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Article XVII.— THE SKULL OF *KOGIA BREVICEPS* BLAINV.

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Plates XXXV–XLIII.

Introduction.

In the collections of the American Museum of Natural History are two skeletons of *Kogia breviceps*, one of an adult female of large size and one of a calf roughly two-thirds grown. The latter was young enough to disarticulate in part and thus afforded an unusual opportunity to study this highly specialized cranium. For permission to utilize this material, I am indebted to the courtesy of the officers of the Museum, in particular to the Staff of the Department of Mammalogy, and I would express to them my sincere appreciation of their many kindnesses in the course of this study.

List of Specimens of Kogia.

The specimens of *Kogia* noted or described by naturalists are so few that they are for convenience of reference listed below in chronological order together with the more important literature dealing with them severally.

(1). *Physeter breviceps.* A skull from the Cape of Good Hope collected by Jules Verreaux and placed in the Paris Museum. Of this de Blainville (1838) published illustrations and gave a brief description. Though shown in his cut, in his text there is no mention of the mid-facial crest which forms so striking a character of the *Kogia* skull and at once distinguishes it from *Physeter*. Gray (1846, 1850) too is silent concerning it, although rightly separating the new form from the genus *Physeter*. To him is due the not universally admired term *Kogia*. In 1866 he reproduced de Blainville's

figures, printing that of the vertex reversed so that the right blow-hole is shown as the larger and the mid-facial crest is convex dextrad. Owen (1869) reproduces the profile from the same source and his cut differs from Gray's in the direction of enhancing the individual peculiarities of this skull. Finally there are excellent illustrations of this type specimen in van Beneden and Gervais (pl. xx, figs. 1–2).

(2). *Euphysetes grayii.* An adult stranded at Maroubra Beach, the carcass much damaged, the skeleton all but complete; collected and placed in the Australian Museum by Wall, who published an account very adequate except in the matter of illustrations (1851). He was able to locate the single blow-hole near the middle of the head and describes the falcate dorsal hump. The mid-facial crest formed by the left maxilla and right premaxilla forms a "prominent thick and sinuated ridge" which is "twisted toward the left side of the head." Mislead by the silence of Gray regarding this character, Wall established a new genus for his specimen, though entertaining some doubt of the validity of the differences between it and the Paris skull, which he suspected had been badly described. The rights of Wall in the work which bears his name have been denied by Gray on a statement from Krefft to the effect that it was in its entirety written by Macleay. In this he is followed by Owen. The charge is a grievous one, for the association of his name with his work is the chief reward of the man of science, and the appropriation of another's honor is a peculiarly vile and heinous crime. At this distance of time it is impossible to ascertain the rights of the case and Gill has pointed out that during his lifetime Macleay raised no question of the authorship of the paper. So the matter must rest, yet the incident is eloquent of the lasting smirch that attaches even to the suspicion of such guilt and ought to serve as a deterrent to the parasitic ambition that covets the credit of another's work.

(3). *Physeter* (*Euphysetes*) *simus.* A female measuring 7 ft. 2 in. in length, with young, collected in the Madras Presidency by Walter Elliot in March 1853. The fœtus was large enough to be skinned and stuffed but unfortunately while left to dry was carried off by a jackal. Of the adult Elliot had drawings made; a first set proving unsatisfactory they were made again, but the unsatisfactory ones were not destroyed. Eventually both sets, together with Elliot's notes and measurements, were forwarded to Professor Owen. Before reaching him an unworthy hand had supplied one of them with a penis, so that Owen, who has himself alone to blame for his disregard of the accompanying memoranda, was led into the error of describing the characters of both sexes from a single specimen (1865). The description given of the skull is the most complete and thorough in the literature. In 1867 Elliot furnished the necessary corrections and gave his own measure-

ments of his specimen, which had attained a length only of 7 ft. 2 in. although it was sexually mature.

(4). *Euphysetes macleayii.* Stranded at Manly Beach near Sidney, and described by Krefft (1865). Krefft sent photographs of this specimen to the Exposition of 1867 at Paris and there is an excellent illustration of it in van Beneden and Gervais which supplies information not to be obtained from the wretched wood-cuts of Krefft's original article.

(5). *Kogia floweri.* A specimen observed by Col. Grayson at Mazatlan, Lower California, of which a portion of one mandible came into the hands of Gill (1871), together with notes upon its external characters.

(6 and 7). *Kogia macleayii.* Gray (1873) records the presence in the British Museum of two specimens from Australia. These are notable as being the first examples of *Kogia* which were not made the basis of new species. It is possible that one of these served as the material for Beddard's description of *K. breviceps* (1900).

(8). *Euphysetes pottsii.* Stranded near Governor's Bay, New Zealand, measured and notes made upon the osteology and external characters by Haast (1873, 1874).

(9). *Kogia breviceps.* From Japan, described and beautifully figured (pl. xli.) by van Beneden and Gervais (1880). The only satisfactory view published of the basis cranii is the one given of this specimen.

(10 and 11). *Kogia.* A jaw in the Royal College of Surgeons. Van Beneden and Gervais (pl. xx, fig. 3). There is a similar fragment in the Hunterian Museum.

(12). *Kogia grayi.* A specimen acquired by the Australian Museum. Haswell has described its brain (1883).

(13). *Cogia breviceps.* A male stranded on the coast of Otago, New Zealand, the soft parts of which and later the skeleton were described by Benham (1901, 1902). His notes upon the skull are intentionally brief because of previous descriptions.

(14). *Kogia breviceps.* Benham mentions a specimen at Napier lacking teeth in the upper jaw.

(15 and 16). *Kogia breviceps.* Two skeletons in the South African Museum, from Greenpoint and from Knysna. Sclater gives measurements of both and cuts of the skull of one of them (1901).

(17). *Kogia breviceps.* A skull in the United States National Museum of which excellent photographs are given by Elliot (1904).

(18). *Kogia breviceps.* A male stranded at Roscoff, France. Careful descriptions are given of the soft parts of the head, of some of the viscera, together with measurements of the skeleton by Le Danois (1910, 1911).

(19). *Kogia breviceps.* A specimen stranded at Ile d'Oléron, collected by Bernard, mentioned by Le Danois.

To these may be added two skeletons of *K. breviceps* in the American Museum of Natural History.

(20). An immature individual obtained by Frank Wood at New Bedford, Mass. No. 34867.

(21). A large female with young collected by R. C. Andrews, having come ashore at Long Beach, Long Island. No. 36595.

Historical.

Upon the individuals above enumerated three genera have been formed, *Kogia* (Gray, 1846), *Euphysetes* (Wall, 1851) and *Callignathus* (Gill, 1871). *Euphysetes* was founded upon an omission in the definition of *Kogia*, as has already been stated, and this supplied (Gray, 1866), must plainly be dropped. *Callignathus* was proposed for *P. simus* of Owen, characterized in the first line by the presence of teeth in the upper jaw, further by the rounded proximal extremity of the mandible, the short rostrum, and the incurved extremities of the transverse crest. This skull has other small peculiarities, as will be noted below, but the proposed genus has not been favorably received and has no supporter among subsequent investigators.

Six species were based upon hardly more specimens. Hector expressed the opinion in 1873 that there was but one species of *Kogia*, in which later writers have concurred with the single exception of Beddard (1900), who considers that there are at most three. For him *K. breviceps* includes *K. macleayi* and *K. grayi; K. simus* is a valid species; and *K. pottsii* less certainly established; *K. floweri* is too vaguely characterized for recognition. Le Danois (1911) has thoroughly reviewed the question and concludes that there is ground for accepting but one species, *K. breviceps* (de Blainville).

Measurements.

The general dimensions of the skull in the American Museum are given below, together with such similar measurements as can be gathered from the literature; in most of the notices of *Kogia* the proportions of the skull and the cranial osteology receive but scanty attention and it has almost become a custom among students of this genus to refer to the accounts of Wall, Owen, van Beneden and Gervais, as containing all that need be known of the cranium.

Measurements of Skull.

	Wall	Owen	Le Danois	Am. Mus., Adult	Am. Mus., Calf
Length of skull from extremity of snout to hinder edge of occipital condyles	16½ in.	10 5/12 in.	40 cm.	17 in.	12¼ in.
Ditto from hinder edge of occipital condyles to hinder wall of nares	R. 6 in. L. —	R. — L. 4 5/6 in.	10 cm.	R. 7¼ in. L. 6⅞ in.	R. 6 in. L. 5½ in.
Length of rostrum from its extremity to the fundus of antorbital notch of the maxilla	7 in.	5 in.	20 cm.	9½ in.	6½ in.
Breadth of head between postorbital processes — maximum breadth	14 in.	9 5/12 in.	34 cm.	14⅞ in.	11 in.
Breadth of rostrum between antorbital processes of maxilla	8 in.	4¾ in.	18 cm.	8⅞ in.	5⅞ in.
Ditto midway between its extremity and the antorbital processes	5 in.			5½ in.	4 in.
Ditto at its extremity	2 in.	1⅓ in.			2 in.
Distance between tips of premaxillaries	1¼ in.	⅓ in.		½ in.	
Left nostril, length	2 in.	1 5/12 in.	4 cm.	2¼ in.	2 in.
" " breadth	2⅕ in.	1 in.	3 cm.	1¾ in.	1⅝ in.
Right nostril, length	½ in.	7/24 in.		⅝ in.	½ in.
" " breadth	1 in.	⅓ in.	1.5 cm.	¾ in.	⅜ in.
Width of occipital foramen	1½ in.	1¼ in.	4 cm.		1½ in.
Distance between lateral margins of condyles	4 in.	2¾ in.	8 cm.		3 in.
Greatest breadth of occipital	11 in.	6⅙ in.	25 cm.	12½ in.	9¼ in.
Greatest height of occipital	11 in.			11¼ in.	8½ in.
Length of mandible	13¼ in.	8½ in.	34 cm.	16¾ in.	11 in.
Length of symphysis	3½ in.	2⅓ in.	7 cm.	4½ in.	1¾ in.

Measurements of Skull — Continued.

	Wall	Owen	Le Danois	Am. Mus., Adult	Am. Mus., Calf
Length of alveolar portion	5¼ in.	2⅔ in.	13 cm.	7⅛ in.	4 in.
Width at proximal end of the symphysis	1¼ in.	¾ in.		1 in.	⅝ in.
Distance between outer edges of articular condyles	13 in.		30 cm.		
Height of mandible in pars papyracea	4¼ in.	2 1/12 in.	9 cm.	4⅛ in.	3⅜ in.

The three large skulls (Wall, Le Danois, the adult of the American Museum) agree in general dimensions quite closely and appear to represent conditions in the full grown animal. They show the greatest variation in the length of the rostrum. The skull recorded by Le Danois, that of a male, is intermediate in length between that described by Wall, sex unknown, and the female in the American Museum. In other respects the differences are slighter; the Le Danois skull however is distinctly narrower than the other two.

For some of the more important dimensions of the skull additional data are available. Those serving for an estimate of the proportion of the skull to the trunk are as follows:

Length of Skull and Percentage of Skull Length.

Observer	Sex	Total length	Length of skull	Percentage Length of skull
Wall, 1851		9 ft.	16½ in.	14.8
Krefft, 1865		10 ft. 4 in.	18 in.	14.1
Owen, 1868	♀	Elliot, 7 ft. 2 in.		12.1
		Owen, 6 ft.	10 in. 5 lines	14.4
Gray, 1873		9 ft.	16 in.	14.8
Haast, 1873	♀	7 ft. 2 in.	13½ in.	15.7
Sclater, 1901	♀	5 ft. 9 in.	10 in.	14.5
Benham, 1902	♂	7 ft. 11½ in.	15½ in.	15.7

The head is therefore approximately one-seventh of the body length, a proportion which is subject to little variation. An important exception occurs only in the Elliot-Owen specimen. Here there is perhaps a possibility of error although the greater length is that given by Elliot from actual

measurements, while the external dimensions of Owen were calculated from the drawing which was not to an exact scale. Elliot in his letter refers to crania of the Wongu, though nothing in Owen's article implies that he received more than one.

In the relation of breadth to length of the skull, the Elliot-Owen specimen again stands somewhat apart from the others, as appears in the following table:

Proportion of length of Skull to Breadth.

	Length of skull	Breadth of skull	Proportional breadth
Wall	$16\frac{1}{2}$ in.	14 in.	84.8
Owen ♀	$10\frac{5}{12}$ in.	$9\frac{5}{12}$ in.	90.4
Haast ♀	$13\frac{1}{2}$ in.	$11\frac{1}{5}$ in.	82.9
Sclater ♀ (1)	10 in.	$8\frac{1}{2}$ in.	85.0
(2)	15 in.	13 in.	86.7
Le Danois ♂	40 cm.	34 cm.	85.0
Am. Mus. Adult ♀	17 in.	$14\frac{7}{8}$ in.	88.2
" " Calf	$12\frac{1}{4}$ in.	11 in.	89.8

The Owen specimen and that of Haast have the same length, 7 ft. 2 in., and both are females, yet they represent the extremes of variation in this ratio. The specimen of Haast is a large headed individual, while that of Owen is in this respect the smallest of the series. It seems probable that the real variable is the length of the rostrum, and it is noteworthy as shown in the following table that the proportionally shortest rostrum belongs not to Owen's but to Haast's specimen.

Proportional Length of Rostrum to Skull.

	Length of skull	Length of rostrum	Percentage of length of rostrum
Wall	$16\frac{1}{2}$ in.	7 in.	45.5
Owen	$10\frac{5}{12}$ in.	5 in.	46.1
Haast	$13\frac{1}{2}$ in.	$5\frac{1}{5}$ in.	39.7
LeDanois	40 cm.	20 cm.	50.0
Am. Mus. Adult	17 in.	$9\frac{1}{2}$ in.	56.8
" " Calf	ca $12\frac{1}{4}$ in.	ca $6\frac{1}{2}$ in.	53.0

The length of the mandible is roughly the same as the breadth of the skull. Its proportion to the length of the skull varies within wide limits but naturally in the same sense as the length of the rostrum. But these proportions do not depend upon sex nor do they seem to bear a definite relation to the size of the animal.

Proportional Length of Mandible to Skull.

	Sex	Length of skull	Breadth of skull	Length of mandible	Breadth between condyles	Proportional length of mandible to length of skull
De Blainville		$15\frac{5}{12}$ in.		$13\frac{10}{12}$ in.	$12\frac{3}{4}$ in.	89.7
Wall		$16\frac{1}{2}$ in.	14 in.	$13\frac{1}{4}$ in.	13 in.	80.0
Owen-Elliot	♀	$10\frac{5}{12}$ in.	$9\frac{5}{12}$ in.	$8\frac{1}{2}$ in.		80.0
Sclater	♀	10 in.	$8\frac{1}{2}$ in.	$8\frac{1}{2}$ in.		85.0
Sclater	♂?	15 in.	13 in.	14.5 in.		96.7
Le Danois	♂	40 cm.	34 cm.	34 cm.	30 cm.	80.5
Am. Mus. Adult	♀	17 in.	$14\frac{7}{8}$ in.	$16\frac{3}{4}$ in.		98.3
Am. Mus. Calf		$12\frac{1}{4}$ in.	11 in.	11 in.		89.8

It would seem therefore that the proportions of the skull of *Kogia* vary in wide limits and these variations are not in the present condition of the record to be assigned to age or sex. The high proportional variability is no doubt in part to be attributed to the varying length of the rostrum, which would indicate that its extreme shortening was a comparatively recent acquisition, perhaps still progressing and not yet become definitely fixed in its degree. In this respect the comparison of the Owen-Elliot and the Haast specimens are particularly instructive for both are females and of equal length. It is much to be regretted that the length of the rostrum of the smallest female, that of the South African Museum, is as yet unrecorded. In the largest specimen of this sex at present known both rostrum and jaw are of excessive length.

The Skull as a Whole.

For the study of the cranial osteology of the adult the chief sources are, first, the imperfect type specimen in the Paris Museum which has been described and figured by de Blainville; Gray (1866) and Owen (1869) have reproduced his cuts, and the specimen has been again and more exactly illustrated by van Beneden and Gervais (1880); second, the description of the Maroubra specimen by Wall (1857); and third, Owen's careful and well illustrated account of the skull from India (1869). There is further an excellent illustration of Krefft's specimen in van Beneden and Gervais (pl. xxii, fig. 8), and these authors give also a description and several figures of a skeleton obtained from Japan (p. 514 and pl. xli), among them the most

satisfactory view of the basis cranii that has been published. Sclater has figured the skull of one of the South African individuals. Finally very excellent photographs of the skull in the United States National Museum are given by Elliot.

In cranial characters Owen's specimen stands somewhat apart from the others, which form a fairly homogeneous group, though showing minor peculiarities among themselves. With them the skull, of the American Museum agree in essentials. That of the adult has been photographed in three views, the norma occipitalis being omitted because of extensive deformation by disease about the foramen magnum.

Norma lateralis.— In the lateral view this skull resembles with minor differences de Blainville's figure as reproduced by Gray. The concavity of the supraoccipital is somewhat less and the condyle is not so projecting. Both of these characters are exaggerated in Owen's cut. The lachrymal and the supraorbital process are more produced and tapering and the frontal ascends further between the maxilla and the supraoccipital. The lateral surface of the maxilla has much the same extent but there are minor peculiarities in the maxillo-malar suture. This on the left side approaches the shape of a very wide inverted W in the skull here described, the maxilla jutting ventrad in three projections of which the middle is the largest. The reëntrant angles between it and the other projections are somewhat rounded, especially the rostral one. The angulation is lacking on the right side and the suture forms a sinuous line, as is the case of both sides of the skull of the calf. In this the malar is triangular with prominent convex dorsal angles, which may be taken as a juvenile character. With the development of these angles into diverging processes the malar acquires a triradiate form and the maxillo-malar suture becomes angulate eventually approaching the shape of a W. Its configuration varies not a little. In the Paris skull the suture courses forward from its deepest point in an upward sweep, which is very pronounced in Owen's cut, where also the change of direction in the caudal segment is minimized. There is a well marked supraorbital notch in the skull here described which does not appear in any of the figures of the Paris specimen. The temporal fossa has the same contours in both, but the fronto-squamous suture is placed more caudally in the Paris skull, indicating the greater participation of the frontal in the wall of the fossa. Owen has added a horizontal line across the squama which can hardly be a suture.

In Wall's specimen the frontal is represented as ascending with a long slender falciform process between maxilla and supraoccipital, the maxillo-malar suture is nearly horizontal and the maxilla has a quadrangular lateral surface; the temporal fossa is more rounded. In other respects the resemblance to the skulls in the American Museum is exact, but with regard both

to resemblance and the differences the very crude character of the plate must be borne in mind.

Krefft's individual has a stubby postorbital process and a blunt free extremity of the malar. The frontal does not ascend between the maxillary and supraoccipital. The temporal fossa has a greater sagittal extent. The concavity of the occiput is marked, the prominence of the condyle but moderate. The lateral surface of the maxilla is very high and the caudal process of the malar is broad, obliterating the angulation of this half of the maxillo-malar suture.

The specimen from Japan is remarkable for the extension of the frontal to the vertex as a thin strip of bone between the occipital complex and the maxilla, which is clearly defined from both by sutures. In this it agrees with Owen's specimen and with the calf's skull of the American Museum, and the inference is that the surface relief of this portion of the frontal becomes reduced and eventually lost in older specimens, fusing with the occipital complex, that is the supraoccipital plus the parietal elements, between which amalgamation is early effected. Only in Owen's specimen and in the skull of the calf is there a patent suture partially intervening between parietal and supraoccipital, though in the calf its obolescent portion can be followed to the vertex as a slight inequality of the surface. Evidently therefore this extension of the frontal on the surface as well as the partial persistence of the lambdoid suture are evidences of immaturity. To them may perhaps be added the small size of the lateral surface of the maxilla, and possibly the relative shortness of the rostrum, for these are all characters in which these three skulls agree. The Japanese skull, however, shows individual peculiarities in the marked concavity of the supraoccipital, in which it stands close to de Blainville's. The condyle however is not prominent; the postorbital process is long and pointed; and the maxillo-malar suture is quite different, convex ventrad in the greater part of its extent, becoming concave at its two extremities. Correspondingly the malar is triangular rather than triradiate in lateral view.

The skull in the National Museum though possessed of teeth in the maxilla yet approaches the skulls hitherto considered quite as much as it does Owen's specimen. It has a slightly concave supraoccipital, a condyle of little prominence, a contracted temporal fossa. The frontal would seem to reach far up between occipital and maxilla; the rostrum is very short and the maxilla has a peculiarly narrow lateral surface. The maxillo-malar suture is V-shaped with no angular change of direction in its diverging arms.

The South African skull figured by Sclater has a short rostrum, a narrow lateral surface of maxilla, a malar directed ventrally without inclination caudad, a V-shaped maxillo-malar suture, an enlarged antorbital process,

a flattish occipital. The frontal does not ascend high on the surface, the condyle projects but little.

Owen's specimen, it will be remembered, was considered to be of different genus by Gill. Its cranial characters were not his only reason for this opinion, though he attached importance to the shortness of the rostrum and the presence of teeth in the upper jaw, both of them characters which are shared with the skull in the National Museum. The ventral direction of the malar, noted both by Owen and Gill, is also present in the South African skull. The high ascent of the frontal is shared with Wall's specimen, the Japanese skull and that at Washington, the narrow lateral surface of the maxilla with the Japanese and African examples. The enlargement of the antorbital process is approached by this last skull and also by the adult of the American Museum. This leaves only the very round contour of the maxillary tuberosity, the S-shape of the maxillo-malar suture, and the convexity of the supraoccipital to characterize Owen's specimen in lateral view, and all three of these characters, while nowhere else attaining precisely this configuration, are subject to variation from skull to skull.

Norma verticalis.— This aspect of the skull has naturally attracted attention from the first. De Blainville described the great transverse crest,[1] but curiously enough failed to mention the equally striking sagittal crest between the nares and the vertex. Gray [2] also is at first silent on this point. In the second edition of his catalogue he copies de Blainville's plate and here the crest is prominent enough, only Gray prints it reversed. The skull is excellently represented by van Beneden and Gervais as far as its deficiencies permit. Meanwhile Wall (1851) was led by the silence of Gray to form a new genus for his specimen, believing that so marked a character as the sagittal crest could not be overlooked if present. Wall correctly described the composition of the crest and described the right premaxilla as extending to the vertex, the left terminating in the wall of the nostril. Gray,[3] however, in 1866, aware of the condition of affairs in the Paris specimen rejects the new genus of Wall, whose work, on the statement of Krefft, he attributes to Mackleay, and lists the Australian animal as a new species of *Kogia*, in part because of the truncated extremity of the rostrum. Wall had described it as "truncated, slightly reflexed and marginate at the extremity." In all of which respects it agrees with the Paris skull as represented by van Beneden and Gervais. Later Gray [4] restored the genus *Euphysetes*, founded

[1] Crêtes frontales. They form the cirque faciale of van Beneden and Gervais.

[2] Gray, J. E. Erebus and Terror, 1846. Catalogue of the specimens of Mammalia in the collection of the British Museum. Pt. I, Cetacea. London, 1850.

[3] Gray, J. E. Catalogue of Seals and Whales in the British Museum. London, 1866.

[4] Gray, J. E. Supplement to the Catalogue of Seals and Whales in the British Museum. London, 1871.

on Wall's individual, and characterized it by the simplicity of its sagittal facial crest as contrasted with *Kogia* of which the Paris skull is the type. This is now endowed with a "crest very sinuous folded so as to form a funnel-shaped cavity." It is true that the crest of the Paris skull is more convex to the left than Wall represents it to be in his skull, but to only a moderate degree, and it is difficult to imagine what is meant by the funnel-shaped cavity. Certainly there are no differences in this feature of the two skulls that could not be attributed to age or individual development.

The crest in question is formed by the left maxilla, to the right side of which the right premaxilla is applied, without however reaching the summit of the crest till near the vertex. The rostral half is strongly convex to the left and the limit of variation in this direction is that of the Paris skull, although it but little exceeds Owen's specimen in this respect. This portion of the crest is highly elevated and overhangs slightly the fossa of the left maxilla. The caudal half of the crest tends to be convex to the right. It is perceptibly so in Wall's, Owen's and the Paris skulls; hardly present in the American Museum specimen, it produces a marked narrowing of the right maxillary fossa in the individual of the National Museum. This is due to the development of the tuberosity of the premaxilla, prominent in all skulls of *Kogia,* into a longitudinal crest which reaches the vertex beside the left maxillary crest, a distinct groove intervening between them. In the lengthening of the tuberosity into a crest the Japanese skull shows an approach to the conditions attained in the Washington specimen. The tubercle of the premaxilla is variable; in the skull of the calf it is a moderate pyramidal elevation and to judge by the concavity behind it, corresponds only to the rostral portion of the ridge of older skulls.

The crest on the left maxilla may be continued between the nares by extensive ossification in the ethmoid; proximad and applied to the termination of the maxillary crest is a cylindrical spur projecting dorsally from the internarial septum. To this on the right is applied the postnarial process of the right premaxilla, which overlies and conceals a similarly placed but smaller spur of the ethmoid on the right side. These solid masses of bone appear to represent the lateral ethmoids, and their position and relations are clear in the skull of the calf. The one on the left side is continuous with the mesethmoid, here deflected to the left and is only partially separated from it by a V-shaped notch dorsally. In the adult skull the notch is largely filled up, only a small foramen and a slight incisure of the border of the internarial septum serving to indicate its position. In the skull of the National Museum there is no remnant of a notch; the internarial septum is very high, the postnarial process of the right premaxilla is strongly developed. If these characters may serve as an index of age they suggest again

the immaturity of Owen's specimen, for there is a wide notch between the septum and the maxillary crest and the postnarial process though long is very slender. On the other hand in the Japanese skull the internarial septum is completely ossified and shows no sign of notch or foramen, yet this skull has other characters which seemed to indicate its immaturity.

The antorbital notch also varies somewhat. In Wall's skull and in the two belonging to the American Museum it is deep, narrow at its fundus and obliquely directed. In the skull of the National Museum and in that of Owen, it is more nearly sagittal, less deep, and somewhat broader at its deepest part. The last two skulls are relatively short, are very broad between their maxillary tuberosities, and the crest between them and the vertex approaches nearly the form of a semicircle. The Japanese skull while sharing these characters has yet a very deep, narrow and sagitally directed notch, which seems to show that the form and character of the antorbital notch is determined more by local variations in the bordering processes of the maxilla than by the general proportions of rostrum and brain-case.

Norma basalis.— The general contour is irregularly pentagonal. The greatest breadth is between the postorbital processes, while the strongly projecting zygomatic processes of the squamosal interrupt the outline between malar and tympano-mastoid. Extending from the antorbital notch to the otocranial plate of the occipital on each side a series of elevations divide a median region from the enormous lateral fossæ, which correspond in a general way to orbit, zygomatic and sphenomaxillary fossæ of less modified skulls. In the roof of this region appear portions of the maxilla, malar, lachrymal, frontal, orbito-sphenoid in part covered by a lateral projection of pterygoid, alisphenoid, squamosal and tympanic. In the maxilla near its caudal boundary is the large orifice of the infraorbital canal, and mesal and somewhat more caudally at the junction of the maxilla, pterygoid and frontal is the naso-palatine foramen. The sphenoidal fissure, optic foramen and foramen rotundum are confluent in the skull of the calf; in that of the adult a narrow bar of bone separates the optic foramen from the sphenoidal fissure. From the ental extremity of this foraminal complex a groove runs forward sagitally towards the infraorbital canal between the lateral process of the pterygoid and the orbito-sphenoid, which from its direction may serve to lodge the superior maxillary nerve. The foramen ovale opens near the suture between the alisphenoid and the squamosal, being prolonged a short way on the latter bone by a groove. The small ectal orifice of the canal for the carotid artery is some distance mesad of the foramen ovale close to the suture with the pterygoid. From it a shallow groove runs caudad and laterad to the extremity of the alisphenoid that rests against

the basioccipital. This orifice and groove in the calf's skull are clearly seen to lie in a triangular plate-like extension of the sphenoid which is probably the processus ali-cochlearis. Laterad the processus ali-cochlearis is limited by a narrow fissure which on the surface runs to the foramen ovale and deeply extends to the secondary internal auditory meatus. In the skull of the calf there is a small foramen near the middle of the triangular area between the processus ali-cochlearis and the groove for the inferior maxillary nerve. The foramen leads entally into a canal which joins the foramen ovale. The suggestion lies near at hand that it is equivalent to the foramen spinosum. It is prolonged by a groove to the margin of the bone which would if the foregoing supposition is correct lodge the meningeal branch of the internal maxillary artery. Mesal to the groove a fissure runs caudo-laterad from the foramen to the margin of the bone and extends deeply to the secondary internal auditory canal. In the adult the configuration of this region is altered by the development of a plate-like extension from the margin of the squamosal which extends to the fissure just described and almost reaches the foramen ovale. In consequence the presumptive foramen spinosum and its arterial groove are concealed in the adult skull.

The median region of the base is included between the great flanges of the occipital (otocranial processes of Owen) and the pterygoids. It narrows rapidly rostrad and comes to be partially closed in by the inflected portions of the pterygoids. Caudal to the tubal notch the margins of these bones are still inflected throughout almost their whole length. In this inversion of the edge as well as in the general ectally concave sweep of the pterygoid as seen in the basal view, the skull of the American Museum differs from the other skulls available for comparison — de Blainville's, Wall's, Owen's, the Japanese and the one in the National Museum. In all of these the pterygoid is straight between the tubal notch and the occipital flange and the included median area of the base is therefore broader relatively to its length. In none of them is the free margin of the pterygoid inverted. The fissure between the basisphenoid and the presphenoid is still open but largely covered by thin scale-like extensions from the alæ of the vomer. These all but meet in the median line and largely conceal the presphenoid.

The rostrum is deeply emarginate at the tip, the sides of the notch being formed by the premaxillæ, small areas of which are interposed between the tip of the vomer and the maxilla (Wall). These latter send thin plates mesad beneath the vomer concealing it more and more towards the base of the rostrum. Upon the development of these thin plates depends the degree of exposure of the vomer in the palate. In Owen's specimen the vomer presents a wide surface between the maxillæ, wider than in any of the other *Kogia* skulls of which the basal view is available for comparison.

In this as in the dimensions of the alveolar sulcus, the widely open basisphenoid-presphenoid fissure unconcealed by extensions of the vomer, the extent of the gap between the pterygoids and the slender form of their hamular processes, Owen's specimen would seem relatively immature, although it was with young when captured. In all of the characters enumerated, except the degree of exposure of the vomer, the Japanese skull closely resembles the one described by Owen.

The pterygoids send a process obliquely rostrad across the palate bone to reach the maxilla. In consequence the palate has two separate areas of exposure between pterygoid and maxilla. The one in the front is semilunar and in contact with the opposite bone at the midline of the palate. The other area is small, subcircular and laterally placed, corresponding to the latero-caudal extremity of the palate bone. The process of pterygoid which thus crosses the palate was very delicate and fragile in the calf. It touched the maxilla but was not ankylosed to it and the palate bone had slid out from beneath and was lost. In the adult the process is broad, strong and firmly united with adjacent bones by suture. In the basal view of the skull of *Kogia* these processes seem as a rule to be imperfect or broken and a correspondingly large area of the palate is represented as exposed. The Japanese specimen in which these pterygoid processes are preserved is intermediate between the two skulls of the American Museum in respect to their size, and the lateral exposed area of the palate bone varies correspondingly.

Norma occipitalis.— This surface attains its greatest breadth between the exoccipitals at the angle in which they terminate against the squamosals. These angles are usually rounded or truncated, but in Owen's specimen produced so that they all but totally conceal the zygomatic process from behind. The junction of the exoccipital with the basioccipital is marked in the margin by a deep incisure. From this a ridge ascends a short distance towards the condyle. This marks the junction between basi- and exoccipital as is shown by an accompanying small sutural remnant in the skull of the calf. Corresponding to it there is a small projection towards the incisure partially subdividing the latter into upper and lower compartments. This is clearly defined only in the skull of the calf. From the summit of the jugular incisure a groove ascends nearly half way to the condyle terminating in a foramen, the hypoglossal canal. The dorsal border of the exoccipital ascends as far as the upper limit of the temporal fossa from which it is separated by a narrow strip of squamosal. Here may be detected a remnant of the lambdoid suture continuing the general direction of the border of the exoccipital towards the transverse crest. In the skull of the calf its all but obliterated remains are discernible as far as the vertex where it reaches the apex of the crest. The parietal thus delimited from supraoccipital extends

from the supra-temporal ridge to vertex. In the temporal fossa it is concealed by the squama and is here reduced to a paper-thin reticulum of bone which in the cranial cavity occupies the interval between frontal, exoccipital, alisphenoid and an extensive secondary ossification of the tentorium. On the surface the parietal has a moderate breadth above the temporal fossa, its convex rostral border participating in the transverse crest and tending to override and fuse with the frontal in older skulls as has already been described. Like the frontal it runs out towards the vertex in a narrow strip which, soon fused with the supraoccipital, all but loses its identity. Of the interparietal there is no trace on the surface. In the skull of the calf it seems in a greatly reduced condition to have fused with the right frontal (*vide infra*).

The contour of the skull in occipital view varies most towards the vertex. In Owen's specimen it is evenly but flatly arched between the parietals. In de Blainville's and Wall's examples it falls off somewhat towards the sides but is still broad and flat, while both skulls of the American Museum agree in greater steepness at the sides and a bluntly pointed vertex. Both have a median concavity in the supraoccipital bounded by lateral convexities, all of which are more developed in the adult.

Mandible.— The lower jaw consists of a tooth bearing portion of moderate strength and an expanded papyraceous portion opened in its whole length by the enormous inferior dental foramen. In this region a frame of thicker bone forms the borders and the remainder is reduced almost to the thinness of paper and is of great fragility. The caudal margin is supported by a crescent of stronger bone attaining its maximum breadth at the ill defined condyle and its horns becoming continuous with the upper and lower borders of the bone. These gradually become raised on the ental surface into ridges which increase rostrad in height and eventually form an inner wall for the dental canal in the alveolar portion of the jaw. Opposite the point of closure the dorsal margin of the bone rises into a flat somewhat everted tubercle, just rostrad of which the dental sulcus begins. This occupies the lateral, not the upper surface of the jaw. It is widely open and imperfectly divided into separate sockets for the teeth which are twelve in number on each side in this adult. For somewhat more than half the length of the alveolar sulcus, the mandibles are united by a symphysis. This involves the lower margins only projecting as a keel ventrad, while above a deep sulcus separates the bones. This mandible differs from others of *Kogia*, so far as can be judged from illustrations, in its slenderness. On account of the great divergence of the rami, however, lateral views are not altogether satisfactory as it is impossible to gauge the degree of foreshortening.

Gill has laid stress on the fact that Owen's specimen differed from other *Kogiæ* in its rounded, almost semicircular proximal extremity. This peculiarity Owen himself describes. Wall characterized this region of the mandible also as semicircular, yet in his illustration the bone differs widely from Owen's and has distinct though rounded angulation at the junction of ventral and caudal margins. This indication of the angle is present in all other *Kogia* mandibles and is perhaps most pronounced in the specimen in the National Museum. This jaw is also peculiar in that its dorsal margin forms a straight line in its whole length. In the adult skull of the American Museum, the postalveolar tubercle separates two well marked concavities in the outline. The Japanese specimen shows an approach to this contour. In the calf, however, the upper border is nearly straight and the angular region well marked, which suggests that these are juvenile characters.

Teeth.— The presence of teeth in the upper jaw has been recorded in three individuals. In Owen's there was one on each side in the maxilla. In the skull of the National Museum each maxilla contains two teeth. Finally Benham describes teeth, one on each side, not contained in the bones of the rostrum but in a 'sclerite' of calcified cartilage. This was situated in front of the premaxilla but separate from it and was grooved ventrally, the depression being continuous with the alveolar sulcus of the maxilla. This singular observation is in need of confirmation, and Benham appears to be mistaken in associating the absence of teeth with the loss of the sclerite, for in two cases they have been observed implanted in the maxillary and the regular persistence of the alveolar sulcus, sometimes with imperfect formation of sockets, implies the retention of teeth to a late period of fœtal life. Their existence in the adult is an individual and not a sexual peculiarity, for Owen's specimen was a female, Benham's a male.

The mandibular teeth, long, curved, slender and lacking enamel, are variable in number and curvature, those at the caudal end of the series being often closer set and with their points directed towards the angle of the mouth. The usual number is thirteen. The least number is that recorded by Owen, nine, which is the same as in Sclater's Greenpoint specimen. Both of these were females and of small size. In the calf skull in the American Museum, the mandible has nine imperfectly formed sockets in the alveolar sulcus on each side. A skull in the British Museum has 14–15 (Beddard), one at Napier fifteen (Benham). The adult of the American Museum has twelve. It would seem probable that this variation may in part depend upon age and that teeth continue to erupt after the animal has attained adult size. Apparently the caudal members of the series are in the process of reduction.

The nares.— The left nostril is oval and in general smooth walled, expand-

ing towards the surface of the head chiefly in the sagittal direction. Caudad it is demarcated from the concavity of the face by a distinct but rounded ridge of the maxilla; rostrad on the premaxilla it has no distinct boundary. A full half of its contour is formed by the maxilla overlayed laterad and in front by the thin scale-like termination of the premaxilla. From below the pterygoid ascends to meet the maxilla and like it forms about one-half of the wall of the passage. When these bones of the calf are articulated a moderate interval is left between them rostrad which must have been occupied by the edge of the palate bone. In the adult the interval is narrowed but a thin strip of palate still appears in the rostro-lateral quadrant of the narial passage. The mesal wall is formed by the mesethmoid, left ectethmoid and ventrally the vomer. In the posterior wall in the gap between pterygoid and maxilla on the one hand, vomer and mesethmoid on the other, is a shallow depression in which appears the lateral ethmoid with the foramen for the nasal nerve. In the suture between maxilla and pterygoid is the orifice of a small canal leading from sphenomaxillary fossa and probably transmitting filaments from the sphenopalatine ganglion.

The right nasal passage at its orifice is bounded by the premaxilla except mesad where the internarial septum is formed by the mesethmoid and left ectethmoid. Deeper in the passage the tuberosity of the vomer forms the rostral and part of the lateral boundary; the exposed maxillary area is much reduced and has the shape of an L reversed, the horizontal arm turning forward between the pterygoid and the tuberosity of the vomer. Near the middle of the horizontal portion of this surface is the orifice of the canal from the spheno-maxillary fossa. Rostrad of the canal the surface of the maxillary is depressed in a small fossa between the pterygoid and the vomer and here, largely covered by the pterygoid, a narrow edge of palate comes into view. Caudal to the maxilla is a second small recess corresponding to that of the right side and closed by the lateral ethmoid with the foramen for the nasal nerve.

Foramina.— Of the foramina for the cranial nerves those of the olfactory appear to be lacking. The foramen between mesethmoid and ectethmoid which leads rostrad into the nasal fossa it seems preferable to interpret as conducting the nasal nerve until evidence of the existence of an olfactorius is forthcoming. For the entrance of this nerve into the cranial cavity there are possible paths in one or other of the small foramina of the orbital plate of the frontal or in the incompletely ossified fissure between that element and the presphenoid.

The optic foramen is confluent with the sphenoidal fissure in the skull of the calf. In the adult it is on both sides separated by a very tenuous osseous lamella. In view of its late ossification the metoptic process would seem to be on the verge of disappearance.

The sphenoidal fissure is closed mesad by a process of the pterygoid and laterad a portion of frontal intervenes between the extremities of the orbitosphenoid and ala temporalis.

The foramen rotundum is confluent with the sphenoidal fissure so widely that it is represented only by a concavity in the margin of the ala temporalis.

The foramen ovale is directed obliquely through the ala temporalis. Its ectal orifice is prolonged laterad into a groove.

The combined jugulo-acoustic canal is bordered caudad by the exoccipital, ventrad by the union of that element with the flange of the basioccipital, the ectal portion of the suture persisting; dorsad the boundary is given by the exoccipital. Rostrad a process of this bone meets the alisphenoid. The portion of the greater wing which here participates is fissured in the whole length of the canal and thus appears divided into two parts. In the cranial cavity the fissure intervenes between the greater wing and a mass of bone which from its position appears to be an ossification of the tentorium. The suggestion is therefore plausible that the lateral of the two parts is a secondary membranous ossification. The cranial orifice of this canal is funnel-shaped bounded rostrad by a sharp ridge composed of the tentorial ossification and the greater wing.

The hypoglossal foramen begins in the caudal wall of this funnel and opens ectally on the caudal surface of the exoccipital near the notch which separates this element from the flange of the basioccipital.

The canal for the carotid artery is of very small size, the chief arterial supply of the brain being no doubt as in other whales by way of the vertebrals. The canal begins as a groove upon the ali-cochlearis and disappears from view in the articulated skull beneath the pterygoid. It pierces the ala temporalis, appearing in the cranial cavity mesal to the foramen ovale at the side of the basisphenoid.

Smaller vascular foramina lie in the fronto-maxillary suture and are continued into canals on the cerebral surface of the maxilla. A small foramen pierces the alisphenoid caudo-lateral to the foramen ovale and joins that canal close to its ental orifice. Just caudal to that orifice a minute canal leads into the fissure between the processus ali-cochlearis and basioccipital.

The cranium of *Kogia* appears from the foregoing compilation to be subject to a considerable degree of fluctuating variation. With the data at present available it is impossible I feel to distinguish sexual characters, for Sclater's inference that the long mandible and implicitly the long rostrum belong to the male appears invalidated by the fact that these characters are highly developed in the adult of the American Museum which is a female.

On the other hand it is possible tentatively to assign certain characters to the period of immaturity and the following list indicates such peculiarities

as are common to the calf of the American Museum and the smaller specimens that are recorded in the literature:

The visible extension of the frontal towards the vertex.

The partial persistence of the parieto-occipital suture.

The sinuous form of the maxillo-malar suture.

The incomplete synostosis of the mesethmoid and left ectethmoid.

The less development of the mid-facial crest and of the tubercle of the right premaxilla.

The tenuity of the infrapalatine processes of the pterygoids.

In the calf alone may further be observed a persistence on one side of the suture between the lachrymal and malar, a confluence of the optic foramen with the sphenoidal fissure, and a faint trace of the compound nature of the pterygoid. The comparison of the calf with the adult female shows further a tendency in maturity to develop free borders into over-riding plates of bone, *e. g.*, from the squamosal upon the alisphenoid, from the maxillaries beneath the vomer and from the orbital plate upon the lachrymal.

Architecture.— The elements of the rostrum are joined to one another by broad simple surfaces of contact, only as the nasal region is approached are interlocking processes and ledges developed. The robust mesethmoid and septal cartilage form a stout axial support to the center of which is applied the strong trough of the vomer. Upon the sides of this axis abut the maxillaries and premaxillaries, the former sending forth a shelf beneath the vomer on each side, the latter at least at the base of the rostrum tending to overlay the vomer and mesethmoid dorsally with a plate produced from their mesal margins to a degree which increases slightly with age. All the sutures between these elements persist in the skull of the adult. This simple apposition of the several elements seems to stand in relation to the shortness and breadth of the rostrum, sufficient rigidity being afforded by the bulk of the individual elements to resist stresses acting with so short a leverage, without the development of a more intimate union and welding together of the component parts.

When it comes to the connection of the rostrum with the cranium, simple contacts seems to be no longer adequate and surfaces of reciprocal reception with interlocking process are substituted. The major rôle in giving stability to this junction devolves upon the maxilla which in the Cetacea establishes intimate and extensive contact with the frontal, coming to override it dorsally and ventrally by supra- and infrafrontal processes. While a greater or less degree of dorsal overriding (suprafrontal process) is regularly present, the infrafrontal process is conspicuous only in Mystacetes. It may be present in a reduced condition however in Odontocetes, as for example, in these

skulls of *Kogia*. When both processes are present as, *e. g.*, in *Balænoptera*, the frontal, in particular its orbital palate, comes to lie between two arms of the maxilla and receives the backward thrust of the rostrum as the beast moves through the water.

The pressure thus brought to bear upon the frontal is no doubt a factor in determining the lateral position of the orbit and from the need of additional support may serve to explain the enlargement caudad of the post-orbital process to the point of fibrous contact with the squamosal.

Though the maxillaries with the right premaxilla thus provide firm support to the rostrum, auxiliary means of fixation are present in the mesethmoid and the two pterygoids. The mesethmoid, however, from its asymmetry and the thinning of its proximal portion by the enlargement of the left nasal passage, can be looked upon as possessing but moderate strength, while the alæ of the vomer are so thin that no real mechanical importance can be attached to them. The pterygoids, extending obliquely from the maxillæ to the stout flanges of the basioccipital, are moderately thick plates projecting ventrally from the skull and so placed as to serve as a brace to the moderate angle formed by the facial and basicranial axes. As it approaches the maxilla, however, the pterygoid becomes greatly reduced in height and expands laterad into a thin plate. Its surface of articulation with the maxillary is but small and that for the palate though wide is not characterized by strong ridges. It would seem therefore that though bracing the rostrum against displacement ventrad and serving also to attach it to the brain case it could hardly be called upon to resist forces of great magnitude in either a transverse or dorso-ventral direction. The latter displacement would seem rather to be provided against by the mesethmoid and in the dorsal direction in addition by the ventral overlapping of the vomer on the part of the maxillaries. Even so, the conformation of the fronto-maxillary articular surfaces and the diminished thickness of the mesethmoid proximad suggest no great demands for support, a supposition borne out by the lightness of the structure of the mandible and the very moderate size of the temporal fossa.

It would seem warranted to conclude therefore that the chief mechanical factor in determining the nature of the attachment of the rostrum to the cranium in *Kogia* is resistance to the pressure of the medium through which the animal moves. The shortness of the rostrum, notwithstanding its breadth, coupled with the delicacy of the lower jaws, would seem to render special provision against dorsal deflection superfluous.

The architecture of the cranium is dominated by the great transverse crest extending between the orbital roofs. While the core of this is, as might be expected, formed by the frontal, yet this bone is compressed to a paper

thin plate between the massive maxillaries and the supraoccipital. There seems to be a reduced interparietal at the vertex, but the parietals have here lost their independence in the calf as well as in the adult. The surfaces of apposition are very broad and the crest forms an arch of massive bone which in section would have slight rostro-caudal extent, but on the other hand a very considerable depth. Traced to the sides it expands into a triangle of thick bone extending rostrad to the orbital plates and caudad including the tip of the alisphenoid, the squamosal and portion of the exoccipital. It thus corresponds in general to the anterior and posterior pillars of the vault with a thickening of the intervening junction of lateral wall and floor of the cranium as compared with other mammals. The sagittal line here indicated is reinforced in Cetacea by the fibrous contact between the postorbital process and the zygomatic process of the squamosal.

In comparison with the transverse arch and its lateral abutments thus enumerated, the remainder of the brain case is less massive, though its rostral wall composed of the maxillaries reinforced by the right premaxilla and the strong facial crest fall but little short of the arcade and far exceed the other parts of the cranium in thickness.

The remaining thickened areas can be briefly enumerated. A ring of thick bone supporting the condyles surrounds the foramen magnum; from this a narrow zone of relatively massive bone extends laterally through the exoccipitals to reach the caudal angles of the triangular lateral thickenings, and a sagittal one reinforces the midline of the supraoccipital reaching the vertex. These all project entad but are apparent on holding the skull to the light.

The elements of the basicranial axis are not conspicuous for their strength but are broad and of only moderate thickness, in fact, on each side of the median line they are translucent when held to the light. As a whole this region does not seem qualified to play more than a subordinate part in supporting the thrust of the spine against the cranium as the animal propels itself with its flukes. Indeed the high position of the condyles and their extension dorsad far above the level of the basicranial axis would preclude the supposition that this force could act directly through the axis. The architecture seems rather to indicate its resolution along the ridges above described, mesally to the transverse crest at the vertex and sidewise to the ends of its lateral expansions. The large proportion of the thrust thus supported may account for the lack of robustness in the elements of the basicranial axis, especially when it is borne in mind that additional bracing is provided ventrally by the articulation of the pterygoids with strong flanges of the basioccipital.

The Cranial Bones.

The cranium of the calf permitted of partial disarticulation. The bones of the rostrum were readily removed as were also the pterygoids, malars and tympanics. One squamosal also was loose and was isolated. The remainder comprising the greater part of the cranial wall was firmly united and many of the sutures were partially or completely obliterated.

The skull is in generally good preservation, although the bones are extremely brittle and some of the processes are broken at their tips. Both palate bones and both periotics are missing as is also the left premaxilla, but its extent is easily determined by its impression upon the maxilla.

The dimensions of this skull have already been given in the comparative table and its salient peculiarities of form have been noted in the description of the skull as a whole. In what follows it is purposed to confine attention to the individual elements in so far as they can be isolated or their extent ascertained.

Occipital.— The several elements of this bone are already firmly united, and in addition the parietals are fused to the supraoccipital and the suture between the basisphenoid and basioccipital has been obliterated. No trace of that between supra- and exoccipitals can be discerned. Ventrally a notch intervenes between the otocranial flange of the basioccipital and the exoccipital and here a small remnant of the suture between these elements persists; a low ridge prolonged towards the condyle seems to mark the obliterated portion of the suture. The condyles are elevated a little above the adjacent surface, are rather narrow, their broader ventral ends are separated by a distinct groove. The greatest breadth lies opposite the slight angulation of the mesal border at the level of the ventral margin of the foramen magnum. Here the right measures 24 mm., the left 27 mm. The right condyle on the other hand is somewhat longer, 69 mm. as against 67 mm. for the left. The foramen magnum also is slightly asymmetrical being distinctly more convex to the right. Its sagittal diameter is 42 mm., its maximum transverse is 38 mm.

Basisphenoid.— The basisphenoid is short and very broad and has already coalesced with the alisphenoids and basioccipital. Entally its union with the latter is marked by an elevated ridge just in front of which at the sides are the orifices of the basisphenoidal canals. The surface in front of the ridge is concave sagittally, convex from side to side. In the midline there are a few vascular foramina and a small conical tubercle (dorsum sellæ). Ectally the surface is flat and broadens caudad to the basioccipital. The median area is smooth. At the sides where the greater wings arise, are

rough triangular areas for the pterygoids, mesal to which a thin, high lamella of bone prolongs the flange of the occipital.

Alisphenoid.— The greater wings are of large size expanding laterad as far as the infratemporal crest and caudad to the jugulo-acoustic canal. The ectal surface beyond the pterygoid area just mentioned is free. Rostrad it is limited by the orbital fissure and the sphenofrontal suture. A broad scallop in its fissural margin represent the foramen rotundum. From the infratemporal crest to the caudal angle extends the spheno-squamous suture. Close to the infratemporal crest the alisphenoid is thin and, drawn out into a triangular plate, overlies the frontal as well as the squamosal. In the rest of the suture the bone abruptly thickens and rests against the squamosal with broad surfaces of apposition which are almost smooth.

Presphenoid.— This is fused with the ethmoid and vomer but free from the orbito-sphenoids. The basal surface is all but concealed by the first mentioned elements. The cranial surface is hexagonal and marked by a low median ridge between shallow concavities. The rostral border is fused with the ethmoid, as has been already stated; faint traces of the suture persist running laterad from the nasal foramina. The rostro-lateral margin articulates with the frontal, the caudo-lateral with the orbito-sphenoid. The caudad border is pitted for cartilage, the fissure between this bone and the basisphenoid being still open. Ventrally the pterygoid covers the presphenoid at the sides in its whole length and sends a process into the cleft between it and the basisphenoid which forms the mesal closure of the sphenoidal fissure.

Orbito-sphenoid.— The ala-orbitalis occupies the mesal portion of the groove in the orbital plate of the frontal. It is fused with this so completely that on the cranial surface its outlines are lost. In the orbit its contour is just perceptible, following the ridge in front of the frontal groove and then arching across the concavity to the end of the sphenoidal fissure. Where it forms the boundary of the fissure it is marked by a deep notch, the optic foramen, from which a groove runs laterad on the orbital surface, a second mesad on the cranial. From the ridge which bounds the former groove mesad, the whole surface of the orbito-sphenoid is covered ventrally by the pterygoid.

Ethmoid.— The mesethmoid occupies the trough of the vomer and is correspondingly broad ventrad and contracted dorsad. In cross-section it is ovoid coming to a point above and strongly concave on the left side. Its rostral extremity, rough and pitted for the attachment of the septal cartilage, lies opposite the prenarial tubercle of the left side. The mesethmoid becomes much thinner where it forms the internarial septum and here it is deflected to the right, strongly in its ventral portion, hardly at all near its

dorsal margin, so that it comes to form an oblique wall between the nares. Caudally it is fused with the presphenoid. The junction is covered at the sides by the alæ of the vomer, also syostotic, but even ventrad where it is exposed by the gap in the vomer no trace of the union can be made out with certainty.

Attached to the dorsal edge of the mesethmoid is an irregular mass of bone which is apparently representative of the lateral ethmoids. Towards the cranial cavity it presents a triangular surface marked off from the presphenoid by a pair of foramina and lateral to them the remnants of sutures; a faint transverse groove connects the foramina. Their ectal orifices are in the nasal fossa close to the dorsal margins of the alæ vomeris, that of the right side distinctly on a more ventral level than the left. The dorsal surface of this ethmoidal mass is rough and irregular. Rostrad it is drawn out into two processes of very unequal size. That on the left is the larger and intervenes in the articulated skull between the narial septum and the extremity of the crest of the left maxilla, being separated from the former by a notch, which in the adult skull is partly closed to a foramen. Its left surface appears in the narial passage and overhangs the orifice of the canal for the nasal nerve. Its right surface is partly covered by its apposition to the postnarial projection of the right premaxilla, in front of which it appears in the mesal wall of the right nostril. The right process is much smaller and depressed ventrad. It enters into the right nasal fossa forming a portion of its caudal wall above the foramen for the nasal nerve. Laterally it articulates with the right maxilla and dorsally is concealed by the postnasal projection of the right premaxillary. These two asymmetrical projections, on account of their relation to the nasal fossæ and to the mesethmoid as well as to the canal for the nasal nerve, are to be interpreted as lateral ethmoids. The area caudal to the right ectethmoid and the rough triangle in which this dorsal surface terminates are covered by the right maxilla which leaves an oval rough facette exposed immediately caudal to the left ectethmoid. This is covered in the articulated skull by the premaxilla.

Nasal bones.— Owen describes these elements as confluent with the midfacial crest. In this he is probably in error, for in all Odontocetes they are displaced toward the vertex. Influenced by conditions in *Physeter*, Wall believed he detected evidences of a scale-like left nasal applied to the surface of the maxillary. Other authors are silent on this matter. In neither of the skulls of the American Museum is there a trace of either nasal bone.

The vomer.— The trough is broad to accommodate the thick septal cartilage; it enlarges slightly to its terminal quarter and then contracts again towards the tip of the rostrum. Its sides ascend well upon the cartilage, attain considerable thickness proximad and terminate in conical prenarial

processes on reaching the confines of the nasal fossæ. These projections are markedly asymmetrical in correspondence to the disparity in size of the nasal passages. That of the left side points laterad at the level of the end of the mesethmoid; the large one on the right is directed caudad and is received in an excavation of the maxillary close to the junction of its rostral and frontal portions. Ventrally the vomer has an axial ridge which terminates caudad in a small elevation concealed in the natural condition of the skull by the palate bones. The ridge however is exposed in the palate, for the maxillaries do not meet here though close together at the point where they are overlapped by the palate bones. Because of the concavity of the borders of the maxillaries, the exposed surface of the vomer has the shape of a narrow oval; this in the calf attains its greatest width in the middle of the rostrum and not in its terminal third as in the adult where its contours also are more angular. Both the medial ridge and elevation of the vomer are faintly grooved. In reference to this ridge, which coincides with the midline of the skull, the vomer is markedly asymmetrical, the width of its left side being approximately half that of the right. Caudal to the elevation in which the ridge terminates the vomer becomes thin and scale-like and following the deviation of the mesethmoid turns to the right and divides into the enormous alæ. These are very thin and at first embrace the sides of the mesethmoid entering into the mesal walls of the nasal passages, they then rotate through 90° and extend as far as the basisphenoid-presphenoid fissure. In the adult they extend farther unlying the basisphenoid with a thin irregular scale of bone. Where they are applied to the presphenoid they are broad and extend far laterad; on the right side a contact is formed with the frontal, on the left a very narrow strip of presphenoid intervenes. While synostosis has already begun between the vomer and the bones of the axis on the left side, it is still possible to follow the contours of the ala in its entirety, on the right its outline is lost in the nasal fossa though retained caudally. On account of the depth of the notch between the alæ, the mesethmoid is exposed ventrally in its internarial portion.

The premaxilla.— The left premaxilla was lacking in the younger skull, save fortunately its narial extremity, a thin scale of bone adhering to the maxilla in the lateral wall of the nostril. The area of its contact with the maxilla could be recognized by the character of the surface of the latter bone.

The right premaxilla is divided by the notch of the naris into a rostral and a frontal portion. The former is curved and its dorsal surface is more tapering than in the older skull; its lateral margin as yet lacks the somewhat angular change of direction in its terminal fourth. A short distance in front of the nostril it presents the orifice of a canal leading from the spheno-maxil-

lary fossa. The lateral margin at the level of the nostril takes part to a minimal degree in forming the wall of a larger canal leading from the same fossa. In the older skull the premaxilla forms nearly a half of the circumference of this foramen, which coupled with the more vertical course of the canal, may indicate relative expansion during growth of this portion of the premaxilla. The ventral surface near its lateral margin presents the orifice of the first of the above mentioned canals, and from this point rostrad is marked by a high strong ridge or projecting plate which is fitted into the interval between the maxilla and the vomer. The terminal portion of this ridge appears as a linear strip on the palatine surface of the rostrum; its subsequent expansion at this point being as yet barely indicated. Lateral to the ridge the surface rests against the maxilla; the surface mesal to it forms with that bone a sagittal concavity which is occupied by the vomer, exception made of two small areas adjacent to the nares. Here the ventral portion is overlapped by a plate arising from the pterygoid, while dorsally a blunt projection forming the rostral boundary of the reduced nostril rests against the mesethmoid.

The frontal process is transversely expanded and prolonged to the summit of a great crest which marks the vertex of the cranium. Near the vertex in the adult the bone is narrowed to a tongue-like process; here it is shorter and broadens gradually into the remainder of the bone. Laterally at the junction of the middle and first thirds near the margin is a low triangular eminence, other than which there is as yet no evidence of the subsequent marked elevation of this margin. Mesally the border rises in a moderate crest, which rests against and is over-topped by a similar sagittal elevation of the left maxilla. The surface turned toward the latter bone is marked by a longitudinal groove which receives a ledge of the left maxillary. Ventral to this the maxillary has a flange which fits into the interval between the premaxillary and the maxilla of the right side. The junction of the bones along the facial crest is by a series of interlocking projections as though this region of the skull had to withstand stress which from the direction of the structures in question would seem to be chiefly in a direction at right angles to the surface. Ventrally the frontal process of the right premaxilla rests broadly upon the maxilla of the same side, towards the median line overlapping that of the left side. Just behind the nostril a process crosses the median line and by its deep surface articulates with the coalesced ethmoidal rudiments.

The maxilla.— The maxillaries, like the right premaxilla, are conveniently divided into rostral and frontal portions, the demarcation afforded by the nasal fossæ and the very deep antorbital notches. Both portions differ markedly on the two sides. The bone of the right will serve throughout as a basis of description, the peculiarities of the left being summarized at the end.

The rostral portion is exposed in about half its breadth. This surface is concave in front of the infraorbital canals; behind them it rises in a broad ridge which forms the median margin of the antorbital notch and presents caudally the orifice of a large canal leading from the infraorbital fossa. The elevation of the lateral margin is inconsiderable, save that the process in front of the antorbital notch is well developed and has about the same configuration as in the adult. The remainder of the dorsum of the rostral portion articulates with the premaxilla and the vomer. A ridge intervenes between their respective areas and becoming high and jagged towards the base of the rostrum passes into the frontal portion of the bone.

This latter is deeply concave, the greatest depression corresponding with the ridge between the frontal surface and lachrymal areas of the ventral surface. Mesad there is the broad rough surface of contact with the premaxilla, convex near the midline but becoming concave laterad where it lodges the expanded part of the premaxillary. Here a sharp ridge limits the articular surface and separates it from the exposed area of the pars frontalis.

The mesal border articulates with the left maxillary. It is thick, rough and convex, and is received in a slight groove in the border of the left bone. The intermaxillary contact extends from the vertex forward to a quadrangular plate on the right side, which projects strongly to the left crossing the midline and intervening between the left maxillary and the ethmoid. This is covered in the articulated bones by a process of the right premaxilla. In front of this the border rests against the ectethmoid, beyond which again is a small L-shaped area which enters the lateral wall of the nasal fossa. In the ventral part of this is a fissure which leads mesad from the region of the infraorbital canal. The rostral arm of the L extends upon the nasal side of the pterygoid elevation of the maxilla and on the right side comes to be largely overlapped by a scale of the pterygoid. Near its rostral extremity is the foramen of a canal leading from the infraorbital fossa. The orifice lies in a lozenge-shaped cleft between the maxilla, palate and vomer, forming a small lateral and rostral extension of the nasal fossa. It is present and slightly larger in the adult, but lacking altogether on the left side. From the foramen rostrad the margin is sharp. It is directed mesad as well as rostrad as far as the articular surface of the palate, whence it recedes more gradually towards the tip of the rostrum. Its most mesal point just fails of reaching the corresponding projection of the opposite maxillary. The lateral margin increases in thickness from the vertex to the antorbital notch, thence diminishing rostrad. The latter segment lacks as yet the upward rolling of the adult.

The left bone differs from the foregoing in the following particulars. In its rostral portion the subvomerine shelf is narrower. The ridge beside

the antorbital notch is small and narrow. The surface of the bone is depressed to form a funnel shaped approach to the nasal fossa. Instead of forming a clearly defined L-shaped area as on the right, it extends ventrad to meet the pterygoid in a long suture in which appears rostrad a narrow edge of palate. The scale-like extremity of the premaxilla simply overlies the maxilla leaving the latter widely exposed in the nasal fossa below it. The concavity of the frontal process is increased by the high sagittal flange which participates in the facial crest, the right bone being excluded by the premaxillary. Finally on the ventral surface the ridge between the cerebral and lachrymal areas is less pronounced.

Ventrally only a triangle of the maxillary is exposed to form the bulk of the palatine surface of the rostrum. This differs only in detail from that of the adult; the alveolar gutter is relatively longer, the concavity mesal to it is shallower; the surface as a whole less extensive transversely and as yet lacks the rolled character of the free margin. This area is limited caudad by an arched line beginning at the most projecting point of the mesal border and extending to the antorbital notch, where it rises into a ridge-like process to articulate with the lachrymal. Caudal to the arched line, at the mesal margin is a triangle for articulation with the palate; this by its caudal apex is continuous with a roughened elevation for the pterygoid. Between the palate and pterygoid mesad and the lachrymal laterad is an exposed surface, less concave than in the adult, near the caudal limit of which appears the large orifice of the infraorbital canal. The mesal margin of this foramen is undermined and jutts out in a thin triangular lingula. Behind this, mesal to the foramen, the bone is marked by transverse sulci one of which deepening to a cleft leads into the nasal fossa. The infraorbital canal at its beginning is an ovoid fossa in the maxillary, considerably larger and deeper on the right than on the left side, from which smaller canals run rostrad and dorso-laterad, the former to open upon the rostral surface of the premaxilla (one) and maxilla (R. five, L. three), the latter (two) upon the frontal process of the maxilla. Of these latter on the right side one opens in the premaxillary-maxillary suture. The exposed surface caudal to the infraorbital canal is formed by a transverse elevation, the lateral extremity of which overrides the tip of the lachrymal and articulates with the frontal. Rostrad it bounds a foramen in the suture with the lachrymal, which was in the adult much the shape of the impression of a finger nail. In this suture are the beginnings of arterial sulci, one passing mesad and one caudad to reach the cranial cavity by way of the fronto-maxillary suture and to be continued as branched systems of grooves on the cerebral surface of the maxilla.

The remainder of the ventral surface consists of a cerebral surface entad and a broad marginal area for articulation with the malar, lachrymal and

frontal. The area for the lachrymal extends from the transverse elevation behind the infraorbital canal to the depression for the conical process of the malar and behind this is prolonged nearly to the border of the bone. The surface for the malar extends from two concavities separated by a low obliquely transverse ridge to the antorbital notch and the lateral margin. The rounded rostral border of the lachrymal is received in a corresponding concavity of the maxillary mesal to the antorbital notch, and here between the notch and the infraorbital canal a scale-like plate of maxillary overlies the lachrymal. In the adult this has increased in size and is marked with ridges interlocking with similar ridges of the lachrymal. In the young skull they are absent on both bones. The tip of the lachrymal fits into a conical depression of the maxilla beneath the elevation immediately caudal to the infraorbital canal.

The surface for articulation with the frontal has two subdivisions; one overlying the orbital roof is relatively smooth and lies in the same plane as the area for the lachrymal. This surface is roughly triangular. The remaining surface of contact with the frontal is marked by parallel ridges which curve from the cranial cavity dorsad and laterad. As a whole this surface is convex latero-mesad. Sagittally it has a sinuous contour with a tendency to angulation at the point where the frontal becomes reduced to a narrow plate.

The cranial surface has a fairly developed vitreous and shows vascular channels directed from the sides horizontal with a marked ascent as they approach the midline. Here the surface is narrowed by the downward projection of the interparietal above and the area for the presphenoid and coalesced ethmoid below.

The malar.— Much uncertainty has prevailed regarding the margin of the orbit in *Kogia*, and in particular the nature of the closure of the gap between the zygomatic process and the extremity of the malar. This is grooved at its tip between two tuberosities and the surface might serve as well for articulation as for the attachment of a fibrous arch. It has therefore been open to question whether the jugal might not have disappeared and the element so named be really interpreted as lachrymal, or perhaps as lachrymal and malar, with the zygomatic process of the latter reduced to ligament. Le Danois has described and figured a fibrous infraorbital arcade, but this extended to the exoccipital and the condition of his specimen was far from favorable. In a dissection of a new born *Kogia*, this structure was found to be the facial nerve. On the other hand, a perfectly definite ligamentous arch was present connecting the tip of the malar to the zygomatic process of the squamosal. Very fortunately the skull of the calf on the left side has a separate malar and lachrymal, the latter mesal

in position and interposed between the maxilla and the frontal. It is evident, therefore, that the usual elements are present but that the zygomatic process of the malar has been reduced so that it no longer appears as bone.

The malar is an irregular pyramid in form. If the lateral surface is taken as the base the three remaining surfaces are indicated in a general way by the direction of its borders. Instead of an apex however there is a notch between two conical processes which are received in corresponding depressions of the maxilla and lachrymal. The dorsal surface abuts against the maxilla; the surface of articulation conforms to the sinuous maxillo-malar suture consisting of two transverse ridges separated by a groove. The ventral surface is covered by the lachrymal as far laterad as the low ridge which runs latero-caudad from the antorbital notch, and this ridge on the left side and in the adult alone serves to demarcate the two bones. The exposed surface beyond the lachrymal calls for little comment. The zygomatic process is directed ventrad almost as in the Owen-Elliot skull and similarly is separated from the preorbital process by a relatively wide fissure. Correlated with this direction of the process is the inclination of the ventro-rostral exposed surface which rises more above the level of the maxilla and faces more mesad than in the adult.

The lachrymal.— This is of but moderate size, its maximum transverse measurement being 54 mm. by 48 mm. sagittally. Its greatest thickness is 19 mm. The ventral surface is divided by a transverse ridge, caudal to which the bone is covered by the frontal. The smaller area in front of the ridge is free except rostrad where it is overlain by a plate-like extension of the maxilla, in consequence of which the exposed surface in the articulated skull is reduced to an L-shaped area. The dorsal surface bears the imprint of the malar in its lateral half. Between the concavities for the two conical processes a spine rises which fits into the notch of the malar. Mesal to this the surface is rugose and articulates with the maxilla.

Frontal.— The frontal ventrally is expanded into a massive orbital process with a considerable extension into the temporal fossa, and correspondingly participates in the closure of the cranial cavity. The remainder is pressed into a thin plate between the maxilla and the parietal extending almost to the vertex and fused to the parietal with which it unites to form the transverse crest. Between the frontals therefore is a wide gap where the maxillæ enter into the cranial wall. The orbital plate is grooved ventrally in its mesal two-thirds and the greater part of the groove is occupied by the orbito-sphenoid. On the cranial surface the suture uniting these elements has been obliterated but a faint remnant can be seen in the roof of the orbit. The frontal sends processes mesad both in front and behind

the orbito-sphenoid. The rostral one is the longer and extends mesad to articulate firmly with the presphenoid and on the right side with the edge of the ala vomeris as well. This it just fails of reaching on the left, there being interposed a narrow strip of presphenoid. The caudal process reaches the extremity of the sphenoidal fissure. The caudal margin of the frontal runs laterad and caudal from the sphenoidal fissure to the infratemporal crest along which it passes caudad to reach the squamosal. It then ascends to the supratemporal crest; following which a short distance it becomes convex rostrad and then turns towards the vertex along the transverse crest. From sphenoidal fissure to infratemporal crest the frontal articulates with the ala temporalis. In the temporal fossa it is in contact superficially with the squamosal but deeply towards the cranial cavity with the reduced and fenestrated plate of the parietal. This bone thickens and comes to the surface at the supratemporal crest and thence towards the vertex is intimately joined to frontal though a remnant of the suture persists on the ectal surface of the skull. The lateral surface of the frontal is much like that of the adult, the pre- and postorbital processes are less developed, especially the latter and the supraorbital notch is feebly indicated. The angle that intervenes between parietal and maxillary is slender and acute and the only difference here from the adult is that the frontal may be followed almost to the vertex and is not yet completely amalgamated with the parietal. At the vertex the frontals are not in contact but are separated by an interval of about 1 cm. which is occupied by parietal and a median ridge of bone partly separate from parietal but synostosed to the right frontal which I take to be the interparietal.

The squamosal.— This bone in the articulated skull is deeply engaged between the frontal rostrad, the 'mastoid' process of the tympanic caudad, the exoccipital and parietal dorsad. Entad it abuts against the ala temporalis and the parietal. The mesal surface falls into two portions of very different character. Where it is in contact with frontal and parietal it is rough and marked with ridges of obliquely caudo-ventral direction. A rather deep groove intervenes between the frontal and parietal areas. The former has the shape of a pyramidal elevation and is received in a depression of the frontal. The parietal area is larger, elongated and imperfectly separated from the cranial cavity by a fenestrated plate of parietal, through the foramina of which it is visible from within. The surface for the ala temporalis, in strong contrast to the foregoing, is smooth and flat. It is roughly quadrangular and is surrounded by elevated edges which embrace the alisphenoid on all sides. These are thin and delicate except the caudal which forms a strong wedge received in a groove of the ala temporalis and abutting upon the junction of that bone with the occipital which excludes

it from the wall of the lacerated foramen. Dorso-caudally the bone articulates with the parietal and exoccipital, meeting the former with a convexity and the latter with a concavity. A ridge separates the surface for the exoccipital from the moderate concavity for the tympano-mastoid. This is limited by a rough projection mesad which is free. Mesad there is another concavity corresponding to but not in actual contact with the periotic.

Of the remaining surfaces the temporal is defined by strong temporal and infratemporal crests. It forms the mesal and caudal wall of the fossa and is correspondingly concave. The lateral and zygomatic surfaces are separated by a long compressed plate, projecting ventrad, broken in the skull of the calf but well preserved in that of the adult. It seems to include the glenoid fossa together with the zygomatic and postglenoid processes. The fossa is an ill-defined concavity of the mesal surface, in a part of which the cortex is deficient, exposing the spongiosum. The zygomatic process is produced ventrad. Near its base is a small tuberosity projecting towards but not meeting the postorbital process. Beyond this the rostral surface is smooth as though for articulation with the malar.

The postglenoid process is thin and little more than a projecting angle. The zygomatic surface slopes away from the glenoid region. It is divided by an oblique ridge into a quadrangular mesal portion fitted between ala temporalis and processus ali-cochlearis and lying in the same plane; and a lateral, depressed and adjacent to the tympano-mastoid which is rough and marked by ridges and tubercles.

The pterygoids.— As a whole the 'pterygoid' forms a plate of general vertical orientation, convex laterad and attached to the basis cranii along an oblique line extending from the maxilla to the basioccipital. Rostrad its palatine portion is strongly inflected, forming a horizontal shelf and meeting its fellow for about one-fourth of its length. In this palatine region the bones are more asymmetrical than in the adult. The left one is broader, more strongly curved and having a greater concavity of its mesal margin, differences which are hardly to be perceived in the skull of the adult. The rostro-lateral angle is drawn out into a plate-like process, thin and narrow as compared with the adult, and by its tip barely touching the maxillary, with which it subsequently articulates firmly. By its deep surface this process is in relation with the palate bone, which in the adult is exposed only in front and behind it. Caudal to this process the border in the calf is smooth and sharp, in the adult jagged and overlying the palate. Caudal again is a rough concavity with elevated thin edges to embrace the pterygoid elevation of the maxilla. Behind this the pterygoid expands transversely, articulating with the ala of the vomer and sending laterad a strong process which is in contact with the adjacent region of the frontal and with the

venter of the ala orbitalis, these elements here excluding it from contact with the presphenoid. Into the interval between the body of the presphenoid and basisphenoid however it projects by a conical process which interrupts the continuity between the sphenoid fissure and the basisphenoid-presphenoid cleft in the dry skull. Caudad to this is a rough triangle to articulate with the processus alaris, beyond which the pterygoid is applied to the lateral surface of the basi-occipital flanges. In this terminal portion the margin is thicker, smooth and received in a groove on the occipital. The free margin has a deep Eustachian notch, not constricted at its entrance as in the adult. The hamular process is thickened, narrower than in the adult and more pointed. In the suture line between the maxilla and pterygoid just behind the pterygoid eminence of the former and partly roofed over by the frontal is a large foramen leading into the nasal fossa. Another canal runs between the ala vomeris and pterygoid.

In the border of the tubal notch is a small furrow, the only indication of the two elements which compose the pterygoid among the Ziphioids. These are a caudo-lateral plate mainly behind the notch and a rostro-mesal which bears the hamular process and corresponds to the internal pterygoid of less modified skulls. Of the pterygoid apophysis of the alisphenoid there is no clear indication.

Os tympanicum.— The tympanic consists of an ental portion or bulla of smooth and very dense bone and a much larger lateral portion of irregularly pyramidal form which fits between the squamosal, the exoccipital and the otocranial flange of the basi-occipital presenting its broad base in the lateral surface of the skull. It thus imposes at first glance as a mastoid but is actually entirely free of the periotic both in the calf and in the adult. The dorsal surface in its ventral third is smooth and flat articulating with the otocranial flange. The remainder of the surface fits against the extremity of the exoccipital which it receives in a groove beyond which the margin is thick and tuberous. The concave surface is marked by narrow parallel furrows so that the bone appears to be made up of osseous strips laid close together and curving dorsad beyond the groove to present their extremities upon the thick margin. Mesal to this striated groove is a rectangular facet of dense bone, slightly convex in both directions and rising at its caudal margin into a low ridge. This region evidently corresponds to the processus petrosus ossis tympanici of Denker. It resembles that process of *Phocæna* further in the cavity in its interior which communicates with the tympanium, but the bone of *Kogia* is remarkable for the enormous expansion of this element into what for want of a better term may be called tympano-mastoid and further in the absence of anchylosis between it and the periotic which in *Phocæna* is established at an early period (Hyrtl). The free ventral

surface of the tympano-mastoid is thick and massive rostrad, depressed into an elongated fossa in its caudal portion. The floor of the fossa is rough with thin osseous lamellæ set on edge. It attains its greatest depth close to the bulla with the result of reducing the processus petrosus to a plate of but moderate thickness at the mesal extremity of which the bulla is attached by a slender pedicle.

The bulla is rather short and broad. Its ventral surface has the shape of an irregular parallelogram. The long axis is nearly transverse. The rostral border is strongly rolled. The processus sigmoideus is large, almost egg-shaped with the smaller end ventrad. From its poles two ridges run mesad bounding a depressed area which has its mesal limit in a small elevation, probably corresponding to Denker's processus conicus anterior. In this case however it is mesal in position for the axis of the bulla is transverse, nearly at right angles to its direction in *Phocæna*. Of the ridges running from the processus sigmoideus, the rostral continues into the free margin of the bulla losing its identity at the point where the malleus is anchylosed. The caudal stops at the extremity of an oblique ridge or rather fold of the ventral surface, for it is visible entally as a groove, the only one

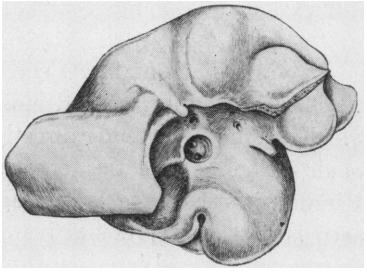

Fig. 1.

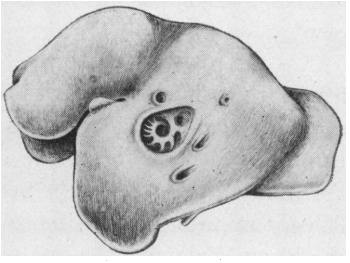

Fig. 2.

Fig. 1. Right periotic of adult, ectal surface. Twice natural size.
Fig. 2. The same, ental surface.

present in this bulla. The processus conicus posterior s. lateralis is obscure. The mesal spout-like portion of the tympanic is short and not much narrower than the lateral portion from which it is set off by a groove ectally and a ridge entally. Just lateral to the groove is a prominent tubercle.

The dorso-rostral surface is turned toward the periotic. This comprises the two lips of the bulla and the interval between them. The caudal lip is heavy and strongly rolled, presenting near its middle a shallow concavity which lies opposite but not in contact with the caudal pole of the pars cochlearis. The rostral lip is thinner and has a more complicated contour; from

the annulus tympanicus it is directed mesad and is notched close to the processes sigmoideus which projecting rostrad overhangs the interval between the lip, of the bulla. At the end of the ridge continuing this process mesad is the attachment of the malleus, and mesal to this the margin is prolonged into an uncinate process which, strongly bent upon itself and with a globose enlargement of its deflected extremity, is received in a concavity of the periotic and firmly anchylosed with that bone.

The bulla is attached to the tympano-mastoid by a pedicle springing from the extremity of the processus perioticus. This consists of a stronger portion directed caudad and mesad from the caudal angle of the process to the caudal lip of the bulla and a thin lamella continuous with this but directed nearly ventrad towards the ventral wall of the bulla. The latter is deeply incised, the incisure together with the notch in the processus sigmoideus evidently serving for the attachment of the drum membrane.

Os petrosum.— The periotic is composed of a rather large pars cochlearis, a relatively small pars vestibularis. From the latter projects laterad a plate-like processus tympanicus (Denker) which Beauregard is no doubt right in interpreting as the regio mastoidea. Mesad a very bulky tegmen tympani projects from the pars vestibularis; to this is anchylosed the hooked process of the tympanic described above and by it excluded from the tympanic cavity.

On the rostral surface the limits of the pars vestibularis and pars cochlearis are defined by a series of foramina. Of these the largest and most dorsal is that of the facial canal, from which the nerve extends directly through the bone to emerge on its tympanic surface above the fenestra vestibuli; a genu upon the nerve, at least in its periotic course, is lacking. A very minute foramen more mesally placed is perhaps representative of the hiatus Falopii. Ventral to the orifice of the facial canal is a deep fossa at the bottom of which is the tractus spiralis foraminosus. In the same fossa but placed somewhat apart from and lateral to the foregoing is a small foramen which I take to be equivalent to the area cribrosa media. Outside the fossa, but close to its margin and ventro-laterally placed is the foramen singulare. Ventral to this at a distance of 2 mm. is the orifice of the aqueductus vestibuli, and at about the same distance farther ventrad the margin is incised by the fenestra cochleæ.

The caudal surface consists of the wall of the tympanum and a massive arch dorsal to this. The latter presents laterally in its mastoid region the facette for articulation with the processus petrosus of the tympanic. There is no anchylosis as in *Phocæna.* Adjoining this is a shallow fossa of triangular form which may represent the attic in a rudimentary condition. This is limited mesad by a sharp ridge of bone, the projecting extremity of which

overhangs the facial groove. Between this and the tuberosity marking the beginning of the tegmen tympani is a vertical groove corresponding in part at least to the fossa incudis. The surface of the tegmen tympani beyond the tuberosity is concave for the reception of a thick hooked process of the tympanic to which it is firmly anchylosed.

In the tympanic cavity the facial canal is open in its whole length from a point above the fenestra vestibuli. In its ventral portion it borders upon a large fossa for the m. stapedius. The fenestra vestibuli is broadly oval, 2.5 mm. in its long axis by 2 mm. dorso-ventrally. Between the fenestra and the tuberosity of the tegmen tympani is a fossa for the head of the malleus. Mesal to the fenestra vestibuli the surface is concave becoming distinctly grooved toward the margin. The groove corresponds when the bones are in apposition to the interval between the lips of the bulla and would seem therefore to enter into the composition of the osseous tuba. In its upper portion a thin ledge projects mesad and ventrad, the processus cochleariformis, the interval between which and the uncinate process would seem to correspond to the usual groove for the tensor tympani. This muscle has been generally recorded as absent in whales, and Denker [1] so reports of *Phocæna.* It is however present in the fœtal *Balænoptera* (Kernan) [2] and the conformation of this region of the periotic, which differs markedly from that of *Phocæna* as given by Denker (Taf. xv, fig. ii), suggests the possibility of the presence of the muscle in *Kogia.*

The promontory is narrow and arched mesad and ventrad about the fenestra cochleæ which is placed at the ventral margin of the bone at the confines of the tympanum. Mesal to the fenestra the pars cochlearis is produced ventrally into a projection which corresponds to the concavity of the caudal lip of the bulla. The fenestra itself is elongated, 3 mm. by 1.5 mm. at its broadest point. A small projection from its lateral margin gives it a slightly reniform contour.

The pars vestibularis is pyramidal and massive; its ventral surface is largely concealed by the processes which arise from it. The mastoid or processus tympanicus is quadrangular, its surface concave and smooth as though covered by an articular cartilage. Its ventral angle overhangs the facial canal. The tegmen tympani is very robust. Its origin from the pars vestibularis is marked by a shallow groove beyond which it presents two tuberosities one above the tympanum mesal to the facette for the malleus, the other above the entrance to the facial canal. The tegmen then narrows, in large part because of the concavity in which is fused the uncinate process

[1] Denker, A. Zur Anatomie der Gehörorgans der Cetacea. Anat. Hefte, Bd. 19, 1902.

[2] Kernan, John D. Jr. In Mem. A. M. N. H., New Series, Vol. I, Pt. VI, pl. XLVII, fig. 3, and p. 493.

of the tympanic, and terminates mesad in two tubercles. Rostrad the surface of the pars vestibularis rises to a blunt point just mesal to which is the minute orifice of the aqueductus vestibuli.

The malleus.— Of the auditory ossicles the malleus alone is present, and of this only the head and processus gracilis are distinguishable; the manubrium has been fractured and lost. The fragment is ankylosed to the tympanic by the lower portion of the caput at the mesal extremity of the processus sigmoideus. Mesal to this the processus gracilis is also synostosed to the lip of the bulla and the anterior ligament is converted into bone. The surface for the incus is divided by a groove into two facettes of which the upper is much the larger and broader.

The foregoing notes on the individual cranial bones substantiate the highly specialized character of the skull adumbrated in its general contours. Among its many peculiarities the entrance of the maxilla into the cranial cavity is perhaps the most astonishing and is so far as I am aware unique. Its history is not difficult to surmise. The great suprafrontal extension of the maxilla in Odontocetes is associated with the development of the rostrum serving to secure that structure to the cranium. It thus comes to overlie the squama of the frontal, to a very high degree in Ziphioids, all but completely in *Physeter* and *Kogia*. In the fœtal skull of *Physeter* in the Royal College of Surgeons, described by Owen,[1] the frontal seems to persist and exclude the overlying maxilla from the cranial cavity. In *Kogia* extensive reduction of the frontal has taken place, possibly in association with the extreme brachycephalism of the smaller whale.

The synostosis between the lachrymal and malar is very complete in the adult, and even on one side of the calf no sign of their primary independence can be distinguished. These conditions afford some ground for the expectation that when suitable material is at hand, the lachrymal may prove to be more generally present in the Odontocetes than at present appears. In the absence of a suborbital bar of the malar, *Kogia* presents an extreme reduction of this bone. The lacking portion is supplied by ligament. An approach to this condition is afforded by *Inia*[2] in which there is a broad gap between the extremity of the malar and the zygomatic process of the squamosal.

The compound nature of the pterygoid is a morphological problem of

[1] Owen, R. Catalogue of the Osteological Series in the Museum of the Royal College of Surgeons, London, 1853; also *op. cit.*, Trans. Zool. Soc. London, VI, 1869.

[2] Flower, W. H. Description of the skeleton of *Inia geoffrensis* and of *Pontoporia blainvillii*, with remarks on the systematic position of these animals in the order Cetacea. Trans. Zool. Soc. London, Vol. VI, 1869.

great difficulty. Of the two elements, the rostral bearing the hamular process and articulating with the palatine and maxillary may with confidence be taken as the internal pterygoid plate, highly developed and gaining a rostral extension. The morphology of the caudal element is doubtful. It can hardly be an external pterygoid plate for that element is uniformily an apophysis of the cartilaginous alisphenoid and lacks even an independent center of ossification. On the alisphenoid itself there is no projecting process it is true, but in the caudo-mesial region where it abuts upon the occipital and enters into the wall of the jugulo-acoustic canal, the bone is deeply fissured. By means of these fissures the bone is resolved into two closely apposed processes; a mesial one adjacent to the basisphenoid canal is possibly the ali-cochlear process, the lateral one may be a highly modified external pterygoid plate. On this assumption the second element of the 'pterygoid' could be interpreted as a reduplication of the internal pterygoid plate, a supposition for which I know of no analogy, or its origin must be sought in some secondary site of membranous ossification, perhaps the wall of the adjacent air sinus. In any event this problem, which pertains to Odontocetes in general, must await its solution until younger material is made available for study.

To summarize: The chief osteological peculiarities of the *Kogia* skull, which is that of a highly specialized eutherian mammal are, proportions and asymmetry apart, its mid-facial sagittal crest, the participation of the maxillæ in the wall of the cranial cavity, the suppression of both nasals, and the complete reduction of the suborbital bar of the malar.

Comparison of Immature Skulls of *Physeter* and *Kogia*.

For purpose of comparison several accounts of young skulls of *Physeter* are available. The first is that of Owen, already referred to, of the fœtal skull in the Museum of the Royal College of Surgeons. A disarticulated skull of about the same size in the Museum of St. Bartholomew's Hospital is mentioned by Flower,[1] who has also reproduced in excellent lithographs the cranium of a half grown specimen from Tasmania. Huxley[2] gives three wood-cuts of a fœtal skull.

Of these the Tasmanian specimen is for our purpose of most importance as most nearly coinciding in size. The rostrum, though far from its adult length, is more robust than in *Kogia* in all its proportions, especially exceed-

[1] Flower, W. H. *Op. cit.*, Trans. Zool. Soc. London, Vol. VI, 1869; also Van Beneden and Gervais, *op. cit.*, pl. xix.

[2] Huxley, T. H. A manual of the Anatomy of vertebrated animals. Fig. 106.

ing it in length. The transverse curvature, ventrally convex, dorsally concave, is pronounced. The wide antorbital notches and less developed maxillary tuberosities lend it an appearance of greater independence from the cranium, against which it is crowded in *Kogia*. The premaxillæ are narrower, separated only by a linear interval at the tip and present longer areas beside the vomer ventrally. The vomerine gutter is also proportionally narrower and rostrad is roofed over by the premaxillæ. Proximad the left bone terminates at the level of the nostril but is less depressed into the funnel of that passage than in *Kogia*. The maxillæ are also more slender, are widely separated in the transverse crest where they overlie the frontal and do not enter into the cranial cavity. The infrafrontal process abuts obliquely on the lachrymo-malar and is not produced backward upon it as in *Kogia*. The palate bones are very large and enter conspicuously into the walls of the nasal passages. The pterygoids are correspondingly smaller, the infrapalatine portions feebly developed and fail by a wide interval of reaching the maxillæ. Caudad their extent is limited also by the transverse direction of the otocranial flanges of the basioccipital. On the whole therefore the rostrum is less complicated in its attachment to the cranium than in *Kogia* and fixation is secured rather by the massive proportions of the elements involved than by very peculiar specialization of their articulations.

In the fœtal skull Owen states that the pterygoid is double the size of the palate, a point not borne out by Huxley's figure, in which however the pterygoid has no infrapalatine process.

In *Physeter* the disproportion of the nostrils is less, the right is slightly more caudal in position and the intervening septum, though deviated, is very robust, and so may play a larger rôle in the fixation of the rostrum. The left nasal bone is a flat scale resting upon the frontal in a position corresponding to the premaxillary of the right side. Laterad it touches the maxilla, rostrad the ethmoid.

The transverse crest while of great height is less robust than in *Kogia*, and in particular the maxillary tuberosities are far less massive. The absence of the mid-facial crest gives this aspect of the skull the form of a simple concavity.

The great fossa on the base lateral to the pterygoid ridge has apparently a less complicated relief than in *Kogia*. Rostrad it passes quite evenly into the venter of the beak. The alisphenoid is of large size and juts rostrad coming to underlie the orbito-sphenoid. This it joins laterad (Owen) thus excluding the frontal from the sphenoidal fissure. In the alisphenoid in addition to the foramen ovale there is according to the same authority a separate rotundum. The optic foramen is likewise separate. In all these

points *Kogia* departs from *Physeter*, the underlying factor perhaps being the backward push of the rostrum and shortening of the whole region in the pigmy whale.

In the adult sperm whale the infraorbital arcade is complete and massive. In the half grown specimen the malar is attenuated at its junction with the zygomatic process of the squamosal. In Owen's fœtus this junction was fibrous, while in Huxley's figure a considerable interval is shown. In this retardation of development of the caudal extremity of the malar is initiated a process which has been carried to the suppression of the whole suborbital bar in *Kogia*. Owen suspected the presence of a lachrymal in both whales, but finding no evidence of its independence in the fœtal sperm whale suggested that it had become connate with the malar. It is to be presumed on the evidence of *Kogia* that in younger fœtuses of the sperm whale it may also be for a time separate.

The temporal fossa of *Physeter* extends higher than in *Kogia* and is less definitely limited above. Its mesal wall is more largely formed by frontal. The orbital plate is very massive, supraorbital notch and pre- and post-orbital process are conspicuous.

The chief peculiarity of the occipital in *Physeter* consists in the very high position of the very prominent condyles, which extend onto the supraoccipital (Owen). In consequence an oblique descending canal is formed leading to the cranial cavity (Flower). The statement that the hypoglossal nerve has no independent canal (Flower) is in need of corroboration.

While differing in contour and notably in the length of the symphysis, the mandible agrees with that of *Kogia* in its marginal thickening of the pars papyracea, a character which distinguishes these whales from the Ziphioids and other Odontocetes in general.

The foregoing comparison has dealt only with the cranial differences between the two genera of the Physeterinæ. It has not seemed desirable to retail the profound resemblance which have served to collocate the two forms since the first observation of the skull of *Kogia*. As compared with one another *Kogia* seems to show more striking modifications of the cranium, in only a few characters does *Physeter* possess equally marked peculiarities. Of these the modification of the occipital region associated with the high position of the condyles is the most notable. To this may be added the enormous length of rostrum, of the mandibular symphysis, the large palatal bone and the extreme development of the processes of the skull. In other important respects, the persistence of the left nasal, the retarded but ultimately complete suborbital arch, smaller pterygoid, less degree of disparity of the nostrils, *Physeter* stands nearer to usual odontocete conditions than does *Kogia*, which in addition to these differences has developed the

mid-frontal crest and has a maxilla which replaces the frontal in the cranial wall. The palatal of *Physeter* it may be well to state is here looked upon as secondarily enlarged, because the infrapalatine process though of considerable size fails to reach the maxilla, while a pterygo-maxillary contact is present in *Kogia* and all the Ziphioids. The conclusion seems therefore warranted, subject to the limitation that cranial characters are alone considered here, that *Kogia* is the more highly modified form but that both have deviated in different directions from the common ancestral type.

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DESCRIPTION OF PLATES.

SKULL OF *Kogia breviceps*.

PLATE XXXV.

Fig. 1. Skull of adult, norma verticalis.
Fig. 2. Skull of adult, norma lateralis.

PLATE XXXVI.

Fig. 1. Skull of adult, oblique ventral view.
Fig. 2. Skull of adult, norma basalis.

PLATE XXXVII.

Fig. 1. Cranium of calf after removal of rostrum, presphenoid and pterygoids.
Fig. 2. Skull of calf, norma occipitals.

Plate XXXVIII.

Fig. 1. Maxillæ and premaxillæ of calf, mesal view.
Fig. 2. Maxillæ of calf, ventral view.

Plate XXXIX.

Fig. 1. Vomer, ethmoid and presphenoid of calf, ventral view.
Fig. 2. Vomer, ethmoid and presphenoid of calf, dorsal view.

Plate XL.

Fig. 1. Vomer, ethmoid and presphenoid of calf, right lateral view.
Fig. 2. Vomer, ethmoid and presphenoid of calf, left lateral view.

Plate XLI.

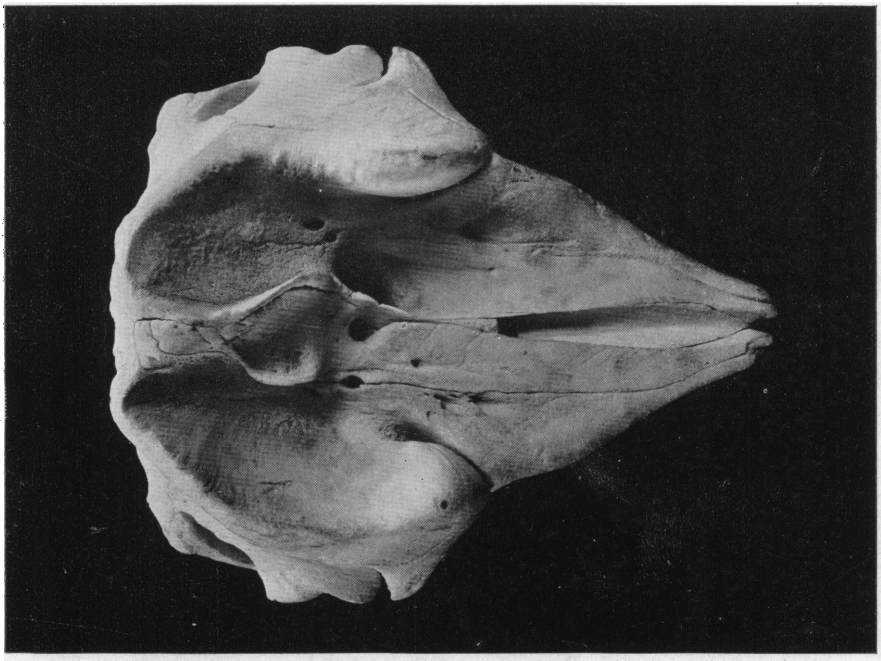
Fig. 1. Right pterygoid of calf, dorsal view.
Fig. 2. Right pterygoid of calf, mesal view.
Fig. 3. Left pterygoid of calf, lateral view.

Plate XLII.

Fig. 1. Rostral cranial wall of calf composed of presphenoid and maxillæ.
Fig. 2. Left malar and lachrymal of calf, ventral view.
Fig. 3. Left malar of calf, dorsal view.
Fig. 4. Left lachrymal of calf, dorsal view.

Plate XLIII.

Fig. 1. Left lateral region of the basis cranii of the calf, the squamosal and pterygoid having been removed.
Fig. 2. Left squamosal of calf, ventral view.
Fig. 3. Left tympanic of calf, ventral view.
Fig. 4. Left tympanic of calf, dorsal view.



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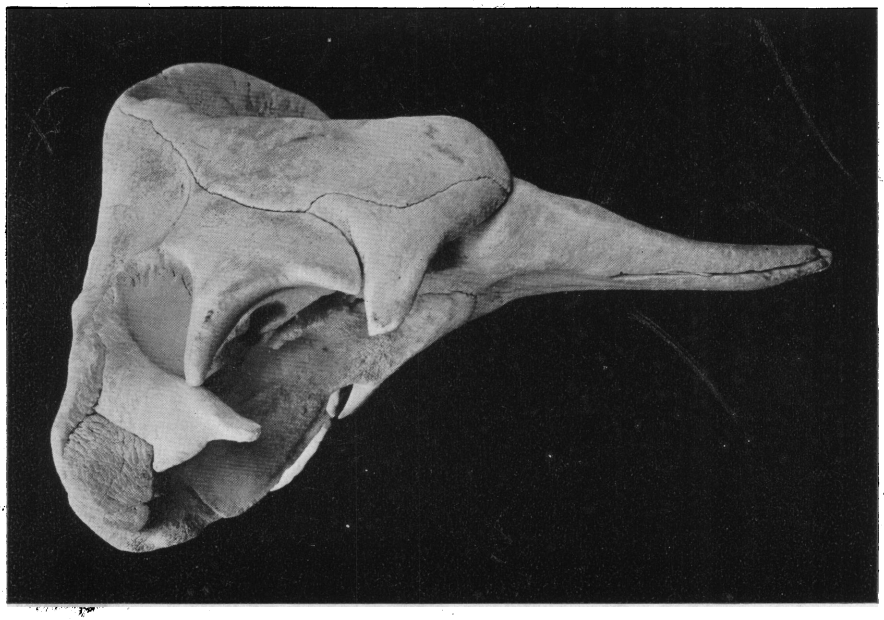

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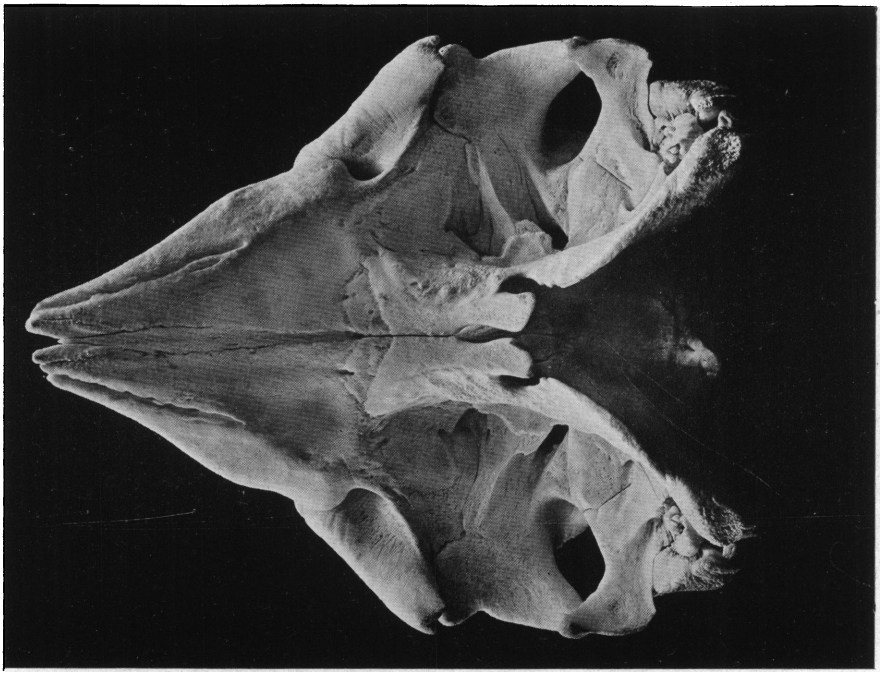

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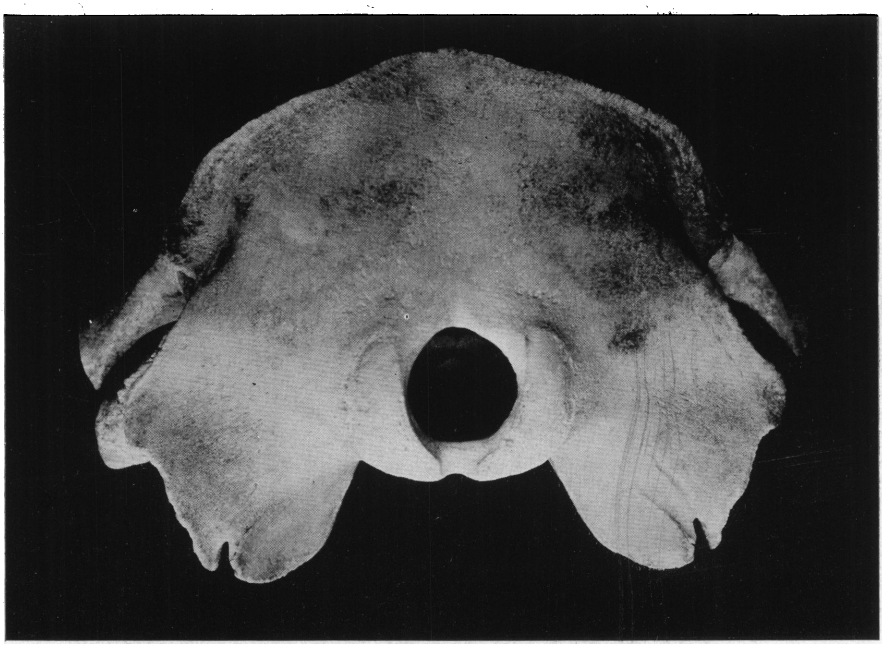

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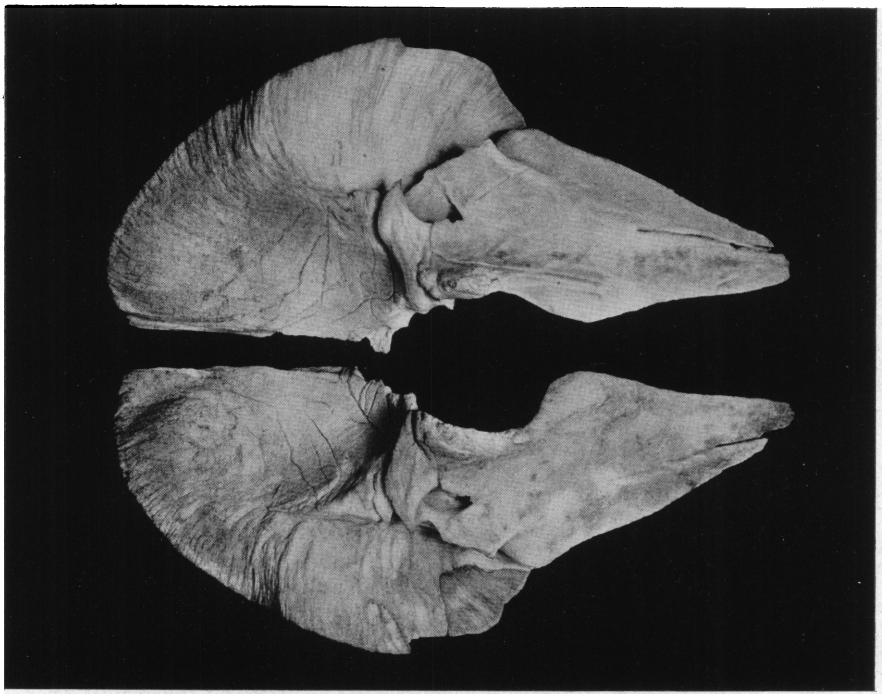

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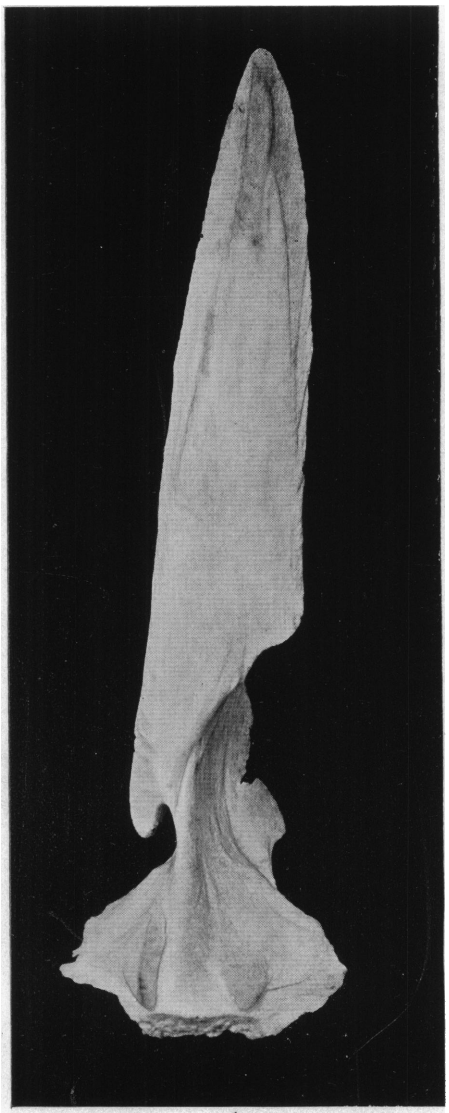

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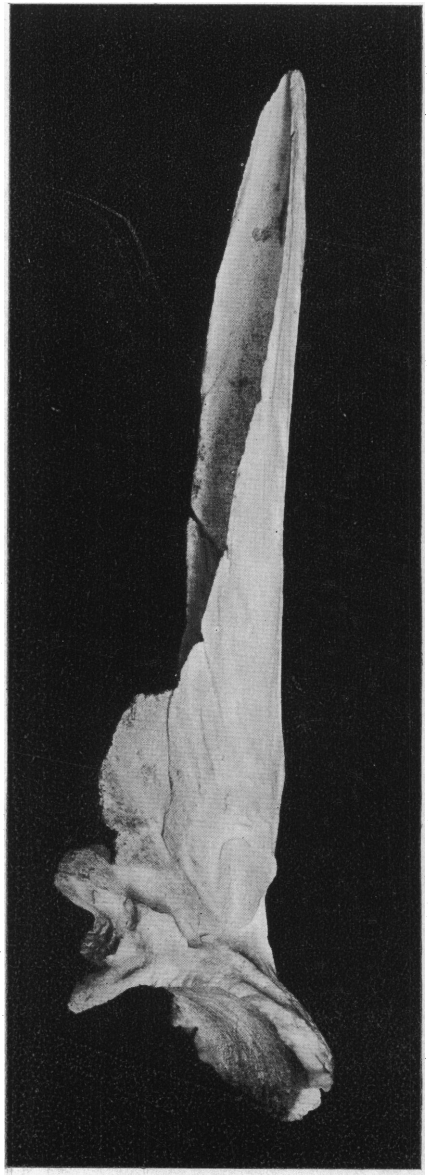

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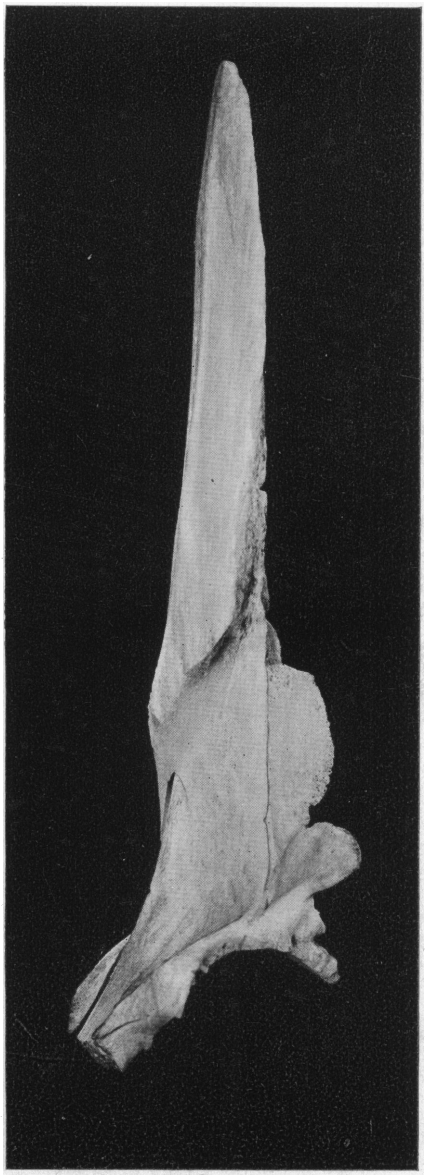

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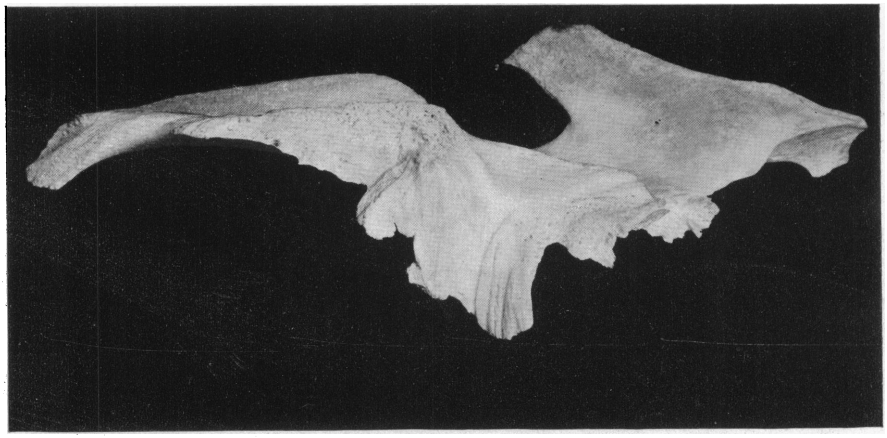

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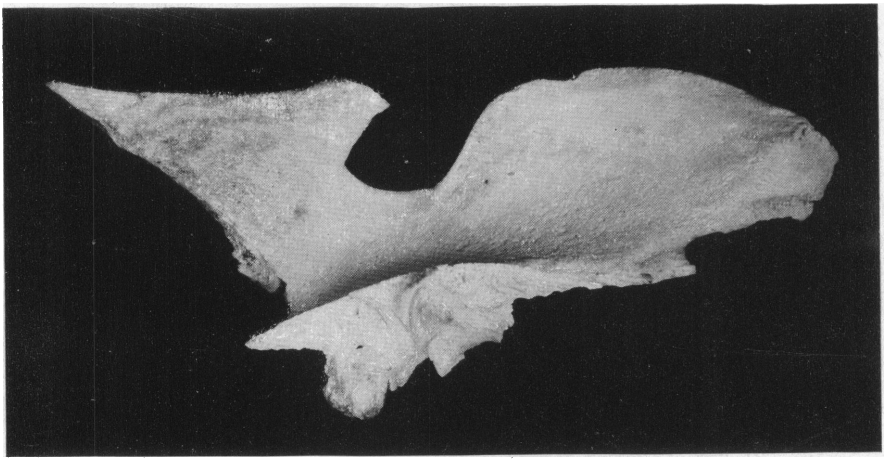

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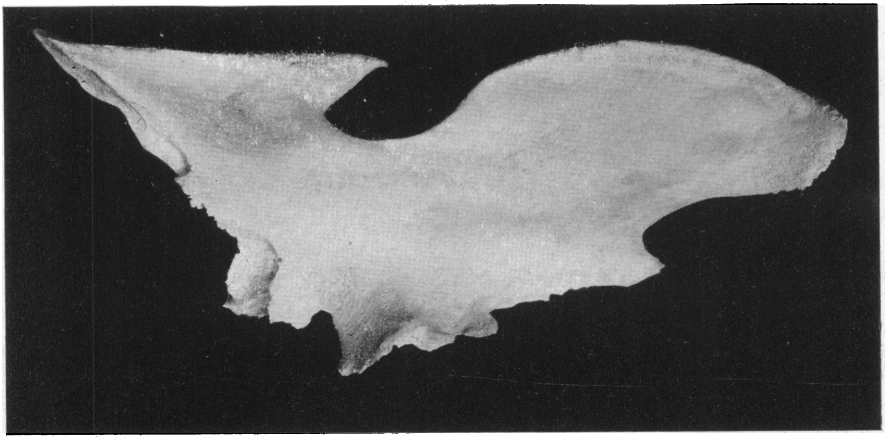

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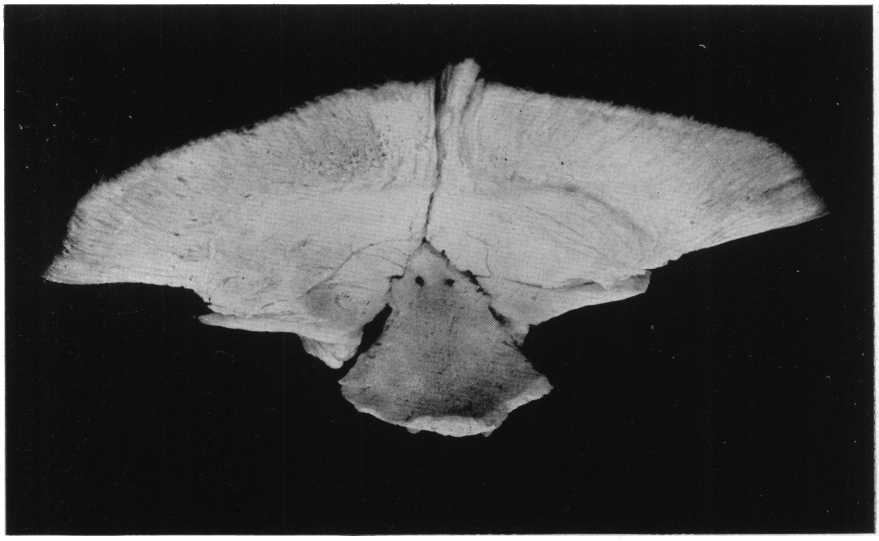

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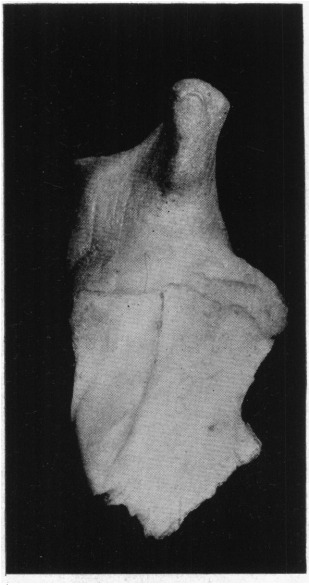

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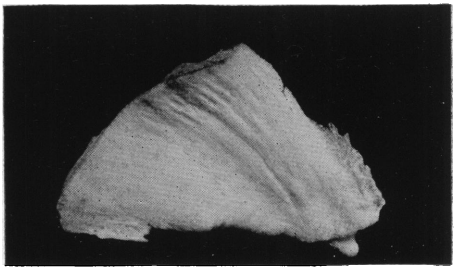

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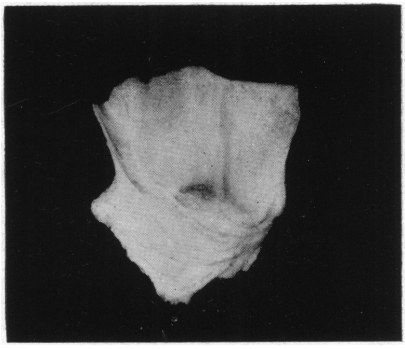

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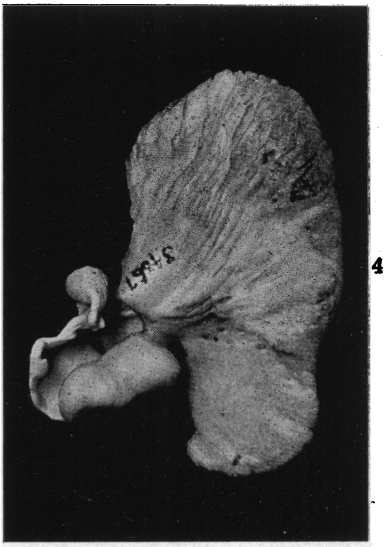

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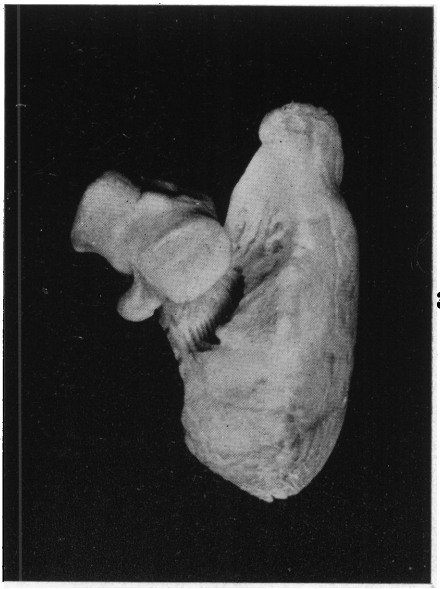

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Kogia breviceps (*Blainville*).