in which its separate elements are related to each other.

The following is the plan upon which he proceeds, and it would be well to use his own words. He says: "It is necessary to call to our aid a mediate method of investigation. As such the excellent method of geometrical drawing of Lucæ has proved itself very valuable to me. With its help it is possible to sketch a profile outline of the vertebræ which comprehends in one plane all the essential points of the bodies as well as the arches, and thus unites the advantages of a median section with those of a view of the arches. With a little practice we obtain such accurate drawings, that several independent sketches prove, in every respect, congruous.

"In the production of the sketches I proceeded to place the vertebra, with the help of the '*Fadenkreuz-Diopter*,' in accurate profile; the separate lumbar vertebræ of the macerated vertebral column, which I used exclusively, were grasped by a vice, and shifted until the upper and lower posterior angles of the body, as well as the highest and lowest point of the two articular surfaces of both segments of the body, coincided. The sketch was then drawn, and the superior articular surface was represented in the interval which exists upon the averted side of the articular process. This could also be very accurately done by using the contour of the processus obliquus, and by means of compass measurement. Finally, in the drawing, likewise by the aid of the compass, the middle points of the upper and lower articular surfaces were determined."

Having thus obtained accurate profile drawings of the five lumbar vertebræ, Merkel proceeds to place them in position, and thus re-construct the lumbar column. He assumes, in the first place, that in the attitude of anatomical rest the central points of the opposing surfaces of the articular processes must coincide with each other, and having placed them accurately in this relation to each other, he shifts the bodies until the upper and lower angles of their fore surfaces fall into a uniform curve (*i.e.* a curve without angular notches). He asserts that it is only possible to form, with the

front faces of the bodies, one quality of curve. If we attempt to construct a curve with a larger radius, then the central articular points refuse to coincide: if, on the other hand, we strive to form a curve with a smaller radius, the vertebræ project over one another. He figures the lumbar regions of twelve individuals which he has reconstructed in this way, and he considers the curve in each case, "die einzig mögliche anatomische Normalkrümmung der Bauchwirbelsäule."

He brings forward additional evidence to show that at least the second and fourth lumbar vertebræ are correctly placed. If the lines joining the central points of the superior and inferior articular processes of these vertebræ be prolonged, they cut each other at an angle of 166° —and this angle is constant throughout the whole series of columns he examined. The position of the third vertebra varies with the height of the individual, but he also endeavours to deduce a law by which its position may be determined. It is only in the case of the first and fifth lumbar vertebræ that he finds himself placed in a dilemma. In the case of the former, he seeks help from the Horner-Meyer schema: as for the latter, its place was fixed, more or less, by the eye. With regard to these vertebræ, he says: "Ich betone nochmals, dass diese Stellung nur eine provisorische ist, und dass sich volle erst Sicherheit über diesen Wirbel, ebenso wie über den ersten Lendenwirbel ergeben kann, wenn eine Construction der ganzen Wirbelsäule vorliegt."

Were it possible to accept without question this highly ingenious method of rebuilding the lumbar column, the advantages proceeding from it would be very great; as Professor Merkel claims, it would enable us to appreciate the relation which the several parts of a vertebra bear individually to the curve, and it would supply us with a ready means of estimating the degree of lumbar curvature in the macerated column. It might, therefore, be employed with great advantage in the determination of the curves of those races of which the fresh spines cannot be obtained. There are, however, decided difficulties in the way of its application. The axiom which is advanced, viz., that the position of anatomical rest is that in which the central points of the opposing articular surfaces coincide, might readily be disputed; and upon this depends the whole theory. But, even granting the accuracy of the method, it has this disadvantage, that by its means we

are only able to fix with certainty the position of two, or at most three, of the vertebræ. Whilst we recognize, therefore, the high importance of this Paper, and note the many original and new points which it discloses, we are satisfied that the curves of the spine can only be properly studied in the fresh vertebral column.

The investigations which I have made in connexion with the lumbar curve in man were chiefly carried out with the view of obtaining a standard with which I might compare the corresponding curve in the apes. It is true that I might have been satisfied for this purpose with the representations of Weber,¹ Braune,² and Pirogoff;³ but as it was important to arrive at some conception as to the range of deviation in the lumbar curve in different individuals, I felt that it was necessary to examine a number of spines. The investigation has not been devoid of interesting results.

In every case the spine was frozen, and divided in the mesial plane with the saw; a piece of fine tracing-paper was then frozen to the surface of the section after it had been cleansed with a stream of water, and an accurate tracing taken of the bodies of the vertebræ. There cannot be a doubt that where it is possible it is advantageous to freeze the entire body, and thus obtain a picture of the spine before it has been removed from its surrounding soft parts; but in a country such as Ireland, where a snow-storm is a rarity, and a continuous hard frost seldom occurs, it is out of the question to attempt the freezing of a number of entire subjects.

The spines, therefore, which I have examined, were removed from the body, but in every case the surrounding muscles and ligaments were left untouched. I have satisfied myself that the changes of curvature which Parow⁴ asserts occur when the spine is isolated do not take place when the subject is maintained in the horizontal position. It is a totally different matter, however, when we are dealing with a subject which is artificially maintained in an erect attitude. In this position it would be strange if the

¹ *Antea*, p. 3.

² "Atlas of Topographical Anatomy."

³ "Anatome topogr. sectionibus per corpus hum. congelatum triplici direct. ductis illustr. Petropol." 1859.

⁴ "Archiv. für pathologische Anat. und Phys." 1864.

changes described by Parow, on removal of the viscera and the thoracic wall, did not take place. It must be evident to everyone, that if in a dead body, held in an upright posture, the abdominal viscera be removed—if in this way the support to the under surface of the diaphragm be abstracted—the upper part of the dorsal region of the column will sink downwards, and at the same time advance forwards: likewise it must be equally clear that the evisceration of the thorax will cause the spine to partially regain its original form. Further, if the ribs and sternum be taken away, and the dorsal region be thus relieved of their weight, it is reasonable to suppose that an increased flattening of the dorsal curve will follow. But all these changes are due to the force of gravity, and exert no influence upon the spine when it is placed in the horizontal position.

But Parow holds that the thoracic walls constitute an integral part of the spine, and that the rings formed by the costal arches and the sternum keep the dorsal region of the vertebral column in a state of tension. He asserts that as soon as the integrity of the thoracic parietes is interfered with, the dorsal arch relaxes, becomes flatter, and forms a curve with a distinctly greater radius. The lumbar curve also completely disappears.

To test the accuracy of the above statement I performed the following experiments:—Having chosen a powerfully-built male subject, the lower limbs were amputated at the junction of the upper and middle thirds of the thighs, and the head removed by disarticulation at the occipito-atlantoid joint. The upper limbs, with the shoulder-girdles, were also taken away. The trunk, thus bereft of the greater part of the lower limbs, the upper limbs, and the head, was placed upon its back in a box about twelve inches longer, and about eight inches broader than itself, and plaster of Paris was poured in so as to fill up the vacant space. In the cervical region this was allowed to rise until it reached the level of the anterior surface of the vertebral bodies; in the dorsal region it was allowed to come forward upon the chest wall to a point a little beyond the nipples, and in the abdominal region until it reached the anterior surface of the front wall. The trunk was therefore immovably fixed in a block of plaster, with its anterior surface alone exposed. Great care was taken to regulate the amount of plaster behind the neck, so that it might corre-

spond to the depth of the head behind the atlas. The viscera of both abdominal and thoracic cavities were then removed by opening the anterior wall of the former: the thoracic wall was in this way preserved intact. During the process of evisceration the spine was supported by the hand of an assistant, so as to prevent any dislocation from the plaster bed. The subject, and also the spine, remained, however, perfectly firm, and did not move in the least degree. After cleaning the front of the vertebral bodies, it was noticed that the first and second lumbar vertebræ had been the seat of caries, and although completely cured, there was yet a distinct depression opposite this portion of the column. The curve was taken by a strip of lead moulded upon the front face of the vertebral bodies, and the tracing thus obtained is represented in fig. 4 (No. 2 A.) It may be regarded as giving the curvature of this spine with the body cavities entire, and occupied by the viscera.

The next step in the experiment consisted in breaking down the plaster block, with the exception of that portion which supported the neck, which was retained throughout the entire experiment. When this was effected the trunk was again placed in the box and again surrounded with plaster, as before, and the curve taken with the strip of lead. The tracing thus obtained is seen in fig. 4 (No. 2 B.) It gives therefore the outline of the spine in the horizontal position after evisceration.

Before breaking down the plaster block a second time the breast-bone and the costal cartilages were removed, and having again embedded the body in the gypsum, the tracing represented in fig. 4 (No. 2 C) was taken. This gives the curvature after the integrity of the thoracic wall has been interfered with.

The last step consisted in freezing the isolated spine, and dividing it in the mesial plane. A tracing (in a reduced form) of this section is given in fig. 4 (No. 2 E.)

The pathological condition of this vertebral column rendered it necessary that the same experiment should be repeated upon a healthy subject; and a tall powerful male was therefore chosen, and subjected to precisely the same process. The only difference in this case was, that the lower limbs were not amputated. In the second embedding the plaster block

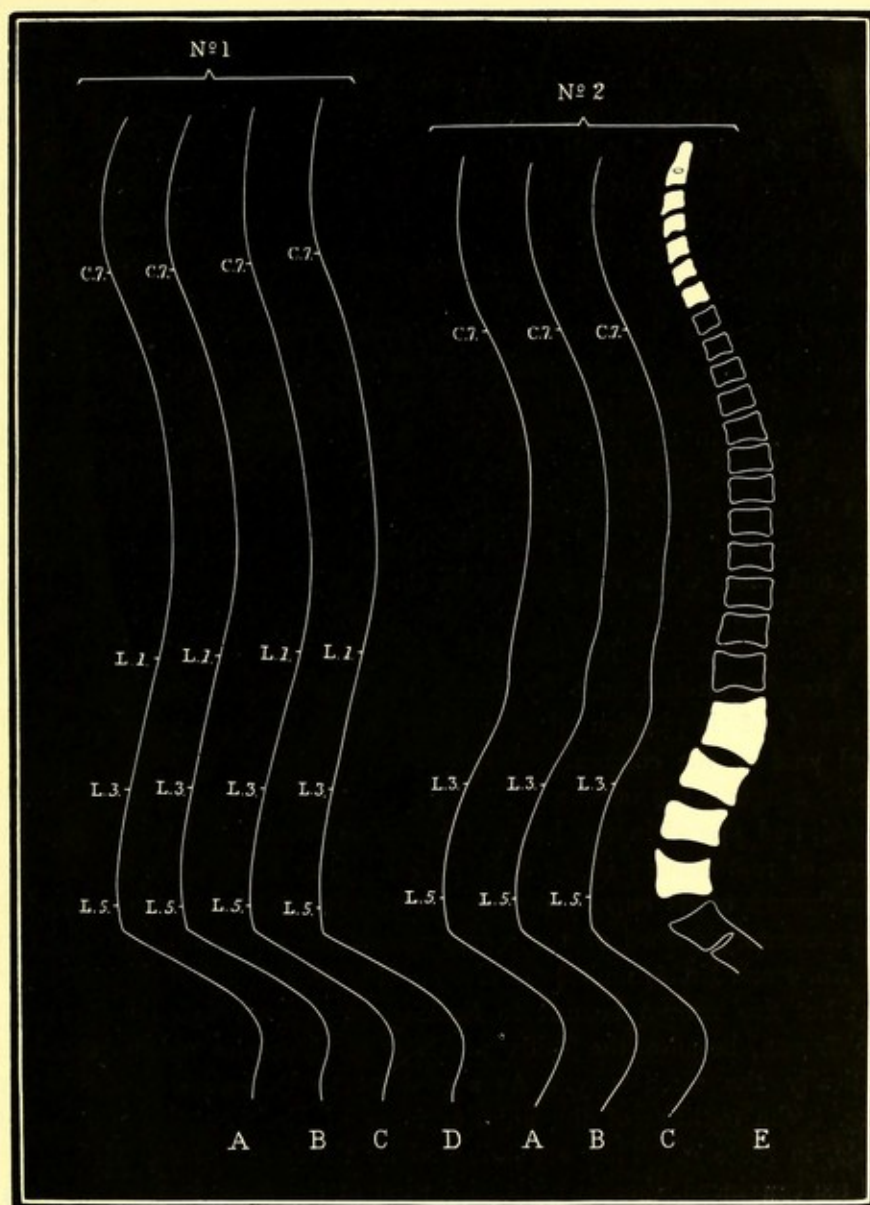


Fig. 4.

supporting the head broke, and thus some differences resulted in the two last tracings of this portion of the column. The curves obtained are represented in fig. 4 (No. 1 A, B, C.) An additional outline is given, viz. D; this was the tracing obtained after all the intercostal muscles, &c., were divided right back to the erector spinæ, and in taking this the trunk was not embedded in the plaster, but was merely stretched horizontally on a table.

It will be seen that the tracings of each spine are very nearly alike, and that the deviations are so slight that they are evidently the result of the method of registering the curves, viz. by a strip of lead. I believe, therefore, that in the horizontal position of the body the removal of the viscera from the abdominal and thoracic cavities does not appreciably affect the curves of the vertebral column; and further, I dispute Parow's proposition that the dorsal region is held in tension by the costo-sternal rings, and that, when the body is in the recumbent attitude, any interference with the integrity of the thoracic walls leads to an alteration of the vertebral curves. No one will deny that in the upright position they exercise an influence by reason of their weight, and that in the movement of inspiration they produce a slight straightening of the dorsal part of the column.

Parow figures the outline of the front surface of a spine which has been isolated, and placed in the horizontal position; and this I have taken the liberty of reproducing in fig. 3 E (p. 40). It is remarkable for the extreme flatness of its curves, more especially in the lumbar region, and at the promontory. Two of the spines which are represented in Plate II. (viz. No. 4 and No. 5, males) are also peculiar on account of their straightness; but this cannot be due to their having been isolated before they were frozen, because the other members of the series were treated in identically the same way. As a contrast to Parow's outline, I place in fig. 3 the outlines of the anterior faces of No. 1, male, and No. 3, female, in Plate II. They are indicated by the letters C and D.

I am convinced, therefore, that isolation of the spine in the recumbent posture does not produce the changes described by Parow as occurring when the trunk is maintained erect. In the series of spines figured in

Plate II. I have introduced reduced tracings of the spines in Braune's representations of the mesial sections of a male and female (No. 2, male, and No. 5, female). Certain of my own tracings closely correspond with these: thus No. 1, male, only differs from Braune's male in the cervical region, and this is evidently due to the position of the head in the latter; again, if No. 3, female, be contrasted with Braune's female, a similar correspondence will be noted.

Braune¹ is unquestionably right when he states that no advantage can be obtained by freezing the body in the upright position. "It is evident," he says, "that it is impracticable to keep a body so balanced, and in such equilibrium, as the muscles are capable of doing during life. The trunk always hangs over to one side to such an extent that the spine partly loses its original curvature, and takes a semi-flexure. It is, therefore, not to be wondered at that the figure which Pirogoff (a. a. O. Tab. 12) gives, taken from a subject frozen in the upright position, exhibits flatter curves, having flatter arcs, than it would have had if the drawings had been taken from one frozen in the horizontal position."

Of course it is impossible to estimate accurately the amount of alteration which the spinal form undergoes in life in the change from an erect to a recumbent attitude. We can only judge of this by measuring the spine in the two attitudes, and the results obtained in this way would certainly seem to indicate that the change of curvature is not so marked as is generally supposed. At all events we are justified in assuming that in a dead subject the spinal form in the recumbent posture approaches more nearly to what it was during life than when the body is artificially maintained in the erect attitude.

In order to obtain an approximate idea as to the amount of the difference in the spinal curvature in the two attitudes, I carefully measured six young, well-formed individuals, with an average age of twenty-eight, and an average height of 5 ft. 6½ in., first in the upright posture, and afterwards in the recumbent position. The average increase in height in the latter attitude was only three-eighths of an inch, no doubt produced by a

¹ "Atlas of Topographical Anatomy," p. 3.

flattening of the dorsal and lumbar curves.¹ A corresponding increase in height can be detected, as is well known, after a night's rest. Hyrtl² states that in measurements instituted upon himself he found his height to be "5 schuh 8 zoll" after seven hours' rest, and only "5 schuh 7 zoll 3 linien" before retiring to bed. In eight individuals (four males and four females), with an average age of twenty-seven, and an average height of 5 ft. 4 in., I found the morning increase of height to be an average of $\frac{7}{16}$ of an inch. This increase depends not so much upon an alteration of the intervertebral discs as upon a change in the curves of the spine, which, during the period of rest, has been relieved from its burden.

It therefore appears to me that the attitude in which the spine should be examined in the dead subject is the horizontal recumbent one, and the spinal form which is then exhibited may fairly be taken as the standard of comparison when we are pushing our inquiries into the curves of the vertebral column in the lower animals.

Differences in Spinal Form in different Individuals.—It is not necessary to examine the spine itself to observe the marked differences in spinal form exhibited by different individuals. The stooping gait of those engaged in sedentary pursuits, the erect bearing of the soldier, and the easy and graceful carriage of the athlete, are all types familiar to the eye. Still these individual differences are brought very prominently before us when we examine a series of spines such as are exhibited in Plate II. The influences at work in producing these differences are clearly those of—(1) age; (2) sex; and (3) occupation.

It is recognized by all anatomists that the spinal form presents different appearances at different periods of adult life. According to Sappey,³ the curvatures of the vertebral column remain stationary only for the short period of five years, viz., between the ages of twenty-five and thirty.

¹ Horner believes the difference to be much greater. He took two points, viz. one opposite the middle of the third sacral vertebra, and the other at the tip of the spinous process of the eighth dorsal vertebra, and measured the distance between them, first in standing, and then with the subject lying upon his side, and found a difference of 30 mm.

² "Lehrbuch der Anatomie."

³ "Traité d'Anatomie Descriptive."

"The curvature then enters upon a new period of increase, and the stature begins to decrease." But it is only in advanced age that the curves become greatly exaggerated, and this exaggeration does not affect the lumbar so much as the dorsal region. In Plate II., No. 1 (male) represents the spine of a man of about fifty-five years; Nos. 3 and 6 (males) are the spines of men of middle age (from forty to fifty years); whilst Nos. 4 and 5 (males) are the spines of, comparatively speaking, young men. Confining our examination to the lumbar region, it will be observed that the most pronounced curves are to be seen in two out of the three oldest spines, viz., Nos. 1 and 6. By referring to Table R. (p. 27) it will be observed that the index of the lumbar curve in these is 10·3 in the former and 12·9 in the latter. No. 3 certainly offers a marked exception, the index being only 6·9. But there are two other peculiarities in connection with this spine, viz. it presents a most unusual abruptness in the transition from the cervical to the dorsal curve, and the average index of the bodies of the lumbar vertebræ is above the standard (101·1).

In the series of female spines represented in Plate II., No. 1 is from a woman thirty years old; No. 3, from a subject thirty-five years old; whilst Nos. 2 and 4 were both about fifty years old. In general curvature the two young spines are undoubtedly the most pronounced, and although No. 4 presents the highest index of lumbar curve (12), No. 2 possesses the lowest (6). The straightness of this latter spine is indeed very striking.

The influence of age, therefore, does not affect all spines, nor all regions of the spine alike. Although there was no decrepitude, and, indeed, no apparent wasting in the subjects from which Nos. 3 (male) and 2 (female) were taken, it is possible that they may have remained in a recumbent position for a longer period than the others before death.

That the life-occupation of an individual exerts an influence upon spinal form must be manifest to all, and doubtless many of the peculiarities observed in the series of spines figured in Plate II. proceed from this cause. Unfortunately, however, with the exception of No. 5 (male) (who, I believe, was a sailor), I have no information as to the pursuits followed by the individuals from whom the spines were taken. Sappey¹ believes that in

¹ *Antea*, p. 52.

the agricultural labourer the upper part of the lumbar region becomes more strongly curved; whilst in the porter it is the lower part of the cervical region that is affected. "Telle est aussi," observes Charpy,¹ "la cambure des gens qui habitent la montagne ou des pays accidentés et marchant sur des pentes, opposée à la rectitude de ceux qui vivent en plaine." All such forms are the result of muscular influence.

The influence of sex upon the general lumbar curve has already been discussed, and it has been noted that in the female it is, as a rule, more pronounced than in the male. Other special sexual distinctions will be alluded to when we come to analyse the character of the lumbar curve.

Racial Differences.—It cannot be disputed that in different races of mankind there are different varieties of spinal form. The very fact of such marked discrepancies being found between the indices of the bodies of the lumbar vertebræ points to this, although it cannot be regarded as a proof of it. As we have already observed, these discrepancies can only be looked upon as indicating a greater or less degree of flexibility—a greater or less degree of power of changing the spinal form under the influence of the muscles, and not as specially indicating a greater or less degree of lumbar curvexity.

Travellers tell us of the erect and graceful bearing of many of the natives of Africa, and speak of the marked hollow which may be seen posteriorly in the region of the loins. The same has been said also of the natives of Australia; but beyond this we have little information, and what knowledge we do possess is far from being of a definite character.

Pruner-Bey,² in his memoir upon the Negro race, says: "Les trois courbures de la colonne vertébrale ne sont jamais aussi prononcées que chez le Touranien et chez l'Aryen." Topinard,³ in his great work upon Anthropology, makes the remark that the *l'ensellure dorso-lombo-sacrée* "est plus prononcée dans les races brunes méridionales de l'Europe par comparaison avec les races blondes et cela dans les deux sexes."

¹ "De la courbure lombaire."—Journ. de l'Anatomie et Physiologie. (Paris.) 1885.

² "Mémoire sur les Nègres," lu à la Société d'Anthropologie de Paris. 1861.

³ "Eléments d'Anthropologie générale." 1885.

Duchenne¹ gives some very interesting facts regarding the difference in spinal form in the Iberian and Anglo-Saxon races. He states that three very different degrees of lumbo-sacral curve exists, and to the most pronounced of these he gives the name of "*Ensellure lombo-sacrée physiologique*." This condition he considers is characteristic of Spanish women, and more especially of the Andalusians. It necessitates curves of compensation in the other regions, and, when these are not exaggerated, much grace is given to the contour of the body: further, it is associated with small hands and feet, elegant pose, and finely-modelled neck. The same characters may be observed in the women of Boulogne-sur-Mer, which he believes to be due to their supposed Spanish origin. In the village of Andresselles, with inhabitants of Anglo-Saxon blood, he has noticed an altogether different type. In these the vertebral column is very straight, and the lumbar curve but slightly marked. Associated with this variety of spinal form there was noticed a stiff body with an angular contour, large hands and feet, and a neck wanting in grace.

M. le Dr. Guerlain,² a physician in Boulogne-sur-Mer, disputes the accuracy of the views advanced by Duchenne. He holds that the cause of the *Ensellure lombo-sacrée* is mechanical, and due to the hilly nature of the district and to the heavy burdens which the inhabitants carry. Lagneau,³ in his Paper upon the Anthropology of France, gives his adherence to the opinions of Duchenne.

I have recently had an opportunity of examining a number of Hottentot-Bushmen, who were exhibited in Dublin by M. Farini. The troupe consisted of two adult males, a boy of six years old, and a girl of twelve years old. In all, the depression in the lumbo-sacral region of the back was very marked, and rendered all the more striking by the great accumulation of gluteal adipose tissue. The lower part of the abdomen was also very protuberant. With the help of an assistant I obtained accurate

¹ "Physiologie des Mouvements." 1867.

² "Sur l'ensellure lombo-sacrée des femmes de Boulogne."—Bulletin de la Soc. d'Anthrop. de Paris. 1867.

³ "Bulletin de la Soc. d'Anthrop. de Paris." 1867.

tracings of the spinal form, in so far as this can be done in the living. Each individual was instructed to stand in an easy upright attitude, and being steadied in this posture, by the assistant placing one hand on the head and the other on the shoulder, I proceeded to mould along the middle line of the back a strip of ductile lead. Owing to the great projection of the buttocks, it was very difficult to obtain an accurate mould of the coccyx, but above this point the form could be taken with the greatest precision. Fig. 5 A, B, C, D (p. 58), gives, on a reduced scale, the tracings which were obtained in this way. The *Ensellure lombo-sacrée* is very pronounced, and it may be measured, as Topinard suggests, by drawing a line from the most prominent point of the dorsal region to the most prominent point of the sacrum, and then noting the depth between this line and the point of maximum curvature. Further, if we take the standard length of the spine as 100, we can formulate an index for the *ensellure lombo-sacrée*. The following Table gives the results of the measurements:—

FOUR HOTTENTOT-BUSHMEN.

Outline in Fig. 5	A.	B.	C.	D.	
Name and Sex,	N'Arkar, ♂	N'Iey, ♀	N'Fun n'fon, ♂	N'Con n'qui, ♂	Average.
Age,	6	12	25	42	
Length of Spine,	384 mm.	427 mm.	462 mm.	559 mm.	458 mm.
Maximum depth of <i>Ensellure</i> } <i>lombo-sacrée</i> , }	24 mm.	34 mm.	36 mm.	37 mm.	32.7 mm.
Index of <i>Ensellure</i> ,	6.6	8.0	7.7	6.6	7.2

The female, although a girl of only twelve, presented the most marked curve, and this could be noted by the eye. In all there was observed a great suppleness in the region of the loins. It is right to mention, that although the age of N'fun n'fon was given as twenty-five years, it is very doubtful if he was more than twenty. He certainly had not the appearance of having arrived at full maturity.

In order to fully appreciate the above figures referring to the *ensellure* in the Hottentots, I measured in the same way two young adult and finely-built Irishmen, and the tracings which I obtained are represented in Fig. 5 (E and F.) The one was a labourer (E), and his spinal form was taken while he was standing in an easy, unrestrained attitude; the other was a tall, athletic man, with a very erect bearing (F), and in his case the tracing was obtained while he stood in an attitude with the shoulders drawn well back, and the loins projected forwards. The following Table gives the results:—

TWO IRISHMEN.

	E.	F.	Average.
Length of Spine,	682 mm.	741 mm.	711.5 mm.
Maximum depth of <i>Ensellure lombo-</i> <i>sacrée</i> ,	21.5 mm.	41 mm.	31.2 mm.
Index of <i>Ensellure</i> ,	3.2	5.5	4.3

The difference between the *Ensellure lombo-sacrée* in the Hottentot-Bushmen and the two Irishmen is therefore very striking, and bespeaks in the former not only a more pronounced lumbar curve, but, perhaps, also a greater obliquity of the pelvis. The index exhibited by F falls considerably short of the average Hottentot index, notwithstanding the fact that it must be regarded as showing a somewhat exaggerated *Ensellure*.

There is, however, still another point of difference, viz., that whereas the point of greatest depth of the *Ensellure* in the two Irishmen is opposite the second lumbar vertebra; in the Hottentot-Bushmen it is placed much lower down, and is opposite the last lumbar vertebra.

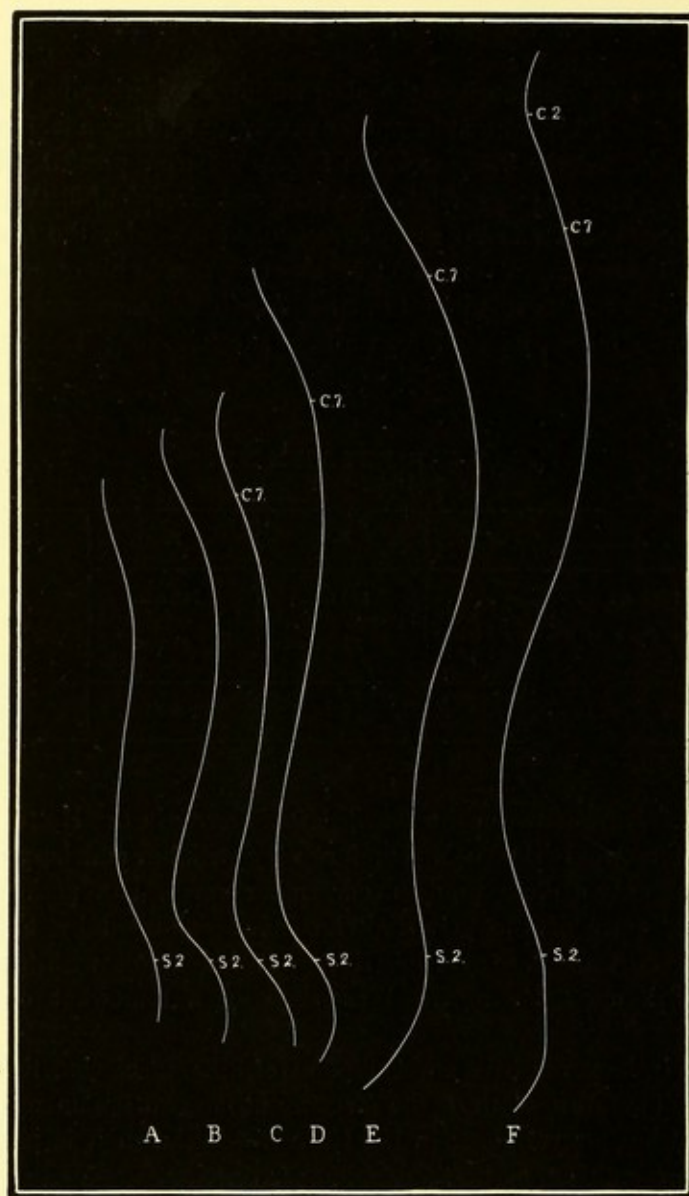


Fig. 5.

Tracings of the posterior aspect of the spine in four Hottentot-Bushmen, viz., A, B, C, and D; and two Irishmen, E and F; taken by means of a strip of lead.

Points of Inflexion of the Vertebral Column.—As mathematical problems are involved in the determination of this question, I sought the aid of the Rev. Dr. Haughton, F. R. S., whose previous well-known work in the field of animal mechanics rendered his help peculiarly valuable. With his usual kindness, he instructed me in the methods which he considered would lead to the most accurate results.

The putting of these methods into practice constituted a very laborious undertaking, and it was executed for me by my friend and former pupil, Dr. Vaughan. I cannot sufficiently express my indebtedness to him for the great assistance which he has given me, and for the many valuable suggestions which, from time to time, I received from him.

Hitherto the vertebral curvature has, as a rule, been regarded as that formed by the outline of the anterior face of the spinal column, and the mean curve has been constructed by drawing a line in relation to the upper and lower anterior angles of the vertebral bodies. This is manifestly an erroneous conception of the spinal curvature. That part of the column which is composed of the true vertebræ constitutes a cone-shaped structure, with a curved outline and a curved axis: its true curvature is that of the axis.¹ But further, the upper and lower angles of the fore surface of the vertebral bodies are very irregular in their degree of projection. Subsidiary curves are thus introduced which throw certain of the vertebræ out of the mean curve altogether. If we endeavour to determine the points of inflexion of the three curves by this method, the results obtained in different spines are by no means uniform. Thus the cervico-dorsal change takes place within a range which varies from the upper border of the third dorsal vertebra to the lower border of the fourth dorsal vertebra: whilst the lumbo-dorsal inflexion may occur at any point between the upper border of the first lumbar vertebra and the lower border of the third lumbar vertebra.

The true vertebral curvature is the *axial curvature*; and this may be determined by finding the central points of the bodies of the vertebræ and

¹ It is right to state that this point was first suggested by Dr. Vaughan in the course of a conversation which I had with him on the subject, and afterwards, in submitting the question to Dr. Haughton, he entirely corroborated the view.

of their interposed cartilaginous discs, and drawing the mean curve through these. When this is done, the change from one curve to the other will always be found at the same point; and it is of great interest to note that the degree of curvature of a spine appears to have no effect in producing variation in the points of inflexion: in a strongly-curved spine, as well as in a feebly-curved spine, the transition from one curve to the other is always at precisely the same spot.

In male and female spines alike (viz., Nos. 1, 3, 4, 5, and 6, males, and Nos. 1, 2, 3, 4, females, Plate II.), the cervico-dorsal point of inflexion is situated in the disc between the 2nd and 3rd dorsal vertebrae. The cervical curve is therefore formed by the upper nine vertebrae.

The lumbo-dorsal point of inflexion is apparently different in the two sexes, and therefore, in so far as my tracings show, it constitutes a sexual distinction. In male spines, Nos. 1, 3, 4, 5, and 6, the change of curvature takes place in the disc, between the 12th dorsal and the 1st lumbar vertebrae. In the female spines, Nos. 1, 2, 3, and 4, it is placed a little higher, viz., in the centre of the body of the 12th dorsal vertebra.

The most diverse views are entertained as to the boundary line between the dorsal and lumbar curves, and this may in all probability be accounted for by the fact, that in the determination of this point the mean curvature of the anterior face of the column has been taken as the standard. Aeby, in his work entitled "*Der Bau des menschlichen Körpers*," holds that the dorsal curve stretches from the middle of the cervical region to the middle of the lumbar region; and, in his memoir upon "*Die Altersverschiedenheiten der menschlichen Wirbelsäule*," he asserts that a point between the second and third lumbar vertebrae constitutes the natural boundary between the concave dorsal and the convex lumbar regions. Humphry¹ and Barwell² state that the lumbar curve begins in the middle of the last dorsal vertebra and ends at the lower edge of the last lumbar. This closely corresponds with what we have found in the female spines. Gegenbaur, in his "*Lehrbuch der Anatomie des Menschen*,"

¹ "The Human Skeleton."

² "Lateral Curvature of the Spine." 1870.

inclines somewhat to the view enunciated by Aeby, and considers that the last cervical and the first lumbar vertebræ enter the dorsal concavity. In the most recent Paper upon the lumbar curve, viz., in the interesting article by Dr. Adrien Charpy¹ this point is discussed with great clearness. He says, "The lumbar curve of the adult has its convexity directed to the front. It comprehends, as a general rule, seven vertebræ, that is to say, the last two dorsal and the five lumbar; more rarely the lumbar alone, or the last nine vertebræ. It is not surprising to see the last two dorsal vertebræ enter into the movement of the lumbar column. Cruveilhier has remarked that, on account of the shortness of their spinous and transverse processes, and also on account of the extreme freedom of the floating ribs, they are in a condition very favourable for mobility; and Broca, who calls them the *false dorsal*, and attaches them to the lumbar system, observes that in quadrupeds they are really isolated from the true dorsal system; the movement of the posterior section of the column upon the anterior taking place exclusively between the last dorsal vertebra with a fixed rib, and the first of the false dorsal vertebræ."

Summit of the Lumbar Curve.—This is placed at a different point in the two sexes. In the case of the curve which is formed by the line drawn through the central points of the vertebral bodies and intervertebral discs, the point of maximum curvature corresponds in the male to the central point of the fourth lumbar vertebra; in the female it is placed at a higher level, and corresponds with the central point of the cartilaginous disc between the third and fourth lumbar vertebræ. No. 1 (female), Pl. II., is an exception to this rule. In this spine the first sacral vertebra is included in the lumbar curve, and the point of maximum curvature is the central point of the cartilaginous disc between the fourth and fifth lumbar vertebræ.

There is also a sexual difference in the point at which the summit of the curve formed by the anterior outline of the lumbar region is situated. In the males the most projecting point is the upper border of the fourth lumbar vertebra; in the females it is the lower border of the third lumbar vertebra.

¹ "De la courbure lombaire."—Journ. de l'Anatomie et Physiologie. Paris, 1885.

In his Text-book upon Human Anatomy, Gegenbaur states that the summit of the curve is to be found in the fourth lumbar vertebra; Henle¹ and Horner², on the other hand, place it on the disc between the fourth and fifth lumbar vertebra; and Henle refers to a drawing representing a mesial section of the vertebral column. In this, however, the summit of the curve is the same as in the male spines figured in Pl. II., viz., the upper border of the fourth lumbar vertebra. Dr. Adrien Charpy, in his article quoted above, considers that the point of maximum curvature varies in position, but that it is always situated in relation to a cartilaginous disc. He believes that, as a rule, it "is upon the disc which unites the third to the fourth lumbar vertebra"; but he has frequently found it between the fourth and fifth; more rarely between the second and third. In the spines which I have figured in Pl. II., we see every degree of curvature, and only one variation in the point of maximum curvature (No. 1, female), and this is entirely due to the peculiar form of the sacrum.

Composition of the Lumbar Curve.—If we analyse the axial curve of the lumbar region we find that it is not composed of the segment of *one* circle, but of segments of *three* circles. The following Table shows the elements which enter into the formation of each of these:—

¹ "Handbuch der Anatomie des Menschen."

² "Ueber die normale Krümmung der Wirbelsäule." Müller's Archiv. 1854.

AXIAL LUMBAR CURVE.

No. of Spine in Plate II.	SEGMENT 1.	SEGMENT 2.	SEGMENT 3.
No. 1 $\frac{1}{2}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3 + L.C. 2 + L.V. 2.	L.V. 2 + L.C. 1 + L.V. 1 + D.C. 12.
No. 4 $\frac{1}{2}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3 + L.C. 2 + L.V. 2.	L.V. 2 + L.C. 1 + L.V. 1 + D.C. 12.
No. 5 $\frac{1}{2}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3 + L.C. 2 + L.V. 2.	L.V. 2 + L.C. 1 + L.V. 1 + D.C. 12.
No. 6 $\frac{1}{2}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3 + L.C. 2 + L.V. 2.	L.V. 2 + L.C. 1 + L.V. 1 + D.C. 12.
No. 2 $\frac{2}{3}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3 + L.C. 2 + L.V. 2.	L.V. 2 + L.C. 1 + L.V. 1 + D.C. 12 + D.V. 12.
No. 1 $\frac{2}{3}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3 + L.C. 2 + L.V. 2 + L.C. 1.	L.C. 1 + L.V. 1 + D.C. 12 + D.V. 12.
No. 4 $\frac{2}{3}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3 + L.C. 2.	L.C. 2 + L.V. 2 + L.C. 1 + L.V. 1 + D.C. 12 + D.V. 12.
No. 3 $\frac{2}{3}$.	L.V. 5 + L.C. 4 + L.V. 4.	L.V. 4 + L.C. 3 + L.V. 3.	L.V. 3 + L.C. 2 + L.V. 2 + L.C. 1 + L.V. 1 + D.C. 12.

L.V. = Lumbar Vertebra.

L.C. = Lumbar Cartilage.

D.C. 12 = Intervertebral Cartilage between the last Dorsal and first Lumbar Vertebrae.

D.V. = Dorsal Vertebra.

From this Table it will be seen that in four of the male spines the same elements enter into the composition of each of the three segments, viz., the fourth and fifth lumbar vertebræ, with the intervening disc, forming the first segment; the second, third, and fourth lumbar vertebræ, with the two cartilaginous discs which separate them, forming the second segment; and the first and second lumbar vertebræ, with the disc between them, as well as the dorso-lumbar disc forming the third segment. No. 2 (female) agrees with these in almost every particular: the only difference being that in the highest segment the last dorsal vertebra is included. No. 1 (female) differs chiefly in the peculiar condition of the sacrum—a condition which excludes the first sacral vertebra from the sacral curve, and places it in the lumbar curve. The lumbar curvature in this spine therefore presents the segments of *four* circles—the abnormal segment being composed of the first sacral and last lumbar vertebræ, with the disc between them. The other segments correspond very closely with those of No. 2 (female), and differ only in the centre of the first lumbar disc constituting the point at which the two upper circles touch.

It will be readily understood that the determination of the composition of the different segments of the curve is one into which many fallacies may creep. A slight inaccuracy in the tracing, or the smallest inaccuracy in marking the central points of the vertebral bodies and intervertebral discs, or even a decided deviation from the mesial plane in sawing the spine, will tend to vitiate the results. No. 4 (female), and No. 3 (male), as will be seen from the Table, differ in a marked degree from the others, and the difference consists in a lengthening of the upper segment, at the expense of the intermediate segment. At the same time it should be noted that both of these spines offered peculiar difficulties in the investigation of this point. Certain of the vertebral bodies were, more or less, displaced in the antero-posterior direction, and showed, in consequence, an irregularity of position in relation to each other, which necessitated a mean curve being taken.

The question now is, Can we reasonably assume that the condition which is exhibited by Nos. 1, 4, 5, 6 (males), and No. 2 (female), is the

usual arrangement?—is this, in fact the composition of the normal lumbar curve? It may be so; but it appears to me that it would be rash, from the facts before us, to insist upon this point. It is vain for us to look for absolute uniformity in the composition of the curve of any region of the vertebral column.

Speaking of the composition of the lumbar curve, Professor Merkel says:—"We see directly that the arc of a circle comprising the whole lumbar column does not exist; but *such a one encloses the three middle lumbar vertebrae*. The first lumbar vertebra projects in front of this; the fifth retires behind it in a not inconsiderable manner; and if we wish to construct a curve which encloses the anterior surfaces of all the five lumbar vertebrae, it would probably approach most nearly a hyperbola." It is true that he refers here to the arc which is formed by the line joining the anterior projecting angles of the vertebral bodies; but it is interesting to note that in the four males mentioned above (Nos. 1, 4, 5, 6, Plate II.) the same vertebrae, with the intervening cartilaginous discs, are included in the second arc of the axial curve, and that in no case is it possible to introduce into this arc either the first or the fifth lumbar vertebra.

The three arcs which together built up the lumbar axial curve present radii of very different lengths, and in no two spines do the corresponding arcs exhibit radii of equal longitude. The lowest arc is a segment of the smallest circle, and it possesses a radius of an average length of 96.5 mm.: it varies in the different spines, however, between the limits of 63 mm. and 136 mm. The second, or intermediate arc, was found to possess an average radius of 341.7 mm.: the longest radius exhibited by this segment was that of No. 4 (male), viz., 440 mm., and the shortest that of No. 4 (female), viz., 272.25 mm. The highest arc is the segment of a circle, so large that it is extremely difficult to arrive at an accurate conclusion as to the length of its radius. The spines under observation gave an average radius of 937.1 mm.; but in one case (No. 4, male) it was no less than 1732 mm., whilst in another (No. 1, female) it was only 555.08 mm.

Speaking generally, then, we may state that the average longitude of the radii of the three arcs which constitute the axial curve of the lumbar

column stand somewhat in the same relation to each other as the following numbers :

$$1 : 3 : 9$$

Professor Merkel, who likewise places the three middle lumbar vertebræ in the segment of one circle, believes that this arc is a very constant one. He states that "it has, in almost all the vertebral columns examined, a radius of 250 mm. . . . The remarkable fact, therefore, remains, that with absolute equality of the curves in the section of the vertebral column in question the smaller preparations have a relatively flatter curve than the greater." This uniformity of radius for the intermediate arc I have not only failed to obtain in my own tracings, but also in the reduced outline figures which illustrate Professor Merkel's Paper; and I may mention, that in the latter I have tested this point both by the examination of the axial curve, and also by the examination of the curve formed by the line joining the anterior angles of the vertebral bodies.

It is true that the average length of the radius presented by the *axial curve* of the three middle lumbar vertebræ of Professor Merkel's figures is 256 mm.; but it varies considerably in the different spines. The determination of the radius of the curve formed by the anterior faces of the same three vertebræ is a much more difficult matter, on account of the varying degrees of development of the vertebral bodies; but it appears to me that, whilst the average radius is very much that which has been given by Merkel, there are, nevertheless, considerable differences in this respect in the different spines.¹ Unless corresponding points are taken in each spine, from which to calculate the radius, the uniformity which results cannot be regarded as having any weight.

And now let us examine the results which have been obtained by Horner.² Although he deals with the curve formed by the anterior face of the column, it is, nevertheless, interesting to compare this with the

¹ Having submitted this difficulty to Professor Merkel, he was so courteous as to send me his original full-size drawings. An examination of these confirms the opinion which I have expressed above.

² Müller's "Archiv." 1854.

axial curve as obtained in the manner I have described. It must be borne in mind, however, that Horner, in his endeavour to arrive at the curvatures of the column as they exist in life, placed the spine under totally different conditions. He includes the two upper lumbar vertebræ in a section of the column which extends from the upper boundary of the ninth dorsal vertebra to the lower border of the second lumbar vertebra. The vertebræ lying within these limits he believes "form an almost completely straight line." The lumbar vertebræ III., IV., and V. constitute a second section, which represents the medium of movement between the lever-arm formed by the first section and the sacrum, and he compares it "to the carpal bones between the stiff metacarpus and the forearm."

It is possible that the anterior faces of the vertebræ which compose the first section may be bounded under certain conditions by a straight line; but it can be easily demonstrated that in no case do the axis lines of two contiguous vertebræ coincide: if prolonged, these lines invariably cut each other at an angle of greater or less magnitude. Merkel, in his criticism of Horner's work, very justly throws doubt upon the view that the greatest freedom of movement is obtained in the lumbar region below the second lumbar vertebra. He considers that the most unrestrained movement can be obtained rather at a point between the lumbar and dorsal vertebræ on the one hand, and between the lumbar vertebræ and the sacrum on the other. The fact that the point of inflexion is placed in the disc between the dorsal and lumbar regions favours this view.

But Horner further holds that the three vertebræ which he includes in the second section (viz., the third, fourth, and fifth lumbar), and which he considers essentially to be "the supporters of movement," are placed in such a position that they constitute the arc of a circle. Certainly, the axial line passing through them cannot be considered as such, and Merkel states that by his method he was not able to obtain such a curve for the anterior surface of this section of the spine.

Development of the Spinal Curves.—The statements which have been made upon this subject by the numerous observers who have studied the condition of the spinal form in the embryo and new-born child are at utter variance with each other. The writings of Horner, Parow, Cleland, Bouland, Balandin, Ravenel, and Charpy, deserve special attention.

To Horner the credit is due of being the first to carefully study the form of the vertebral column in the fœtus. The results of his investigations were published in 1854.¹ He says—"We know that the outline of the vertebral column in an embryo of a few weeks forms a straight line; that in the 5-6 months fœtus the projection of the promontory, the bending of the sacrum—which later possesses the most distinct curve—are still almost nil. Also the new-born child shows in its vertebral column relationships which deviate so distinctly from those of the adult, that already this difference is sufficiently great to show fully the significance of those factors (muscle activity and gravity), and the necessity of an investigation of their influence. But that the vertebral column of the new-born child is no longer straight can surprise no one who considers that muscle traction exercises its influence in the mother's body." He gives an outline of the vertebral column of a new-born child, and in this traces of all the curves are distinctly visible. In estimating the differences between this and the spinal form of the adult he makes the fatal error (as Balandin points out) of giving the pelvis of the new-born the same inclination which Meyer gives the pelvis of the adult in the erect attitude.

According to Parow² (1861), the dorsal concavity is the first curve which appears, and this is determined by the position of the fœtus in the uterus, and also by the connexion of the dorsal column with the thoracic walls. Even at this early date he appears to consider that the costosternal connexions keep the dorsal column in a state of tension. The accuracy of this view has been already discussed (p. 47). The cervical curve, he states, makes its appearance when the child raises its head; and with regard to the lumbar region he observes: "The already indicated convexity of the loin part of the new-born child must become more strongly

¹ Müller's "Archiv."

² Virchow's "Archiv."

pronounced under the influence of the weight of the head and upper part of the trunk."

In 1863, Professor Cleland, in a Paper communicated to the Biological Section of the British Association,¹ brought forward some entirely new and highly important points in connexion with the vertebral column of the new-born child. He demonstrated the influence which is exerted by the position of the lower limbs upon the form of the vertebral column, and the degree of inclination of the pelvis; and exhibited two drawings of mesial sections of new-born children. Of these, the one showed the condition of the vertebral column when the head is depressed upon the chest and the thighs are flexed, whilst the other represented the changes which are produced in the spinal form when the lower limbs are brought into a line with the trunk and the head raised. These tracings he has been so good as to place at my disposal. In the first, the vertebral column down to the sacrum forms one deep concavity; in the second attitude "the limbs could only be made to lie straight with the trunk by bending the pelvis back, so as to develop the lumbar convexity forwards of the column. Thus the straightening of the limbs when the child begins to walk is shown to be affected, not by mere motion of the hip-joint, but by development of the lumbar convexity of the vertebral column. In the drawing of the stretched body the brim of the pelvis is vertical; in the other drawing it is 52° removed from being in a straight line with the lumbar vertebræ immediately above it."

Dr. Bouland's Paper² upon this subject appeared in 1872. In estimating the curves in the new-born child he adopted a method of investigation which was altogether inappropriate for the purpose, and therefore his results cannot be regarded as possessing much value. At this period of its development the spine is extremely flexible: the slightest touch is sufficient to bend it in any direction, and therefore the most delicate manipulation is necessary to determine its natural curvature. Bouland removed the head, limbs, viscera, and soft parts, leaving only the thoracic walls and ligaments in position. He then, following the method of Weber, embedded the spine in plaster of Paris and divided it in the

¹ "Proc. Sect.," 1863, p. 112.

² "Journ. de l'Anatom. et Phys." Paris, 1872.

mesial plane with a saw. Infants of from five to six months, and children of three years old he treated in the same way. We need not be surprised, considering his plan of investigation, that his results, in so far as the lumbar region is concerned, were variable. In most cases the lumbar curve was absent both in the new-born child and in the infant of five or six months; but in certain cases it was observed to be established in both. The cervical and dorsal curves he found in a well-marked form at each of these periods. "During the first year the spine appears to retain the same configuration, but towards the end of the second year the lumbar curve commences to become more frequent. To start from this epoch, the vertebral column presents, in the majority of cases, the three curves which are present in the adult; at length, towards the fifth year, the spine presents all its antero-posterior flexures." His observations regarding the cervical curve are vitiated by the fact of his having removed the head. As we shall see further on, this flexure in the new-born child is entirely dependent upon the position of the head in relation to the anterior chest wall. The occasional lumbar curve, which he describes in the new-born child and five-months-old infant, was, no doubt, produced by a tilting back of the pelvis in the process of embedding in the gypsum.

Without doubt, the most important observations upon the development of the spinal curvatures are those by Dr. Balandin,¹ of St. Petersburg; and yet it must be admitted that he has brought forward little that is absolutely new. He confirms and extends the information which is given by Parow upon the origin of the cervical and dorsal curves, and corrects the views of this author in regard to the lumbar curve. Unfortunately, he was unacquainted with the observations of Cleland, which appeared ten years prior to the publication of his Paper in 1873; for he states, as a new and prominent fact—a fact, indeed, upon which a great part of his research hinges—the influence which the position of the lower limb exerts upon the moulding of the lumbar curve. The following is a brief account of the results which he obtained in the course of his very elaborate investigation.

¹ "Beiträge zur Frage über die Entstehung der physiologischen Krümmung der Wirbelsäule beim Menschen." Virchow's "Archiv." 1873.

The dorsal curve is the first to make its appearance. It may be observed in an embryo of two months, but it does not consolidate until the fourth month. Balandin is in some doubt as to the causes which operate in the production of this primary curve, and gives, perhaps, undue importance to Parow's views in connexion with the relation of the thoracic walls to the spine. Much more likely it is due to the growth of the viscera. In the new-born and mature infant he holds that the cervical part of the column is straight, whilst the dorsal and lumbar portions, from the seventh cervical to the fourth lumbar vertebra, form a continuous concavity. At other times two concavities exist, viz., from the seventh cervical to the ninth or tenth dorsal vertebra, and a second flatter one from the tenth dorsal to the fourth lumbar vertebra. In some cases he observed the lower section to be in a straight line. The fifth lumbar vertebra "always exhibits a deviation towards the pelvis." It is a curious fact that he found the dorsal curve in the foetus more stable than in the new-born child.

The same author believes that the origin of the cervical and lumbar curves is associated with the straightening of the body, from the bent position of the new-born child. Two stretchings take place at different periods, and in different situations. By the first the head is raised, the visual axis is brought parallel to the horizon, and the chin leaves the chest. This, as a rule, takes place at the third month, when the child is placed upright in the nurse's arms, and its result is the appearance of the cervical curve; at first this curvature is evanescent, but about the fifth month it consolidates.

The lumbar curve is the consequence of the second "stretching," which consists in the attempts which are made by the child to bring the trunk into a line with the thigh. This occurs at the end of the first year, or at the beginning of the second year, of life; or, in other words, when the child begins to make attempts at walking. The lumbar curve is long of consolidating. Balandin examined it in different subjects at the tenth, twelfth, sixteenth, and twentieth year, and found that by stretching the column he could cause the convexity to disappear. He considers, therefore, that it does not become absolutely stable until adult life.

But how is it that, when a dead newly-born child or a foetus is placed on its back, the forcing of the thighs into a line with the trunk produces so marked a change in the inclination of the pelvis, and at the same time leads to a convexity forwards of the lumbar part of the column? Balandin goes into this point very fully, and he comes to the conclusion that the factor at work is the ilio-femoral ligament. He asserts that when this structure is divided on both sides, no movement of the limbs will alter the position of the pelvis or the form of the lumbar column. In moving the fully-flexed thighs of an infant in a recumbent attitude, so as to bring them into a line with the trunk, the first part of the movement occurs at the hip-joints; soon, however, the extension is brought to a close, by the ilio-femoral ligaments: the femur and pelvis now move *en bloc*, and the spine becomes curved in the lumbar region.

It is a very difficult point to decide whether the ilio-femoral ligament in the child is relatively shorter than in the adult. With the ligament intact, the thigh of the child has apparently the same range of movement at the hip-joint as the thigh of the adult. But then, in the combined movement of thighs and pelvis, which is required to bring the lower limbs of the child into a line with the trunk, the pelvis assumes a greater degree of obliquity than in the erect adult. As Cleland has shown, the brim of the pelvis in this forced attitude is vertical, or nearly so; further, the artificial lumbar convexity which is produced is more prominent than the natural curve in the adult in the proportion of 11 to 9. (Plate III. female foetus.) This, perhaps, might be regarded as an indication that the infantile ligament is relatively slightly shorter: although it is just possible that the hitherto unstretched ilio-psoas muscle may also exercise an influence in this direction. At the same time it is obvious that the relative range of movement which exists at the hip-joint in the infant and the adult, and the agents which influence this, can only be satisfactorily ascertained by a study of the growth of the hip-joint. The innominate bone, and the relation of the head and neck of the femur to its shaft, undergo marked changes in their transition from the infantile to the adult condition.

Ravenel,¹ in his measurements of the spine, comes to the conclusion that "the infantile vertebral column is a neutral form, which later on is differentiated in a specific way". In three newly-born children he found that the anterior and posterior faces of the different regions of the column were equal in length, and that consequently the new-born spine is devoid of curvatures of any kind. We cannot place much reliance upon these measurements, when we remember that the pliability of the flexible infantile column was exaggerated by the removal of the neural arches. If it were examined upon a flat surface, we need not be surprised that the measurements of its two faces presented equal results.

Charpy² has given utterance to the most recent views on the development of the spinal curves, and these are somewhat startling. He holds that in the four-months fœtus the dorsal curve is alone present; that in the last months of gestation the cervical curve becomes more and more manifest, and that at the eighth month the lumbar curve may be recognised. In spite of the "doubled-up" position of the fœtus in the uterus all the curves are developed before its birth. He says: "I have always in the new-born child verified the existence of the lumbar curve. It is, perhaps, very feeble, but it is constant; its 'flèche' may be scarcely measurable, but a thread stretched vertically renders the arc manifest to the eye". Further, he considers that the lumbar curve remains rudimentary until the child begins to walk, and that the type becomes fixed towards the fifth year. He is evidently unacquainted with the important observations of Cleland regarding the effect produced on the infantile lumbar column by the straightening of the thigh; and we shall see later on that the comparison which he draws between the human vertebral column, at different stages of its development, and that of the quadruped and anthropoid, is altogether untenable.

Enough has been said to show how varied are the views of those anatomists who have dealt with the development of the vertebral curves.

¹ "Die Maasverhältnisse der Wirbelsäule und des Rückenmarkes beim Menschen." *Zeitschrift für Anat. und Entwicklungsgeschichte.* 1877.

² "Journ. de l'Anatomie et Physiologie." Paris, 1885.

This diversity of opinion has undoubtedly arisen from a failure to recognize the important effect which the position of the limbs and the head exerts upon the pliable column of a foetus or mature infant. My own work in this field has been limited to the examination of the embryo at different stages of growth and to the newly-born child. The difficulty of obtaining material rendered it impossible for me to push my inquiries further. Still the field was wide enough to enable me to arrive at very definite conclusions as to the order and manner in which the curves appear, and also as to their relation to the intra- and extra-uterine periods of life. The method which I employed for the three new-born infants which I examined was that of freezing the entire body, and then making a mesial section by means of a fine saw. In each case the child was frozen on its back, with its head and limbs in a given position. The embryos were hardened in spirit, and then divided with a sharp knife in the mesial plane.

In the very young embryo the vertebral column, or, I should rather say, the parts which represent it at this early stage, are bent in the form of a single arch, with the concavity to the front. The curvature in the lower portion, which corresponds to the sacral and the coccygeal regions, is more abrupt than above, and thus the extremity of the segmented column is turned up in front of the lumbar region like a hook. This condition can be seen in the beautiful drawings which are given by Professor His in his work entitled, "*Anatomie menschlicher Embryonen.*" A second curve soon makes its appearance, and this is accomplished by the bending back of the sacral and coccygeal portions of the column. The vertebral column now presents two curves—both concave to the front—viz. an upper curvature, which involves the cervical, dorsal, and lumbar regions, and a lower sacro-coccygeal concavity. These increase in depth, but no further flexure of the spine takes place so long as the foetus is retained *in utero*. Fig. 7, D (p. 76) represents a full-sized tracing of an embryo, 46 mm. long, in which both of these flexures are exhibited. The long upper concavity, according to Gegenbaur,¹ may be looked upon "as an adjustment to the less stretched-out ventral parts of the

¹ "*Lehrbuch der anatomie des Menschen.*"

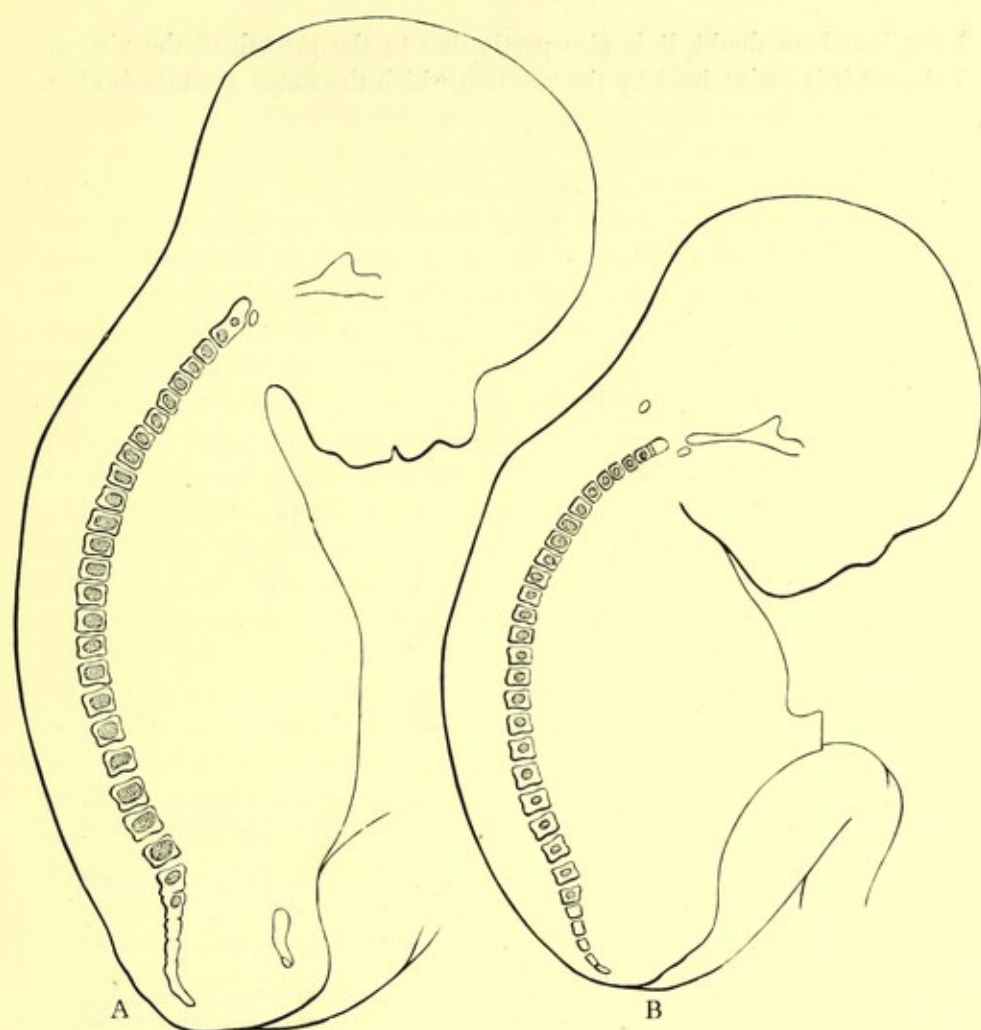


FIG. 6.

Full-size tracings of the vertebral column of two embryos, of different periods of growth, cut in the mesial plane :—

- A. Embryo, 153 mm. in length.
- B. Embryo, 122 mm. in length.

In both the promontory is evident and the two initial curvatures apparent.

body," and no doubt it is also partly due to the growth of the viscera. Later on it is maintained by the position which the fœtus assumes *in utero*.

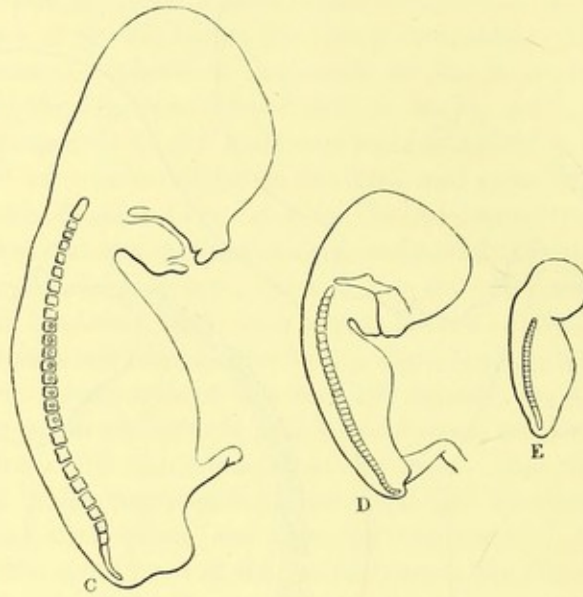


FIG. 7.

The woodcuts represent full-size tracings of mesial sections of three embryos of different periods of development:—

- C. Embryo, 87 mm. in length: the promontory is quite apparent, and the two concavities of the column very evident.
- D. Embryo, 46 mm. in length: two curvatures are visible, but the promontory is just beginning to make its appearance.
- E. Embryo, 27 mm. long. The long upper curve is present, but not the sacral. Still, even here, a tendency to a backward inclination of sacrum is seen. The section was not very successful. The specimen was one which I found in the stores of the Trinity College Museum, and it had not been hardened properly. It was, therefore, impossible to obtain an accurate outline of the body. The form of the vertebral column, however, is fairly well reproduced.

The demarcation between the sacrum and the upper part of the vertebral column is foreshadowed at a very early period—very much earlier indeed than Horner would have us believe. A feeble, but distinct,

promontory, caused by the bending back of the sacrum from the line of the rest of the column, is evident in embryos of 70 mm. long. But even before this stage of development the backward sweep of the pelvic part of the column can be detected: in these early stages, however, the transition is gradual, and no promontory is visible. This can be seen in fig. 7 D, which represents an embryo 46 mm. long; and even in fig. 7 E, which shows the spinal form of an embryo only 27 mm. long.

In the new-born child, when it is laid upon its back with its head flexed so that the chin rests upon the chest, and with the lower limbs lying easily and without restraint, two concave curves are alone visible, as can be readily proved by freezing an infant in this attitude, and then dividing it by a saw in the mesial plane. The first curve, which extends from the summit of the spine to the last lumbar vertebra, shows a gentle and continuous concavity to the front; the second curve is the sacral curve, and both are sharply marked off from each other by a feeble promontory. It is true that I have only examined one child in this posture, but I am confirmed in my views by one of the tracings which Professor Cleland has so kindly put into my hands. This represents the mesial section of an infant in a similar attitude. The only difference is, that in his drawing he represents the dorsal concavity as being deeper than I have seen it. This is probably due to the fact that he examined the child while placed upon its side. Balandin states that in all cases he found the fifth lumbar vertebra deviated towards the sacrum. I have not observed this, and certainly it is not the case in Cleland's drawing.

If the head of the child is now raised so as to cause the chin to leave the chest, a change of form in the vertebral column is seen to take place in the cervical region.¹ This corresponds to "the first stretching" of Balandin. The cervical column now shows a gentle convexity to the front. Fig. 1, Plate III. represents the reduced tracing of the mesial section of a child frozen in this attitude. The dorso-lumbar concavity still remains: the only change is in the neck. As we have seen, Balandin fixes the date of the first appearance of this curve at the third month, and con-

¹ This can also be seen in the young embryo. Raise the head, and immediately a cervical curve appears.

siders that it consolidates in the fourth and fifth months. It is true that a child does not raise its head for a short time after birth, but still the curve will occur in a transient manner every time its head falls over the arm of its nurse.

In Plate III., Fig. 2, a reduced tracing is given of the mesial section of a child which was frozen on its back, and with its thighs forcibly extended, and retained in this position by long pins thrust through the knee-joints so as to nail them closely to the board upon which the infant was lying. The head was allowed to assume the position most natural to it, and this was a position in which the chin rested upon the chest. The cervical and dorsal columns form one continuous concavity to the front, whilst the lumbar region is arched forwards in a most remarkable way. This attitude represents, therefore, the "second stretching" of Balandin—a stretching which takes place when the child begins to make attempts at walking. Reference has already been made to the probable factors at work in producing this extraordinary tilting back of the pelvis, and consequent arching forwards of the lumbar column, so we need not enter further upon this point. It is certainly a very beautiful provision for the determination of the lumbar curve in the proper direction.

Cleland's representation of the mesial section of a child in this attitude shows a position of the pelvis almost identical with that figured in Plate III., but the lumbar column is not bulged forwards to the same extent.

Balandin is probably right as to the period at which the lumbar curve consolidates. Certainly Bouland and Charpy give for this a much too early date. Dr. Symington, at the meeting of the British Association held in Aberdeen (1885), exhibited drawings of mesial sections of a boy of six years old, and a girl of thirteen years old, and in both of these the curve is feebly marked. Although his work upon "The Topographical Anatomy of the Child," is not yet published, he has kindly allowed me to introduce reduced tracings of the spines as exhibited in his drawings (Plate III. girl, *aet.* 13; boy, *aet.* 6).

In the forced lumbar curve exhibited in Plate III. (female child), the dorso-lumbar point of inflexion is in the intervertebral disc between the two

regions. Balandin remarks that the younger the foetus the higher is this point of inflexion, and the greater, therefore, is the portion of the dorsal region which is involved in the lumbar curve.

From what has been said, we may therefore conclude that the cervical and lumbar curves are secondary, and that they are first called into existence by muscular action: the muscles which raise the head give the initiative to the cervical curve, and the great mass of the multifidus and the erector spinae, which draws the upper part of the trunk backwards into a line with the thigh, when the child first begins to make efforts at standing erect, performs a like office in the case of the lumbar curve.¹ Of course in producing the artificial lumbar curvature, which is figured in Plate III. (female foetus), by the straightening of the lower limbs, the process is the opposite of what takes place in life, inasmuch as it is the pelvis that is tilted backwards upon the spine by the bending of the lumbar region, and not the spine upon the pelvis: in both cases, however, the result is the same.

The relative Length of the Lumbar portion of the Spine.—Luschka² and Hyrtl,³ both state that the lumbar portion of the vertebral column is relatively somewhat longer in the female than in the male; but they do not enter into any particulars as to how they have established this fact, nor do they give the amount of the difference between the two sexes. Having tested the accuracy of the statement by measurements instituted upon the frozen spine, I am in a position to corroborate it. The following Table gives the relative lengths of the three regions of the spine, taking the standard 100 as representing the total length of the vertebral column when measured along its fore-surface.

¹ Merkel believes that the lumbar curve is produced by the unequal growth of the neural arches and vertebral bodies. The rate of growth of the bodies and intervertebral discs is much more rapid than that of the arches, and as a consequence the lumbar convexity is developed. As we have seen, the explanation of the manner in which this curvature springs into existence is much more simple.

² "Die Anatomie des Menschen."

³ "Lehrbuch der Anatomie."

RELATIVE LENGTH OF DIFFERENT REGIONS OF THE ADULT VERTEBRAL
COLUMN. FORE-SURFACE OF ENTIRE COLUMN = 100.

M A L E S.				F E M A L E S.			
No. of Spine in Plate II.	Cervical region.	Dorsal region.	Lumbar region.	No. of Spine in Plate II.	Cervical region.	Dorsal region.	Lumbar region.
No. 1,	22.2	45.4	32.4	No. 1,	21.2	46.9	31.9
No. 2,	22.2	46.3	31.4	No. 2,	21.1	45.8	33.1
No. 3,	23.1	45.7	31.2	No. 3,	21.9	43.8	34.3
No. 4,	21.3	46.9	31.8	No. 4,	20.6	46.6	32.8
No. 5,	21.6	46.8	31.6	No. 5,	23.0	46.0	31.0
No. 6,	20.0	48.0	32.0	—	—	—	—
Average,	21.8	46.5	31.7	Average,	21.6	45.8	32.8

The average difference in relative length of the lumbar region in the males and females is therefore—

31.7, males,
32.8, females.

And the increased length in the female is accompanied by a corresponding shortness of the dorsal region, viz.,

46.5, males,
45.8, females.¹

If we measure from the central point of the upper surface of the first sacral vertebra—(a) to the central point of the upper surface of the first lumbar

¹ Since writing the above I observe that Aeby, in his Paper upon "Die Altersverschiedenheiten der menschlichen Wirbelsäule" (Arch. für Anat. und Entwick, 1879), although he states in his text-book that he could find no essential difference in this respect between the male and female, gives the measurements of thirteen adults of both sexes, and these agree in the most remarkable manner with the results in the above Table. The following are his figures:—

	Lumbar region.	Dorsal region.
Males,	31.3	46.6
Females,	32.8	45.7

vertebra, and then—(b) to the tip of the odontoid process, and compare the measurements obtained, we find for the spines figured in Plate II. the following results:

Males,	30·3
Females,	31·0

The relative difference in the length of the lumbar segment of the spine in the male and female is in this case somewhat reduced, and this reduction is due to the greater degree of curvature in the female.

Topinard,¹ from measurements of a large number of “colonnes montées et munies de leur disques,” gives the relative length of the dorsal region to the lumbar region as 3 to 2. This is a fairly accurate estimate, and it speaks well for the skill with which the skeletons he examined are mounted.

In the newly-born child the proportions which are exhibited by the different regions of the vertebral column are very different from those of the adult spine. The lumbar region is relatively much shorter, whilst the cervical and dorsal regions are both relatively longer. Aeby was the first to point out this peculiarity of the infantile spine, and he gives the following figures, based on the measurements of five new-born children:—

Cervical region.	Dorsal region.	Lumbar region.
25·6	47·5	26·8

The results which I have obtained by measuring the frozen spines of three infants are almost identical with those of Aeby, viz.:—

Cervical region.	Dorsal region.	Lumbar region.
25·1	48·5	26·4

The following Table gives the proportions of the different regions of the spine in three fœtuses of different periods of development:—

¹ “Des anomalies de nombre de la colonne Vertébrale.” *Revue d'Anthrop.* Paris, 1877.

RELATIVE LENGTH OF DIFFERENT REGIONS OF SPINE IN THE FŒTUS.
FORE-SURFACE = 100.

	Cervical region.	Dorsal region.	Lumbar region.
A.—Fœtus 153 mm. in length, as measured from the summit of the head to the opposite extremity of trunk, }	26.8	47.4	25.8
B.—Fœtus 122 mm. in length, measured in same manner as A, }	23.4	50.6	26.0
C.—Fœtus 87 mm. in length, measured in same manner as A, }	24.4	47.3	28.3

From this it would appear that the lumbar region in the very young fœtus has a proportionate length, which approaches more closely to that of the adult than that of the more fully developed fœtus or the newborn child. Further investigation, however, would be necessary to confirm this point. Still, the bodies of the lumbar vertebræ at this early period, so far as the eye can judge, seem long and narrow in comparison with those of more advanced specimens: they present a shape, indeed, which recalls somewhat the appearance of the lumbar vertebræ of certain of the lower apes.

ANTHROPOID APES.

The condition of the lumbar column in the anthropoid apes must now claim our attention. Most observers deny the existence of the lumbar curve in all animals, save man.

Goodsir,¹ in his lectures upon "The Dignity of Man," states that "in no form of animal vertebral column are the secondary curvatures so highly developed as in the human, and no animal possesses the lumbar curvature." Sir William Turner² is equally positive, and asserts that "in the human spine alone are the lumbar vertebræ convex forwards." Sir Richard Owen expresses no opinion upon this point, in so far as the chimpanzee and gibbon are concerned; but he denies the presence of the curve in the gorilla, and in the orang. With regard to the first he says:—"The whole series of true vertebræ in the gorilla form but one curvature, which is slightly concave forwards, especially in the dorsal region;³" and of the orang he remarks that "the entire vertebral column has one general curve dorsad, from the atlas to the commencement of the sacrum, where there is a slight curve in the contrary direction."⁴

According to St. George Mivart⁵ "the beautiful sigmoid curve formed by the dorsal and lumbar vertebræ of man exists in no other species; but the nearest approximation to it is found not in the highest apes, but in the *Cynocephalus*." He repeats this statement in his treatise entitled "Man and the apes." Professor Macalister⁶ is of opinion that "the curves in the spine of the apes exactly correspond to the curves in the spine of an exceedingly young human infant, and they never assume the adult human curve."

¹ "Anatomical Memoirs of John Goodsir": edited by Turner.

² Introduction to "Human Anatomy," vol. i.

³ "Comparative Anatomy and Physiology of Vertebrates," vol. ii.

⁴ "Osteology of the Chimpanzee and Orang-utan."—*Trans. Zool. Soc.* 1835.

⁵ "Axial Skeleton in the Primates."—*Proc. Zool. Soc.* 1865.

⁶ "Discourse delivered before the Royal Dublin Society." 1862.

Professor Aeby¹ discusses this question at some length; but the premises upon which he proceeds are utterly erroneous. It would be well to quote his own words. He says:—"The curvatures of the human vertebral column are, it is known, the result of its elasticity, when under weight. In time, however, they lead to a permanent transformation of the vertebral bodies, and, as I have already shown elsewhere, by measurement, they effect a wedge-like diminution of these towards the concave side. The process is a mechanical one, and there is no doubt but that the laws by which it is governed are of equal force when applied to every vertebral column as well as to the human one. On these premises I maintain that in the case of the spinal column of the gorilla the form of the vertebral bodies permits us to draw a conclusion as to the spinal curves, and also to determine the direction in which the column is bent. . . . The difference in height of the vertebral bodies in man and the gorilla are so great and so characteristic that their value is of typical interest. In man the wedge-like diminution in front extends from the fifth to the twenty-first; in the gorilla from the sixth to the twenty-fourth vertebra, *i. e.*, in man from about the middle of the neck to the middle of the lumbar region; in the gorilla, however, to the lower end of the lumbar region. The lower true vertebræ, therefore, preserve with strict exactness the characters of their fellows higher up, whereas it is just the opposite in man. The difference is too manifest to allow the contradictory proof of some individual case, or to expect a compensation from the shape of the intervertebral substance. In other words, the characteristic curvature of the loins in man is wholly wanting in the gorilla. Its vertebral column, as Owen has shown, extends in an uninterrupted curve concave to the front down to the sacrum; and Huxley is surely wrong when he gives it a curvature similar to that of man." Aeby likewise gives the measurements of the lumbar vertebræ of two gibbons, and comes to a similar conclusion in respect to these members of the anthropoid group.

We have already seen enough to be aware that the argument which Professor Aeby uses in support of his assertion that the gorilla is destitute

¹ "Beiträge zur Osteologie des Gorilla."—*Morph. Jahr.*, vol. iv.

of a lumbar curve is utterly valueless. Many of the lower races of man show a condition of vertebræ closely analogous to that of the gorilla, and we know that in certain of these races the lumbar curve, so far from being absent, is indeed exaggerated. Further, the vertebræ of the chimpanzee are much more wedge-shaped (with the broad end backwards) than the vertebræ of the gorilla, and, as we shall see later on, the former animal possesses a very evident lumbar convexity. In short, everything goes to prove that the intervertebral discs alone are quite sufficient of themselves to build up a lumbar convexity, even in cases where the vertebral bodies are shaped in a fashion antagonistic to the curve. I am even inclined to believe that once the direction of the curve is determined in such a case, the greater amount of elastic material in the column is likely to lead to an exaggeration of the curvature. This would account for the increased lumbar curve in the Hottentots and the other low races in which it has been stated to exist.¹

Dr. Adolf Pansch² in his lectures to advanced students, makes a very decided assertion regarding the lumbar curve. He calls it "the characteristic badge of the upright human attitude," and he goes on to say that if we investigate the matter even in the gorilla and chimpanzee, when they walk upon their lower limbs, we will convince ourselves that "they have no proper loin curve, and also that they have no proper upright walk."

And now let us look at the statements that have been put forward upon the opposite side of this question. Three anatomists, viz. Huxley, Broca, and Topinard, have advocated the presence of a lumbar convexity in the anthropoid ape; but in several points these observers are not quite in accord with each other in this matter.

Huxley³ was the first to give definite information regarding the lumbar curve in the anthropoid apes. In 1863 he writes as follows:—"The vertebral column of the gorilla as a whole differs from that of man in the less marked character of its curves, especially in the slighter

¹ The same might account for the very distinct *ensellure lombo-sacrée* in a child when standing erect—a condition which disappears at once when the child assumes the horizontal position.

² "Anatomische Vorlesungen."—Theil, i. 1884, p. 44.

³ "Man's Place in Nature." 1863.

convexity of the lumbar region. Nevertheless the curves are present, and are quite obvious in the young skeletons of the gorilla and chimpanzee, which have been prepared without the removal of the ligaments. In young orangs similarly preserved, on the other hand, the spinal column is either straight, or even concave forwards throughout the lumbar region." In his work upon the "Anatomy of vertebrated animals,"¹ he compares the dorso-lumbar portion of the column of the orang to that of a new-born child, and repeats his statement as to the correspondence of curvature in the gorilla, chimpanzee, and man.

But the examination of skeletons, whether natural or artificial, is not calculated to convey absolutely correct information upon a matter so difficult to appreciate as the exact amount of spinal curvature in a given animal; and, therefore, we need not be surprised that Huxley makes the remark that "the question of the curves of the column in the apes requires further investigation."

Broca differs from Huxley in so far that he denies the presence of a lumbar convexity in the gorilla. The dorso-lumbar region, according to this authority, forms a continuous concavity; or the last two lumbar vertebræ may be straight, and be related to the column above in the same way that "the handle of a vine-knife is related to its blade." In the orang he limits the lumbar curve to the last lumbar vertebra, and in the chimpanzee to the lower two lumbar vertebræ: above that level in each the lumbar vertebræ participate with the dorsal vertebræ in the formation of a continuous concavity. Further, Broca states that among the anthropoid apes the gibbon possesses the most perfect lumbar convexity—the saimang only differing from the human type in the degree of curvature. Indeed, the convexity occupies the entire extent of the lumbar region. In the *Hylobates agilis*, and in the gibbon of Raffles, the lumbar curve is not quite so strongly marked, but it succeeds the dorsal curve at the same level.

Topinard, in his work on Anthropology, follows Broca closely in the views which he has expressed upon the spinal curvature of the anthropoid apes.

¹ 1882. p. 404.

The Gorilla.—The only evidence which I have to offer regarding the lumbar curve in the gorilla is that which is afforded by an examination of the macerated vertebræ. I found it impossible to obtain the fresh spine of a specimen of this ape.

The lumbo-vertebral index of the gorilla approaches more closely to that of man than the corresponding index of either the chimpanzee or the orang. Indeed in this respect it is only removed from the lower races by the high index of the last lumbar vertebra. On this account I am inclined to believe that in the gorilla the lumbar convexity must be highly developed. It is true that we have noticed that the lumbo-vertebral index is by no means a sure and safe guide to follow in drawing inferences in regard to the curvature of the lumbar region; but that it has some value is shown by the fact that in the European spines the lumbo-vertebral index was found to have a general correspondence with the degree of convexity. Moreover, in the gorilla the last lumbar vertebra approaches more closely the shape of that of man than the corresponding vertebra in any of the other anthropomorphic apes, and this appears to me to be a fact of some significance. Still, in view of the opposite and contradictory statements of Broca, Owen, and Huxley, it must be admitted that the question of the lumbar curve in the gorilla can only be satisfactorily determined by the examination of a fresh specimen by the method I have adopted for the other apes.

Chimpanzee.—In the prosecution of this investigation I have been so fortunate as to secure four chimpanzees very shortly after their death. The two largest specimens—a male and a female—I purchased from Mr. Cross of Liverpool; another female I received from the Council of the Zoological Society in Ireland, whilst the remaining specimen was presented to me by Dr. William Fraser of Dublin. None of these specimens had attained maturity.

Three of these chimpanzees I divided in the mesial plane with a saw, after they had been thoroughly frozen. In each case the animal was placed on its back in a zinc box. Great care was taken to have

it properly straightened, so that the vertebral column might be cut exactly in the mesial plane in all its length. By driving a long pin into the interval between the two central incisor teeth of the upper jaw, a second pin into the middle of the sternum, and a third into the centre of the symphysis pubis, and stretching a string between the projecting parts of the pins, the body could be very accurately adjusted. No support whatever was given to the back, and the limbs were allowed to lie naturally, and without restraint of any kind. The latter precaution, as we shall see later on, is a matter of great importance. The box was now placed in the freezing mixture, and it was found to be necessary to allow it to remain in this for about seventy-two hours to obtain a satisfactory result. The bushy hair of the animal tended very much to delay the process of freezing.

The section of the male was very successful; the vertebral column was cut as nearly as possible in the mesial plane, along its whole length. In plate III. (*Troglodytes niger*; male No. 1), a reduced tracing of the cut surface is given. Figure 3, plate IX., which is taken from a photograph of the animal after it was cut, and while still in the frozen condition, shows the line of the section, and also the position of the trunk and limbs. In front the section is not accurately in the middle line, but the deflection is so slight that it did not materially affect the section of the vertebral column. Plates VII. and VIII. are full-size coloured lithographs, which were prepared from tracings of the cut surfaces of the two sides of the section, while the body was still in the frozen state.

The following were the dimensions of this chimpanzee:—

Length of trunk, $20\frac{1}{4}$ inches.

From the summit of the head to the sole	} $28\frac{1}{2}$ inches.
of the foot, when the lower limb was	
extended as far as it would go without	
using force (the thigh remained partially flexed),	

The milk teeth were still in place. In all probability it was between three and four years of age; but this is a point which is extremely difficult to determine.

The female, which in Plate III. follows the male (*Troglodytes niger*; female No. 1), was apparently a little younger; its entire length was $27\frac{1}{2}$ inches, whilst its trunk measured $19\frac{1}{2}$ inches. Unfortunately, in placing the box which contained it into the freezing mixture, the animal was allowed to shift its position; it was therefore found impossible to cut the entire length of the vertebral column in the mesial plane. Sufficient, however, is divided for us to determine the degree of lumbar curvature.

The third specimen was a very young female, which was rescued from the hands of a bird-stuffer by Dr. William Fraser. When it came into my possession it was completely flayed, and its head and limbs had been removed. A very successful section of the trunk was obtained, and the reduced tracing of the cut surface is given in Plate III. (*Troglodytes niger*; female No. 2). The length of the headless trunk was only 14 inches; so that it is not likely that this animal was more than two years old.

The last specimen was a large female, 32 inches long. None of the milk teeth were shed, and I believe that it must have been between four and five years old when it died. This animal I did not consider it necessary to freeze. Having removed the head and viscera, and cleaned the anterior face of the vertebral column, I obtained a tracing of the spinal curvature by means of a strip of ductile lead. This, on a reduced scale, is given in Plate III. (*Troglodytes niger*; female No. 3).

All these specimens came into my possession within twenty-four hours after death, so that they were examined in a perfectly fresh condition.

A glance at the four tracings in Plate III. will be sufficient to show that the spinal curvature of the chimpanzee, is very similar to that of man, and what difference there is is chiefly to be found, not in the secondary curves, but in the primary dorsal and sacral curves. These are not so pronounced, and owing to the small degree of sacral obliquity the promontory is altogether wanting.

Points of Inflection.—The point at which the dorsal and cervical axial curves meet is the same as in man, viz. the central point of the intervertebral disc, between the 2nd and 3rd dorsal vertebræ. In the male chimpanzee (*Troglodytes niger*; male, Plate III.), the point of demarcation, between the dorsal and lumbar axial curves, is the central point of the intervertebral disc, between the 12th and the 13th dorsal vertebræ; whilst in female No. 2 it is placed a little higher, viz. in the body of the 12th dorsal vertebra. Here again there is a close correspondence with what we have already noticed in the human vertebral column. The lower limit of the lumbar curve is different. Owing to the feeble obliquity of the sacrum, the first sacral vertebra is included in the lumbar curve in three of the specimens, whilst in the young female (No. 2) the two upper sacral vertebræ enter into the construction of the curve. This constitutes the essential difference between the lumbar curve of man and that of the chimpanzee; the upper limit of the curve is the same in both; but, owing to the absence of the promontory, one or two of the sacral vertebræ lie in the same line of axial curvature. But an approach to a similar arrangement is occasionally met with in the human subject. In Plate II. the spine of a female (No. 1) is depicted, in which the first sacral vertebra is included in the lumbar curve. Further, in the tracing of the boy (*æt.* 6.) in the same Plate, it will be noticed that the first sacral vertebra occupies a position which brings it very nearly into the line of the axial lumbar curve.

Degree of Lumbar Curvature.—Owing to the greater proportionate length of the lumbar curve in the chimpanzee than in man, it is difficult to compare the degree of curvature in each. Still if we exclude the sacral part in the chimpanzee, and strike an index of curve, as we have already done in the case of the human spines, for that portion which is composed of the lower five true vertebræ, we shall obtain sufficiently accurate results. This index, which expresses the degree of curvature of the anterior face of this section of the column, is calculated, as we have already seen, by taking the length of the section composed of the five lower true vertebræ (measured from the centre of the upper surface of

the thirteenth dorsal vertebra to the centre of the lower surface of the fourth lumbar vertebra) as the standard, and equivalent to 100, and then comparing it with the distance between the intersecting line (see tracings, Plate III.) and the point of greatest prominence. The most projecting point in the male and in the young female (No. 2) was the upper border of the third lumbar vertebra (corresponding in this respect with the male human vertebral column), whilst in female No. 1 the most projecting point was the lower border of the second lumbar vertebra, as in the human female. The following indices of curve were obtained:—

Male Chimpanzee,	7.1
Female Chimpanzee, No. 1,	8.7
Female Chimpanzee, No. 2,	10.0
Female Chimpanzee, No. 3,	9.2

These give an average index for the four specimens of 8.7, which is very nearly the same as we obtained for the seven adult male human spines figured in Plate II. (viz. 8.8), and tabulated in Table R., p. 27.

These results are very extraordinary, when we remember that none of the chimpanzees which were examined had reached maturity; indeed it is very questionable whether the oldest of them was more than four and a-half years old. It is still further strange that the youngest female (No. 2), which certainly was not more than two years old, should have the strongest lumbar curve (index 10). In the spine of the boy, figured in Plate III. (*æt.* 6), the curve index is 4.1; and in the girl (*æt.* 13) it is 6.4.

From these facts, therefore, we are justified in concluding—(1) that the lumbar convexity in the chimpanzee is apparently as pronounced as in the adult human male; and (2) that the lumbar curve is established at a very much earlier date. I am not aware if it is known at what age a chimpanzee reaches maturity; but there cannot be a doubt but that its growth and development proceeds more rapidly than in the human child. At two years old a chimpanzee is more advanced than a child of the same age; and this, no doubt, is the reason of the earlier development of the lumbar convexity.

It is well known that the chimpanzee does not possess the power of fully extending the thigh at the hip-joint. The limit of downward movement of the thigh is reached when the femur forms with the axial line of the trunk an angle of 131° open to the front; but if force be employed, the limb can be brought into the same line with the trunk: in this case, however, the movement is not at the hip-joint; the thigh and pelvis move together, and the bending takes place in the lumbar region of the spine, and the consequence is a great increase of the lumbar convexity. In performing this experiment on female No. 1, after it had been divided in the mesial plane, I found that not only did the convexity become more pronounced, but that when the thigh reached a point where its axis line corresponded with that of the trunk, the lumbar curve had involved the dorsal region, as high as the 10th dorsal vertebra. This is interesting when we remember that in the new-born child the bringing of the thigh and trunk into the same line is attended with very similar results.

We may summarize the foregoing facts regarding the spinal curvature of the chimpanzee thus:—

- (1). The dorsal curvature is flatter than in man.
- (2). There is no promontory, and a very small degree of sacral concavity.
- (3). The axial dorsal curve is limited above by the central point of the intervertebral disc between the 2nd and 3rd dorsal vertebrae, and below by the central point of the disc between the 12th and 13th dorsal vertebrae, or by the central point of the 12th dorsal vertebra.
- (4). The lumbar curve includes one or two of the sacral vertebrae.
- (5). The lumbar convexity is developed at a very early period, and is probably as strongly pronounced as in the adult human male.
- (6). The axial line of the thigh can only be brought into correspondence with the axial line of the trunk by bending the trunk in the lumbar region, and thus increasing the lumbar curve until it attains a degree much in advance of that in man.

Orang-utan.—One specimen of the orang-utan I froze and cut in the mesial plane, under the same conditions as the three chimpanzees. It was a young female, which I purchased on the day of its death from Mr. Cross of Liverpool. It possessed its full complement of milk teeth, and measured 28 inches from the summit of the head to the sole of the foot when the lower limb was extended, so as to lie in the same line with the trunk. Bischoff¹ reckoned the age of a young orang, which measured 60 cm. ($23\frac{2}{3}$ inches), from the crown of the head to the heel, to be about four years. The specimen under consideration would, according to this computation, be at least five and a-half years old. I am very doubtful, however, if it had attained that age.

A very successful section was obtained of this animal, and a reduced representation of a tracing which was taken from the surface of the section while it was still in the frozen state is given in Plate III.

The statement which is made by Owen that in the orang there is but one curve, concave to the front, from the atlas to the sacrum, is seen to be erroneous. Nor, as Huxley has asserted, can the vertebral curvature in the orang, with truth, be compared with the curvature which is exhibited in a new-born child. It is likewise very different from what we find in the adult human spine, and in the chimpanzee. A glance at the tracing, however, will be sufficient to show that it bears a striking resemblance to the condition which is represented by Symington as present in a boy of six years old (Plate II.). There is the same sudden bend backwards in the upper dorsal region, and the same almost straight condition of the lower dorsal and lumbar regions. In the orang there is a feeble promontory and a sacro-vertebral angle of 158° ; in the boy the promontory is also very deficient, and the sacro-vertebral angle 150° . And now, having noted these general points of resemblance, let us look more closely at the spinal curvature as it is exhibited in the orang figured in Plate III.

The cervical convexity is well marked, more especially in its lower part, and the axial curve of this segment of the column, as in man and

¹ "Ueber das Gehirn eines Orang-Outan," von Herr Prof. v. Bischoff. Sitzung. der math. phys. Classe der K. Vayer. Akad. der Wissens. München, vom. 17. Juni 1876.

in the chimpanzee, passes into the dorsal concavity at the central point of the intervertebral disc, between the 2nd and 3rd dorsal vertebræ.

The dorsal curve may be said to be limited entirely to the upper part of the region, and it is of a very abrupt nature; from the 7th dorsal vertebra down to the cartilaginous disc, between the 1st and 2nd lumbar vertebræ, the column is virtually straight. It is true that a close examination shows that no two vertebræ can be said to lie accurately superimposed, the one above the other; the axis lines of all the vertebræ, if prolonged, cut each other, and the 7th and 8th dorsal vertebræ stand a very small degree in front of those above and below; but to all intents and purposes we may regard this segment of the column as straight.

The lumbar curve is reduced to a minimum; but still it exists, and it is not so restricted as Broca and Topinard would have us believe. It involves the three lower lumbar vertebræ with the intervening cartilaginous discs. The convexity is very slight, and, curiously enough, the index of curve is identical with that of the spine of the boy figured by Symington (Plate II.), viz. 4.1. The special points, then, which are noticed in connexion with the vertebral column of the orang are:—

- (1.) It resembles, in a striking manner, the spine of the boy, aged six, which has been figured by Symington.
- (2.) The cervical curve presents the same limits as in man and the chimpanzee.
- (3.) The segment of the column which succeeds this (viz., from disc between the 2nd and 3rd dorsal vertebræ to disc between the 1st and 2nd lumbar vertebræ) presents an upper curved portion, with the concavity to the front, and a lower straight part.
- (4.) The lumbar curve is feeble, and involves the lower three lumbar vertebræ. It resembles that of man in being cut off from the sacrum, and differs from that of the chimpanzee in not including the first sacral vertebræ.
- (5.) There is a feeble promontory.

In the orang the mobility of the lower limbs at the hip-joint is very

remarkable. It is a mistake to say that in man alone can the hip and knee-joints be fully extended, so that the leg is brought into a line with the thigh, and the thigh into a line with the trunk. The thigh in the orang can even be hyper-extended or dorsi-flexed, so as to form a very decided angle (153°), open to the back, with the axis line of the trunk, and yet produce no material change upon the condition of the vertebral column. The forcible bending back of the thigh beyond this point brings about a manifest increase of the lumbar curve; in other words, the further dorsi-flexion of the thigh can only be effected by a bending of the column in the lumbar region; and the further the limb is carried backwards the higher does the lumbar curve extend up the vertebral column. It is a question how far this extreme mobility of the lower limb at the hip-joint, as compared with the limited range of extension at the same joint in the chimpanzee, can be said to be associated with the feeble lumbar curve in the orang.

Gibbon.—The gibbon which I had an opportunity of examining was a nearly mature female specimen of the wauwau (*Hylobates agilis*), which I purchased from Mr. Cross of Liverpool. With its lower limb extended as far as it would go without using force, it measured thirty-one inches from the crown of the head to the sole of the foot. It was frozen and divided in the mesial plane in the same manner as the chimpanzees and the orang. The neck, unfortunately, was not accurately straightened before the freezing, and in consequence the saw passed through the cervical vertebræ a short distance to the left of the mesial plane, so as to cut the bodies close to their junction with the pedicles. The value of the section, however, was not much impaired, as the curves of the column could be accurately made out; and as the deviation was due merely to a twisting of the vertebræ, the head was cut as nearly as possible in the mesial plane.

It was with some interest that I examined the curves of this spine, seeing that I had been led to expect, from the description given by Broca, a lumbar curve more highly developed than in any other member of the anthropomorphic group. This is not the case, however: in this respect the gibbon stands intermediate between the chimpanzee and the orang; but with this difference, that the feeble curve of the orang, as well as the more

strongly marked curvature of the chimpanzee, appear to be more firmly stamped upon the vertebral column than in the case of the gibbon.

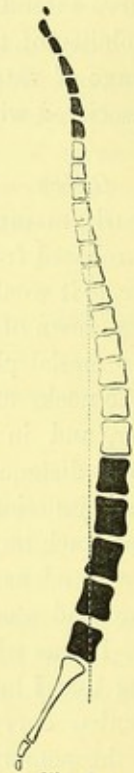
In Plate XII. a reduced tracing of the surface of the section of the gibbon is given. The spinal form presents some points of similarity to that of the boy (*æt.* 6) whose spine is figured in Plate II. The lumbar convexity, however, is more prominent, and in this respect it holds an intermediate position between the spine of the boy and that of the girl *æt.* 13, figured in the same Plate. The curve indices are as follows:—

Girl (<i>æt.</i> 13),	6.4
Gibbon,	5.0
Boy (<i>æt.</i> 6),	4.1

The lumbar curve involves the five lumbar vertebræ, and is cut off below from the slightly marked sacral concavity by a feeble promontory.

Such was the condition of the spinal curvature when the gibbon is placed upon its back; but when it was laid upon its side, after the section had been made and it had thawed, a complete change in the curvature took place. This was brought about by the ligamenta subflava, which are developed to an enormous extent, and more so in the lumbar than in the dorsal or cervical regions. These ligaments, by approximating the neural arches, caused the lumbar curve to extend up the column until it had involved the lower two-thirds of the dorsal region; so that a line drawn from the lower and anterior angle of the fifth lumbar vertebra to the upper and anterior angle of the fourth dorsal vertebra passed behind, and not in front of, the lower dorsal and upper lumbar regions (Fig. 8).

This extraordinary development of the ligamenta subflava in this gibbon (*H. agilis*) is clearly a provision for the purpose of increasing the elasticity and spring of the vertebral column, and must be of service in enabling it to make those remarkable flights from one tree to another for which it is so famous.



We have previously noted that Broca describes different degrees of lumbar curvature in different members of this group; and he gives to the saimang, in this respect, a pre-eminence over all the others. I am inclined, however, to believe that these apparent differences have been due to the agency of the ligamenta subflava, and to the position in which the animal has been examined.

The mobility of the thigh at the hip-joint is intermediate in degree between that of the chimpanzee and the orang. The lower limb can be extended until the axis line of the thigh forms, with the axis line of the trunk, an angle of 146° , open to the front. At this point the movement at the hip-joint ceases; and the further straightening of the limb can only be effected by bending the spine in the lumbar region, and thereby increasing the lumbar curvature.

It is a curious circumstance, that in the three anthropoid apes we have examined the degree of consolidated lumbar curve is in inverse proportion to the degree of mobility at the hip-joint: the more extended the range of movement at the hip-joint, the less prominent do we find the lumbar convexity.

Proportionate lengths of the different Segments of the Column in the Anthropoid Apes.—We have already called attention to some very interesting points in connexion with the relative length of each section of the vertebral column in man, and we have noticed characteristic peculiarities according to sex and age. It is well to compare these with measurements of the corresponding spinal regions in the chimpanzee and orang. Taking the anterior surface of the vertebral column as the standard, and equal to 100, we obtain for the different regions of the spine the following indices:—

	M A N .			ANTHROPOID APES.		
	6 Adult males.	5 Adult females.	3 New-born children.	2 Chimpanzees.	1 Orang.	1 Gibbon.
Cervical region, . .	21·8	21·6	25·1	23·9	25·9	20·5
Dorsal region, . .	46·5	45·8	48·5	45·5	49·5	47·7
Lumbar region, . .	31·7	32·8	26·4	30·6	24·6	31·8

In the case of the chimpanzee, the thirteenth dorsal vertebra was included in the lumbar segment, and measured with it; in the orang, the four lower true vertebræ were taken as representing the lumbar region; and in the gibbon the thirteen dorsal vertebræ were measured as the dorsal region.

We have already noted the great proportionate shortness of the lumbar region, and the corresponding proportionate length of the dorsal and cervical segments in the new-born child, as compared with the adult. The chimpanzee, in this respect, holds a somewhat intermediate position: its cervical region is relatively longer than that of the adult human subject, whilst its dorsal and lumbar regions are slightly shorter, but not in so marked a degree as in the new-born child. By referring to the tables which are given by Aeby,¹ in his able paper upon the "Age-differences of the Vertebral Column," we find that the proportionate lengths of the three segments of the column in the chimpanzee closely correspond with those of a boy of two years old.² For the latter Aeby gives the following indices:—

Cervical region,	23·3
Dorsal region,	46·7
Lumbar region,	30·0

The orang, while it differs widely in the relative length of the three segments of the vertebral column from the adult man, corresponds closely in this respect with the new-born child. Although the lumbar region of the orang is composed of only four vertebræ, the relative length

¹ Die Altersverschiedenheiten der menschlichen Wirbelsäule. Archiv für Anat. und Entwicklungsgeschichte. 1879.

² It must be borne in mind, however, that the average age of the two chimpanzees which were measured was probably not more than three years. Further, there is a difference in the indices of the two specimens corresponding to what we find, at corresponding periods of growth, in man, viz.:

	CHIMPANZEE.	
	Male (say 4 years old).	Female (say 2 years old).
Cervical region,	23·2	21·0
Dorsal region,	45·9	45·0
Lumbar region,	30·9	30·3

of this segment is very similar to that of a newly-born human infant. The gibbon in this respect shows a close correspondence with the adult human subject; and, although an additional vertebra is included in the dorsal region, the proportionate length of these two regions in man and the gibbon is very similar, viz. :—

Dorsal region, man (adult),	46·5
Dorsal region, gibbon (adult),	47·7

It would be outside the scope of this memoir to take part in the controversy which has arisen with reference to the homologies which exist between the vertebræ of spines belonging to different animals. Welcker¹ maintains that the vertebræ are not numerically homologous with each other, but that the separate segments of different columns—lumbar, dorsal, cervical, and so on—may be regarded as homologous, and as extending or diminishing the number of their elements, according to the needs of the animal. Dr. Emil Rosenberg² of Dorpat has advanced a different theory. He does not regard the absent lumbar vertebra of the orang as being suppressed, but as being merely shifted downwards, so as to constitute in this animal the first sacral vertebra. He advocates, therefore, a numerical homology of the vertebræ of the column. In this he is opposed by Holl,³ who regards the first sacral vertebra as a fixed quantity, and therefore primary.

At first sight the correspondence in relative length between the lumbar region of the orang and that of the human child, and also between the dorsal region of the gibbon and that of man, comprising as each does a different number of elements, might be considered as giving some measure of support to the view propounded by Welcker; on the other hand we must not forget the enormous proportional length which is attained by the different segments of the column in certain of the lower apes, and in certain of the quadrupeds. It is obvious, therefore, that measurements of the different regions of the spine will throw little or no light upon this question.

¹ "Archiv für Anat. und Entwicklungsgeschichte," His und Braune. 1881.

² Upon the development of the Vertebral Column, and upon the Os centrale in the Human carpus. Morph. Jahr., vol. i. 1875.

³ Sitzungsberichte der Akademie der Wissenschaften zu Wien, lxxxv. 1882.

LOWER APES.

In endeavouring to arrive at a proper conception of the nature of the curvature of the lumbar section of the vertebral column in the lower apes, I have followed the same method which I adopted in the case of the anthropoid apes. At the same time I am fully aware that in placing the lower apes in a recumbent attitude I have given them a posture which they seldom assume in life, and which therefore must be regarded as being somewhat unnatural. Almost all my attempts to freeze these animals in a sitting or oblique attitude failed; and, even in the few cases where the experiment was successful, it was apparent that the results could not be compared with those obtained for the anthropoid apes which had been frozen in the recumbent position. One advantage the recumbent attitude undoubtedly has, and it is this: it cannot be charged with the production of curves which do not naturally exist. It must exert, indeed, a directly opposite effect, and tend to flatten the dorsal concavity, and also the lumbar convexity, when such a curvature exists. When curves, therefore, are obtained in the dorso-lumbar region by this method of freezing, we may reasonably conclude that they are more or less inherent in the vertebral column. With respect to the cervical region, the curvature is entirely dependent upon the position of the head, as we have seen to be the case in a newly-born child.

Two methods which I adopted for the purpose of obtaining the curves of the spine in the sitting posture gave fairly good results. In one case I placed a small monkey (*Cercopithecus ruber*, No. 1, Plate v.) in a long narrow glass preparation jar, with the thighs flexed, and the weight of the body resting upon the ischial tuberosities. After freezing it for a few hours, so as to stiffen the superficial soft parts, I took it out of the freezing mixture, and proceeded to obliterate all the lateral curvatures of the spine, taking the utmost care not to interfere with the antero-posterior curves. When this was accomplished the animal was replaced in the jar and the freezing completed. In the second case, the ape (*Cercocebus fuliginosus*,

No. 1, Plate v.) was placed upon its side on a table, and put into an attitude as nearly as possible resembling the sitting posture. A plaster of Paris jacket, which surrounded it on all sides, except that which was in apposition with the surface of the table, was then applied. When the plaster was firm the whole preparation was placed in a zinc box, and the animal frozen. The gypsum covering, however, was found to interfere very much with the freezing of the specimen. Before using the saw the plaster was removed.

In all, I have frozen and divided in the mesial plane fifteen different species of the lower apes, and the reduced tracings of the greater number of these sections are reproduced in Plates iv., v., and vi. The majority of these specimens I purchased from Mr. Cross of Liverpool, but some of the rarer forms I received from the Zoological Gardens in London, through the kindness of my friend the Prosector, Mr. F. E. Beddard. I have also to thank the authorities of Trinity College for their generosity in procuring for me such apes as died in the Zoological Gardens in Dublin.

That the lumbar convexity exists in a more or less permanent form in certain of the lower apes there cannot be a doubt. Thus we find it well marked in specimens of *Macacus*, *Cercocebus*, *Semnopithecus*, and of the New World monkey, *Cebus capucinus*, which have been frozen in the recumbent position with the thighs flexed upon the abdomen. The flexibility of the spine in these forms is very great; in life they constantly assume many postures which must obliterate completely the special curvature in the lumbar region. This cannot be regarded, however, as militating against the assertion that they possess such a curve. Even in the European, where the lumbar curve may be regarded as being more firmly established than in any other race of man, the convexity in the region of the loins is in a great measure, if not completely, effaced when the spine is flexed. It would be wrong, on the other hand, to assert that the lumbar curve in the lower apes is stamped so permanently on the spine as in man or the anthropoid apes.

In my examination into this matter I very early perceived that the position of the lower limb exerted a most important influence upon the condition of the lumbar region in all the lower apes. The moment a

monkey endeavours to assume an upright posture, by bringing the trunk more into a line with the thigh, a manifest increase of the lumbar convexity occurs. In other words, the power of extending the thigh at the hip-joint is limited, and the animal raises its trunk by bending the spine in the region of the loins.

Macacus.—I have examined three specimens of the macaque monkey, viz. two of *Macacus nemestrinus*, and one of *Macacus rhesus*, and tracings of the sections of these are given in Plate iv. Unfortunately, both examples of *Macacus nemestrinus* shifted in the freezing-box, giving rise to a lateral bending of the neck. It was found impossible, therefore, to obtain a section of the cervical region. The sections of the dorsal and lumbar segments, however, were altogether satisfactory.

Macacus nemestrinus No. 1 was frozen on its back, with its thighs flexed upon the abdomen. A very distinct sigmoid dorso-lumbar curve exists. The lumbar convexity involves the lower three lumbar vertebræ, and is more pronounced than in the orang. Two points in this section cannot fail to attract notice, viz.—(1) the condition of the last lumbar vertebra, and (2) the sacral obliquity. The fact that the last lumbar vertebra is deeper in front than behind, and thus presents an index considerably below the standard, is apparent to the eye. This is a character which distinguishes many of the macaque monkeys from the higher apes, and, as we have already seen, it constitutes a point of resemblance to man (*vide* p. 7). That it is not a constant feature, however, will be seen by referring to Table Q, p. 21. The sacral obliquity is also very apparent. St. George Mivart's¹ statement that "in most Primates the sacrum and lumbar vertebræ appear (as far as one can judge from skeletons alone) to lie almost, or quite, in one line, so that the promontory is very slightly marked," can hardly be regarded as true for any member of this order.

Macacus nemestrinus No. 2 was a much larger specimen, which was frozen on its back; but in this case the thighs were extended before the freezing was commenced. The effect upon the lumbar curve is

¹ "Axial Skeleton in the Primates."—*Proc. Zool. Soc.*, 1865, xxxvi.

very marked. It is distinctly increased both in degree and in extent. It now involves the five lower lumbar vertebræ, and is as pronounced as we find it in the chimpanzee.

Macacus rhesus gave very remarkable results. It was frozen on its back with the thighs flexed on the abdomen. In none of the lower apes is the lumbar convexity so strongly marked, and in none, with the exception of *Cynocephalus*, is the sacral obliquity so abrupt.

The lumbar curve, as will be seen in the tracing, involves the five lower true vertebræ, and is very nearly as prominent as in the chimpanzee. The sacrum forms a distinct promontory, and presents a concave anterior surface.

Cercocebus fuliginosus.—Two specimens of this species were examined. The first (Plate v., No. 1) was placed on its side in an attitude resembling the sitting posture, and was then enveloped in a plaster of Paris jacket and frozen. As might be expected, the dorsal curve is more marked than in those varieties which were frozen on the back; but although the trunk was slightly bent forwards, a lumbar curve is manifest. It is of small extent, however, and only involves the lower two true vertebræ. Had the weight of the upper part of the trunk and the upper limbs been transmitted downwards through the column, it is probable that the convexity would have been of greater extent.

No. 2, Plate v., gives the tracing of the mesial section of another specimen of the same species, which was frozen on its back, with the thighs flexed on the abdomen. Next to *Macacus rhesus* it presents the most perfect lumbar convexity which I have observed amongst the lower forms of ape. The obliquity of the sacrum is also well marked, although it is not so pronounced as in the Macaque.

No. 3, Plate vi., is a reduced tracing which was taken from No. 2 after it had thawed, and with the lower limb extended to the extent indicated in the drawing. The increase of the lumbar convexity by this proceeding is well illustrated; and the increase is not only one of degree, but also of extent, because now the curve includes the lower six lumbar vertebræ.

Semnopithecus entellus (Plate iv.).—The lumbar convexity in this species appears to be limited to the last two lumbar vertebræ. The last lumbar vertebra is deeper behind than in front, and the sacrum presents a considerable amount of obliquity. The straightness of the entire spine is remarkable.

Cercopithecus.—In no member of this group have I found a strongly marked lumbar curve when the animal was frozen on the back. The Malbrouch monkey (*Cercopithecus cynosurus*) of West Africa was the only one in which it was very apparent. In this specimen the curve included the lower three lumbar vertebræ.

In *Cercopithecus mona*, No. 1 (Plate v.), *Cercopithecus campbelli*, No. 1 (Plate iv.), and in *Chlorocebus sabaeus*, No. 1 (Plate vi.), all of which were frozen in the recumbent position, hardly a trace of the lumbar convexity can be detected. No. 2 tracing in each case represents the same animal after it had thawed, with the lower limb extended. By this proceeding a strong lumbar curve at once sprang into existence. In other words, the thigh could only be approximated to the line of the trunk by a bending of the spine in the lumbar region.

In Plate v. two tracings of *Cercopithecus ruber* are represented. No. 1 tracing was obtained from an individual of this species, which was frozen in a sitting posture in a tall glass jar. The curves of the column resemble those of man and the chimpanzee much more than those of the specimen of *Cercocebus fuliginosus*, No. 1, which was also frozen in a sitting attitude. In the *Cercopithecus*, however, the weight of the upper part of the trunk was transmitted downwards through the column. No. 2 tracing was taken from the same animal after it had thawed, and with the lower limb extended. The increase of the lumbar curve is manifest.

Colobus vellerosus.—Not a trace of the lumbar curve can be detected in *Colobus*. The dorsal and lumbar vertebræ form one continuous concavity, which is only interrupted below by the promontory (No. 1, Plate iv.). The wedge-shaped appearance of the last lumbar vertebra

and the obliquity of the sacrum are very marked, which shows that these conditions can exist independently of a lumbar convexity. It is possible, indeed, that a high degree of sacral obliquity may in some cases replace the lumbar convexity.

No. 2 gives a view of the changes which are brought about by extending the thigh. Even now the lumbar curve is not so pronounced as we might have anticipated. The bending appears chiefly to have taken place at the sacro-vertebral articulation. This is evident from the fact that the dorsal tilting of the pelvis has become much more apparent.

Cynocephalus anubis.—The baboon which I had the opportunity of examining was a very large specimen. It measured $27\frac{1}{2}$ inches from the crown of the head to the root of the tail, and it was frozen like the others, on its back, and with its thighs flexed. A lumbar convexity can hardly be said to exist (Plate VI.); but still the lowest three lumbar vertebræ are not included in the dorsal concavity, but are placed as nearly as possible in a straight line. The dorsal tilting of the sacrum is very pronounced—more so, indeed, than in any other ape. St. George Mivart, in his important Paper¹ on the Axial Skeleton of the Primates, mentions this peculiarity. It is possible that this very character may, in a measure, have been the cause of the obliteration of a lumbar curve, because the greater the backward sweep of the pelvis, the greater will be the tendency for a lumbar convexity to become flattened, when a heavy animal is placed upon its back. On the other hand, it would almost appear as if the absence of a lumbar curve was compensated for, in many cases, by a more striking sacral obliquity.

New World Apes.—Two specimens of the Capuchin monkey gave evidence of a lumbar curve. The tracing of one of these is reproduced in Plate VI. (*Cebus capucinus*), and in this the convexity is very strongly marked, and involves the lower four lumbar vertebræ. The second specimen of this species, which was frozen under similar circumstances,

¹ "Proc. Zool. Soc., London," 1865.

and of which I have the tracing in my possession, did not exhibit so strong a lumbar convexity; but, on the other hand, the sacrum was placed more obliquely.

A Marmoset, which I received from the London Zoological Gardens, was unfortunately so much disturbed in the freezing box, that I only obtained a section of the lumbar region. This, however, gave clear indications of being the seat of a slight anterior convexity. The extent of this, or indeed its degree, it was not possible to estimate accurately, seeing that the section through the bodies of the vertebræ was very oblique.

Different appearance presented by the Vertebræ of different Apes when seen in section.—A glance at the plates in which the sections of the spines of the apes are represented will be sufficient to show that the bodies of the lumbar vertebræ present very different appearances in different apes. In *Cynocephalus* the bodies of the lumbar vertebræ approach in shape those of man and the anthropoid apes: the antero-posterior diameter is very nearly equal to the vertical diameter. The lumbar vertebræ of the macaque, in a less degree, are fashioned in a similar style; but in *Cercopithecus* the difference is very apparent. In this genus the length of the vertical diameter of the vertebral body is double that of the antero-posterior diameter. Further, the eye of itself is sufficient to determine that in this respect *Colobus* occupies an intermediate position between the macaques and *Cercopithecus*. To bring these facts out more clearly, and at the same time more accurately, I have measured the third lumbar vertebra in four races of man, and two children, the second lumbar vertebra in *Troglodytes*, and the fourth lumbar vertebra in several of the lower apes; and by taking the sagittal diameter of the centrum as equal to 100, we can frame an index which will express the relation between the vertical and sagittal diameters. According to this method of comparison, the higher the index is, the longer is the vertebral body in relation to its sagittal axis.

The following are the results; but it must be borne in mind that only one specimen of each was measured:—

RELATION OF VERTICAL TO SAGITTAL DIAMETER OF THE CENTRUM OF A LUMBAR VERTEBRA, TAKEN FROM THE MIDDLE OF THE SERIES.

Sagittal diameter = 100.

Negro,	75.0
Malay,	80.9
Chimpanzee,	82.1
Gorilla,	83.0
European,	88.2
Andaman,	90.7
New-born child,	93.0
Child, <i>æt.</i> 4,	100.0
<i>Cynocephalus anubis</i> ,	102.1
<i>Macacus nemestrinus</i> ,	123.0
<i>Colobus vellerosus</i> ,	140.0
<i>Semnopithecus entellus</i> ,	200.0
<i>Cercopithecus</i> ,	200.0

Certain interesting points are brought out by the above indices. It is curious to find the Negro and Malay separated from the European and Andaman by Troglodytes. The small vertical depth of the bodies of the lumbar vertebræ in the Negro is peculiar, and is characteristic of the two Negro skeletons in my possession. It is further strange, considering the affinities which are said to exist between the Andaman and the Negro, that in this respect the former deviates so much from the latter. It would appear, however, that this difference is merely one of those infantile characters which Prof. Flower¹ has shown distinguish in so prominent a degree the Andaman race. By referring to the above Table

¹ "Journal of the Anthropological Institute," 1879.

it will be seen that the lumbar vertebra of a child aged four (or thereabouts) possesses an index of 100; in other words, the sagittal and vertical diameters are equal in length, and in this it closely approaches the baboon. In the new-born child the same deviation from the adult form is to be noted, but not in so marked a degree.

A very instructive index may also be formulated, by means of which the coronal or transverse diameter can be compared with the vertical diameter. We take the former as the standard, and as equivalent to 100:—

RELATION OF CORONAL DIAMETER TO VERTICAL DIAMETER OF THE CENTRUM OF
A LUMBAR VERTEBRA, TAKEN FROM THE MIDDLE OF THE SERIES.

Coronal diameter = 100.

Gorilla,	.	.	.	.	.	60·4
Chimpanzee,	.	.	.	.	.	62·3
Negro,	.	.	.	.	.	62·5
Malay,	.	.	.	.	.	63·7
European,	.	.	.	.	.	65·4
New-born child,	.	.	.	.	.	67·0
Andaman,	.	.	.	.	.	72·4
Child, <i>æt.</i> 4,	.	.	.	.	.	77·0
Cynocephalus anubis,	.	.	.	.	.	92·0

In this case the gorilla and the chimpanzee head the list, and therefore show a greater proportionate breadth of the vertebræ than the others. The indices of the Negro, Malay, and European, however, are not very different, whilst the Andaman exhibits a decided approach towards the child and the baboon.

QUADRUPEDS.

On submitting the foregoing results to Professor Flower, of the British Museum, he was good enough to point out that the investigation would be incomplete unless the condition of the lumbar segment of the spine in a quadruped was examined. In adopting his suggestion, I encountered the same difficulty which had occurred to me in the case of the lower apes, viz., the position in which the animals should be frozen. If it is unnatural to place an ape upon its back, it is much more so to deal similarly with a dog. And yet it was necessary to do this in order that the results in each case might be compared with each other. That this experiment might be checked, I froze a second dog in a position as nearly approaching the standing attitude as it was possible so to do.

With the exception of Dr. Charpy, no one, so far as I know, has ever even hinted at the possibility of a quadruped possessing a lumbar curve. This author says¹:—"I have been able to verify in a fresh squirrel, an animal with an intermittent erect attitude, at least for the trunk, that its long, supple lumbar region, which can be curved without difficulty into the arc of a circle, had an anterior convexity recalling, in every respect, that of the new-born child; the arch, occupying all the lumbar region, had its summit or maximum very low, at the disc between the sixth and seventh vertebræ." Whilst I cannot accept the accuracy of his statement with regard to the new-born child, I have every belief in the accuracy of his observation regarding the lumbar column in the squirrel.

The general view which is entertained by anatomists, and one which is figured in various treatises, may best be understood by quoting from the recent anatomical lectures by Dr. Adolf Pansch.² He says:—"It is of interest to take a glance at the form of the vertebral column in animals. The quadrupeds have essentially only two curves—a dorsal and a cervical. If

¹ "De la courbure lombaire," &c.—*Journ. de l'Anat. et de la Phys.* Paris, 1885.

² "Anatomische Vorlesungen." Berlin, 1884.

you take the caudal curve, then we obtain a serpentine vertebral column; but the relationships are quite different from man, because the spine is horizontal. The most important curve is that of the back; it carries, like a spring, the weight of the trunk and viscera, and this load draws downwards the arch, and acts, therefore, as a diminisher of the curve, whilst both ends of the curve are placed upon the support of the legs. The cervical curve arises through a pressure of the head operating in a horizontal direction, whilst the ligamentum nuchæ and the neck muscles from the front part of the dorsal curve hinder the head from falling downwards. These curves of quadrupeds have arisen first in the course of development, and have become permanent; they likewise suffer diminution and augmentation through increase and decrease of the weight. But what happens if these animals stand upright? If you observe a horse in the circus, with straightened hind-legs, or in a sitting posture, or if you study an upright-walking dog, you find the same neck and back curve as in quadrupedal walking—you find, in spite of the 'walking upon two legs,' *no loin bending in these animals*. The lumbar convexity is absent."

In Plate VI. *a* the reduced tracings of sections of the spine in three dogs, which were frozen in different attitudes, are figured, and in all an approximation to a lumbar curve is more or less manifest. No. 1 (a fox-terrier) was frozen on its back, with its limbs unrestrained. No. 2 (a large Scotch collie) was placed in a position as nearly resembling the standing attitude as possible. Having amputated the limbs just beyond the lower surface of the body the stumps were arranged so as to support the weight of the trunk, whilst the head was supported by means of a block placed under the lower jaw. No. 3 (a Maltese poodle) was frozen on its back, but the hind limbs were drawn backwards into the position which a dog frequently assumes when stretching himself.

In each region the curvature is very characteristic. The cervical region in both No. 1 and No. 2 shows a double curve, viz., a gentle concavity¹ downwards in its upper part, and an abrupt bend, convex downwards,

¹ The concavity in the cervical region is very probably a *post mortem* condition, and due to the relaxation of the muscles which give support to the head.

which also involves one of the dorsal vertebræ, where it passes into the dorsal concavity. The straightness of the cervical vertebræ in No. 1 is clearly due to the position of the head.

The dorsal curve begins at the second dorsal vertebra, and ends at the third lumbar vertebra, and it constitutes an arch which has its summit formed by the last dorsal vertebra.

The posterior lumbar vertebræ show a slight convexity downwards in No. 1 and No. 2, whilst in No. 3, where the lower limb was stretched, the lumbar curve is very strongly marked.

It is very evident, then, that the dorso-lumbar portion of a quadruped's spine does not form a simple arch, but that even in these animals there is exhibited a tendency to the formation of a lumbar convexity.

In Plate VI.*a* an outline tracing is given of the anterior curvature of a bear. This was obtained by moulding a strip of lead upon the front surface of the vertebral bodies, after the animal had been eviscerated, and while it was lying upon its back. It shows a very distinct lumbar convexity.

It has been too much the habit of anatomists to draw loose comparisons, upon insufficient data, between the infantile vertebral column and the spine of the apes. To this charge I must also plead guilty, in a lecture published in Edinburgh in 1881, under the auspices of the Health Society. Dr. Charpy,¹ reasoning in the same direction, arrives at conclusions which are different from those ordinarily in vogue, but which are nevertheless equally untenable. He says: "The human spine passes through a series of progressive phases, which correspond to animal forms: the foetal column is that of a quadruped; the infantile column that of an anthropoid; the human type is the termination of a design roughly sketched in the animal or embryo."

At no stage in its development can the human column be regarded as corresponding in the character of its curvatures with that of the full-grown quadruped. The infantile column may be compared, however, in this

¹ "Journal de l'Anatomie et de la Physiologie." 1885.

respect, with the spine of Colobus or certain forms of Cercopithecus; although even in this case the comparison is somewhat strained. The orang, in its spinal form, closely approaches a boy aged six; the gibbon presents some features in the outline of its spinal curvature which are intermediate between those of a boy aged six, and a girl aged thirteen, but it is sharply marked off from the latter by its feeble promontory; whilst the chimpanzee exhibits a spinal curvature somewhat similar to that of an adult man. These comparisons, however, will not bear too close examination; and, although a general similitude may be noted, we may positively affirm that at no stage in its growth is the curvature of the human column an exact counterpart of that of the column of any of the lower animals in their full-grown condition.

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PART II.

TOPOGRAPHICAL ANATOMY OF THE CHIMPANZEE, ORANG, AND GIBBON.

So far as I am aware, this is the first time that the method of dividing the frozen body in different planes has been employed for the elucidation of facts bearing upon Comparative Anatomy. Its range of utility is limited, but it is unquestionably a valuable means of enabling us to institute a closer comparison between the anthropoid apes and man. Certain relations of distinct morphological importance cannot be ascertained with accuracy by any other method; and further, by referring the position of the viscera to the different vertebræ, we can determine whether the assumption of the upright walk by man has led to any subsidence of the viscera.

Brain.—The question as to how far the cerebrum in the anthropoid apes projects backwards, in relation to the upper surface of the cerebellum, has given rise to much discussion. At the present moment we have convincing proof on the part of Gratiolet,¹ Huxley,² Flower,³ Marshall,⁴ Rolleston,⁵ Turner,⁶ and Wilder,⁷ that, throughout the entire order of

¹ "Plis cerebraux de l'homme." 1861.

² "Man's Place in Nature," and also in *Proc. Zool. Soc.*, 1861, "On the Brain of Ateles."

³ "On the Posterior Lobes of the Cerebrum of the Quadrumana." *Phil. Trans.* 1862.

⁴ "On the Brain of a young Chimpanzee." *Nat. Hist. Review.* July, 1861.

⁵ "On the Affinities of the Brain of the Orang." *Nat. Hist. Review.* April, 1861.

⁶ "On the Anatomical Relations of the Surfaces of the Tentorium to the Cerebrum and Cerebellum in Man and the lower Mammals." *Proc. Roy. Soc.: Edinb.* 1862.

⁷ At the meeting of the American Association for the Advancement of Science, in Philadelphia in 1884, Professor Burt G. Wilder, of Ithaca, N. Y., exhibited the brain of a young chimpanzee which he had hardened *in situ*. It was a very beautiful preparation, and showed a certain amount of projection of the posterior lobes beyond the cerebellum. (*Proc. American Association*, 1884, p. 527.)

Primates, with the single exception of the Lemurs, the posterior lobes of the cerebrum extend backwards beyond the cerebellum. Such being the case, it is not a little surprising to find an anatomist of the repute of Dr. H. C. Chapman,¹ in two of the more recent Papers which have appeared upon the structure of the anthropoid apes, expressing a doubt as to whether the posterior cerebral lobes in the chimpanzee can be considered as completely covering the cerebellum. In his latest article on the orang he says:—"The cerebellum of my orang was relatively larger than that of man, but smaller than that of either of the chimpanzees I have dissected, and was just covered, and no more, by the posterior lobes of the cerebellum." Further on he remarks: "In the account I gave of the female chimpanzee, I stated that I found the cerebellum uncovered. I had the opportunity a short time since of verifying that statement in the male, noticing *in situ* that the cerebellum was uncovered by the posterior lobes. This was found to be the case by Mr. Arthur Browne, the superintendent of the Phila. Zool. Gardens, in a third chimpanzee which died there. With all deference to Professor Marshall's photograph of a plaster cast of the brain of a chimpanzee, and however it may truthfully represent the relations of the cerebellum in his specimen, I must say that it would be simply monstrous if accepted as an illustration of either of mine, and with profound respect for Professor Huxley's opinion, regarding the interior of the skull being a guide for the determination of the proportion between posterior lobe and cerebellum, I find it anything but a safe one as regards the anthropoid apes. For the space between the posterior lobes of the brain and dura mater and bone, both posteriorly and laterally, I find very variable *in situ*, due to the state of the blood-vessels, and amount of fluid in arachnoid and subarachnoid cavities."

It may, perhaps, appear to be a work of supererogation on my part to reopen this question; but I think that it will be generally admitted that the precise extent of cerebral projection in the different members of the order

¹ "On the Structure of the Chimpanzee." *Proc. Acad. Nat. Sci. Philadelphia*. 1879. "On the Structure of the Orang." *Proc. Acad. Nat. Sci. Philadelphia*. 1880.

Primates cannot be regarded as having been absolutely defined; and where this has been attempted, certain inaccuracies, due to the method of investigation employed, have occurred.

It must be evident to everyone that there is only one way of obtaining absolutely positive and trustworthy information regarding the exact relationship which exists between the cerebrum and cerebellum, and that is by making sections through the frozen head. Whilst the parts are still in the frozen state, and therefore fixed immovably in their several places, tracings of the cut surface can be taken, and a permanent record of their mutual positions obtained. Undoubtedly, the next most reliable method consists in an inspection of the cranial cavity in section, or in the examination of a plaster cast of the interior of the skull; but it must be admitted that both of these plans are open to the objections which have been urged against them by Chapman. All dealings with the soft swaying brain, after the cranial wall has been removed, must be regarded as misleading; and the same also, but to a less extent, may be said for those methods, by which attempts are made to harden the brain *in situ*, by the injection through the carotids of preservative fluids. The best proof of what I say is to be found in the strange want of unanimity of opinion which exists upon a point apparently so simple as the relative extent to which the posterior lobes of the cerebrum project beyond the cerebellum.

With the object of determining the point at issue, I have made sections of the heads of two chimpanzees, one orang, one gibbon (*Hylobates agilis*), a certain number of the lower apes, one adult man, and two newly-born children. In each case a definite plan was followed. The first section was made as far as possible in the mesial plane, with the view of dividing the central lobe or vermiform process of the cerebellum. The second section was made in the sagittal direction, and parallel to the first, a short distance to the outer side of the mesial plane, so as to cut the posterior point of the cerebral hemisphere, and the most bulging part of the cerebellar hemisphere; lastly, a third sagittal section was made parallel to the others, and in such a plane that it passed through the middle of the eyeball. The drawings which are reproduced in

Plates x., xi., and xii., were constructed from accurate tracings, taken from the more important of these sections while still in the frozen state. The reduced tracing of the orang, which is given in Plate iii., represents the mesial relationship of the cerebrum to the cerebellum. In all the sections, with the exception of those of the gibbon, the cerebrum was found to project backwards in a marked degree beyond the cerebellum.

The relative extent of this projection in the mesial plane in the different specimens is given in the following Table. All the measurements which are indicated in this and the succeeding Tables were made with the head in such a position that the face looked directly forwards. Professor Burt G. Wilder remarks, with truth, that the relative position of parts depends entirely "upon the way in which the brain is held."

DISTANCE WHICH THE CEREBRUM PROJECTS BEYOND THE CEREBELLUM IN THE MESIAL PLANE, *i. e.* WHERE THE SECTION HAS PASSED THROUGH THE VERMIFORM PROCESS, OR CENTRAL LOBE OF THE LATTER.

	Actual amount of projection in millimetres.	Proportion—taking Cerebrum as equal to 100.
Adult male, ¹	25.5 mm.	15.9
Adult female (Braune's Atlas),	27.0 mm.	17.0
Newly-born male child, ¹	9.0 mm.	9.0
Newly-born female child, ¹	7.0 mm.	7.5
Male chimpanzee, ^{1 2}	10.0 mm.	10.0
Orang, ¹	10.0 mm.	10.6
Baboon,	10.5 mm.	11.2
Cebus capucinus,	5.5 mm.	8.7

¹ All these specimens are mounted as permanent preparations in the Anatomical Department of Trinity College, Dublin.

² The measurement which is given here was not obtained from the tracing from which the large coloured Plate of the male chimpanzee was constructed, because this section did not pass accurately through the vermiform process.

The projection of the posterior lobes of the cerebrum beyond the cerebellum is most strongly marked in the mesial sections, because in this plane it is the vermiform process which is cut, and the antero-posterior length of this is considerably less than that of the cerebellar hemisphere. In the male chimpanzee and the orang the amount of projection measured 10 mm.; in the adult human male which I examined it amounted to 25.5 mm., whilst in the mesial section of a female represented by Braune¹ it measures 27 mm. If we regard the length of the cerebrum as being equal to 100, the proportion in the different specimens will be found to be expressed by the following numbers:—

Man (average of two specimens),	16.4
Orang,	10.6
Chimpanzee,	10.0

In the newly-born child it is interesting to note that the distance to which the posterior lobes of the cerebrum are carried beyond the cerebellum is not nearly so great as in the adult, and indeed not so great as in the chimpanzee or orang. It corresponds more to what we find in the *Cebus capucinus*, and the proportion is—

Human child (newly-born),	8.2
<i>Cebus capucinus</i> ,	8.7

But the baboon (*Cynocephalus anubis*) approaches man in this respect more closely than either of the two anthropoid apes. The proportion in this animal was 11.2. Referring to the great backward projection of the cerebral lobes in this animal, Flower remarks:—"Gratiolet has demonstrated that the principal cerebral characteristic of this genus is the great development of the occipital lobes. In a nearly full-grown example of *C. porcarius* I find that they project $\frac{4}{16}$ ths of an inch beyond the cerebellum, or rather more than $\frac{1}{2}$ th of the entire length of the hemisphere, proportionally more, therefore, than in man." 1

¹ "Atlas of Topographical Anatomy."

can confirm the accuracy of this statement in all respects, except in so far as the comparison with man is concerned. Calculating the proportional projection of Professor Flower's specimen by the method employed above, we obtain an index of 11.1. This is almost identical with the index I have obtained for *C. anubis*; but it is very far below that of an adult man (16.4).

Let us now examine the results obtained by dividing the frozen head a very short distance to the outer side of the mesial plane. As a standard of comparison in man I have taken the drawing of a mesial section of a male adult by Professor Braune.¹ In this the section is represented as deviating slightly to one side of the mesial plane, but still it cannot be regarded as affording an altogether satisfactory standard of comparison. In Plate XI., Fig. 2, is a full-size drawing of a section of the head of a female chimpanzee nearly in the same plane, but slightly oblique, and a little further out; and in Plate XII., Fig. 2, a section of the head of the gibbon in a plane very similar to that of Braune's male is represented. In both man and chimpanzee the projection of cerebrum beyond cerebellum is not so marked at this point as in the mesial plane; but man still maintains a pronounced pre-eminence, as will be observed by comparing the indices given in the subjoined Table.

DISTANCE WHICH THE CEREBRUM PROJECTS BEYOND THE CEREBELLUM,
AS SEEN IN A SAGITTAL SECTION OF THE HEAD IMMEDIATELY TO
THE OUTER SIDE OF THE MESIAL PLANE.

	Actual amount of projection in millimetres.	Proportion—length of Cerebrum = 100.
Adult human male (Braune),	23.5 mm.	14.5
Female chimpanzee ² (Fig. 2, Plate XI.), .	8.5 mm.	8.8
Female gibbon ² (Fig. 2, Plate XII.) . . .	3.0 mm.	4.0

¹ "Atlas of Topographical Anatomy."

² These specimens are mounted as permanent preparations in the Anatomical Department of Trinity College, Dublin.

Perhaps the most instructive section of all is that which is taken in the line of the eyeball. By such a section one realizes more fully the different degrees of projection, and above all the distance which separates man in this respect from the other members of the order Primates. In Plate x. sections, in this plane, of the heads of the male chimpanzee (Fig. 1), *Cebus capucinus* (Fig. 2), and man (Fig. 3), are depicted; in Plate xi. a corresponding section of the head of the female orang is represented (Fig. 1); and in Plate xii. (Fig. 3), a similar section of the head of the gibbon is figured. We can readily detect by the eye the different degrees of projection in each case; but the precise measurements are given in the following Table:—

DISTANCE WHICH THE CEREBRUM PROJECTS BEYOND THE CEREBELLUM, AS SEEN IN A SAGITTAL SECTION THROUGH THE HEAD TAKEN SO AS TO BISECT THE EYE-BALL.¹

	Actual amount of projection in millimetres.	Proportion—length of Cerebrum = 100.
Adult human male (Plate x., Fig. 3), .	25.0 mm.	15.4
Newly-born female child,	11.0 mm.	11.5
Male chimpanzee (Plate x., Fig. 3), .	7.0 mm.	8.6 ²
Female chimpanzee,	6.0 mm.	6.3
Female orang (Plate xi., Fig. 1), . .	7.0 mm.	8.1
Female gibbon (Plate xii., Fig. 3), .	0.0 mm.	0.0
<i>Cebus capucinus</i> (Plate x., Fig. 2), .	5.5 mm.	9.6

The gibbon is remarkable for the small extent to which the posterior

¹ All these specimens, with the exception of *Cebus*, are preserved as permanent preparations in the Anatomical Department of Trinity College, Dublin.

² The proportion expressed here is, perhaps, slightly above what it should be, because the section having passed a short distance to the outer side of the middle of the eyeball, the full length of the cerebrum was not obtained.

lobes of the cerebrum project beyond the cerebellum. Immediately to the outer side of the mesial plane the projection in my specimen amounted to only 3 mm. (Plate XII., Fig. 2), whilst in the line of the eye-ball the posterior limits of cerebrum and cerebellum corresponded exactly; or, if there was any difference at all, it was in favour of the cerebellum (Plate XII., Fig. 3). Huxley has already called attention to this peculiarity in the gibbon.¹ The siamang, he states, "is remarkable for the short posterior lobes of the cerebrum, which in this anthropomorphous ape do not overlap the cerebellum as they do in all the others." On the other hand Bischoff,² in his memoir upon *Hylobates leuciscus*, asserts that in his specimen the cerebellum was completely covered by the occipital lobes; and further, he disputes the statement that in the gibbon there is any remarkable reduction of the cerebrum as compared with the other anthropoid apes.

In Plate XI., Fig. 3, the drawing of a coronal section of the head of the female chimpanzee is given. The section passed through the widest part of the cerebellum, and comparing it with a corresponding section which I have made through the adult human head, I find that proportionally the extent to which the cerebrum overlaps the cerebellum is the same in both.

It appears to me that a good deal of the diversity of opinion that has been expressed upon this subject has been due to a want of perception of the great extent to which the posterior cerebral lobes project beyond the cerebellum in man. Thus Dr. Chapman³ remarks: "Why should it be necessary to replace the brain of the chimpanzee or the orang in the skull, to make plaster casts, &c., if there is no difference between their brains and those of man and the monkeys, for there is no necessity of having recourse to such measures to prove that the cerebellum is covered in the latter?" In the human brain, when removed from the cranial cavity, we find little or no projection of the posterior lobes beyond the cerebellum; and when I removed the right half of the brain of the orang which is

¹ "Anatomy of Vertebrated Animals," p. 411. 1882.

² "Beiträge zur Anatomie des *Hylobates leuciscus*." München, 1870.

³ "Structure of the Orang-outang."—*Proc. Acad. Nat. Sci. Philadelphia*, 1880, p. 13.

figured in Plate III., I found that it required some manipulation to place the cerebrum in such a position that it would completely cover the cerebellum. In the one case the swaying forwards of the cerebrum upon the crura cerebri causes the posterior lobes to advance until they become flush with the posterior border of the cerebellum; in the other, by the same process, a portion of the cerebellum is left bare.

Prof. Huxley¹ claims for the *Chrysothrix* a pre-eminence over man in the extent to which the posterior lobes of the cerebellum are carried backwards, and he supports this claim upon the evidence afforded by an examination of the interior of the skull in each. Unfortunately I have not had an opportunity of making sections of the frozen head of this animal.

Prof. Flower² calls attention to the fact that "on comparing the form of the brain in *Cercopithecus* with that of the human subject very great similarity is seen in the contour of the posterior half of the cerebrum; but the anterior lobes in the monkey are much reduced, being narrowed almost to a point, flattened, and largely excavated in the orbital regions." This similarity of the posterior portion of the cerebrum in certain of the lower apes to that of man is brought out in a very striking manner by means of the sections of the frozen head, and the plane in which it is most apparent is in that in which the head is divided in the line of the eyeball. In Plate x., Fig. 2, which represents a section through the head of *Cebus capucinus*, and Fig. 3, a section in the same plane through the head of man, render the correspondence of outline of the back part of the brain in these forms very manifest, and it is evident that in this respect *Cebus* resembles man more than either the chimpanzee (Plate x., Fig. 1) or the orang (Plate xi., Fig. 2). At the same time it should be noted that *Cebus* presents a greater fulness, and a greater relative depth of the posterior lobes, than man.

It is true that in *Cebus* the difference between the anterior lobe of

¹ "Man's Place in Nature."—See page 79, where the interior of the skull of an Australian is figured alongside that of the *Chrysothrix*.

² "Phil. Trans.," 1862.

the cerebrum and that of man is very marked. Its narrow and pointed character, and its strong orbital excavation, as exhibited in Plate x., stand out in strong contrast to the full, massive, and rounded frontal lobe of man. At the same time it will be noticed that the frontal lobe apparently advances further forwards than in man. If we let fall a plumb-line from the fore extremity of the cerebrum in *Cebus*, it cuts the eyeball immediately behind the lens, whereas in man such a line falls behind the equator of the eyeball. Further, if a vertical line be drawn upwards from the tip of the temporo-sphenoidal lobe, and the distance in each be measured from this line to the anterior extremity of the frontal lobe, it will be found to be relatively greater in *Cebus* than in man, in the proportion of 23.6 to 18.2.

Unfortunately the same comparison cannot be instituted in the case of the male chimpanzee (Plate x., Fig. 1), because the section is slightly oblique, and in front it cuts the eyeball a little to the outer side of its middle point. In the female chimpanzee and in the orang (Plate xi., Fig. 1) accurate sections were obtained, and the line drawn vertically downwards from the extremity of the frontal lobe cuts the eyeball in both a short distance behind the equator, whilst in the gibbon (Plate xii., Fig. 3) a corresponding line cuts the eyeball at a point still further back. Of course we cannot place much confidence in this relation between the frontal lobes and the eyeball, because the position of the latter cannot be regarded as being a fixed standard for purposes of comparison¹; still it is interesting to observe in the drawing of *Cebus* that if the anterior bounding-line of the frontal lobe, as it ascends from the Sylvian fissure, be carried upwards with a gentle curve, so as to cut off the pointed extremity of

¹ It should also be borne in mind, that a very slight deviation of the section to one side or the other will produce a marked difference in the relation of the anterior limit of the cerebrum to the eyeball; and it is difficult to get a series of sections in precisely the same line. Thus, Rüdinger ("Topographisch-chirurgische Anatomie des Menschen. Dritte Abtheilung") represents a sagittal section of the human head which in front passes through the eyeball, apparently a little to the inner side of its central point. In this drawing a vertical line drawn downwards from the anterior extremity of the cerebrum passes through the crystalline lens. The outline of the entire cerebrum is peculiar, and differs in a marked degree from Fig. 3, Plate x.

the frontal lobe, the entire brain will then present a contour which exhibits a considerable resemblance to that of the chimpanzee or orang.

In the section of the chimpanzee's head (Fig. 1), and in the section of the human head (Fig. 3), figured in Plate x, the posterior and descending cornua of the lateral ventricle of the right side are opened. If the axes of these two recesses be prolonged, they will be observed to cut each other at a very different angle in the two sections. In the chimpanzee the posterior and middle cornua lie very nearly in the same line, and their prolonged axes form an angle of about 160° ; in man, on the other hand, they both slope more or less downwards, and their axes cut each other at an angle of about 140° . In the chimpanzee, as we have seen, the section is not quite in the same plane as in the human head, and therefore the hippocampus minor has escaped division, but it can be seen on the lower and inner walls of the posterior cornu.

In the three brains of the chimpanzee which I have had an opportunity of examining (two by frozen sections, and one after removal from the cranial cavity), I was much struck by the large size of the hippocampus minor, and, on comparing it with the corresponding structure in the European brain, it was observed to be relatively of larger size. Professor Flower¹ has noticed the same point. In his memoir upon the posterior cerebral lobes he remarks:—"The hippocampus minor is one of the most striking characteristics of the typical simian brain, as it is greatest in *Cercopithecus*, *Macacus*, *Cynocephalus*, and *Cebus*, less in the anthropoid apes, and least of all, in proportion to the mass of cerebral substance contained in the lobe, in man." Marshall,² in his able account of the bush-woman's brain, states that the posterior horn of the lateral ventricle is long in proportion to that of the European, and that the hippocampus minor was of large dimensions, and measured 1.1 inches in length.

Two years ago I received from the late Dr. Hart, of Sierra Leone, who contributed so many valuable specimens to the Trinity College Museum, and whose untimely death we have recently had cause to deplore, six negro brains. Of these, only two were hardened sufficiently well to

¹ "Phil. Trans.," 1862.

² "Phil. Trans.," 1864.

admit of an examination of the internal parts, but in both the hippocampus minor was seen to be of larger dimensions than is usually the case in the European.

The measurement of the hippocampus minor is a difficult matter in the human brain, on account of its very gradual subsidence as we trace it backwards. It is therefore not easy to make out the exact point at which it ends. In three Europeans, two negroes, and three chimpanzees (taking the hippocampus major as the standard, and equal to 100), I found the approximate proportional length of hippocampus minor to be as follows:—

European,	72·3
Negro,	77·6
Chimpanzee,	84·4

It is right to add, that Tiedemann¹ asserts that the hippocampus minor of the negro is in no respect different from that of the European.

I am unable to include the orang in the above comparison, because in the left half of the brain, which was removed after the animal had been divided in the mesial plane, there was not a trace of the posterior horn of the lateral ventricle. The calcarine fissure was strongly marked and very deep, but owing to the absence of the ventricular cavity in the posterior lobe of the cerebrum there was no free hippocampus minor. Of course this must be looked upon as an individual peculiarity: the presence of the posterior cornu and the hippocampus minor in the orang has been thoroughly established by several observers. Still it is an interesting anomaly, and it suggests the possibility that Sir Richard Owen, in his statements regarding the posterior lobe, posterior ventricular horn, and hippocampus minor, may, in the first instance, have been misled by an abnormal brain of this kind.

¹ "On the Brain of the Negro compared with that of the European and the Orang-Utan."—*Phil. Trans.*, 1836.

In the gibbon, owing to the reduction of the posterior lobes, the hippocampus minor is very short. In breadth and prominence, however, it is considerably in advance of the chimpanzee, and it reaches backwards to within 5 mm. of the posterior extremity of the occipital lobe. Its proportional length to the hippocampus major is as 70·8 to 100.

Professor Flower, in his exhaustive memoir upon the brain of the *Quadrumanus*,¹ suggests a very useful and reliable method of obtaining a proper conception of the relative length of the posterior lobes. He says:—"As it seemed desirable to possess an exact means of estimating the length of the posterior lobes in different animals by a criterion derived from internal structure, I have taken the most prominent part of the convex border of the hippocampus major as the limit between the antero-median and posterior portions of the cerebrum. In man and the *Quadrumanus* the angle formed at the junction of the hippocampus major and minor readily indicates the exact spot on which to place the compasses." The relative length of these two divisions of the brain may be compared in different animals, by taking the antero-median portion as the standard and equal to 100. Professor Flower gives the index for man calculated in this manner as 53; and for the orang as 50. Professor Marshall, for the brain of the bushwoman, obtained an index of 54·6, indicating a greater proportional length of the posterior lobes than in the European; and for the chimpanzee an index of 52. In two well-preserved negro brains I obtained an index of 53, which is identical with that given by Professor Flower for the European; and in three chimpanzees I obtained an average index of 50·3. It should be noted, however, that this low index for the chimpanzee is due to an unusual shortness of the posterior lobes in the female specimen; the individual indices were 51·8, 52·3, and for the female, 47·0. My orang gave an index of 52·8; whilst the gibbon yielded an index of 41·1.

A Table, containing the results indicated above, may be constructed thus:—

¹ "Phil. Trans.," 1862.

LENGTH OF ANTERO-MEDIAN AND POSTERIOR PORTIONS OF THE BRAIN
AS DEFINED BY PROFESSOR FLOWER.

			Actual length in millimetres.		Proportion.		Average proportion for the posterior portion.
			Antero-median portion.	Posterior portion.	Antero-median portion.	Posterior portion.	
MAN.	EUROPEAN, (Prof. Flower).		—	—	100·0	53·0	53·0
	NEGRO.	Aku, from Sierra Leone.	105·0	57·0	100·0	54·2	53·0
		Timanee, from Sierra Leone.	108·0	56·0	100·0	51·8	
	BUSHWOMAN, (Prof. Marshall).		—	—	100·0	54·6	54·6
ANTHROPOID APES.	ORANG.	No. 1. (Prof. Flower).	—	—	100·0	50·0	51·4
		No. 2, figured in Plate xi.	61·5	32·5	100·0	52·8	
	CHIMPANZEE.	No. 1, (Prof. Marshall).	—	—	100·0	52·0	50·8
		No. 2 (Male).	59·0	31·0	100·0	52·3	
		No. 3 (Female).	68·0	32·0	100·0	47·0	
		No. 4, from Sierra Leone.	54·0	28·0	100·0	51·8	
	FEMALE GIBBON,		53·5	22·0	100·0	41·1	41·1

The foregoing facts all go to sustain the statement which has been made by Huxley regarding the shortness of the posterior lobes in the gibbon. In fact, as will be seen in the above Table, they are at least ten

per cent. shorter than the corresponding lobes in the chimpanzee or orang, and thirteen per cent. shorter than in man.

One of the most important differences between the brain of man and that of the anthropoid apes is to be found in the condition of the corpus callosum. The very varying degrees of development which this structure exhibits throughout the mammalian class might indeed lead us to expect this. It is true that its function is buried in obscurity; and this is all the more the case since a new light has been shed by Prof. Hamilton¹ upon the connections established by its fibres. Certain it is, however, that the degree of development exhibited by the corpus callosum bears a very direct relation to the degree of intelligence exhibited by an animal. The brain of anthropoid apes, as compared with that of man, is distinguished by the diminutive size of the corpus callosum, and there are good grounds for the belief that appreciable differences in this respect may also be found to exist between the different races of man. Thus, Marshall in his description of the bushwoman's brain, says:—"compared with the area of the internal surface of one hemisphere, the sectional area of the corpus callosum is in the bushwoman's brain as 1 to 25, in the European as 1 to 12·5, and in the chimpanzee as 1 to 28·5; so that the corpus callosum, thus estimated in proportion to the cerebrum, is in the bushwoman, only half as large as in the European, and not much larger proportionally than in the chimpanzee."

Measurements of the corpus callosum can only be satisfactorily made in mesial sections of the frozen head. As soon as the brain is removed from the cranium, the corpus callosum loses its finely arched form, and its proportions are altered. In the two succeeding Tables I give the dimensions of the corpus callosum, ascertained upon the frozen heads of three adult human subjects—a girl of thirteen years old, a boy of six years old, and two newly-born children. The measurements of two of the adults were taken from Braune's² representations of a male and female in mesial section; those of the girl and boy were obtained from drawings of similar sections by Dr. Symington of Edinburgh; whilst the others were measured directly from sections made by myself.

¹ "Journ. Anat. and Phys.," 1885.

² "Atlas of Topographical Anatomy."

Taking the entire length of the cerebral hemisphere as 100, indices can be calculated which give us a ready means of comparing the length of the corpus callosum with the extent of cerebrum in front of it, and the extent of cerebrum behind it. In the following Table these are termed, respectively—callosal length, pre-callosal length, and post-callosal length.

LENGTH OF CEREBRUM = 100.

	Pre-callosal length.	Callosal length.	Post-callosal length.
Adult human female, (Braune).	18.6	47.5	33.9
Adult human male, (Braune).	22.3	44.7	32.9
Adult human male,	22.8	43.8	33.2
Girl <i>æt.</i> 13, (Symington).	23.8	42.5	33.7
Boy <i>æt.</i> 6, (Symington).	22.4	41.0	36.5
Newly-born female child,	29.0	35.5	35.5
Newly-born male child,	25.7	36.1	38.2

	Average Pre-callosal length.		Average Callosal length.		Average Post-callosal length.	
	Absolute length.	Percentage length.	Absolute length.	Percentage length.	Absolute length.	Percentage length.
Three adults,	34.4 mm.	21.2	73.3 mm.	45.3	54.0 mm.	33.3
Girl <i>æt.</i> 13, (Symington).	41.0 mm.	23.8	73.0 mm.	42.5	58.0 mm.	33.7
Boy <i>æt.</i> 6, (Symington).	35.0 mm.	22.4	64.0 mm.	41.0	57.0 mm.	36.5
Two newly-born children,	24.5 mm.	27.2	33.5 mm.	35.8	34.5 mm.	36.8

The corpus callosum in the newly-born child is very different from that of the adult. It is relatively much shorter; it stands to the latter as 35·8 to 45·3. On the other hand, both the post-callosal and pre-callosal lengths are relatively much greater. In the boy of six years old, the corpus callosum is still shorter than in the adult; but its growth has taken place chiefly in an anterior direction, so that whilst the pre-callosal length corresponds with that of the adult, the post-callosal length is relatively as long as in the new-born child. The girl of thirteen approaches in this respect the adult form. By this time, therefore, the corpus callosum may be considered to have very nearly attained its full development. In the young embryo the front extremity of the corpus callosum is first called into existence, and it gradually extends backwards from this. In the new-born child, therefore, one would naturally expect to find the deficiency chiefly behind; but this is not the case. The deficiency is as marked in front as it is behind, and in its further development it appears to extend in the first place forwards, and afterwards to extend backwards, until it gains the proportion which it exhibits in the adult.

I applied the same test to the six negro brains which I had received from Sierra Leone, but as these had all been hardened after their removal from the cranial cavity, we cannot place much reliance upon the results. The arched form of the corpus callosum was gone, and, in consequence, its average length in the six specimens was greater than in the Europeans. Still it was evident that the depth of the corpus callosum in the negro, especially at its two thickened extremities, was less than that of the European. The following are the average indices which were obtained:—

Six Negroes, .	{	Pre-callosal length, . . .	19·4
		Callosal length, . . .	47·0
		Post-callosal length, . . .	33·5

In the anthropoid apes the corpus callosum is of small size, as compared with the same structure in an adult man. Not only is it shorter,

but its vertical depth is distinctly less in proportion to the size of the brain. Further, in the orang, and also in the chimpanzee, the front extremity or genu, when seen in mesial section, presents a different appearance. The thickening of this portion is feebly marked, and the bend which it takes is not sharp and sudden, as in man, but gentle and gradual, so that it presents a broad and bold convexity to the front, and a wide concavity to the back. This is particularly well seen in the orang (Plate III.). In the orang, also, the corpus callosum is considerably shorter than in the chimpanzee. The following Table gives its relative length in three anthropoid apes, and in three of the lower apes.

	Pre-callosal length.		Callosal length.		Post-callosal length.	
	Absolute length.	Percentage length.	Absolute length.	Percentage length.	Absolute length.	Percentage length.
One chimpanzee, . . .	29.0 mm.	27.1	39.0 mm.	36.4	39.0 mm.	36.4
One orang,	25.0 mm.	26.5	29.0 mm.	31.0	40.0 mm.	42.5
One gibbon,	19.0 mm.	25.3	32.0 mm.	42.7	24.0 mm.	32.0
One baboon,	20.5 mm.	21.8	41.0 mm.	43.3	33.0 mm.	34.9
One colobus,	13.0 mm.	20.3	29.0 mm.	41.6	26.5 mm.	38.1
One cebus,	16.0 mm.	25.0	27.0 mm.	42.0	21.0 mm.	33.0

The close resemblance which this Table brings out between the chimpanzee and the newly-born child is remarkable. The orang differs in presenting a relatively shorter corpus callosum, and a greater post-callosal length. Indeed, in no form which I have examined is the post-callosal length so great. In the gibbon the callosal length is relatively much greater than in the other anthropoid apes, and in this respect it makes a decided approach towards man, and, at the same time, resembles closely

certain of the lower apes. On the other hand, the post-callosal length is shorter than in any ape examined.

Another curious point is indicated in the above Table, viz., that the corpus callosum of the baboon presents very nearly the same relative length as in man. To a certain extent this might have been anticipated, seeing that the backward projection of the posterior lobes of the cerebrum in this animal is more marked than in any other form we have examined. Not only is the callosal length similar, however, but so also is the post-callosal length and the pre-callosal length.

Both *Cebus* and *Colobus* are, likewise, less removed from man in this respect than are the anthropoid apes. *Cebus* differs chiefly in presenting a slightly shorter corpus callosum and a longer pre-callosal region. The greater length of the latter has already been pointed out, and it is even evident to the eye in Figure 2, Plate x. *Colobus* differs in a marked degree from *Cebus*, in its great post-callosal length. In this respect it resembles the orang, but deviates from it in the greater relative length of the corpus callosum.

Spinal cord.—In the different anthropoid apes the distance which the spinal cord extends downwards in the spinal canal is by no means the same, and in this respect they all deviate from man. In the chimpanzee¹ it reaches the posterior aspect of the disc between the first and second lumbar vertebræ, and approaches somewhat the condition which is found in the human infant. It must be borne in mind, however, that the specimen which was examined was probably not more than four years old. In the gibbon the spinal cord is relatively longer than in the chimpanzee, and extends downwards to the level of the middle point of the third lumbar vertebra. In the orang it is remarkable for its shortness. In my specimen it ended in the usual conus medullaris opposite the lower border of the eleventh dorsal vertebra.

But certainly the feature in the spinal cord of the anthropoid apes which is most calculated to arrest attention is the condition of the

¹ The first lumbar vertebra in the chimpanzee corresponds to the second lumbar vertebra in man.

cervical and lumbar enlargements. The former exhibits a development which corresponds exactly with the length of the upper limbs. In the gibbon, therefore, the cervical swelling attains its maximum dimensions; in the orang it is also of great proportionate size; whilst in the chimpanzee it is considerably reduced, but still distinctly larger than in man.

On the other hand, the lumbar swelling in the anthropoid apes is relatively much smaller than in man, as might be expected from the meagre proportions of the lower limbs in the apes.

Mouth, Tongue, and Larynx.—In the mesial section of an anthropoid ape, the elongated form of the mouth, and, as a consequence of this, the quadrupedal shape of the tongue, constitute a very prominent feature. In this respect the gibbon and chimpanzee deviate more from man than the orang: in the last of these the arrangement of the lingual papillae is very similar to what we find in the case of the human tongue.

Quite recently Dr. Symington¹ has called attention to the change of position which the human larynx undergoes in the transition from the infantile to the fully developed adult condition. In the adult the lower border of the larynx corresponds to the intervertebral disc between the sixth and seventh cervical vertebrae; in the newly-born child it is placed as high as the middle or lower border of the fourth cervical vertebra. Between infancy and adult life, therefore, the larynx undergoes a very manifest descent. Symington considers that there is a downward movement of the entire larynx, and he believes that this is caused by the growth of the facial portion of the skull. In adopting this view of the case, he has overlooked the fact, that the upper border of the larynx, as represented by the epiglottis, does not descend to an equal extent with the inferior border as represented by the lower margin of the cricoid cartilage. In the newly-born child (as may be noted in two mesial sections of the entire frozen body in the Trinity College Anatomical Department) the tip of the epiglottis corresponds with the disc of cartilage which separates the odontoid process from the body of the

¹ "Journ. Anat. and Phys.," 1885.

axis vertebra. In the adult its position may be studied in the mesial sections of a male and a female represented by Braune: in the former it is placed opposite the upper border of the third cervical vertebra, and in the latter opposite the lower border of the same vertebra. It follows from this that the upper border of the larynx descends a distance corresponding to the depth of the bodies of two cervical vertebræ with the disc intervening between them; whilst its lower border travels a distance corresponding to the depth of two and a-half vertebral bodies and two intervertebral discs.

But the face in the anthropoid apes is much greater than that of man, and its development in the transition from the infantile to the adult condition is still more striking. If the growth of this part of the skull, therefore, pushes down the human larynx, we would naturally expect the displacement to be more marked in the apes than in man. So far from this being the case, we find in the former a more infantile condition of affairs. In the chimpanzee and orang the tip of the epiglottis is placed opposite the junction between the odontoid and the body of the axis vertebra; whilst the lower border of the cricoid cartilage lies opposite the intervertebral disc between the fifth and sixth cervical vertebræ.

Another point which must enter into our calculations in considering this matter is, that in the newly-born child the cervical region of the vertebral column is proportionally longer than the same segment in the adult, and therefore its subsequent growth takes place at a slower pace than in the case of the dorsal and lumbar regions.

I am inclined to believe that the alteration in the position of the larynx which accompanies the growth of a child is very largely due to the organ growing more in a downward than in an upward direction; and, further, that the entire displacement, which is evident from the sinking downwards of the epiglottis, is in all probability due to the vertebral column outstripping the larynx in its upward growth. It is difficult to conceive how the growth of the face could materially affect the position of the larynx.

The laryngeal pouch in the chimpanzee, as will be seen in Plates VII. and VIII., extends downwards in front of the sternum to the lower border

of the manubrium; it stretches in an upward direction until it abuts against the hollow posterior surface of the hyoid bone. In Plate VII. a glass rod is represented as passing from the larynx into this pouch, and in Plate VIII. the narrow throat of communication is seen in section.

In the orang the laryngeal pouch, although it was prolonged down to the top of the sternum, was not continued in front of it, as will be observed in the outline tracing in Plate III.

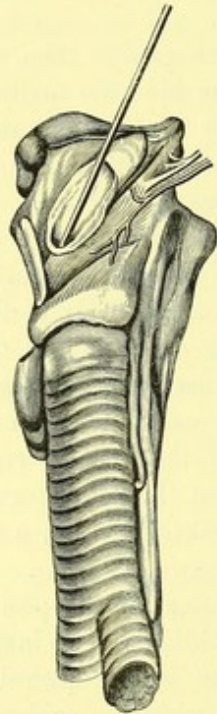


Fig. 9.

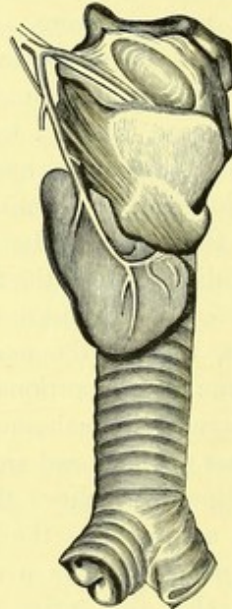


Fig. 10.

The two sides of a human larynx preserved in the Anatomical Department of Trinity College, Dublin, in which the laryngeal ventricles show an unusual degree of development. This specimen was described by Dr. E. H. Bennett in the "Trans. Path. Soc. of Ireland."

I have introduced two woodcuts (Figs. 9 and 10), to show the occasional enlargement which occurs in the laryngeal ventricles of man.

The specimen which these represent was described by Dr. E. H. Bennett in the "Transactions of the Pathological Society of Ireland," and I am indebted to him for the use of the wood-blocks.

Thoracic and Abdominal Viscera.—It is well known to anatomists that the topographical anatomy of the thoracic and abdominal viscera in the infant and child is very different from that of the adult. If we take the vertebral column as our standard, the viscera of the infant are placed at a higher level, and they undergo a gradual subsidence as life advances. Such being the case, it has occurred to me that it might be of interest to compare the relative positions of the viscera in man and the anthropoid apes. By this means we should be able to arrive at a conclusion as to whether the erect attitude which has been assumed by man has led to any material displacement of the viscera in their relation to the vertebral column.

The representations which are given by Braune of mesial sections of a male and a female will serve us for purposes of comparison in so far as the adult man is concerned: the facts relating to the newly-born infant I have obtained from two sections (of a male and a female) which I have made myself.

On comparing the various sections, I was surprised to find that in the position of the thoracic and abdominal viscera there is very little difference between the chimpanzee and the adult man; and this is all the more remarkable, when we bear in mind that the chimpanzee with which the comparison was instituted was far from being a mature specimen.

In the orang we observe a different state of affairs. The viscera hold positions, in reference to the vertebral column, almost identical with those of the viscera in a newly-born child. Thus we find the bifurcation of the trachea taking place in both at the level of the third dorsal vertebra; in both the arch of the aorta rises as high as the second dorsal vertebra, which in the orang carries it above the level of the manubrium sterni; in both the lower surface of the heart is placed at a level corresponding to the body of the seventh dorsal vertebra. But it is needless to enumerate in detail other points of similarity, as these can be more easily appreciated by an examination of the following Table:—

POSITION OF VISCERA IN RELATION TO VERTEBRAL COLUMN IN MAN AND THE ANTHROPOID APES.

	ADULT MALE (Braune).	ADULT FEMALE (Braune).	CHIMPANZEE.	NEWLY-BORN INFANT.		ORANG.	GIBBON.
				Male.	Female.		
Tip of the Epiglottis,	C. III. (upper border).	C. III. (lower border).	Junction of Odontoid with C. II.	Junction of Odontoid with C. II.	Junction of Odontoid with C. II.	Junction of Odontoid with C. II.	Middle point of C. II.
Lower border of Cricoid Cartilage,	Disc between C. VI. & C. VII.	C. VII. (upper border).	Disc between C. V. & C. VI.	C. IV. (lower border).	C. IV. (lower border).	Disc between C. V. & C. VI.	—
Bifurcation of Trachea,	D. IV.	D. IV.	D. V.	D. III.	D. III.	D. III.	—
Summit of Aortic Arch,	D. IV.	D. IV.	D. III.	D. II. (upper border).	D. II.	D. II.	—
Right Pulmonary Artery,	D. V.	Disc between D. V. & D. VI.	Disc between D. V. & D. VI.	D. IV.	D. III.	D. IV.	—
Lower Surface of Heart,	Disc between D. VIII. & D. IX.	Disc between D. IX. & D. X.	Disc between D. IX. & D. X.	Disc between D. VII. & VIII.	D. VII.	D. VII.	D. VIII. & D. IX.
Upper border of Manubrium Sternal,	D. III.	D. II.	D. II.	D. I.	C. VII.	D. III.	Disc between D. I. & D. II.
Stomach,	L. I. & L. II.	L. I.	D. XIII. & L. I.	D. XII. & L. I.	L. I. & L. II.	D. XI. & D. XII.	D. XI., D. XII., & D. XIII.
Duodenum,	L. III.	L. II. & L. III.	L. II.	L. II. & L. III.	L. II.	L. I. & L. II.	—
Pancreas,	D. XII., L. I., & L. II.	D. XII., L. I., & L. II.	D. XIII., L. I. & L. II.	L. I. & L. II.	L. I. & L. II.	D. XI., D. XII. & L. I.	D. XII. & D. XIII.
Bifurcation of Aorta,	L. IV.	L. IV.	L. IV.	—	—	Disc between L. III. & L. IV.	L. IV.

C = cervical vertebra. D = dorsal vertebra. L = lumbar vertebra.

Pelvic Viscera.—In Plate IX. two views are given of the human pelvis in mesial section. Fig. 1 is the pelvis of a newly-born child, and Fig. 2 that of an adult. They are introduced in order that they may be compared with the corresponding region in the chimpanzee, as exhibited in Plates VII. and VIII. A striking difference exists in the position of the pelvic viscera in the adult man and the anthropoid apes. The rectum in the chimpanzee is almost straight; in man it pursues a curved course, and its terminal portion is bent backwards. In these respects the newly-born child stands midway between the anthropoid apes and the adult man; the rectum is much straighter than it is later in life, and the terminal portion proceeds almost vertically downwards.

These differences are largely due to the degree of obliquity of the pelvis, and to the degree of curvature of the sacrum and coccyx. As is well known, a long distance intervenes in the anthropoid between the tip of the coccyx and the anus, so that the rectum and bladder are to a great extent unprotected on the posterior aspect of the body. It is interesting to note that the distance between the tip of the coccyx and the anus in the new-born child (as made out by measurements on the frozen body) appears to be relatively greater than in the adult man.

APPENDIX.

In the first section of Part I. of this Memoir the form adaptation of the bodies of the lumbar vertebrae, with reference to the lumbar curve, is alone considered, and it has been noted that the bones contribute very little to the curve. In the following Table the part which the intervertebral discs play in the construction of the curvature is given in five spines (three females and two males), and indices have been calculated for these upon the same method as we have previously adopted for the vertebral bodies (p. 4). It will be noticed, as indeed might have been foreseen, that a low lumbo-intervertebral index is always accompanied by a high lumbo-vertebral index, and *vice versa*. As a general rule the indices of the vertebrae diminish in the European in a regular manner from the first to the fifth lumbar vertebra; but this is not the case with the indices of the discs. A considerable amount of irregularity is observed in these.

INDICES OF THE VERTEBRAL BODIES AND INTERVERTEBRAL DISCS OF THE LUMBAR REGION
IN FIVE IRISH SPINES.

	FEMALE SPINE.			FEMALE SPINE, No. 3, PLATE 2.			MALE SPINE, No. 1, PLATE 2.		
	Actual depth in Millimetres.		Index (anterior depth = 100).	Actual depth in Millimetres.		Index (anterior depth = 100).	Actual depth in Millimetres.		Index (anterior depth = 100).
	Front.	Back.		Front.	Back.		Front.	Back.	
I. Lumbar Vertebra, .	26.0	27.5	105.7	25.5	27.0	105.8	26.5	30.0	113.2
I. Lumbar Disc, .	8.0	4.0	50.0	8.0	5.0	62.5	7.0	7.0	100.0
II. Lumbar Vertebra, .	28.5	28.0	98.2	27.0	27.0	100.0	29.0	29.0	100.0
II. Lumbar Disc, .	7.5	4.5	60.0	9.5	7.0	73.7	8.0	9.0	112.0
III. Lumbar Vertebra, .	29.0	27.5	94.8	27.0	27.0	100.0	29.5	26.5	89.8
III. Lumbar Disc, .	8.0	5.5	69.0	8.0	4.0	50.0	9.5	8.5	89.4
IV. Lumbar Vertebra, .	29.5	27.0	91.5	27.0	26.0	96.3	28.5	25.0	87.7
IV. Lumbar Disc, .	8.5	6.0	70.6	8.5	7.5	88.2	9.5	9.5	100.0
V. Lumbar Vertebra, .	30.0	25.0	80.3	26.0	24.0	92.3	29.0	25.0	79.3
V. Lumbar Disc, .	12.0	3.5	29.1	17.5	6.0	34.2	16.5	8.0	48.4
Lumbo-vertebral Index, .	..	..	94.4	..	..	98.4	..	..	93.6
Lumbo-intervertebral Index, .	..	..	54.1	..	..	57.4	..	..	83.1

EXPLANATION OF THE PLATES.

PLATE I.

CHARTS to show, in a graphic manner, the form-adaptation of the lumbar vertebræ to the lumbar curve.

CHART A exhibits the form-adaptation of the lower five true vertebræ in the chimpanzee, gorilla, orang, Australian, Andaman, and European. The dotted lines refer to the apes, and the solid lines to man. For fuller explanation see p. 7.

CHART B shows the sex-differences in the form-adaptation of the lumbar vertebræ to the lumbar curve in the Irish, Tasmanian, Australian, Andaman, and Negro. For further explanation see p. 30. In this chart the dotted lines refer to the females, and the solid lines to the males.

CHART C brings out the sex-differences in the form-adaptation of the lumbar vertebræ to the lumbar curve in the Irish, Australian, and Andaman, see. p. 30. The dotted lines indicate the females, and the solid lines the males.

PLATE II.

This plate represents a series of reduced tracings of mesial sections of the human spine. Two of these, viz. No. 2 (male) and No. 5 (female), have been taken from Professor Braune's *Atlas of Topographical Anatomy*. Another adult male spine is a reproduction of the tracing which is given by the Brothers Weber in their "*Mechanik der menschlichen Gehwerkzeuge*" (1836). This spine was imbedded in plaster of Paris, and then divided in the mesial plane. The outlines of the spine of the girl, *et.* 13, and that of the boy, *et.* 6, were obtained from two drawings in an important work upon the *Topographical Anatomy of the Child* which will shortly be published by Dr. Symington of Edinburgh.

The remaining five representations of male spines, and four representations of female spines, are reduced tracings of mesial sections of the frozen and isolated vertebral column. In every case the tracing was taken when the spine was still in the frozen condition, and the reduction effected by photography, so as to obtain absolutely reliable results.

By means of the line which intersects the lumbar region the degree of lumbar prominence may be estimated. The indices of curve, which are obtained by comparing the distance of the most projecting point in front of this line with the length of the lumbar segment of the column, as well as the indices of the vertebræ of these spines, &c., &c., are given in Table R, p. 26.

PLATE III.

This plate shows the spinal curvature in two newly-born children, four chimpanzees, and one orang-utan.

Full-time human fœtus (male).—A mature child, still-born. It was placed on its back, and the lower limbs were allowed to assume the position most natural to them: in other words, the thighs remained semiflexed, and everted. The chin was raised slightly from the chest. In this position the child was frozen, and then divided in the mesial plane. The tracing was taken when the preparation was still in the frozen state, and it was reduced by photography. The raising of the head has produced a feeble cervical curve; the dorsal and lumbar regions form a continuous concavity, somewhat flattened, from the child having been placed on its back. The promontory is very feeble, and the curve of the sacrum by no means conspicuous.

Full-time human fœtus (female).—This is a reduced tracing of a full-time still-born child. It was frozen on its back; but in this case the head was allowed to remain flexed upon the chest, while the lower limbs were straightened. The thighs were placed close together, and then the knees were pressed forcibly backwards until they came in contact with the surface upon which the child was lying. In this position they were fixed. The tracing was taken from the frozen child after it had been divided in the mesial plane, and it was reduced by photography. In this case there was no cervical curve, because the head was flexed; but the straightening of the limbs has produced a strong lumbar convexity—a curve, indeed, which is stronger than in an adult, in the proportion of 11 to 9. Further, the pelvis has been tilted back until the brim is nearly in a line with the spine. This can be seen from the position of the symphysis pubis.

Troglodytes niger (male, and female No. 1) are reduced tracings of mesial sections of a young male and a young female chimpanzee. In both cases the animal was frozen on its back, and the lower limbs placed under no restraint. Unfortunately, the female specimen got twisted in the freezing box, and thus it was impossible to cut the entire length of the spine in the mesial plane.

Troglodytes niger (female, No. 2) represents a mesial section of headless and flayed carcass of a very young chimpanzee which I obtained from Dr. Wm. Frazer, of Dublin.

Troglodytes niger (female, No. 3) represents the outline of the anterior face of the spine of a female chimpanzee, obtained by moulding a strip of ductile lead upon the front of the vertebral column. The dotted line intersects the outline at the level of the lower border of the fourth lumbar, and of the upper border of the thirteenth dorsal vertebra.

All these tracings of the chimpanzee were reduced by photography.

Simia satyrus (female).—This is the tracing of a mesial section of an orang-utan, reduced by photography. It was frozen on its back, and no restraint was put upon the lower limbs. The outline of the brain, and of some of the other organs, is given. The relative position of cerebrum to cerebellum is seen; the shortness and the forward position of the corpus callosum

is manifest. In the abdomen, the stomach, which is cut close to the pylorus, lies close under the liver; and in the pelvis, the relative positions of bladder, uterus, and rectum may be noted.

PLATE IV.

Tracings of mesial sections of a number of the lower apes reduced by photography. The tracings were taken when the preparations were still in the frozen state.

Macacus nemestrinus, No. 1, was frozen on its back, with the thighs flexed on the abdomen; owing to the head being slightly bent to the side the cervical region was not cut in the mesial plane.

Macacus nemestrinus, No. 2, was frozen on its back; but in this case the thighs were extended. This was the first section which was made, and the outline of the body was omitted to be taken.

Macacus rhesus: frozen on its back, with the thighs flexed on the abdomen.

Cercopithecus campbelli, No. 1, was frozen on its back, with the thighs flexed on the abdomen. No. 2 is the same animal thawed, placed on its side, and the lower limbs extended to the extent indicated in the tracing.

Semnopithecus entellus was frozen on its back, with its thighs flexed on the abdomen. The straightness of the spine in this case is very remarkable.

Colobus vellerosus (white-thighed colobus), No. 1, was frozen on its back, with its thighs flexed upon the abdomen. No. 2 is the same animal thawed, placed on its side, and the lower limb extended.

PLATE V.

Reduced tracings of mesial sections of a number of the lower apes. These were taken when the animals were still in the frozen condition, and the reduction was effected by photography.

Cercopithecus ruber, No. 1, was frozen in the sitting posture in a tall glass jar, in the manner described in p. 98. No. 2 is the same animal after it had thawed, and with the lower limb extended.

Cercopithecus mona, No. 1, was frozen on its back, with the thigh flexed on the abdomen. No. 2 is the same animal after it had thawed, and with the lower limb extended.

Cercocebus fuliginosus, No. 1, was frozen in a plaster-jacket in the sitting posture, in the manner described in p. 99. No. 2 is another specimen of the same species, which was frozen on its back, with the thighs flexed on the abdomen.

PLATE VI.

Tracings of mesial sections of certain of the lower apes reduced by photography.

Cercocebus fuliginosus, No. 3, is the same animal that is figured as No. 2 in Plate V. This tracing was taken after the preparation had thawed, and with the lower limb extended.

Chlorocebus sabaicus, No. 1, was frozen on its back, with the thighs flexed on the abdomen. No. 2 is the same animal thawed, and with the limb extended.

Cynocephalus anubis.—This was a large adult baboon, which was frozen on its back with its thighs flexed.

Cebus capucinus was treated in the same manner as the baboon. The curvature of the spine is more quadrupedal in its character than that of any of the other apes examined. Compare it with the tracings of the dog in the following plate (VIa.)

PLATE VIa.

This plate exhibits the curvature of the spine in the quadruped.

Dog.—No. 1. is the tracing of a fox-terrier which was frozen on its back with its limbs unrestrained.

Dog.—No. 2 is a tracing taken from the mesial section of a collie. It was frozen in an attitude approaching the standing posture (p. 108).

Dog.—No. 3 is a tracing of a poodle which was frozen on its back with its hind limbs extended. As it was disturbed in the freezing-box, the anterior portion of the spine was not cut in the mesial plane, and is therefore not represented.

Bear.—The outline of the anterior surface of the spine of a large bear, taken by moulding a strip of ductile lead on the front of the column.

PLATES VII. AND VIII.

These plates are large coloured drawings of the two sides of the mesial section of the male chimpanzee. They were drawn within the tracings, which were taken from the preparation while it was still in the frozen state, and therefore may be regarded as giving accurate representations of the topographical anatomy of this anthropomorphic ape.

PLATE IX.

Fig. 1.—Mesial section of the pelvis of a mature human male fetus. The entire body was frozen, so that the position of the viscera is natural.

Fig. 2.—Mesial section of the pelvis of an adult human male. The entire body was frozen, so that the viscera might be obtained in their natural positions.

Figs. 1 and 2 are introduced for the purpose of comparison with the pelvis of the chimpanzee, as exhibited in plates VII. and VIII.

Fig. 3 is a drawing from a photograph of the male chimpanzee represented in plates VII. and VIII. The photograph was taken immediately after the section was made by applying the two sides of the animal to each other: it shows the attitude of the limbs and the line of the section. Although the cut is slightly to the one side of the mesial plane in front, it is accurately in the middle line behind.

PLATE X.

Sagittal sections through the heads of a chimpanzee, *Cebus capucinus*, and man. The section in each case is made in a line with the middle point of the eyeball.

Fig. 1.—Chimpanzee. This drawing was made from a photograph of the section, slightly smaller than the specimen. Anteriorly the section has deviated outwards, so that it does not pass accurately through the middle of the eyeball.

Fig. 2.—*Cebus capucinus*. Full-size drawing built up within a tracing taken from the frozen surface of the section.

Fig. 3.—Man. This was drawn directly from the specimen, but within a tracing which had first been reduced.

PLATE XI.

Sections through the frozen head of the chimpanzee and orang.

Fig. 1.—Section through the frozen head of the orang in the sagittal direction, and in a line with the central point of the eyeball. The drawing is a full-size representation, and was constructed within the tracing which was taken from the frozen surface.

- a.* lenticular nucleus.
- b.* choroid plexus peeping out of the descending horn of the lateral ventricle, which is opened along its outer margin.
- c.* lateral venous sinus.
- d.* lateral sinus cut at another point.
- e.* cochlea.
- f.* superior maxillary sinus.

Fig. 2.—Sagittal section through the frozen head of a chimpanzee immediately to the outer side of the mesial plane. The tracing was taken from the frozen surface, and the drawing is the size of nature. Only the posterior part of the head is represented.

- a.* lateral venous sinus.
- b.* calcarine fissure.
- c.* corpus dentatum of the cerebellum.
- d.* margin of the foramen magnum.
- e.* posterior arch of the atlas.

Fig. 3.—Coronal section of the frozen head of the chimpanzee opposite the widest part of the cerebellum. The tracing was taken when the specimen was still frozen, and the drawing is the size of nature.

- a. posterior horn of the lateral ventricle. The dotted line ends upon the bulb of the cornu.
- b. hippocampus minor.
- c. calcarine fissure.
- d. corpus dentatum of the cerebellum.
- e. and f. lateral venous sinus.

This plate was drawn for me by Dr. St. John Brooks, Demonstrator of Anatomy, Trinity College, Dublin.

PLATE XII.

This plate, which is also the work of Dr. Brooks, represents sections through the frozen gibbon (*Hylobates agilis*—the wauwau).

Fig. 1 is a reduced outline tracing of a mesial section of the gibbon.

Fig. 2 is a full-size drawing of a section through the frozen head of the gibbon. The tracing was obtained when the animal was still in the frozen state.

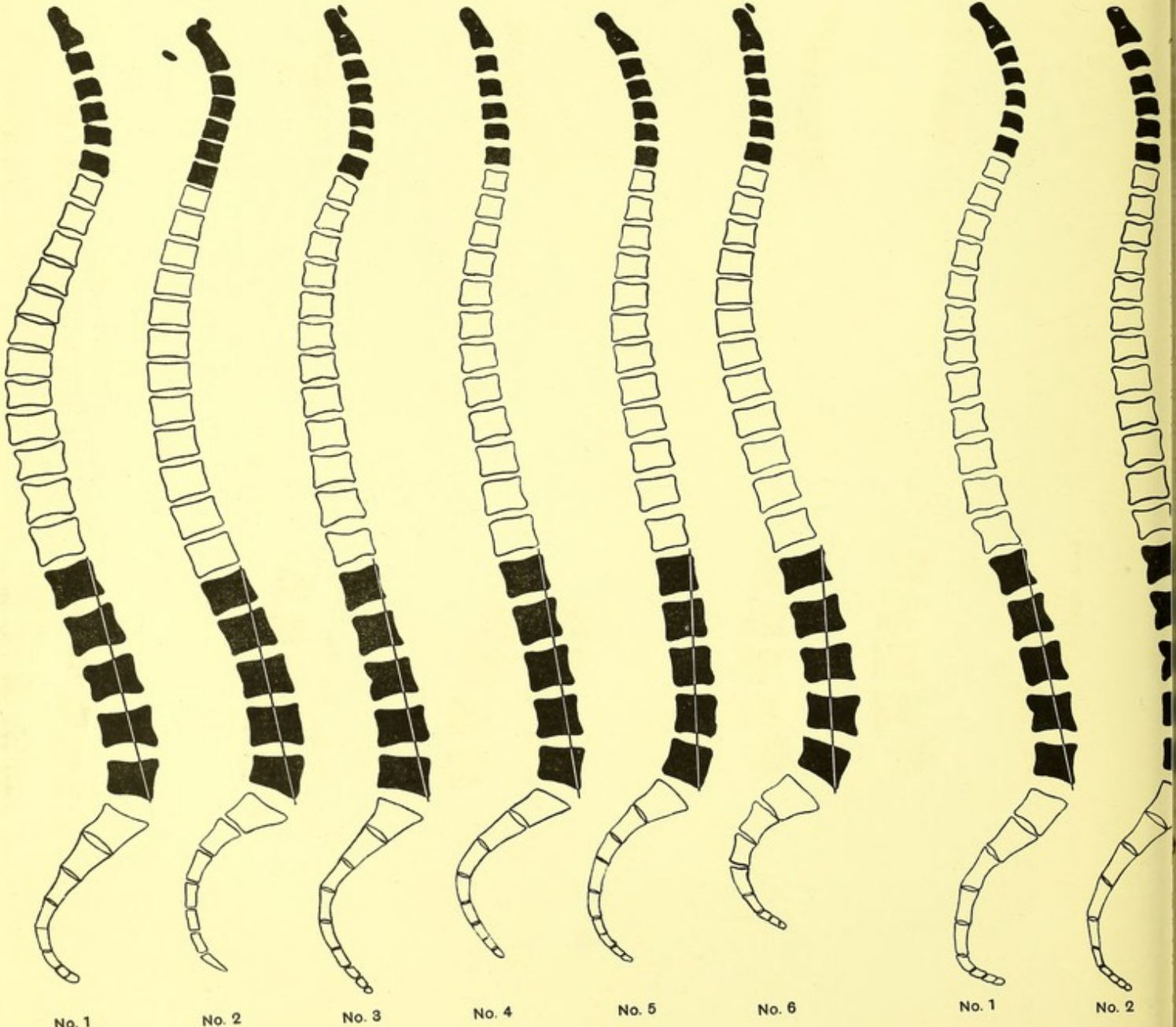
- a. lateral venous sinus.
- b. internal parieto-occipital fissure.
- g. superior longitudinal sinus.
- h. portion of the falx cerebri.
- i. anterior pillar of the fornix.
- k. anterior commissure.
- m. sphenoidal sinus.
- n. corpora quadrigemina.

Fig. 3.—Sagittal section through the frozen head of the gibbon, in a line with the central point of the eyeball. The tracing was taken when the specimen was still in the frozen state, and the drawing is the size of nature.

- a. lateral sinus.
 - b. descending cornu of lateral ventricle.
 - c. cochlea.
 - d. dentate fissure.
 - e. lenticular nucleus.
-



MALE



No. 1

No. 2
(BRAUNE)

No. 3

No. 4

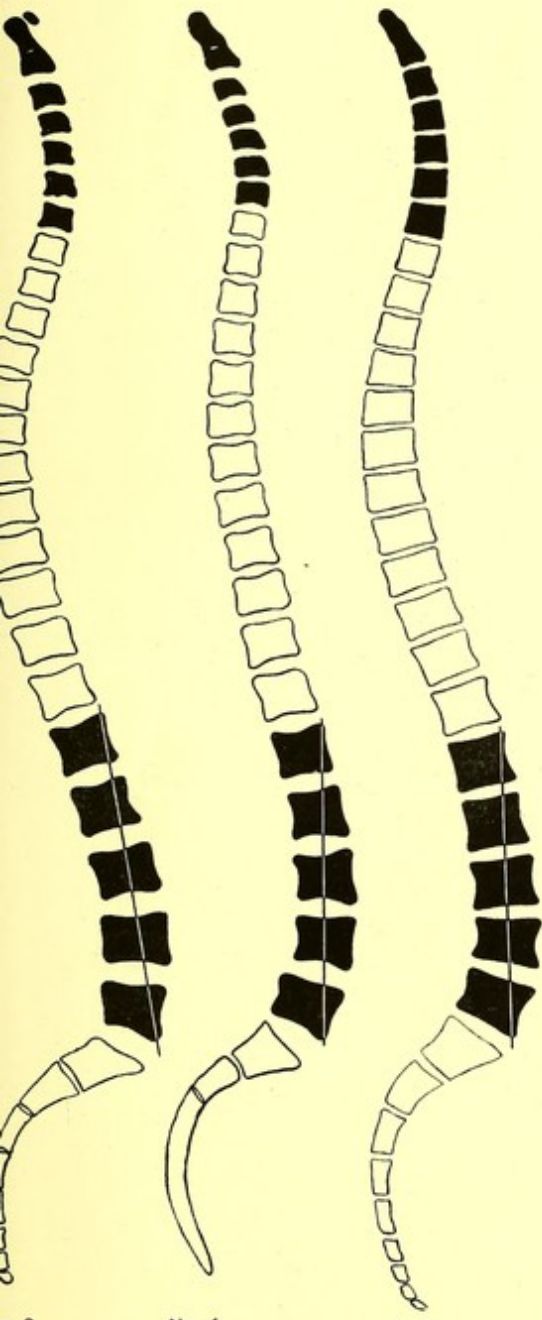
No. 5

No. 6

No. 1

No. 2

MALE

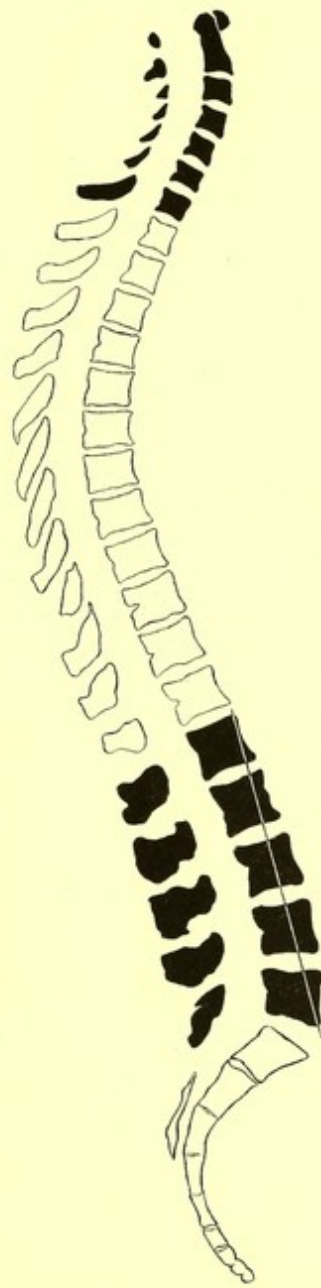


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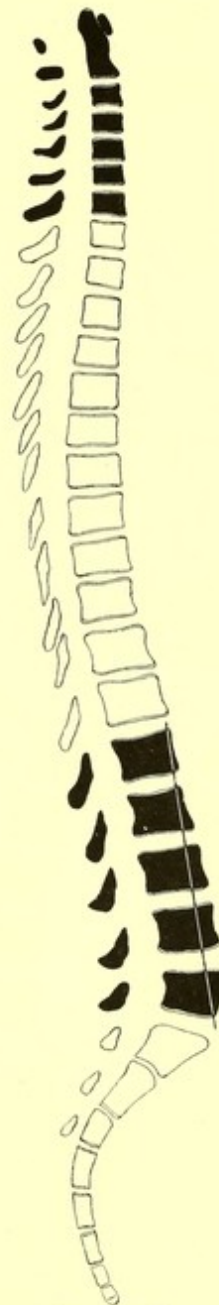
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No. 5

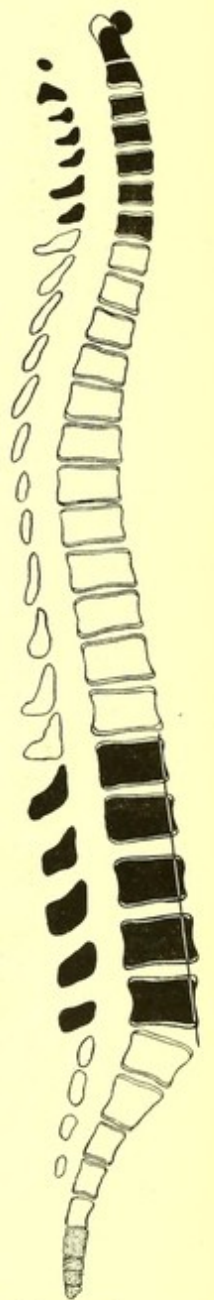
(BRAUNE)



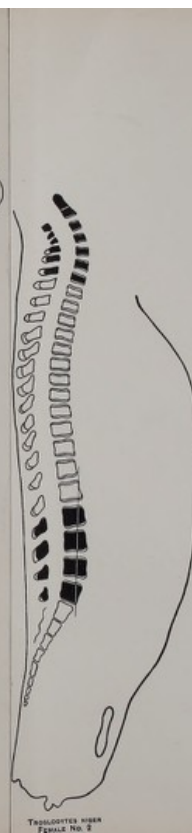
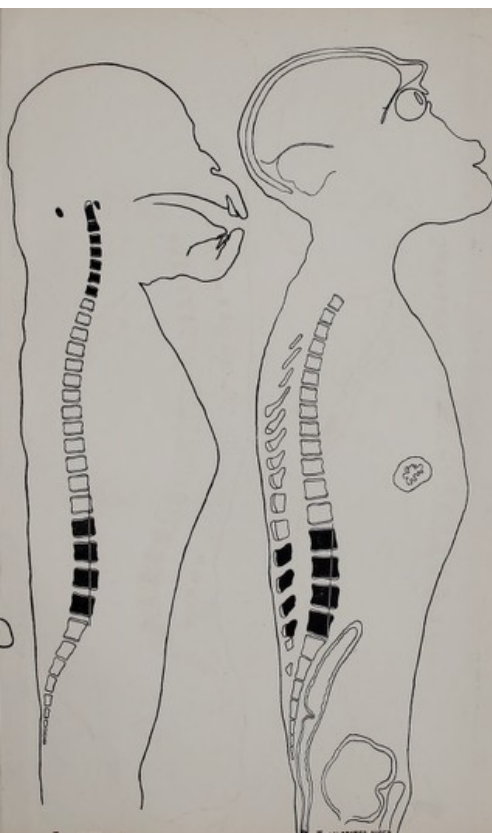
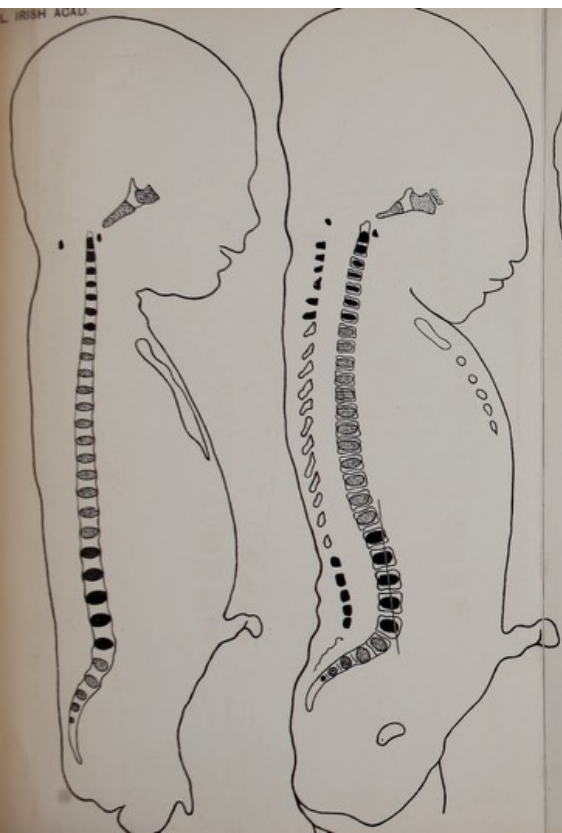
ADULT MALE.
(WEBER.)



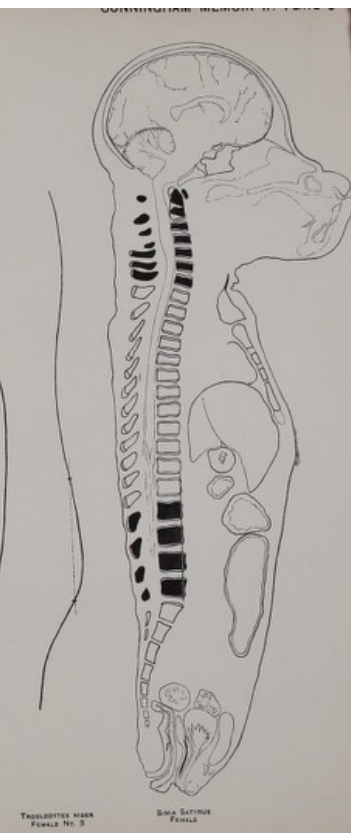
GIRL. AET. 13
(SYMINGTON)



BOY. AET. 6
(SYMINGTON)

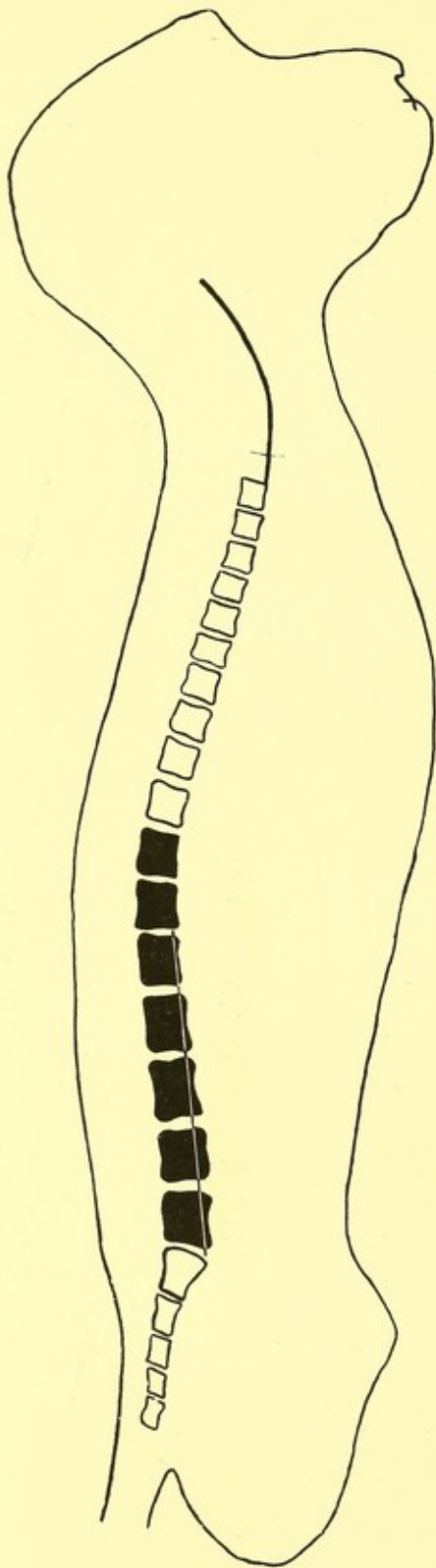


TRICHOPTERUS NIGER
FEMALE No. 3



TRICHOPTERUS NIGER
FEMALE No. 3

SWIA SATIUS
FEMALE

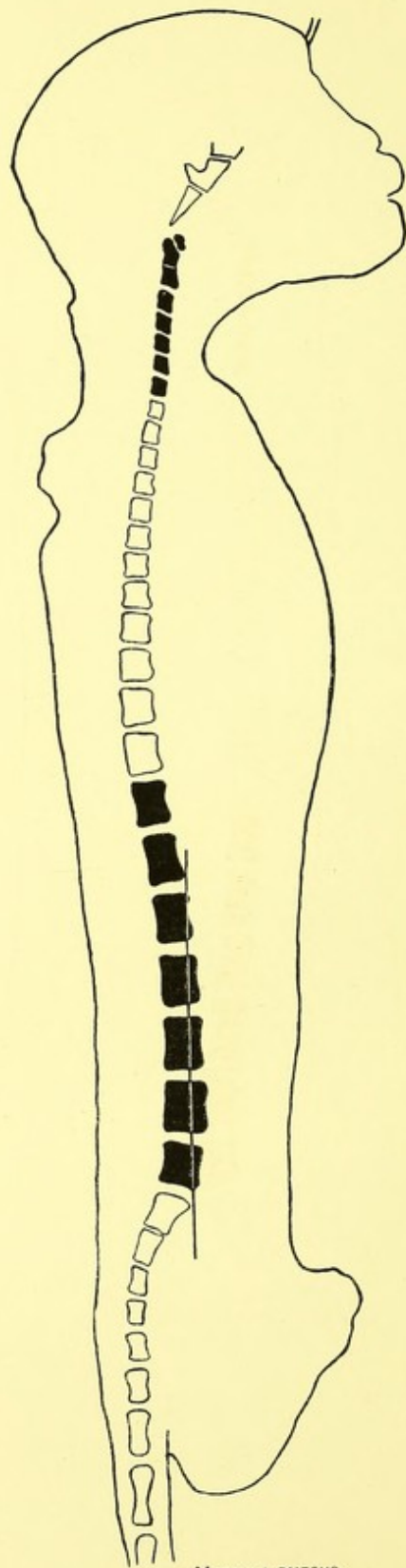


MACACUS NEMESTRINUS.
No. 1

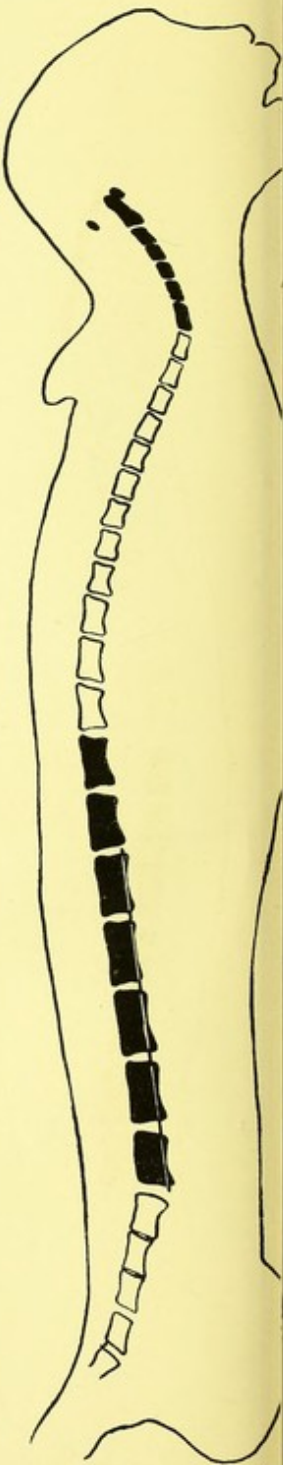
D. J. C. del.



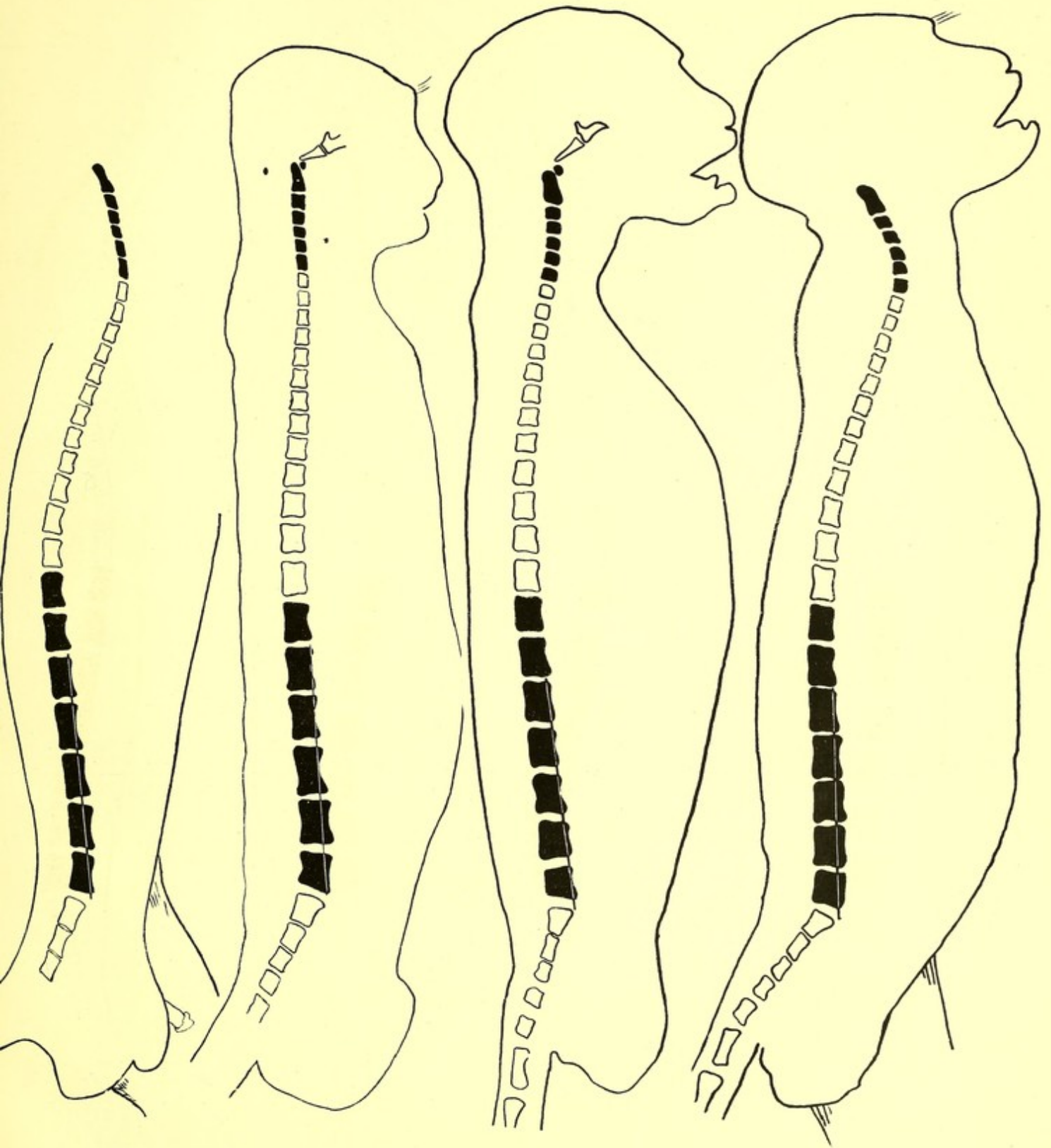
MACACUS NEMESTRINUS.
No. 2



MACACUS RHESUS.



CERCOPITHECUS CAMPBELLI.
No. 1

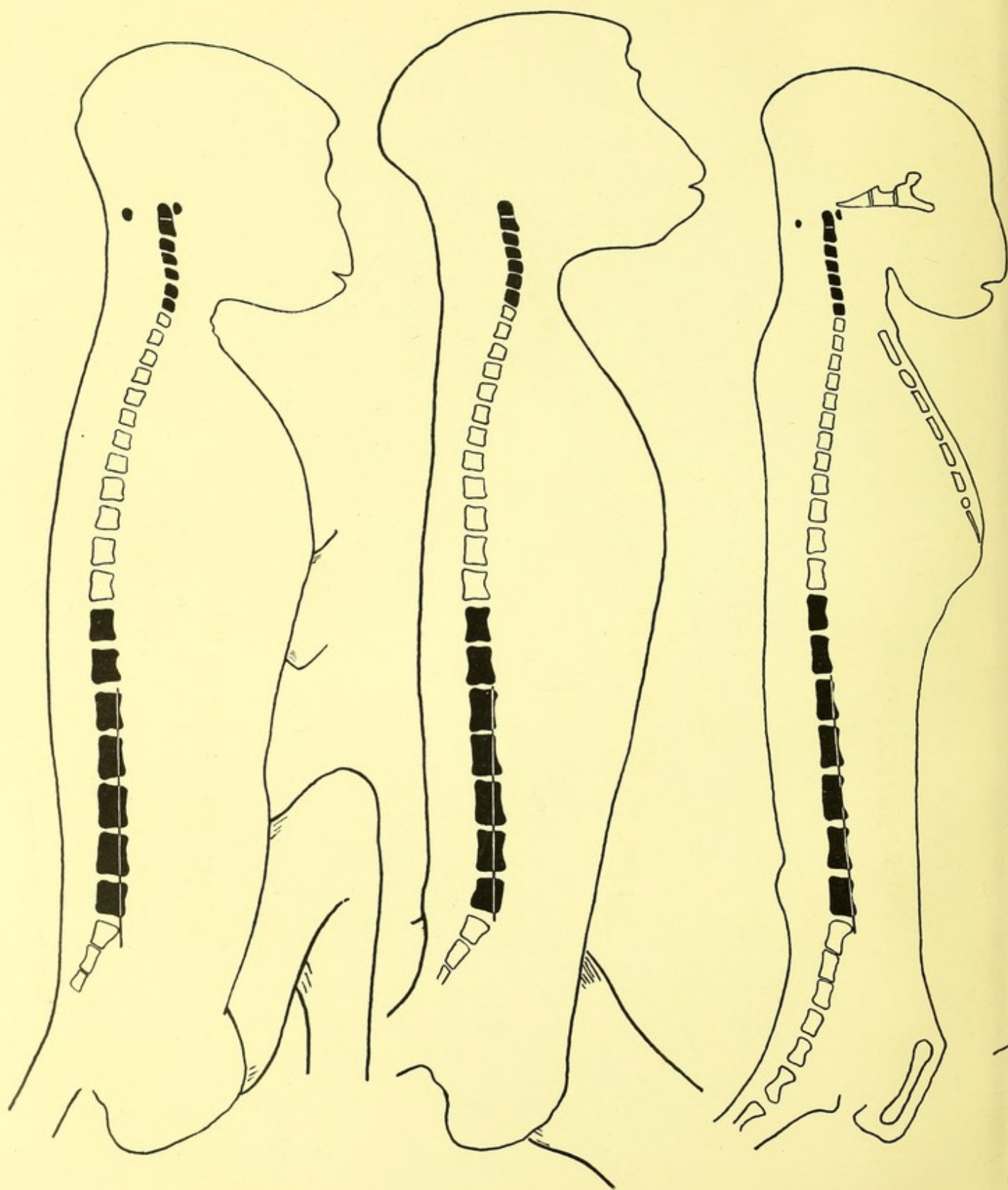


CERCOPITHECUS CAMPBELLI.
No. 2

SEMNOPITHECUS ENTELLUS.

COLOBUS VELLEROSUS.
No. 1

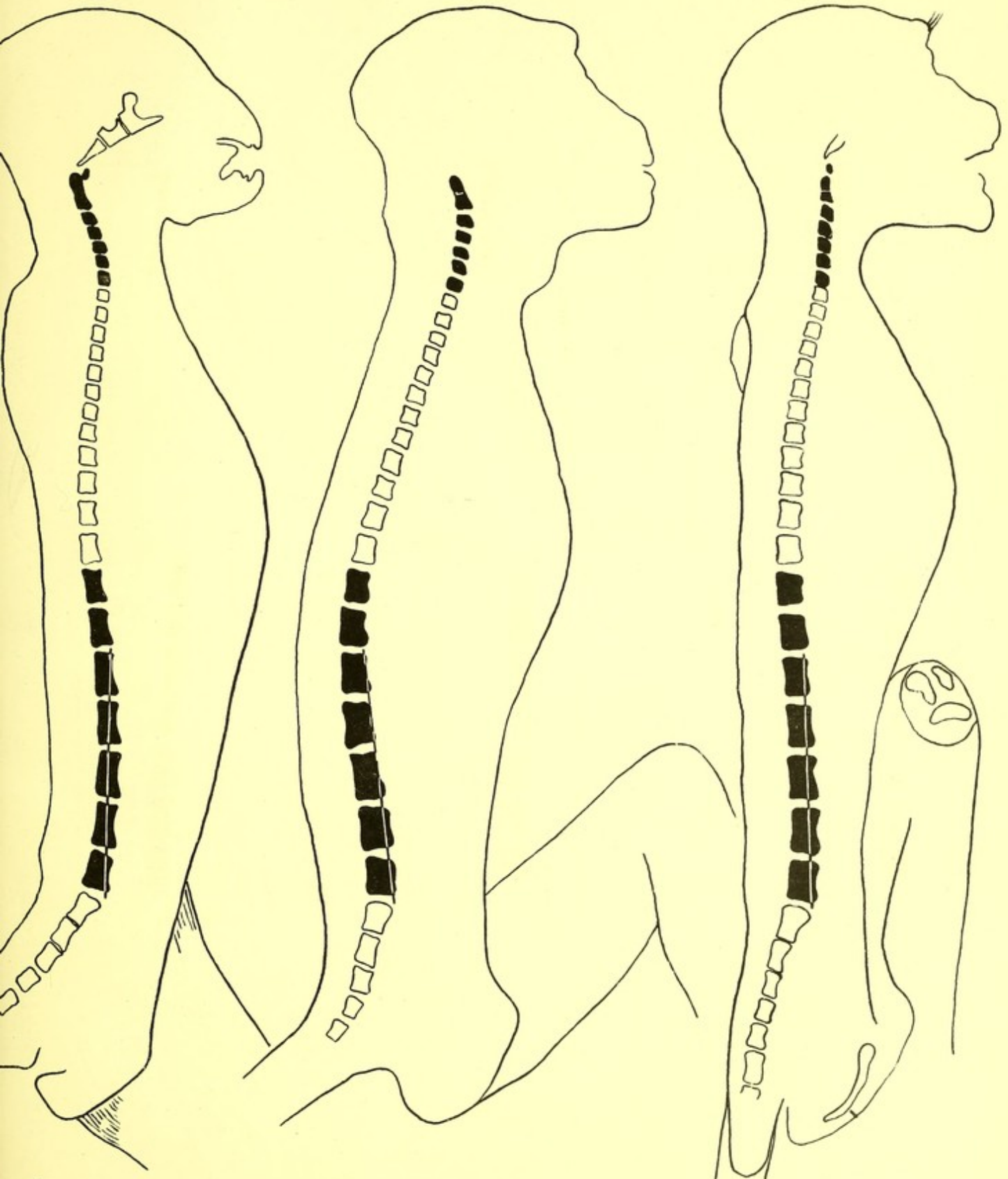
COLOBUS VELLEROSUS.
No. 2



CERCOPITHECUS RUBER.
No. 1

CERCOPITHECUS RUBER.
No. 2

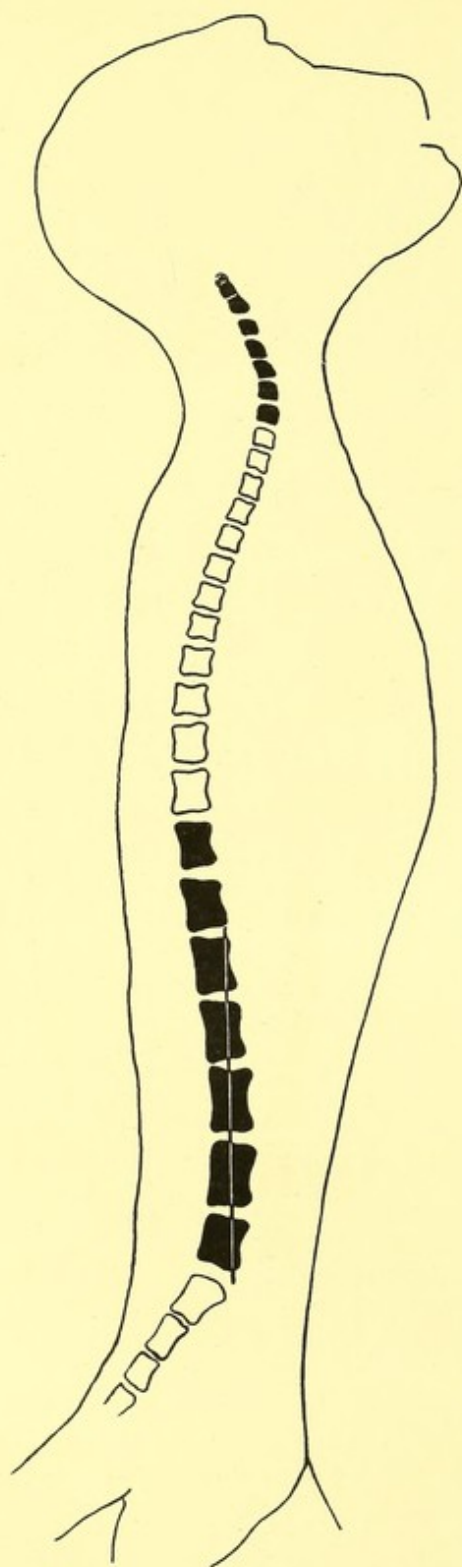
CERCOPITHECUS MONA.
No. 1



CERCOPITHECUS MONA.
No. 2

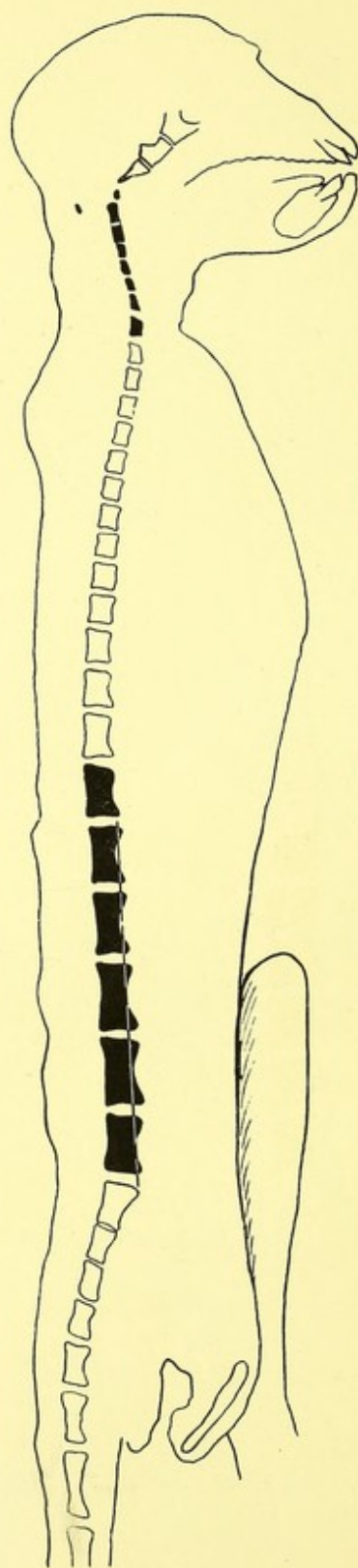
CERCOCEBUS FULIGINOSUS.
No. 1

CERCOCEBUS FULIGINOSUS.
No. 2

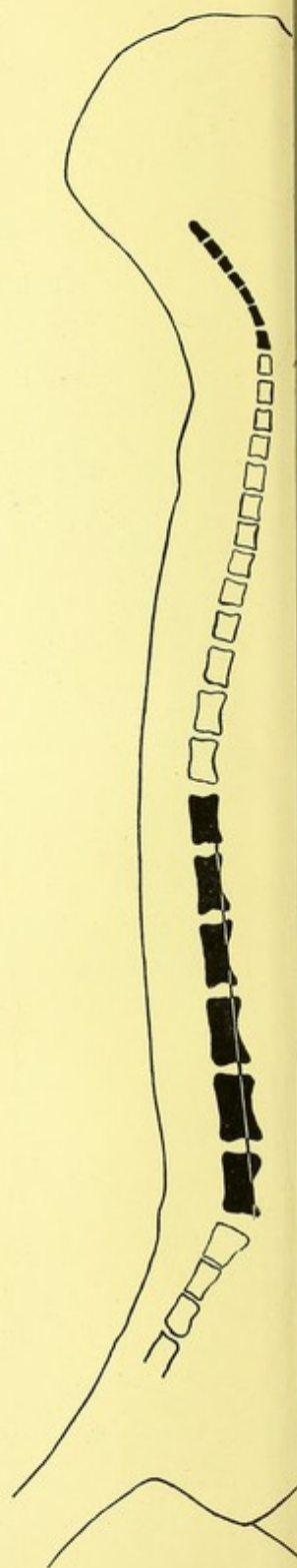


CERCOCEBUS FULIGINOSUS.
No. 3

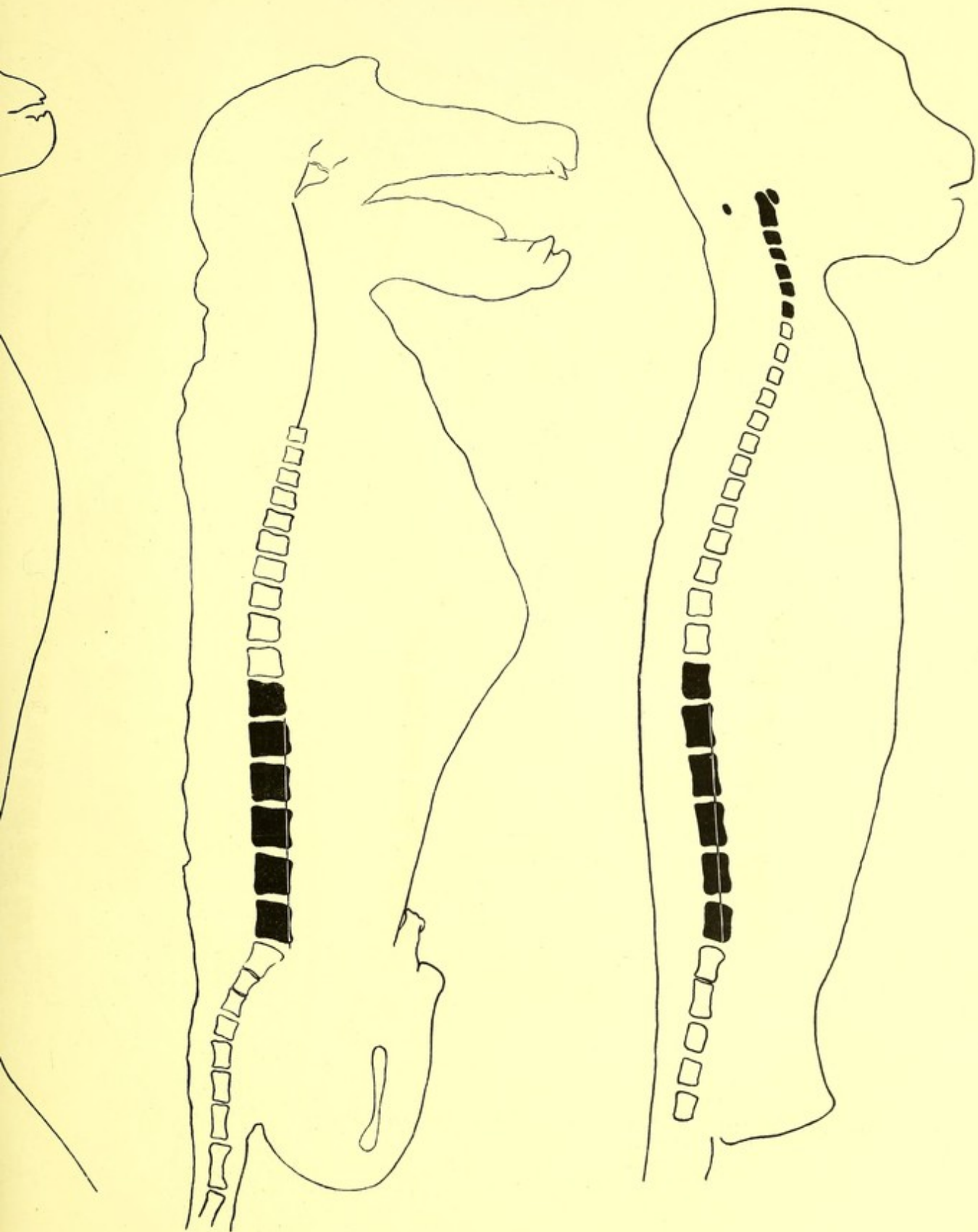
D. J. C. del.



CHLOROCEBUS SABAEUS.
No. 1

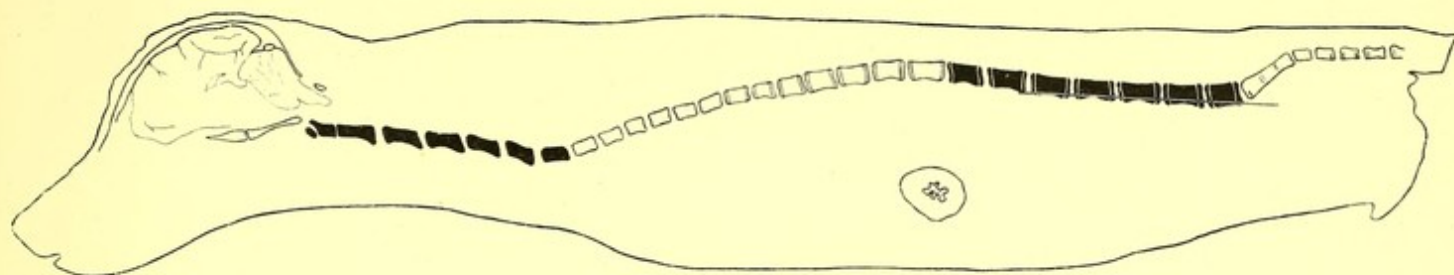


CHLOROCEBUS
No. 2

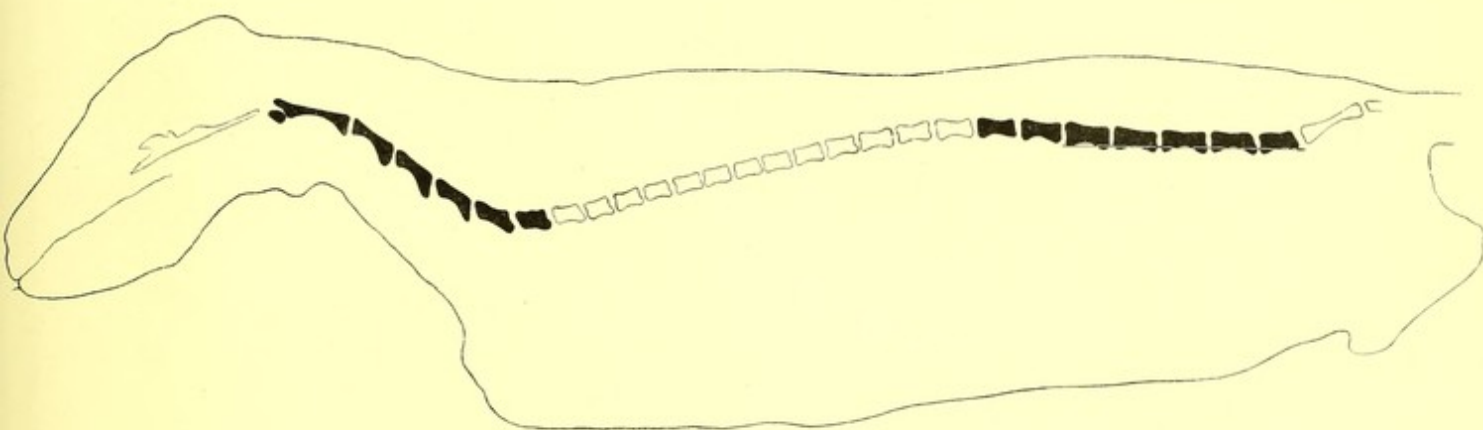


CYNOCEPALUS ANUBIS.

CEBUS CAPUCINUS.



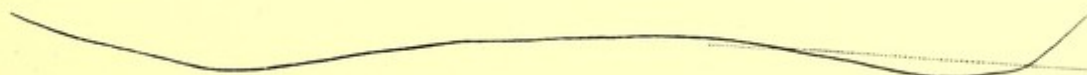
Dog No. 1



Dog No. 2

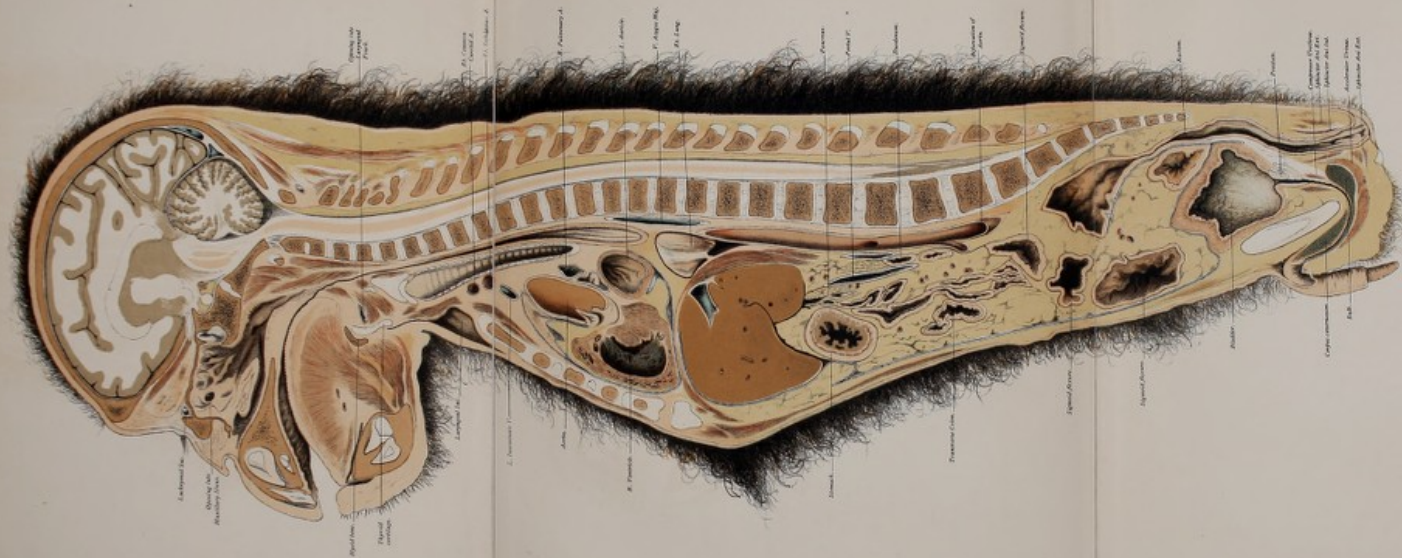


Dog No. 3



BEAR





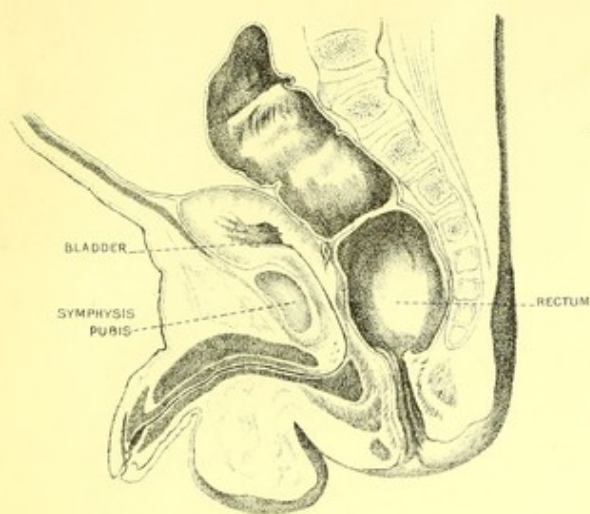


Fig. 1.

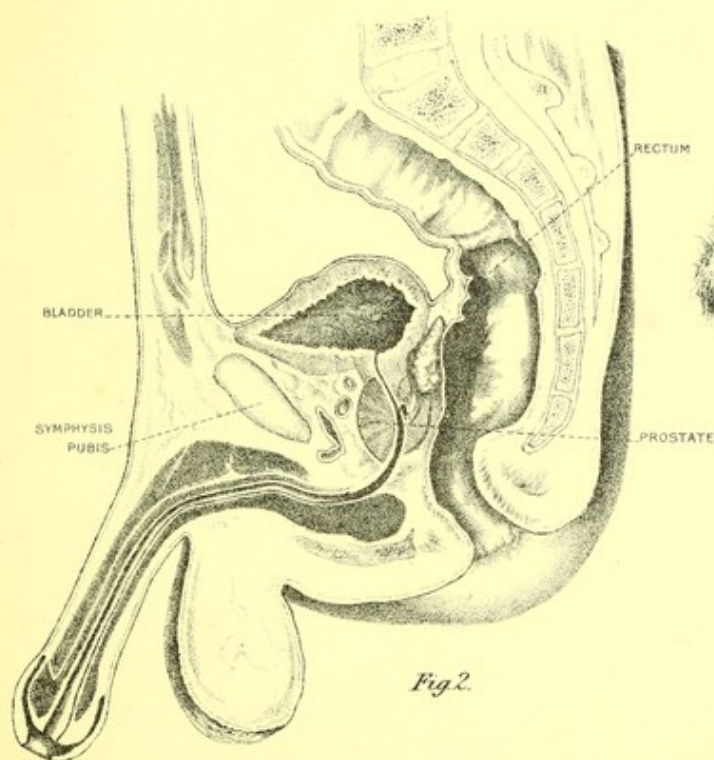


Fig. 2.

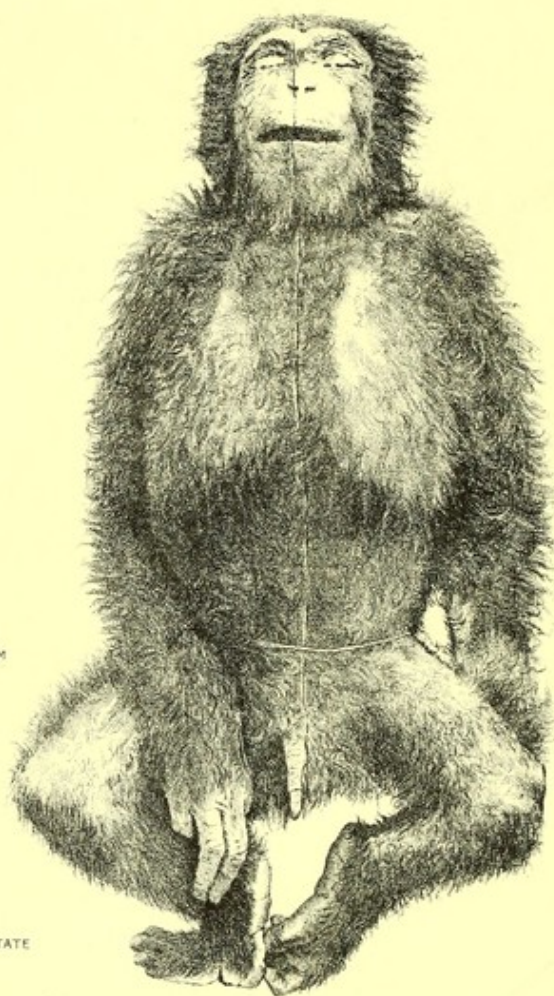


Fig. 3.

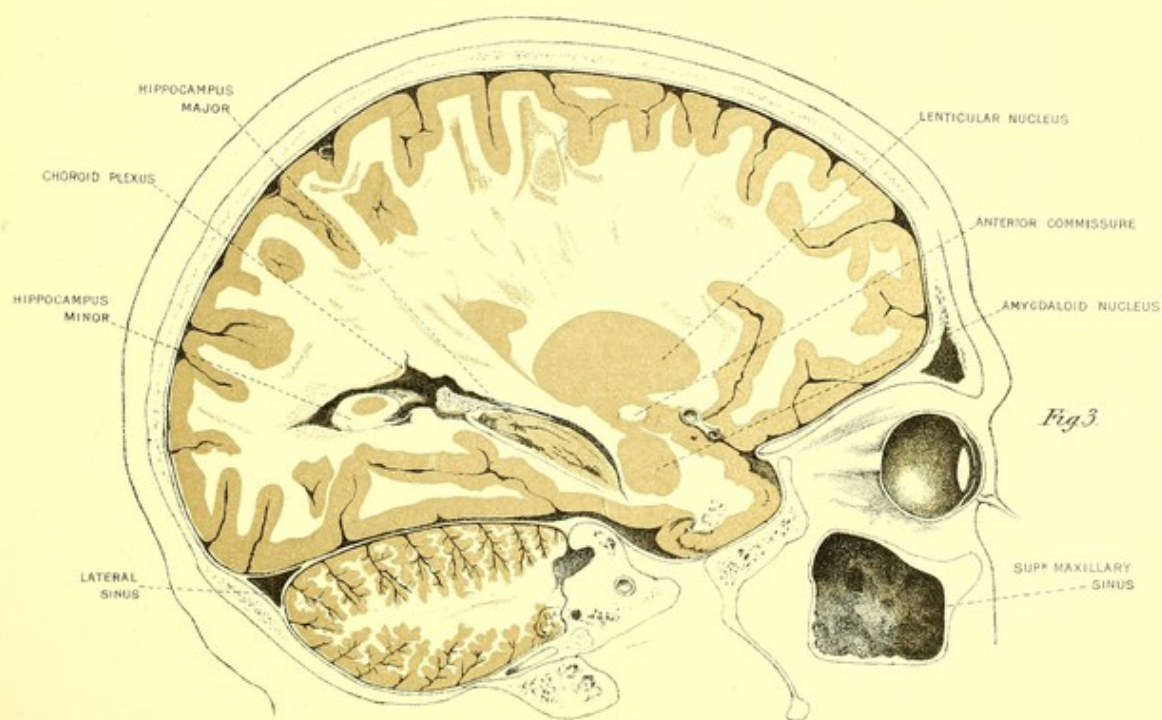
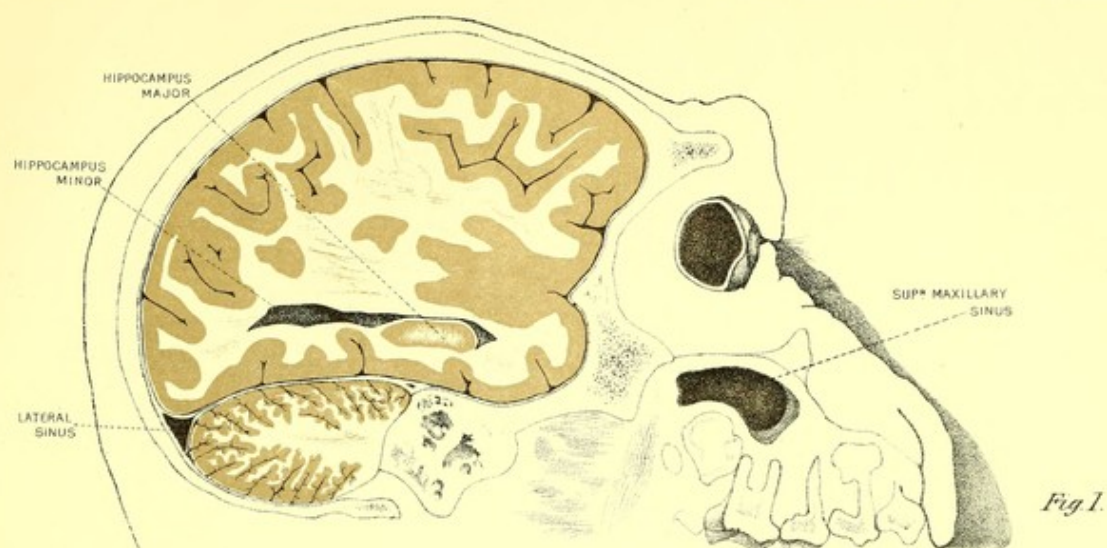


Fig. 2.

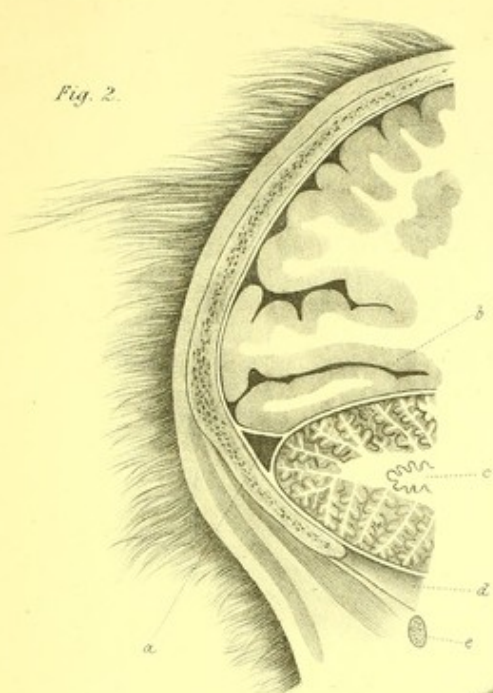


Fig. 3.

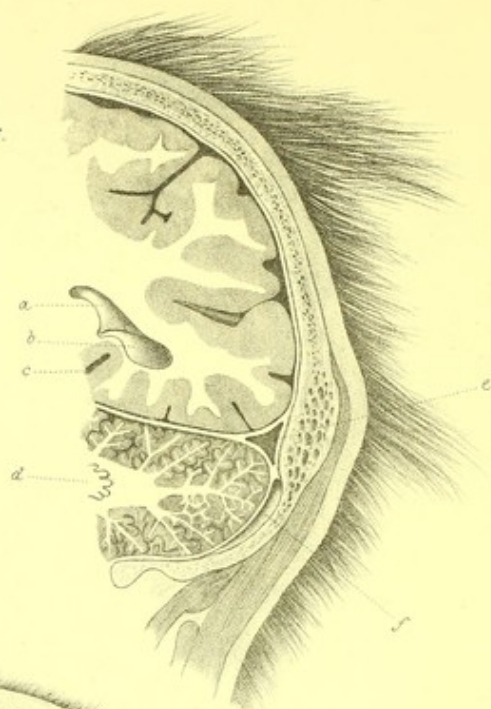
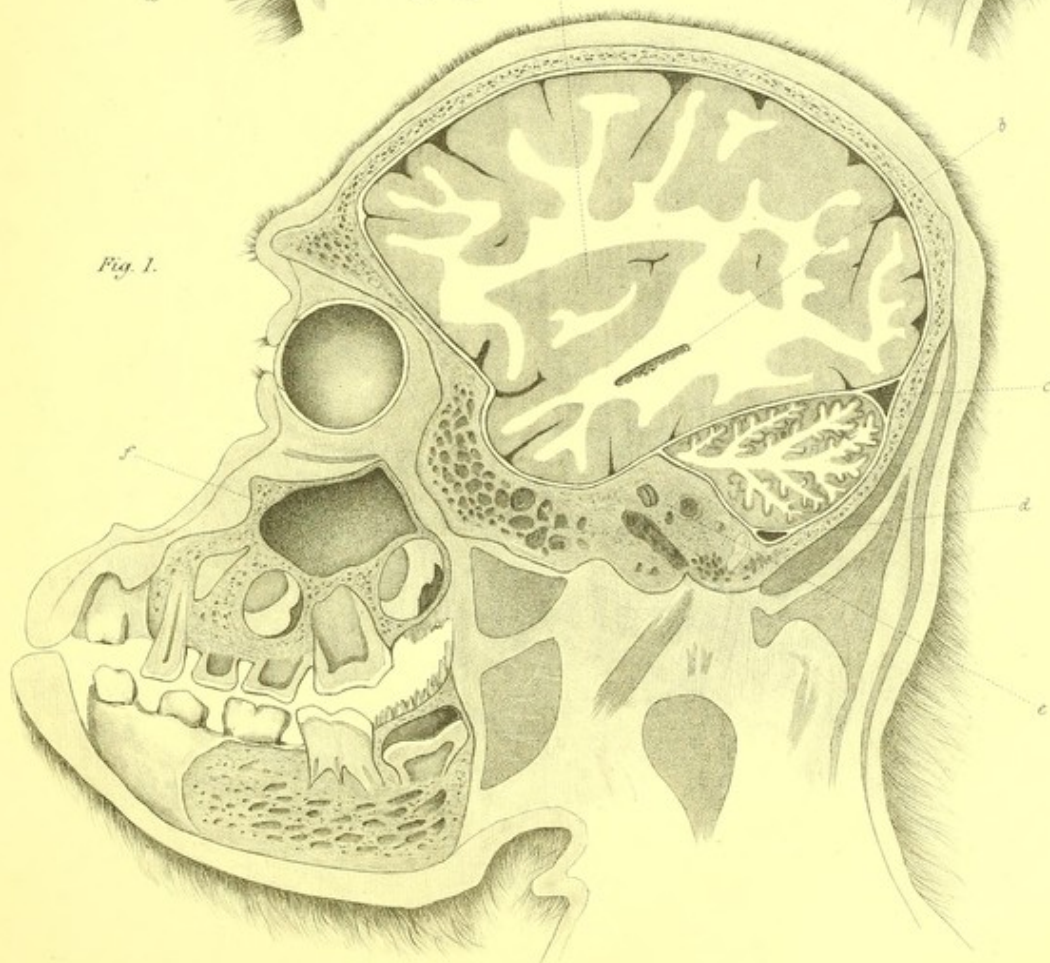


Fig. 1.



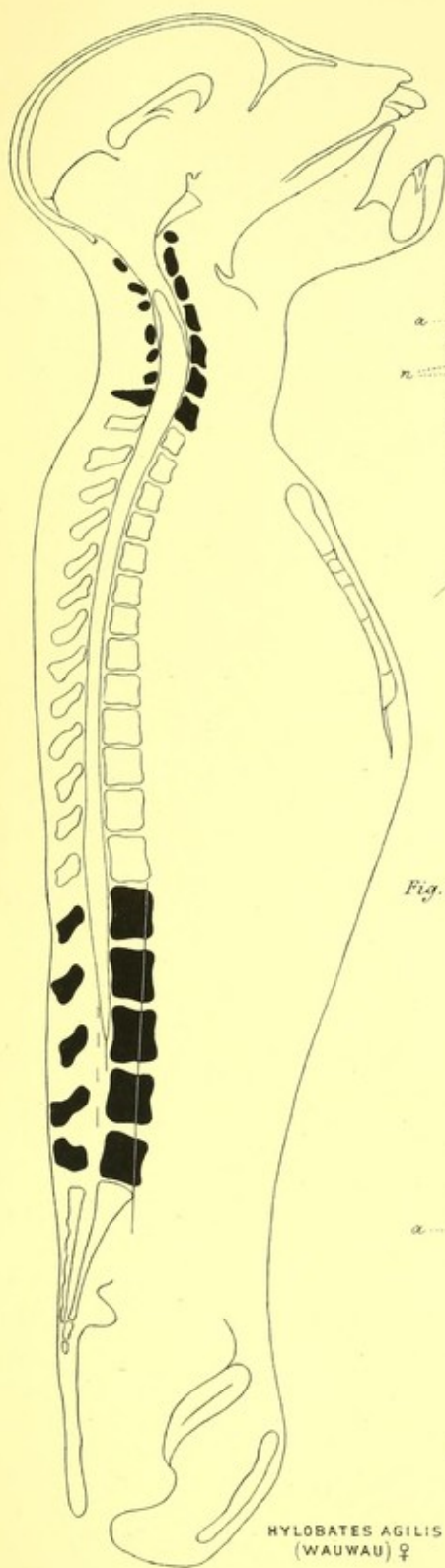


Fig. 1.

HYLOBATES AGILIS
(WAUWAU) ♀

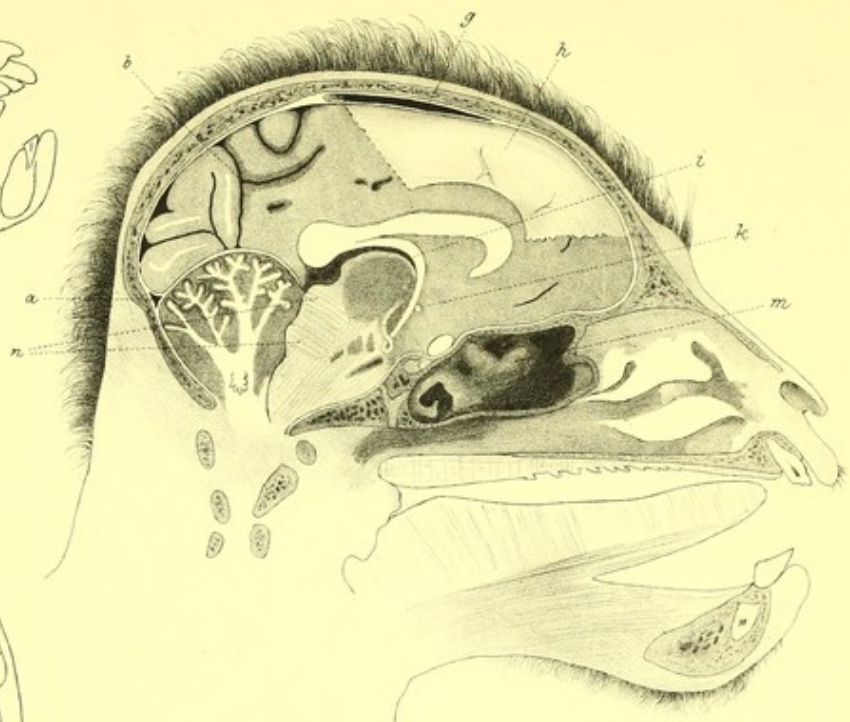


Fig. 2.

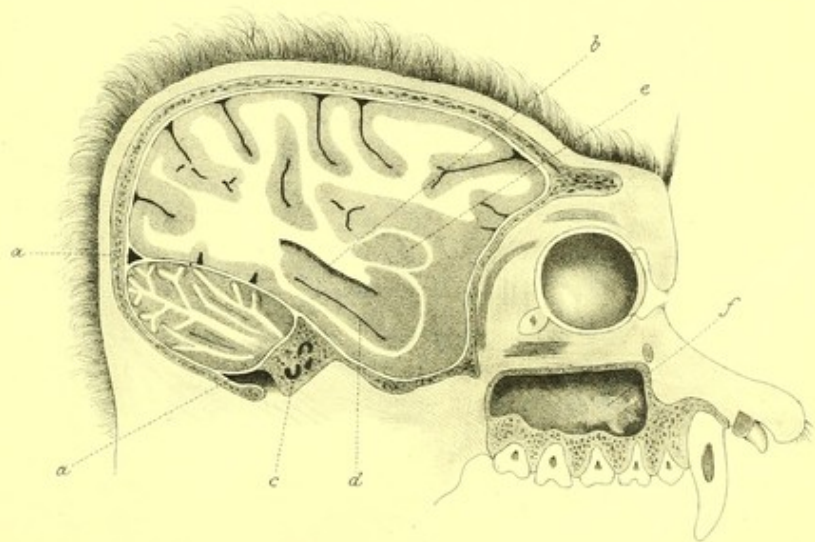


Fig. 3.



