Cetothere Skeletons From the Miocene Choptank Formation of Maryland and Virginia

1. THE SKELETON OF A MIOCENE CHOPTANK CETOTHERE

Discovery of additional mysticete skulls in Oligocene marine formations would furnish a much more authoritative basis for speculative opinions relative to their early geological history. The apically attenuated triangular supraoccipital shield of *Cetotheriopsis lintianus* (Brandt, 1873, pl. 19), which was recovered near Linz, Austria, from the white quartz sands of the Oligocene Chattian stage, represents an advanced phase in the remodeling of the mysticete skull. The pronounced forward thrust of the posterior cranial bones of this skull clearly supports the conclusion that the remodeling of the cranial architecture of these Tertiary whalebone whales had progressed beyond the initial overriding of the intertemporal region by the supraoccipital prior to the Miocene.

Furthermore, three distinct types of posterior cranial remodeling represented by *Morenocetus parvus* (Cabrera, 1926, fig. 1), "*Plesiocetus*" *dyticus* (Cabrera, 1926, fig. 3), and *Aglaocetus moreni* (Kellogg, 1934), and for which no prior geological antecedents are as yet known, have been excavated in the lower Miocene Patagonian marine formation.

The skull of *Aetiocetus cotylalveus* (Emlong, 1966), which was discovered in the upper Oligocene marine Yaquina formation of northwestern Oregon, and which has the horizontally divided posterior end of the maxillary projecting backward above and below the supraorbital process of the frontal, a typical mysticete interlocking structural relationship, cannot be considered to be in the direct antecedent lineage of the mysticetes, but does suggest what may have been basic ancestral skull architecture. This Oligocene cetacean seems to have had the usual diphyodont mammalian dentition, the crowns of the cheek teeth having serrated edges. Vestigial cheek teeth are present in the jaws of fetal Recent mysticetes. On all archaeocete skulls thus far described, including *Protocetus*, *Prozeuglodon*, *Basilosaurus*, *Dorudon*, and *Zygorhiza*, molar teeth are located on the hinder end of the maxillary, which projects backward beneath the supraorbital process of the frontal, and not anterior to this process as in *Patriocetus*, *Microzeuglodon*, and *Aetiocetus*, and probably also in *Agorophius* and *Archaeodelphis*.

The direction, elongation, and curvature of the upper and lower transverse processes of the sixth cervical vertebra indicate that the cervical extension of the thoracic retia mirabilia had been previously developed and acquired by this Oligocene *Aetiocetus*.

On the *Aetiocetus* skull the transversely narrowed posterior ends of the palatine bones, separated medially by the vertical plate of the vomer, are prolonged backward beyond the level of the anterior end of the pterygoid fossa, much farther backward than on the skull of any known Eocene archaeocete. This backward prolongation of the palatines increased the length of the internal choanae. The narial fossa in front of the elongated nasal bones is situated at the middle of the length of the skull. The conformation of the bones enclosing the internal choanae may not, however, possess any particular phylogenetic significance. The backward shift of the external nares and the associated narial fossa in the mesorostral trough does not appear to have any causal relationship with the prolongation of the internal choanae on all skulls of Recent cetaceans. For instance, the palatines on the skull of the finback, *Balaenoptera physalus*, are not extended backward beyond the level of the anterior end of the pterygoid fossa although the relatively small nasal bones behind the narial fossa are situated almost entirely posterior to the level of the anterior end of the orbit. Conversely on the skull of the bowhead, *Balaena mysticetus*, the palatines extend backward to the occipital condyles and the narial fossa is located far forward on the rostrum, approximately behind the middle of the length of the skull. Among Recent odontocetes the most pronounced backward extension of the palatines is observable on ziphioid skulls belonging to the genera *Berardius*, *Ziphius*, and *Mesoplodon*.

A gradual improvement in the steering function of the forelimb is evidenced in the trend toward shortening of the humerus according to Mchedlidze (1964, pp. 45–46), a trend he thought appeared earlier in the geological history of the cetotheres than in the Delphinoidea. The forelimbs are employed in turning, diving, and balancing.

Howell (1930, p. 231) mentioned the phenomenal shortening of the humerus of Recent cetaceans and also directed attention to the observable variability in the radial length. The humerus of many Recent odontocetes is shorter than the radius, but there are exceptions to this condition. The humerus of *Physeter*, *Kogia*, *Pontoporia*, and *Platanista* is definitely longer than the radius, the length of the humerus of the Ganges river dolphin being twice the radial length. The significance of this discordance in the relative lengths of the humerus and radius among living odontocetes is not readily apparent. The humerus of at least four Calvert Miocene porpoises, *Squalodon calvertensis*, *Eurhinodelphis bossi*, *Kentriodon pernix*, and *Delphinodon dividum*, is longer than the radius; the radius of an adult *Squalodon* is about three-fourths of the length of the humerus. The presumed original mobility of the elbow joint of these four fossil porpoises has been largely lost. There are unquestionably several different factors, including the shifting of the origin and insertion of the intrinsic musculature, that have accelerated and/or retarded the shortening of the humerus in some cetaceans.

The humerus of the North American archaeocetes *Basilosaurus cetoides* and *Zygorhiza kochii* is elongated, the length of the radius being equivalent, respectively, to one-half to seven-tenths of the length of the humerus. Both of these archaeocetes have retained the ball and socket character of the shoulder joint and the synovial character of the elbow joint.

Conversely, the humerus of the large Calvert cetotheres is shorter than the radius, being equivalent to 66 percent of the length of the radius of *Pelocetus calvertensis*, in contrast to a ratio of 74 percent (USNM 23058) and 77 percent (USNM 23059) for two other large individuals from this formation, and at least 75 percent for the balaenopterid "*Eschrichtius*" *cephalus* Cope. The humerus of this Choptank cetothere is equivalent to 67 percent of the length of the radius. These Miocene cetotheres have retained the ball and socket character of the shoulder joint, but have lost the synovial character of the elbow joint.

This shortening trend has not proceeded as far in the slow swimming Balaenidae as in the balaenopterine whales, the length of the humerus of both *Balaena mysticetus* and *Eubalaena glacialis* being equivalent to or at least nine-tenths of the length of the radius. The pectoral flippers of these smooth-throated whales are wide and stubby, and are equivalent to 12 to 18 percent of length of whale.

Shortening of the humerus seems unrelated to swimming speed. The entire forelimb of the rather slow swimming humpback (*Megaptera novaeangliae*) is excessively elongated, occasionally one third of the whale's length, and yet the relative lengths of the two upper arm bones are not materially different from those of a large-fin or furrow-throated whale (*Balaenoptera*), the length of whose humerus was equivalent to about 65 percent of the length of the radius.

An efficient steering organ would serve a more useful function for a rapid than for a slow swimmer. The sei whale (*Balaenoptera borealis*) is considered to be the fastest swimmer among living balaenopterids and is reputed to attain a speed of 35 knots an hour for several minutes. The length of the pectoral flipper, tip to axilla, of the adult sei whale is equivalent to 8 to 11 percent of the total length of the whale, which compares favorably with 8 to 10 percent for the finback and 10 to 12½ percent for the blue whale. Blue and finbacks have been observed to maintain a speed of 18 to 20 knots for 10 or 15 minutes, their normal cruising speed being 10 to 12 knots. The length ratio of the humerus to the radius of one 45-foot adult sei male is 49 percent. For other living balaenopterid whales, however, especially *Balaenoptera acutorostrata* and *B. physalus*, this length ratio is as low as 58 and as high as 70 percent.

There is, thus, no evidence of a direct relationship between either the overall length of the pectoral flipper or the length ratio of humerus to radius and the cruising speed of the whale. Until skeletons of Oligocene or geologically older predecessors of the middle Miocene cetotheres are discovered, further speculation may not prove very informative.

Thinocetus,[1] new genus

TYPE-SPECIES.—*Thinocetus arthritus*, new species.

DIAGNOSIS.—Atlas massive, thick; a short rugose, transversely widened hyapophysial process present. Odontoid process of axis slender, unusually elongated.

[1] *Thinos*, shore, in allusion to the presumed stranding of this mysticete on the shore.

Pedicles of neural arch of third to sixth cervicals short, widened; neural canal low, unusually wide; roof of neural canal slightly arched, almost horizontal. Neural spines of first to fourth dorsals short, nearly vertical, not noticeably slanting backward and their height equivalent to less than half vertical diameter of corresponding vertebra, in contrast to somewhat longer backward slanting neural spines of ninth to twelfth dorsals whose height is equivalent to or slightly more than half vertical diameter of corresponding vertebra. Neural canals of first to eighth dorsals low, very wide; roof of neural canal not arched, nearly horizontal; diapophyses stout, broad, dorsoventrally compressed. Elongated, backward slanting neural spines present on first to ninth lumbars; metapophyses rather slender. Transverse process of first to fourth caudals short and broad, not widened distally. Scapula wide, acromion broad, coracoid process short and stout, and prescapular fossa very narrow. Length of humerus about 67 percent of length of radius. Posterior process of periotic elongated, rather slender, increasing in diameter distally; anterior process compressed from side to side, deeply concave internally and convex externally; posterior profile from a ventral view deeply indented between pars cochlearis and posterior process.

Thinocetus arthritus, new species

Type-specimen.—USNM 23794. Posterior portion of cranium, incomplete; right and left tympanic bullae, right and left periotics, left mandible lacking section near anterior end, atlas, axis and 3 cervicals, 12 dorsals, 12 lumbars, 12 caudals, 3 chevrons, right scapula complete, left scapula lacking anterovertebral angle, right and left humerus, right and left ulna, right radius, 7 carpals, 7 metacarpals, 3 phalanges, 22 ribs. Collectors, Albert C. Myrick, Jr., and Charles F. Buddenhagen, September 21–25, 1966.

Horizon and locality.—Low cliff east of Mud Cliffs on south shore of Potomac River (7/10 mile west of Haulover Point on Haulover Inlet), 180 feet west of Md.-Va. Boundary Monument 24, Westmoreland County, Virginia. In greenish sandy silt in transitional layer three feet ten inches below zone 17 shell bed containing *Isognommen*, *Pecten madisonius*, *Pecten marylandica*, *Saxolucina* D.P., *Crassatella turgidula*, and *Ecphora quadricostata*. Choptank formation, middle Miocene.

Referred specimen.—One, as follows: USNM 22961; left mandible lacking portion of ramus behind coronoid process, axis, third cervical, lumbar, and a terminal caudal, coll. Thomas E. Stokel, November 1962, in zone 17 at Cape St. Marys, east of Hollywood and on Patuxent River, St. Marys County, Md. Choptank formation, middle Miocene.

SKULL

Prior to excavation the entire rostrum and all of the braincase in front of the lateral protuberances of the basioccipital had been broken off and destroyed when the skull was exposed on the face of the cliff either during erosion by the Potomac River at flood time or subsequent slumping.

The vertical partition between the choanae, which seemingly diminished rapidly posteriorly, is continued backward to within a few millimeters of the end of the horizontally flattened portion of the vomer which conceals the transverse contact between the basisphenoid and the basioccipital. No remnants of either pterygoid remain attached to this portion of the basicranium (pl. 1, fig. 1). The ventral surface of the large descending knob-like protuberance on each side of the basioccipital is somewhat eroded. This protuberance does not, however, contribute the inner wall of the notch or incisure for the jugular leash, although it is continuous posteriorly with the thin descending external border of the basioccipital which does limit this side of the posterior lacerated foramen. The external wall of this notch is formed by the exoccipital. The inner faces of these lateral protuberances are separated by an interval of 50 mm.

The greatest width of the tympanoperiotic recess did not exceed 50 or 60 mm. In front of each tympanoperiotic recess the pterygoid bone that constitutes most of the osseous walls of the pterygoid fossa has been destroyed on this basicranium.

The right postglenoid process is broken off at the base and the zygomatic process is also missing.

The left squamosal lacks the anterior face of the postglenoid process and all of the zygomatic process. This left postglenoid process is deflected obliquely backward and its thin anteroposteriorly compressed extremity is extended at least 50 mm. below the level of the lateral protuberances of the basioccipital. Viewed from behind the acute profile of the ventrally prolonged postglenoid process results from an oblique external truncation and a shallowly concave internal curvature. Between the posterior process of the periotic and the base of the concavely curved posterior face of the postglenoid process is the deep transverse channel for the external auditory meatus; this channel is narrower externally than internally. A broad shallow concavity on the ventral surface of the right squamosal external to the pterygoid fossa extends backward to its sharp-edged posterior margin. The bifurcated anterior end of the squamosal, which encloses the dorsoventrally compressed foramen ovale (length 21 mm.), is preserved on the right side.

The external angles of the exoccipitals project backward barely beyond the level of the posterior articular surfaces of the occipital condyles. A small cavity on the ventral edge of the exoccipital, limited internally by a sharp-edged ridge, marks the area for attachment of the stylohyoid.

The occipital condyles are large and the foramen magnum rather narrow. The articular surfaces of each condyle are more strongly convex from end to end than from side to side and they are separated ventrally by a deep narrow groove.

See table 1 for measurements of the skull.

Table 1.—*Measurements (in mm.) of the skull, USNM 23794*

Exoccipital width	500±
Transverse distance between outside margins of zygomatic processes	670±
Transverse distance between outer margins of opposite occipital condyles	176
Greatest or oblique-vertical diameter of right occipital condyle	104
Greatest transverse diameter of right occipital condyle	67
Greatest transverse diameter of foramen magnum	56
Posterior face of right occipital condyle to posterior end of vomer	105
Transverse distance between external margins of lateral protuberances of basioccipital	165
Distance between opposite foramina ovale	270±

TYMPANIC BULLA

Both tympanic bullae (USNM 23794) were crushed against the corresponding periotic and consequently the anterior and posterior pedicles were completely demolished. The malleus, however, is attached to the outer lip of the right bulla; the three little inner ear bones were found in the matrix between the left bulla and the periotic. The bulla of this Choptank cetothere is larger and also strongly attenuated anteriorly in contrast to the bulla of the contemporary species (USNM 23636).

Except for the loss of the anterior and posterior pedicles, the type right bulla is essentially complete. Viewed from the dorsal aspect (pl. 2, fig. 7), the involucrum is creased transversely by thin grooves, commencing in front of the posterior pedicle and continuing as far forward as the level of or a little in advance of the front edge of the base of the anterior pedicle. The posterior pedicle seems to have projected chiefly from the involucrum and was separated by a thin cleft from the blunt posterior conical apophysis. The eustachian outlet of the tympanic cavity is rather wide, but behind this outlet scarcely exceeds in width the gap between the overarching thin outer lip and the involucrum. The width of the involucrum is gradually diminished toward the eustachian outlet.

The distally rounded and transversely twisted sigmoid process is fused along its anterointernal border with the stalk-like anterior process of the malleus and is separated posteriorly by a thin cleft from the posterior conical apophysis.

Viewed from the ventral side (pl. 2, fig. 8) the posterior end of the bulla is noticeably wider than the anterior end; this somewhat rugose ventral surface slopes from the internal to the external border except posteriorly at the broad anteroposterior furrow which commences at the level of the posterior conical apophysis and is continued upward on the posterior face of the bulla.

Viewed from the external aspect (pl. 2, fig. 6), one observes that the vertical diameter of this bulla posteriorly is greater than anteriorly, and that the posterior profile is more nearly vertical in contrast to the rounded anterior profile.

See table 2 for measurements of the right tympanic bulla.

Table 2.—*Measurements (in mm.) of right tympanic bulla, USNM 23794*

Greatest length	74
Greatest width	47. 5
Greatest depth of bulla on external side, ventral face to tip of sigmoid process	58

PERIOTIC

When the basicranium (USNM 23794) was excavated each periotic was firmly lodged in the broad groove between the exoccipital and the base of the postglenoid portion of the zygomatic process of the squamosal. Through a fortunate circumstance of preservation it was possible to detach the periotics for examination and comparison.

When viewed from the ventral side (pl. 2, fig. 4), the most noticeable peculiarity of this periotic is the deep indentation of the posterior profile between the pars cochlearis and the internal end of the elongated posterior process. This modification is attributed to the enlargement of an extension of the air sac system (Fraser and Purves, 1960), which has resulted in the deep excavation of the internal end of the posterior process above the channel for the facial nerve and the development of a shallow depressed, smooth surface (vertical diameter, 15–21 mm.) on the posterior face of the pars cochlearis above and behind the foramen rotunda as well as an outward extension of this smooth depression on the surface behind the fossa for the stapedial muscle.

On the internal third of the ventral surface of the posterior process the facial nerve on its outward course traverses a deep groove, which becomes indistinct beyond this region as the result of the rather marked flattening of this surface. Although somewhat triangular in cross-section, the vertical thickness of the posterior process decreases from the internal end to the external end. The basal portion of the posterior pedicle of the tympanic bulla remains ankylosed to the anterointernal angle of the posterior process of the periotic.

From a ventral or tympanic view (pl. 2, fig. 4) the fenestra ovalis is entirely concealed by the overhanging external face of the pars cochlearis and by its almost vertical position; it is separated from the orifice of the Fallopian aqueduct and the groove for the facial nerve by a thin rim. Behind the fenestra ovalis there is a small stapedial fossa which extends downwards also on the external face of the pars cochlearis. An ill-defined shallow concavity for the reception of the head of the malleus is located behind the basal portion of the attached slender anterior pedicle of the bulla and in front of the orifice of the Fallopian aqueduct. A small pit serves as the fossa incudis.

The pars cochlearis is relatively small; the internal half of its ventral surface is irregularly depressed below the narrower convex or inflated external half. On the cerebral face of the pars cochlearis (pl. 2, fig. 5) the centrally located circular internal acoustic meatus is actually smaller than the cerebral aperture of the Fallopian aqueduct. The vestibular aqueduct opens into a deep, narrow, elongated fossa behind and above the internal acoustic meatus. Ventral to this vestibular aperture is the small orifice of the cochlear aqueduct. The entire cerebral surface above the internal acoustic meatus, including the anterior process is unusually rugose, pitted and ornamented with short bony spicules. The short anterior process is compressed from side to side, somewhat convex and creased externally, but flattened internally.

See table 3 for measurements of the periotic.

Table 3.—*Measurements (in mm.) of the periotic, USNM 23794*

	Right	*Left*
Greatest dorsoventral depth of periotic, from most inflated portion of tympanic face of pars cochlearis to most projecting point of cerebral face	37	38
Distance between epitympanic orifice of Fallopian aqueduct and extremity of anterior process	48	47.5
Length of posterior process, distance from external end to outer wall of groove for facial nerve	128	125
Distance from external end of posterior process to anterior end of anterior process (in a straight line)	168	173

AUDITORY OSSICLES

Association of the three little inner ear bones with the tympanic bulla and periotic has rarely been observed among specimens recovered from Miocene geological deposits in Maryland and Virginia. The recovery of a detached malleus, an incus, and a stapes in close association with the left bulla and periotic, as well as a malleus attached to the right bulla of this Choptank cetothere does not, however, provide additional information relative to the functioning of these auditory ossicles.

Malleus.—The slender stalk-like anterior process (USNM 23794; pl.2, fig. 7) of the malleus is fused with the anterointernal border of the sigmoid process of the bulla. The nearly vertical large hemicircular facet (pl.2, fig. 1) meets the smaller horizontal facet at a right angle in the usual manner of other mysticetes. At the internal end of the protuberant tubercle (processus muscularis) the little acuminate manubrium is bent outward and the scar for attachment of the ligamentary process of the tympanic membrance is located on the ventral surface. Two circular nodules similar in position to those on the malleus of *Parietobalaena palmeri* (Kellogg, 1968, p. 188) are present on the anterior face of the head of the malleus. The head of the left malleus measures 12 mm. in length and 9 mm. in width.

Incus.—The incus (USNM 23794; pl.2, fig. 2) exhibits a much closer resemblance to the form of *Physeter catodon* (Doran, 1878, pl.62, fig. 34) than to that of *Metopocetus durinasus* (Kellogg, 1968, pl.48, fig. 1), which is characterized in part by its more robust crus longum. Two articular facets divided by a ridge, which comprise the surfaces by which the incus is fitted to the malleus, meet almost at a right angle. The largest and longest facet, which is subcrescentic in outline and shallowly concave, occupies the base of the body of the incus. The smallest facet, which is rather deeply concave, is situated at the base of the body on the ventral side. The crus longum is relatively slender, rather abruptly incurved, and on its extremity it bears a slightly expanded concave and ovoidal Sylvian apophysis, which articulates with the head of the stapes. Absorption of the crus longum has reduced the body of the incus. The crus breve is short, conical and acuminate, and is projected at a right angle to the crus longum. A small facet on the dorsal surface of the apical portion of the crus breve serves as the area of contact with the fossa incudis of the periotic.

From the apex of the crus longum to the base of the body, the incus measures 7.4 mm., and the greatest diameter of the base is 6 mm.

Stapes.—The stapes (USNM 23794; pl. 2, fig. 3) has the normal balaenopterine form; it is narrower at the base and slightly more elongated than that of *Metopocetus durinasus* (Kellogg, 1968, pl. 48, fig. 2). The circular intercrural aperture connecting elongated cavities on opposite sides is open and not partially obstructed. The crura are straight and less divergent than on the stapes of *Balaenoptera acutorostrata* (Doran, 1878, pl. 62, fig. 31). An oval concavity or umbo occupies the vestibular face of the footplate of the stapes. The footplate had been displaced from the fenestra ovalis prior to removal of the enveloping matrix. A well-defined scar on the posterointernal angle below the head marks the area of attachment of the stapedial muscle. An ovoidal facet on the head of the stapes marks the area of contact with the corresponding facet on the head of the crus longum of the incus.

The greatest length of the stapes is 7.8 mm., and the greatest diameter of the footplate is 4 mm.

MANDIBLE

The left mandible of the type-specimen (USNM 23794) lacks a section approximately 290 mm. long near the anterior end. Slender branches of the roots of a tree growing in the earth immediately above this skeleton had penetrated into the mandibular canal through the external mental foramina and in the course of their enlargement during growth disrupted and disintegrated a lengthwise strip of bone in which the orifices of these foramina were located. Hence the number and position of these foramina cannot now be determined.

There is a noticeable flattening of the anterior two-thirds of the internal surface of this mandible (fig. 1), in contrast to the dorsoventral convex curvature of the external surface. Ventrally the external surface of the horizontal ramus meets the internal surface to form a well-defined angular edge, but not comparable to the elevated dorsal ridge or rim which is quite thin posteriorly and extends forward about 400 mm. in front of the coronoid process and also progressively increases in thickness. Below and internal to the base of this dorsal ridge, about 100 mm. anterior to the apex of the coronoid process, the orifice of the posteriormost small internal nutritive foramen is located. This lengthwise series of small foramina, separated by intervals that progressively lengthen from 15 to 60 mm., rise to the dorsal edge of the mandibular ramus anteriorly, the terminal foramen opening into the long (140 mm.) anteriorly directed narrow and rather deep groove.

On the left mandible (USNM 22961) tentatively referred to this species, the posteriormost internal nutritive foramen is located 1100 mm. behind the anterior end of the mandibular ramus; the largest of these small internal foramina is located 9 mm. below the edge of the thin dorsal rim. There are nine mental foramina along the outside curvature of the anterior 860 mm. of this left mandible, each of which opens into an anteriorly directed groove of variable length. These mental foramina are located behind the anterior end of the mandibular ramus as follows: first 275 mm.; second 100 mm. behind the first; third 60 mm. behind the second; fourth 45 mm. behind the third; fifth 50 mm. behind the fourth; sixth 70 mm. behind the fifth; seventh 95 mm. behind the sixth; eighth 60 mm. behind the seventh; and ninth 90 mm. behind the eighth. A large terminal mental foramen is present below the long, narrow dorsal groove on this referred mandible, but is closed on the type mandible.

Above the ventral edge of the anterior end of the mandibular ramus and below the short longitudinal crease, the flattened lower border (measuring 35 mm. dorsoventrally on the type mandible) of the internal surface is depressed.

Although the apex of the small coronoid process is eroded, the curvature of the preserved portion shows that it was low, subtriangular and everted apically, concave internally and convex externally, and also located

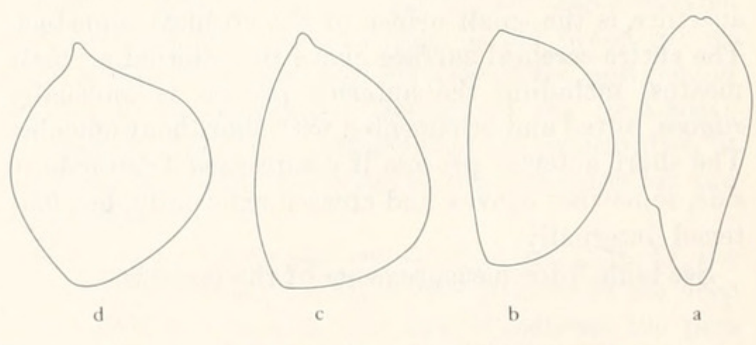

Figure 1.—Cross-sections of left mandible, USNM 23794, of *Thinocetus arthritus*. *a*, 100 mm. behind anterior end; *b*, 1100 mm. anterior to hinder articular surface of condyle; *c*, 700 mm. anterior to hinder articular surface of condyle; *d*, 360 mm. anterior to hinder articular surface of condyle.

above and in front of the anterointernal rim of the entrance to the mandibular canal.

The condyle (106×164 mm.; fig. 2) of the type left mandible is large, expanded transversely in an oblique direction above the middle of its vertical diameter and is more convex from side to side than dorsoventrally. Above the protuberant and convex angle, the deep groove for the attachment of the internal pterygoid muscle tends to impart a contour to the internal edge similar to the external edge of the condylar articular surface. Dorsally the attenuated condylar articular surface merges anteriorly with the curved thin rim of the horizontal ramus behind the coronoid process, and although narrowed is actually more noticeably transversely thickened than on Calvert mandibles of similar length. The forward curving internal and external borders of the condyle project noticeably beyond the lateral surface of the adjacent portions of the ramus. One may assume that this condyle was enveloped by a thick fibrous pad, similar to that of Recent mysticetes (Turner, 1892, p. 69), which served as the means of attachment to the glenoid fossa of the zygomatic process.

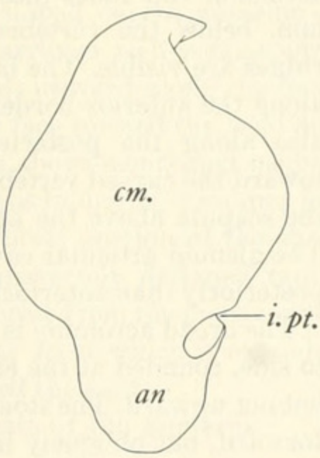

FIGURE 2.—Posterior view of condyle of left mandible, USNM 23794, of *Thinocetus arthritus*. *an*, angle; *cm.*, condyle of mandible; *i.pt.*, groove for internal pterygoid muscle.

Of the several mysticete mandibles recovered during the excavations in the Antwerp basin, this Choptank mandible exhibits the closest resemblance to *Mesocetus pinguis* (Van Beneden, 1886, pl. 44, fig. 10; right condyle, 96.5×164 mm.), except that the angular portion of the condylar articular surface below the inner groove for attachment of the internal pterygoid muscle is narrower and prolonged farther downward. The vertical diameter (123 mm.) of the anterior end of the right mandible of *M. pinguis* (MHNB 13) is greater than the corresponding measurement (108 mm.) of this Choptank mandible, but is narrower (39.5 mm.) in this region than the latter (43 mm.). Proportional growth rates of portions of the mandibular ramus of these fossil mysticetes are not as yet definable.

See table 4 for measurements of the mandibles.

TABLE 4.—*Measurements (in mm.) of left mandibles*

	USNM 23794	*USNM 22961*
Greatest length in a straight line, as preserved	1575+	1285+
Greatest vertical diameter 100 mm. behind anterior end of ramus	108	99
Greatest transverse diameter 100 mm. behind anterior end of ramus	43	46
Greatest vertical diameter 1350 mm. anterior to posterior face of condyle (300 mm. behind anterior end of ramus)	–	92
Greatest transverse diameter 1350 mm. anterior to posterior face of condyle (300 mm. behind anterior end of ramus)	–	55
Greatest vertical diameter 1150 mm. anterior to posterior face of condyle (500 mm. behind anterior end of ramus)	–	93
Greatest transverse diameter 1150 mm. anterior to posterior face of condyle (500 mm. behind anterior end of ramus)	–	64
Greatest vertical diameter 950 mm. anterior to posterior face of condyle (700 mm. behind anterior end of ramus)	95	97
Greatest transverse diameter 950 mm. anterior to posterior face of condyle (700 mm. behind anterior end of ramus)	63	72
Greatest vertical diameter 650 mm. anterior to posterior face of condyle (1000 mm. behind anterior end of ramus)	106	–
Greatest transverse diameter 650 mm. anterior to posterior face of condyle (1000 mm. behind anterior end of ramus)	71	–
Greatest vertical diameter through coronoid process	164	–
Horizontal distance from center of coronoid process to posterior face of condyle	240	–
Greatest vertical diameter of posterior end including condyle	165	–
Greatest transverse diameter of condyle	106	–

FORELIMB

The right forelimb is represented by the scapula, radius, ulna, six carpals, four metacarpals, and four phalanges. An incomplete scapula, humerus, ulna, one metacarpal and one phalange belong to the left forelimb. Assuming that the number of phalanges in the longest finger was seven, similar to *Balaenoptera acutorostrata*, the length of the manus would be approximately 450 mm. and the skeletal length of the fore flipper from head of humerus to distal end of terminal phalange about 1070 mm. (42 inches). The distance from the vertebral margin of the scapula to the distal end of the radius is 890 mm. (about 35 inches). The length of the humerus (258 mm.) is 67 percent of the length of the radius (385 mm.). The length of the fore flipper, tip to axilla, is estimated to have been about one-fifth (19.5 percent) of the entire length of the skeleton of this Choptank mysticete.

The pectoral flipper of this Miocene Choptank cetothere was undoubtedly capable of being elevated, depressed or tilted. Except for the ball and socket articulation of the scapula and the head of the humerus, all other joints of the forelimb had lost their synovial character and were assuredly joined together and stiffened by fibrous interosseous tissue. This fibrous tissue did, however, give considerable elasticity to the nonjointed flipper. The elbow had become incapable of bending. Bending of the elbow seems not to have been needed during either propulsion or balancing.

The scapula of these Miocene mysticetes conforms in general structure to that of the Eocene *Basilosaurus*. This fan-shaped shoulder blade has a prominent acromion, usually a somewhat smaller coracoid process, and the crista scapulae (spine) is limited to a vertical ridge. Since the forelimb of the mysticete is employed as a steering oar, the necessary surface for attachment of the muscles that provide the leverage for manipulation of this flipper are differently positioned than on the humerus, radius, and ulna of a land mammal. The radius and ulna are compressed and lack obvious muscle crests as well as grooves for ligaments. In position, the radius is situated in front of the ulna, an arrangement that existed during the Eocene in both *Basilosaurus* and *Zygorhiza*. The distal trochlea on the archaeocete humerus, however, has been replaced by anterior and posterior contact surfaces on the exterointernally compressed distal end of the mysticete humerus, providing a stiffened connection with the radius and ulna. The metacarpals of Recent mysticetes, which are compressed in an extensor-flexor direction almost to the same extent as the phalanges, are readily distinguishable by being thicker, more cylindrical and less flattened in the manus of this Choptank whale. The number of phalanges have undoubtedly increased by reduplications above the usual three in the fingers of land mammals, resulting in an elongation of the three middle digits.

Five of the six carpal bones associated with the right forelimb were found lying in a nearly normal position at the extremities of the radius and ulna. These carpal bones are ossified and have an irregularly roughened circumference which is indicative of attachment of fibrous tissue. The flattened area of the inner (flexor) surface of each carpal is larger than the outer (extensor) face. A narrow flipper, similar to that of the living balaenopterids is suggested by the spacing of the radiale, intermedium, and ulnare. Among Recent mysticetes ossification of these carpal bones has been retarded to such an extent that they are represented by relatively insignificant centers of ossification in the hyaline substance, although in old individuals these bony centers are visible on the surface of the cartilage.

One of the four metacarpals of the right manus has a somewhat shorter shaft than the others, but unfortunately the proximal epiphyses of all except one were detached and missing. Flattening of the shaft has commenced but does not materially alter its shape. These metacarpals are distinguishable from the more noticeably flattened phalanges. The number of digits is uncertain.

SCAPULA

The large fan-shaped scapula (USNM 23794; pl. 3, fig. 1) has a broad acromion, a short, stout coracoid process and a very narrow prescapular fossa which is progressively reduced below the anterovertebral angle toward the acromion; the ratio of height to the greatest width is about 3 to 5. The spine is represented by a ridge that extends upward from the dorsal basal edge of the acromion and fades into the external surface about 40 mm. below the vertebral margin. No other external ridges are visible. The broad blade, which is thickened along the anterior border internal to the acromion and also along the posterior border becomes quite thin toward the curved vertebral edge. The posterior edge of the scapula above the articular end is nearly straight. The glenoid articular cavity is deeply concave, broader posteriorly than anteriorly.

The broad acromion is strongly compressed from side to side, rounded at the extremity and directed forward but not upward. The stout coracoid process also projects forward, but obliquely inward.

See table 5 for measurements of the scapula.

TABLE 5.—*Measurements (in mm.) of the scapula, USNM 23794*

	Right	*Left*
Greatest anteroposterior diameter of scapula	492	488±
Greatest vertical diameter, articular head to vertebral margin	310	300±
Length of acromion	90	–
Posterior angle of blade to end of acromion	470	–
Length of coracoid process, dorsal margin at base to distal end	38	39
Posterior face of articular head to distal end of coracoid process	162	160
Greatest anteroposterior diameter of articular head	112	114
Greatest transverse diameter of articular head	83	84

HUMERUS

Both humeri (USNM 23794) are well preserved and retain both epiphyses firmly ankylosed to the shaft. Although the length of the right humerus of this Choptank mysticete is nearly equivalent to that of *Pelocetus calvertensis* (USNM 11976; 266.5 mm.) it is less massive as regards other measurements. Anteriorly, the large, smooth, and convex head (pl. 3, fig. 2) is elevated above the greater or radial tuberosity; on the right humerus the head is also separated from this tuberosity by a well-defined groove in contrast to the humerus of *P. calvertensis*. The head projects outward and backward. In Recent mysticetes the rugose greater tuberosity, which projects internally, serves as the proximal area for the attachment of the deltoid muscle. There is a large, irregular nodular tuberosity centrally placed on the internal face below and between the head and the greater tuberosity.

The shaft is more noticeably compressed transversely than that of *P. calvertensis*. An elongated welt-like enlargment (length, 115 mm.; pl. 3, fig. 2) continuous with the greater tuberosity is developed on the anterior or radial face of the shaft. A narrower welt commencing at the distal ulnar facet extends upward along the inner border of the hinder or ulnar face toward the head and coalesces proximally with the above-mentioned median proximal tuberosity on the right humerus; crushing has obliterated this welt on the dorsal portion of the shaft of the left humerus. The transversely flattened radial facet is set off by a ridge-like crest from the more convex transverse surface of the ulnar facet which is extended upward on the posterior face of the shaft.

See table 6 for measurements of the humerus.

TABLE 6.—*Measurements (in mm.) of the humerus, USNM 23794*

	Right	*Left*
Greatest length of humerus	260	255
Greatest anteroposterior diameter of proximal end	141	147
Greatest anteroposterior diameter of head	123	123
Greatest exterointernal (transverse) diameter of head	106	104
Least anteroposterior diameter of shaft	91	93
Least exterointernal (transverse) diameter of shaft	51	51
Greatest anteroposterior diameter of distal end	123	121
Greatest exterointernal (transverse) diameter of distal end	62	60
Greatest anteroposterior diameter of radial facet	75	71
Greatest anteroposterior diameter of ulnar facet (in a straight line)	77	75

RADIUS

The right radius (USNM 23794; pl. 3, fig. 3) has the distal epiphysis detached from the shaft, but it was preserved with the associated carpal bones. This distal epiphysis measures 72×45 mm. and has a maximum thickness of 23 mm. The right radius is slightly shorter than that of *P. calvertensis* (USNM 11976; length, 397 mm.). This forelimb bone of the Choptank mysticete is rather stout, slightly curved, and transversely compressed, measuring 385 mm. in length. The proximal facet, which articulated with the radial facet on the distal end of the humerus, is shallowly concave; the articular surface of this facet rolls over on the internal face of the proximal end of the shaft. The facet on the posterior face of the proximal end of the shaft for articulation with the olecranon of the ulna is semicircular in outline, its transverse diameter being 49 mm. and its dorsoventral diameter 32 mm.

The outer surface of the shaft is slightly more convex than the internal face. The distal half of the posterior edge of the shaft is more compressed than the anterior edge. The deeply concave distal end of the shaft is pitted for attachment of the cartilaginous connection with the epiphysis.

See table 7 for measurements of the radius.

TABLE 7.—*Measurements (in mm.) of the right radius, USNM 23794*

Greatest length (lacking distal epiphysis)	385
Greatest anteroposterior diameter of proximal end	81
Greatest transverse diameter of proximal end	56
Least anteroposterior diameter near middle of shaft	76
Least transverse diameter near middle of shaft	33
Greatest anteroposterior diameter of distal end	88
Greatest transverse diameter of distal end	42

ULNA

Both ulnae (USNM 23794) were associated with this skeleton; the distal epiphysis was detached from each shaft. The proximal end of the ulna (pl. 3, fig. 4) is expanded to form the somewhat hatchet-like olecranon process which has a rugose straight vertical posterior edge. The articular surface of the greater sigmoid cavity, which limits movement of the distal ulnar facet of the humerus, is truncated horizontally on its elevated dorsal edge (width, 36 mm.) and is expanded ventrally (transverse diameter, 48 mm.) at its anterior end. The vertical portion of this articular surface terminates about 20 mm. below the apex of the olecranon process. The vertical and the more or less horizontal portions of this greater sigmoid articular surface meet at an abrupt angle. Below its ventral anterior margin the articular surface of the greater sigmoid cavity meets at a right angle the hemicircular facet for articulation with the opposing facet on the proximal end of the radius; the vertical diameter of this facet is 30 mm. The curved shaft is compressed from side to side, more noticeably distally than below the radial facet, and is distinctly broader than that of *P. calvertensis*. Viewed from the side, the posterior profile is more curved than the anterior profile of the shaft. The posterior edge is somewhat thinner than the anterior edge of the shaft and this condition persists at the rugose distal end which has the posterior angle extended backward. The distal epiphysis of the right ulna is quite narrow, attenuated toward its posterior end and measures 84 mm. in length; its greatest thickness is 25 mm.

See table 8 for measurements of the ulna.

TABLE 8.—*Measurements (in mm.) of the ulna, USNM 23794*

	Right	*Left*
Greatest length of ulna (lacking distal epiphysis)	397	400
Distance from dorsal to ventral end of greater sigmoid cavity (in a straight line)	71	72
Least anteroposterior diameter of shaft (near middle of shaft)	55	53
Least exterointernal (transverse) diameter of shaft (near middle of shaft)	23	23
Greatest anteroposterior diameter of distal end of shaft	95	99
Greatest exterointernal (transverse) diameter of distal end of shaft	32	37

MANUS

The bones of the right manus were lodged under the transverse processes of the second to fifth dorsal vertebrae. The carpals were in close contact with one another and with three metacarpals. The other finger bones were less closely associated.

CARPALS.—Five of the six carpal bones associated with the right forelimb were preserved seemingly in more or less normal relationship at the extremities of the radius and ulna. The irregular roughened circumference of these carpals clearly indicates that they were held in position by interposed fibrous tissue. The inner (flexor) surface of each carpal is considerably larger than the opposite (extensor) surface. The presence of a smooth, curved surface on the anterior face of the radiale suggests a synovial joint, which may have permitted limited movements by the first metacarpal. The other carpal bones are thought to have been incapable of facilitating such movement by the corresponding metacarpals. At least six centers of ossification are represented by individual carpal bones in the right manus. There are certainly three carpals—radiale, intermedium, and ulnare—in the first row which when exposed by the preparator were found to be nearly in contact with the detached ossified epiphysis on the distal ends of the right radius and ulna. This pisiform, if present, was not preserved.

The position and characteristics of these three carpals show that tentative identifications of carpals of *Pelocetus calvertensis* (Kellogg, 1965, pl. 17) were incorrect. On the basis of this Choptank manus the carpal figured as the radiale (ibid., pl. 17, fig. 9) is the intermedium, and the supposed second row carpal (ibid., pl. 17, fig. 7) corresponds to the radiale. The ulnare (ibid., pl. 17, fig. 8) seems to agree with that carpal in the Choptank carpus.

The radiale (pl. 4, fig. 13) is the smallest of the three carpals in the first row; a proximodistal compressed protuberance is present on the posterior portion of the roughly sculptured circumference. The smooth surface on the outer (extensor) face, which curves upward on the anterior face to the opposite inner (flexor) face of this carpal may indicate a direct articulation with the first metacarpal as in the manus of *Squalodon* (USNM 22902). In the manus of *Balaenoptera musculus* and *B. acutorostrata* skeletons in the U.S. National Museum the radiale, however, is the largest carpal in the first row.

The intermedium (pl. 4, fig. 14) is the largest of the carpals in the first row, the maximum dimensions of the inner (flexor) surface being 52 and 59 mm. The flattened inner face of this carpal is about twice the opposite more convex outer (extensor) face. The circumference of the intermedium is unusually rugose and pitted.

The quadrangular flat inner (flexor) face of the ulnare (pl. 4, fig. 15) is about twice the size of the opposite oval extensor face; the irregular circumference is likewise rugose and pitted. The greatest diameter of the inner (flexor) face is 46 mm.

A carpal (pl. 4, fig. 17) as large as the radiale, which is tentatively identified as the centrale, was located in the matrix almost in contact with the distal face of the ulnare. The outer face is not quite as rugose as the circumference of this carpal; the ovoidal inner (flexor) face is, however, flat.

The carpal (pl. 4, fig. 16) tentatively identified as the trapezoid is elongated (length, 54 mm.); its width posteriorly (34 mm.) is equivalent to the outer-inner (extensor-flexor) diameter. The elongated outer (extensor) face is noticeably flattened in contrast to the irregularly depressed inner (flexor) face. This carpal was present in the second row distal to the interval between the radiale and the intermedium.

An ovoidal (38×35 mm.) carpal (pl. 4, fig. 18) that has smooth flattened inner and outer surfaces and a rugose circumference, whose maximum thickness (21 mm.) is less than half the corresponding measurement (44 mm.) of the intermedium, obviously was shifted behind the ulnare from its original position in the manus. It may have been either the unciform or the magnum.

Metacarpals.—Four metacarpals were associated with the right forelimb and one with the left. The two identified as the third and fourth lay distal to the carpal thought to be the centrale. The first metacarpal was found distal to the radiale. The second metacarpal was misplaced and lay on the adjoining ulna. The shafts of all the metacarpals are thicker, more cylindrical and less compressed in an extensor-flexor direction than those of *Pelocetus calvertensis* (Kellogg, 1965, pl. 18).

The shortest metacarpal (pl. 4, fig. 5; length, 63 mm.), which was embedded in the matrix distal to the radiale, is identified as the first. The triangular proximal end is about twice as large as the distal end; the shaft is somewhat narrowed distally and its anterior face is thicker than the compressed posterior face. Both ends are rather smooth and lack distinct rugosities for attachment of cartilaginous connections.

The metacarpal (pl. 4, fig. 1; length, 95 mm. including epiphysis) tentatively identified as the second, has an ossified proximal epiphysis which was not fused with the shaft. Before being covered with sediments this bone had been dislodged and moved to the anterior side of the flipper. The distal end of the shaft is more compressed in an extensor-flexor direction than the proximal end and is pitted for attachment of cartilage.

The third metacarpal (pl. 4, fig. 2; length, 90 mm.) and the fourth metacarpal (pl. 4, fig. 3; length, 78 mm.) seem to have retained their normal position in the flipper distal to the intermedium and ulnare. The proximal end of the third is oval and that of the fourth almost quadrangular; their distal ends are wider and more compressed in an extensor-flexor direction than their proximal ends. Both ends of each metacarpal are rugose.

See table 9 for measurements of the metacarpals.

Table 9.—*Measurements (in mm.) of the metacarpals, USNM 23794*

	R.I	R.II	R.III	R.IV	L.IV
Greatest length	63	82	90	78	79
Minimum transverse diameter of shaft	27	28	30	27	28
Minimum thickness of shaft	19	22.5	23.5	22	21.5
Greatest transverse diameter of proximal end	37	41	39	35	–
Greatest transverse diameter of distal end	28	41	44	43.5	43+

Phalanges.—Four phalanges were associated with the right forelimb and only one with the left. Two (pl. 4, figs. 9–10) of these phalanges are rather slender and not flattened except distally; they seemingly represent the same bone in the first finger of opposite flippers. Attached to the proximal end of the phalange in the right flipper is a lump of ossified cartilage. The largest phalange (pl. 4, fig. 6; length, 62 mm.) is distinctly flattened in an extensor-flexor direction, expanded more transversely at the proximal than at the distal end, both ends being roughened for attachment of connecting cartilage. Both of the subterminal phalanges (pl. 4, figs. 7–8) are compressed in an extensor-flexor direction, the shortest bone (length, 46 mm.) being nearest the end of the finger.

See table 10 for measurements of the phalanges.

Table 10.—*Measurements (in mm.) of the phalanges, USNM 23794*

	Plate 4				
	fig. 6 Right	*fig. 7 Right*	*fig. 8 Right*	*fig. 9 Right*	*fig. 10 Left*
Greatest length	62	53.5	46	63	62
Minimum transverse diameter of shaft	31	22	22.5	17.5	16
Minimum thickness of shaft	16.5	14	16	15	13.5
Greatest transverse diameter of proximal end	45	32	29	27	24.5
Greatest transverse diameter of distal end	36.5	31	25	25.5	23

VERTEBRAE

CERVICAL VERTEBRAE

The atlas, axis, third, fourth, fifth, and sixth cervicals were excavated with this skeleton (USNM 23794). On the right side of the axis and of the third cervical the lateral processes are broken off at the base. Pedicles of the neural arch are preserved on the fourth, fifth, and sixth cervicals, but all lateral processes except for basal portions are missing on the centra. Both epiphyses are firmly fused with the centra of all cervicals. Except for the fusion of the centra of the axis and the third cervical, the cervicals were free. The pedicles of the neural arch of the third to sixth cervicals, inclusive, are low and wider transversely than anteroposteriorly. Shortening of the pedicles, as indicated on the third cervical, and flattening of the roof of the neural arch has resulted in an unusually low neural canal. On the third cervical the upper transverse process is united distally with the extremity of the lower process to enclose the large cervical extension of the thoracic retia mirabilia, which also passes through the foramen transversarium on the transverse process of the axis. The atlas and axis are massive, broad and thick, with a low neural spine which on the atlas rises to a blunt apex. The atlas has a short rugose hyapophysial process. The odontoid process of the axis is slender and abnormally elongated. The total length of the cervicals, including the cartilaginous intervertebral disks, did not exceed 305 mm. (12 inches). See table 11 for measurements of the cervical vertebrae.

Atlas.—This massive, broad and thick atlas (USNM 23794) has a short, laterally compressed neural spine, a high neural canal, and a nodular remnant of an upper transverse process. The anterior facets (pl. 5, fig. 1) for articulation with the occipital condyles of the skull are deeply concave, widest near the middle of their height and separated ventrally by a shallow groove. The vascular foramen which normally pierces the neural arch on each side is closed. The lower transverse process is short, thick, and projects outward below the smaller, nodular upper remnant. A short, broad, rugose hyapophysial process is present. An upward, forward sloping concave surface (pl. 5, fig. 2) for reception of odontoid process of the axis separates ventrally the reniform articular surfaces for the axis.

Additional measurements are as follows: greatest distance between outer margins of posterior articular facets, 177 mm.; greatest vertical diameter of right posterior articular facet, 83 mm.

Axis.—On the right side of this axis (USNM 23794) the transverse process is broken off at the base. The complete left process (pl. 5, fig. 3) is elongated, bent backward, and perforated by a large foramen transversarium; the lower bar of this process is very thick (38 mm.) at the base and the upper is thin, anteroposteriorly compressed. The small neural canal is low, wider (54 mm.) than high (37 mm.). The neural spine is reduced to a low thick anteroposterior ridge. The odontoid process is slender, unusually elongated and concave dorsally at its distal end. The vertical diameter (right, 94 mm.) of the deeply concave anterior articular facets exceeds the transverse diameter. The anterior median angle of the neural arch is not extended forward to articulate with the neural arch of the atlas. The posterior face of the centrum of the axis is fused with the opposite surface of the third cervical as also the pedicles of the neural arches of both cervicals. This fusion may represent the initiation of the subsequent coalescence of the cervical series of some mysticetes during later geological time.

Third cervical.—The broadly eliptical posterior face of the third cervical (USNM 23794) is concave. The pedicles of the neural arch are short, their minimum width (39 mm.) greater than their anteroposterior diameter (23 mm.). A marked increase in the transverse diameter (67 mm.) of the neural canal (pl. 5, fig. 4) characterizes this cervical. The slender upper transverse process (diapophysis) on the left side projects outward and downward from the pedicle of the neural arch and is united distally with the curved upward and

Table 11.—*Measurements (in mm.) of the cervical vertebrae, USNM 23794*

	Atlas	*Axis*	*C.3*	*C.4*	*C.5*	*C.6*
Greatest vertical diameter of vertebra, tip of neural spine to ventral face of centrum	140	128	113	–	–	–
Greatest anteroposterior diameter of centrum	97 [a]	95 [b]	36	32	32	34
Greatest tranverse diameter of centrum anteriorly	195	181	110 [c]	108	100+	104
Greatest vertical diameter of centrum anteriorly	–	–	83 [c]	85	86	88
Greatest vertical diameter of neural canal anteriorly	58	37	21	–	–	–
Greatest transverse diameter of neural canal anteriorly	63	54	67	66	73+	80
Greatest distance between outer ends of diapophyses	–	–	276±	–	–	–
Greatest distance between outer ends of parapophyses	220	323±	282±	–	–	–
Least anteroposterior diameter of right pedicle of neural arch	55	54	23	17	16.5	16
Greatest distance between outer margins of anterior articular facets	182	179	–	–	–	–

[a] Dorsally; [b] Plus odontoid process; [c] Posteriorly.

transversely widened lower process (parapophysis) to enclose the large cervical extension of the thoracic retia mirabilia. This parapophysis is dorsoventrally compressed toward its base.

Fourth cervical.—All lateral processes as well as the pedicles of the neural arch are broken off near the base on this cervical (USNM 23794). The anteroposteriorly compressed upper transverse process (diapophysis) projected outward from the pedicle of the neural arch; the parapophysis projected outward and downward. The anterior face of the centrum is more flattened than convex in contrast to the concave posterior face.

Fifth cervical.—Except for a noticeable increase in the width of the neural canal, this cervical (USNM 23794) does not differ materially from the preceding.

Sixth cervical.—Minor alterations including a gradual decrease in the anteroposterior diameter of the pedicle of the neural arch, an increase in the transverse diameter of the neural canal, and the vertical diameter of the centrum are observable from the third to the sixth cervical (USNM 23794). Upper as well as lower transverse processes were present.

DORSAL VERTEBRAE

All twelve dorsal vertebrae (USNM 23794) were found at the time of excavation in their original undisturbed sequence, although only the neural arch and neural spine of the first dorsal was found. The centrum of this dorsal and its diapophyses had previously been broken off and removed by some visitor at the site. Both epiphyses are firmly ankylosed to the centrum of each of these eleven dorsals. Spondylitis deformans or osteophytosis presumably limited the movement but did not bind together the third to tenth dorsals, inclusive, which have bony outgrowths protruding posteriorly on one or both sides from the ventral border of the centrum.

On each side of the centrum of the second to seventh dorsals, inclusive, the facet for the head of the following rib is located obliquely on a well-defined posterior tuberosity below the level of the floor of the neural canal on the second but gradually becomes located higher on the lateral surface.

The pedicles of the neural arch on the seven anterior dorsals are very low and broader transversely than anteroposteriorly. Shortening of the pedicles and flattening of the roof of the neural canal had produced an unusually low neural canal, the vertical diameter anteriorly being equivalent to less than one third (second, 78×27 mm.) to one fourth (sixth, 70×17 mm.) of the transverse diameter. A median longitudinal ridge on the floor of the neural canal increases in prominence behind the seventh dorsal. The total length of the twelve dorsals, including the cartilaginous intervertebral disks, is about 960 mm. (37¾ inches). See table 12 for additional measurements of the dorsal vertebrae.

First dorsal.—The neural spine of this dorsal (USNM 23794) was short, rising 35 mm. above the roof of the broad neural canal, and truncated obliquely from its anterobasal edge to its posterodorsal apex.

Second dorsal.—Except for the left diapophysis this dorsal (USNM 23794; pl. 6, fig. 1) is complete and shows no indication of osteophytosis. The stout right diapophysis (length, 115 mm., pl. 7, fig. 1) projects outward, slightly downward and somewhat forward; the large, triangular terminal facet for the tuberculum of

Table 12.—*Measurements (in mm.) of the dorsal vertebrae, USNM 23794*

	D.2	D.3	D.4	D.5	D.6	D.7	D.8	D.9	D.10	D.11	D.12
Anteroposterior diameter of centrum	54	60	67	68	72	76	83	93	99	103	106
Transverse diameter of centrum, anteriorly	114	120	121	115	112	113	124	117	114	115	112
Vertical diameter of centrum, anteriorly	80	78	84	80	79	79	82	87	88	87	88
Minimum anteroposterior length of pedicle of neural arch	27	31	31	37	38	43	57	57	63	68	66
Transverse diameter of neural canal, anteriorly	78	78	77	72	70	67.5	52	49	43	41	38
Vertical diameter of neural canal, anteriorly	27	23	20	22	22	18	22	33	29	29	39
Distance between end of parapophyses	–	–	–	–	–	–	–	275	307	362	415
Distance between ends of diapophyses	275±	240	235	228	225	218	240	–	–	–	–
Dorsal edge of metapophysis to ventral face of centrum, anteriorly	95	94	95	107	111	105	117	131	134	137	153
Tip of neural spine to ventral face of centrum posteriorly	154	156	162	175	170	195	207	240	233	245	246
Transverse diameter of centrum, posteriorly including posterior capitular facets	128	125	135	137	138	140	132	123	117	117	114
Vertical diameter of centrum, posteriorly	79	80	82	77	80	82	89	86	87	86.5	87

the second rib slopes obliquely downward and inward from dorsal to ventral margin. The strong pedicles of the neural arch are broad (right, minimum transverse diameter, 41 mm.) and very short; they support the roof of the neural canal as well as contributing a portion of the base of the diapophysis. The small ovoidal prezygapophysial facets are limited externally by a low ridge. The postzygapophysial facets are elongated, much larger, and slope obliquely downward from external to internal margins. The distally attenuated neural spine (pl. 8, fig. 1) rises 54 mm. above the roof of the neural canal. The dorsoventrally elongated hemicircular and protuberant facet on the posteroexternal angle of the centrum for the head of the third rib seemingly does not share this function with a similar opposing surface on the anteroexternal angle of the centrum of the third dorsal. Viewed from in front the centrum is uniformly elliptical.

Third dorsal.—A decrease in the length (98 mm.) of the diapophysis, a shift in the direction of the main axis of the terminal facet for the tuberculum of the third rib from dorsoventral to anteroposterior and an increase in the thickness of the centrum characterize this vertebra (USNM 23794). Very little if any alteration in the dimensions of the neural canal are observable. Each broad diapophysis (pl. 7, fig. 2) projects outward but more strongly forward than on the preceding dorsal. The wide pedicles (36 mm.) of the neural arch support the low roof of the neural canal as well as contributing a portion of the base of the diapophysis. An external sharp-edged ridge limits externally the elongated (length, 60 mm.) shallowly concave prezygapophysial facet. Both postzygapophysial facets are pitted and partially deformed by osteophytosis. The short, distally attenuated neural spine (pl. 8, fig. 2) rises 62 mm. above the roof of the neural canal. The posteroexternal hemicircular facet for the capitulum of the fourth rib is smaller than, but is as protuberant as, the corresponding facet on the preceding dorsal. Viewed from in front the centrum (pl. 6, fig. 2) is elliptical, dorsoventrally compressed. A dorsoventrally compressed bony process projects backward for 20 mm. from the ventroexternal border of the centrum on the left side.

Fourth dorsal.—Each broad (minimum width, 55 mm.) dorsoventrally compressed diapophysis (pl. 6, fig. 3) projects outward from the short stout pedicle of the neural arch and extends forward beyond the anterior face of the centrum. The extremity of the diapophysis is horizontally widened to provide an elongated facet (40 mm.) for the tuberculum of the fourth rib. Each elongate and concave prezygapophysial facet (pl. 7, fig. 3) slopes obliquely downward from the external sharp-edged ridge or crest to its inner thin edge. The distance between these external ridges anteriorly is 110 mm. The narrow elongate postzygapophysial facets slope obliquely downward from external to internal margins. The low roof of the neural canal is almost horizontal. No material change in either the transverse or vertical diameter of the neural canal is observable. The short distally rounded neural spine (pl. 8, fig. 3) rises 67 mm. above the roof of the neural canal. The protuberant posterior hemicircular facet for the capitulum of the fifth rib is larger than that of the preceding dorsal. Viewed from in front the profile of the centrum (USNM 23794) is more quadrangular than elliptical. Ventrally the rims of the anterior and posterior epiphyses are extruded and irregular.

Fifth dorsal.—An increase in the minimum anteroposterior diameter (37 mm.) of the right pedicle of the neural arch, a reduction in the transverse diameter (72 mm.) of the neural canal (pl. 6, fig. 4), but no appreciable reduction of the distance (109 mm.) between the external crest-like margins of the opposite prezygapophysial facets anteriorly characterize this dorsal (USNM 23794). Both dorsoventrally compressed diapophyses (pl. 7, fig. 4) are a little broader (minimum width, 57 mm.) but shorter than those of the preceding dorsal; they project outward and extend forward well beyond the level of the anterior face of the centrum and have a more elongated (length, 45 mm.) ovoidal concave tubercular facet at the extremity. Prezygapophysial and postzygapophysial facets are similar to those of the preceding dorsal. The distally truncated neural spine (pl. 8, fig. 4) has increased in width and rises 82 mm. above the roof of the nueral canal. No increase or decrease in the size of the hemicircular protuberant posteroexternal facets for the capitulum of the following rib is observable. Dorsoventrally compressed bony excrescences project backward from the posteroventral edge of the centrum on each side.

Sixth dorsal.—This dorsal (USNM 23794) has a large bony excrescence (pl. 8, fig. 5) projecting backward from the ventral border of the centrum on the right side which certainly limited freedom of movement of this vertebra. A less noticeable decrease in the transverse and vertical diameters of the centrum and of the neural canal (pl. 6, fig. 5) has occurred. The distance between the outer margins of the deeply concave prezygapophysial facets has been reduced to 95 mm. and the postzygagophysial facets have become somewhat narrower. The diapophyses (pl. 7, fig. 5) have been slightly shortened, but are extended forward beyond the level of the anterior face of the centrum; the terminal concave facet of the diapophysis for the capitulum of the sixth rib extends farther inward on the ventral surface. The horizontally truncated neural spine rises 78 mm. above the roof of the neural canal. Protuberant postero-external facets for the capitulum of the seventh rib are developed on both sides of the centrum.

Seventh dorsal.—This dorsal (USNM 23794; pl. 8, fig. 6) has a large nodular bony excrescence projecting forward from the ventral border of the centrum on the right side, which in conjunction with the backward projecting excrescence of the preceding dorsal increased the intervertebral space. An increase in the length (76 mm.) of the centrum, a reduction in the distance (214 mm.) between the ends of the diapophyses (pl. 6, fig. 6) and a marked increase in the height (100 mm.) of the neural spine above the roof of the neural canal are the most obvious differential characteristics. The dorsoventrally compressed diapophysis projects horizontally outward from the stout pedicle of the neural arch and extends forward beyond the level of the anterior face of the centrum. At the extremity of the diapophysis the facet for the tuberculum of the seventh rib is divided horizontally into two articular surfaces. The prezygapophysial facets (pl. 7, fig. 6) are narrowed and separated anteriorly by an interval of 80 mm. The postzygapophysial facets are narrower than those of the preceding dorsal. No visible posteroexternal facet for the capitulum of the eighth rib is developed on the left side; a malformed protuberance is present on the right side. The height (18 mm.) is less than one third of the width (67.5 mm.) of the neural canal.

Eighth dorsal.—Malformation (pl. 6, fig. 7), possibly the result in part of downward pressure, has shortened the right pedicle of the neural arch and depressed the right diapophysis, so that this process is directed outward and obliquely downward. The left diapophysis is bent upward toward its extremity. Both diapophyses (USNM 23794) are dorsoventrally compressed and widened at the extremity (pl. 7, fig. 7), on which the facet for the tuberculum of the eighth rib is located mainly on the ventral surface. Each low metapophysis is thickened, projects forward beyond the anterobasal edge of the diapophysis, and contributes the external limit to the narrow prezygapophysial facet. The prezygapophysial facets are separated anteriorly by an interval of 47 mm. Postzygapophysial facets are not developed. A somewhat wider neural spine (pl. 8, fig. 7) rises 104 mm. above the roof of the neural canal. No posteroexternal facets for the capitulum of the ninth rib are present. A similar, but somewhat smaller bony excrescence projects forward from the anterolateral border of the centrum. Viewed from in front the profile of the centrum is elliptical, but flattened dorsally. The neural canal is low (height, 22 mm.), but is reduced in width (52 mm.). On the right side of the centrum a wide backward projecting excrescence is located below the usual position of the posteroexternal facet for the capitulum of the following rib.

Ninth dorsal.—The broad, dorsoventrally compressed and bent upward parapophysis projects outward solely from the dorsoexternal surface of the centrum (USNM 23794). The thin (right, 18 mm.) anteroposteriorly widened (83 mm.) extremity of this process is deeply excavated on its ventral surface for attachment of the head of the ninth rib. The thick metapophyses (pl. 7, fig. 8) are separated anteriorly by an interval of 38 mm., project forward beyond the level of the anterior face of the centrum, and contribute the outer limit of the short, narrow, and concave prezygapophysial facets. The broad, backwardly inclined, and distally truncated neural spine (pl. 8, fig. 8) rises 120 mm. above the roof of the neural canal; the transverse diameter (49 mm.) exceeds the vertical diameter (33 mm.) of the neural canal. The elliptical profiles of the anterior (pl. 6, fig. 8) and posterior ends of the centrum are quite similar as are also their vertical and transverse diameters. A large laterally compressed bony excrescence projects forward from the anteroexternal edge on the left side of the centrum. On the posterior half of the right side of the centrum a nodular excrescence projects laterally but is not in contact with the low elongate malformation bordering the anterior epiphysis.

Tenth dorsal.—On the right side of the centrum (pl. 8, fig. 9) of this dorsal (USNM 23794) a large laterally compressed bony excrescence projects forward from the anteroexternal edge and another of similar size extends backward from the posteroexternal edge. The left side of the centrum is normal. Longer parapophyses, narrower neural canal (43 mm.), and longer centrum conform to the usual sequential modification of cetothere dorsal vertebrae. Each parapophysis (pl. 7, fig. 9) projects almost horizontally outward from the upper portion of the external surface of the centrum and increases in width toward its extremity. On the extremity (right, length 94 mm.) a deep concave facet for the head of the tenth rib occupies the posterior half, largely on the ventral surface. The thin pedicles (right, minimum length, 63 mm.) of the neural arch extend two-thirds of the length (99 mm.) of the dorsal surface of the centrum. The profile of the anterior face of the centrum (pl. 6, fig. 9) approaches subcordate, flattened dorsally. The backward slanting neural spine rises 125 mm. above the roof of the neural canal; the width (43 mm.) exceeds the height (29 mm.) of the neural canal. Thickened metapophyses project forward beyond the level of the anterior end of the centrum; distinct prezygapophysial facets are not developed.

Eleventh dorsal.—Wide, dorsoventrally compressed parapophyses, which project outward from near the middle of the external surface of the centrum, a broad distally truncated backwardly slanting neural spine, (pl. 8, fig. 10) which rises 137 mm. above the roof of the neural canal, and long (right, minimum length, 68 mm.) thin pedicles of the neural arch characterize this vertebra (USNM 23794). Each parapophysis has a thick concavely curved posterior edge, a thin rounded anterior edge on distal half of its length, and an ovoidal (right, length 50 mm.) facet for head of eleventh rib located posteriorly on extremity. The large metapophyses (pl. 7, fig. 10), separated anteriorly by an interval of 38 mm., project forward beyond the level of the anterior face of the centrum. The elliptical profiles of the anterior (pl. 6, fig. 10) and posterior ends of the centrum are quite similar as are also their vertical and transverse diameters. No protruding bony excrescences attributable to osteophytosis are present on this vertebra.

Twelfth dorsal.—Rather wide (minimum diameter, 65 mm.) and dorsoventrally compressed parapophyses project outward from near the middle of the external surface of the centrum (USNM 23794); the anterior and posterior edges of this process are thin and the extremity is obliquely truncated from the anterior edge to the posterodistal angle, which is thickened but not otherwise modified for attachment of the head of the twelfth rib. The large laterally compressed metapophyses (pl. 10, fig. 1) rise 60 mm. above the floor of the neural canal and are separated anteriorly by an interval of 40 mm.; they project forward noticeably beyond the level of the anterior face of the centrum. The distally truncated neural spine (pl. 8, fig. 11) is inclined more strongly backward and rises 125 mm. above the roof of the neural canal. This vertebra (pl. 6, fig. 11) has the narrowest (width, 38 mm.) and the highest (39 mm.) neural canal of all the dorsal vertebrae. No protruding bony excrescences are present on this vertebra. A prominent longitudinal median ridge extends the length of the floor of the neural canal.

LUMBAR VERTEBRAE

The cervicals, the dorsals, and the nine anterior lumbars comprising the anterior portion of the vertebral column (USNM 23794), were found to lie in normal sequential contact with one another. Behind the ninth lumbar the tail portion of the skeleton, and at least two or possibly three of the lumbars, was broken off and presumably washed forward alongside the dorsal vertebrae, but reversed so that the terminal caudal was almost on a line with the cervicals. Two of the posterior lumbars were displaced; one lay between the rows of dorsal and caudal vertebrae and the other was almost in contact with the first of the twelve consecutive caudal vertebrae. Since twelve lumbar vertebrae normally comprise the lumbar series of the Calvert cetotheres, the disassociated vertebrae was either the tenth or the eleventh. On the basis of measurements, the displaced vertebra is regarded as the tenth, the lumbar almost in contact with the first caudal as the twelfth, and the eleventh as missing.

The epiphyses are firmly ankylosed to the centrum of all these lumbar vertebrae. Except on the posteriormost lumbar no protuberant bony excrescences are present. Arranged in serial sequence the centra of these lumbars increase in length, width and height from the anterior to the posterior end of the series. No median longitudinal ridge or keel is developed on the first lumbar; this ridge is rather faint on the second lumbar, but increases in prominence toward the posteriormost lumbar. The parapophyses decrease in length from the first to the twelfth lumbar. The thin pedicles of the neural arch attain their greatest anteroposterior diameter (minimum, 73 mm.) on the sixth lumbar. The transverse diameter of the neural canal and the length of the metapophyses diminishes from the anterior toward the posterior end of the series. Neither pre nor postzygapophysial facets are developed on these lumbars. Backward slanting neural spines increase in height from the first to the sixth lumbar and then become progressively shorter before a more abrupt decrease reduces their height to that of the first caudal.

Circumstances of preservation including localized pressure from weight of overlying strata on sediments of unequal consistency in which the vertebral column was embedded resulted in the tilting of the neural spine leftward and the partial collapse of the left pedicles of the neural arch and the sequential deformation of the neural canal from the third, fourth, fifth, and to a lesser extent the sixth lumbar.

The total length of the consecutive series of twelve lumbar vertebrae, including the cartilaginous intervertebral disks, did not exceed 1375 mm. (54⅛ inches). See table 13 for measurements of the lumbar vertebrae.

First lumbar.—This vertebra (USNM 23794) was excavated in normal sequential contact with the twelfth of the consecutive dorsal vertebrae and hence is unquestionably the first lumbar. No ventral longitudinal ridge or keel is developed on the centrum and the outline of the anterior end (pl. 9, fig. 1) is more ovate than elliptical. An increase in the length of the parapophyses and in the height of the backward slanting neural spine

TABLE 13.—*Measurements (in mm.) of the lumbar vertebrae, USNM 23794*

	L. 1	*L. 2*	*L. 3*	*L. 4*	*L. 5*	*L. 6*	*L. 7*	*L. 8*	*L. 9*	*L. 10*	*L. 11*	*L. 12*
Anteroposterior diameter of centrum	108	109	111	114	117	120	124	126	132	134	–	138
Transverse diameter of centrum, anteriorly	106	108	109	112	114	117	115	123	124	130	–	139
Vertical diameter of centrum, anteriorly	89	91	94	97	98	103	102	104	104	108	–	113
Minimum anteroposterior length of pedicle of neural arch	63	68	66	70	72	73	65	66	65	64	–	62
Transverse diameter of neural canal, anteriorly	35	35	–	34	30	29	34	28	24	23	–	18
Vertical diameter of neural canal, anteriorly	42	40	–	–	–	–	35	39	40	–	–	–
Distance between ends of parapophyses	425	415	415±	380±	375±	365±	340±	350±	340±	305±	–	295±
Dorsal edge of metapophysis to ventral face of centrum, anteriorly	155	152	148	150	150	147	154	151±	169±	–	–	–
Tip of neural spine to ventral face of centrum posteriorly	265	268	246	285	305	310	315±	320±	320	295±	–	280±
Transverse diameter of centrum, posteriorly	114	113	110	116	118	117	114	123	127	136	–	135
Vertical diameter of centrum, posteriorly	91	94	96	97	100	99	97	106	107	117	–	120

(pl. 11, fig. 1), which rises 152 mm. above the roof of the neural canal, also mark the commencement of the lumbar series. The thin dorsoventrally compressed parapophyses otherwise do not differ materially in shape from those of the twelfth dorsal. The neural canal is higher (42 mm.) than wide (35 mm.) and a prominent longitudinal median ridge extends the length of the floor of the neural canal. Neither pre- nor postzygapophysial facets are present; both metapophyses (pl. 10, fig. 2) are compressed from side to side, slope obliquely downward from external to internal edges and project forward beyond the level of the anterior face of the centrum. No protruding bony excrescences are present on this lumbar.

SECOND LUMBAR.—A reduction of the distance (415 mm.) between the extremities of the parapophyses and an increase in the minimum anteroposterior length (68 mm.) of the thin pedicle of the neural arch are the most obvious features distinguishing this lumbar (USNM 23794) from the preceding vertebra. No increase in the height of the backward slanting distally truncated neural spine (pl. 11, fig. 2), which rises 145 mm. above the roof of the neural canal, is observable. Each dorsoventrally compressed, elongated, subspatulate, and narrow (minimum width, 60 mm.) parapophysis (pl. 10, fig. 3) tapers to its rounded extremity. The metapophyses (pl. 9, fig. 2) rise 60 mm. above the floor of the neural canal. A rudimentary median ventral longitudinal ridge is present on the centrum. A prominent median longitudinal ridge extends the length of the floor of the neural canal. No bony excrescence is developed on this vertebra.

THIRD LUMBAR.—Downward pressure collapsed the left pedicle of the neural arch (pl. 9, fig. 3), tilting the neural spine leftward, and deforming the neural canal. Except for the extremity of the thin left parapophysis (pl. 10, fig. 4) this vertebra (USNM 23794) is otherwise complete. The thin pedicles of the neural arch support the elongated metapophyses which project forward noticeably beyond the level of the anterior face of the centrum. The backward slanting neural spine (pl. 11, fig. 3) rises 138 mm. above the roof of the neural canal. A distinct median longitudinal ridge is developed on the dorsal and ventral surface of the centrum. The profile of the anterior end of the centrum is subcircular.

FOURTH LUMBAR.—This lumbar (USNM 23794; pl. 10, fig. 5) lacks the distal end of both parapophyses, but is otherwise complete. No bony excrescences are present. The curvature of the anterior and posterior edges of the basal portions of these transverse processes show that they were shorter but similar in shape to those of the preceding lumbar. The high neural spine (pl. 11, fig. 4), which rises 185 mm. above the roof of the neural canal, is bent leftward, deforming the neural canal, but not affecting the forward projection of the elongate metapophyses. The posterodistal angle of the neural spine as a result of this strong slant extends backward to less than 10 mm. from the level of the posterior face of the centrum of the fifth lumbar. The anteroposterior diameter (70 mm.) of the thin pedicle of the neural arch has increased. An accentuated median longitudinal ridge is developed on the ventral face of the centrum.

FIFTH LUMBAR.—As compared with the preceding lumbar, the width and vertical diameter of the centrum

(USNM 23794; pl. 9, fig. 5) has increased slightly. The elongated metapophyses, which rise 50 mm. above the floor of the neural canal, project considerably beyond the level of the anterior face of the centrum. The distal end of the left parapophysis (pl. 10, fig. 6) is missing; the spatulate and dorsoventrally compressed right parapophysis is complete, projecting outward and downward from near the middle of the lateral surface of the centrum. The backward slanting neural spine (pl. 11, fig. 5) rises 200 mm. above the roof of the neural canal and is bent leftward, deforming the neural canal. The median longitudinal ridge is more strongly developed on the ventral surface of the centrum than on the floor of the neural canal. No bony excrescences are present.

Sixth lumbar.—The extremity of the left parapophysis (pl. 10, fig. 7) is missing, but otherwise this vertebra (USNM 23794) is complete. On this lumbar the backward slanting neural spine (pl. 11, fig. 6) is not only wider (minimum anteroposterior diameter, 78 mm.) than those on the preceding lumbars, but is also longer, rising 208 mm. above the roof of the neural canal. This neural spine (pl. 9, fig. 6) is less noticeably bent leftward, although the neural canal is deformed in that direction. Very little reduction in the length of the dorsoventrally compressed subspatulate parapophysis or in the anteroposterior diameter of the thin pedicle of the neural arch is discernible. The median longitudinal ridge does not extend the length of the ventral surface of the centrum; no bony excrescences are present.

Seventh lumbar.—A marked reduction in the size and forward projection of the metapophyses (pl. 11, fig. 7) and in the length (minimum anteroposterior diameter, 65 mm.) of the thin pedicles of the neural arch, as well as a shortening of the parapophyses are the most obvious distinguishing features of this lumbar (USNM 23694). Most of the right parapophysis (pl. 10, fig. 8) as well as the distal end of the neural spine are lost. The transverse diameter (34 mm.) of the neural canal (pl. 9, fig. 7) at the floor almost equals the vertical diameter (35 mm.) anteriorly. The neural spine is essentially vertical, not bent leftward as on preceding lumbars. A medium longitudinal ridge is present on the ventral and dorsal surfaces of the centrum. No bony excrescences are present.

Eighth lumbar.—The convex curvature of the posterior edge of the thin outward and downward projecting left parapophysis (pl. 10, fig. 9) accentuates its slight forward direction, although its rounded extremity does not extend forward beyond the level of the anterior face of the centrum (USNM 23794). The extremity of the right parapophysis is missing and both metapophyses are incompete. The backward slanting neural spine (pl. 11, fig. 8) is vertical and rises 197 mm. above the roof of the neural canal. The vertical diameter (39 mm.) exceeds the transverse diameter (28 mm.) of the neural canal (pl. 9, fig. 8). A median longitudinal ridge is present on the ventral and dorsal surface of the centrum. No bony excrescences are present.

Ninth lumbar.—Measurements of the centrum (USNM 23794) are not materially different from the eighth lumbar. The neural canal of this lumbar (pl. 9, fig. 9) has been reduced in width (24 mm.), the vertical but backward slanting neural spine (pl. 11, fig. 9), which rises 187 mm. above the roof of the neural canal, has been slightly shortened, and there is a slight increase in the length (132 mm.) of the centrum. A sharp-edged median longitudinal ridge is present on the ventral face of the centrum; the corresponding ridge on the floor of the neural canal is low. Both metapophyses are incomplete and the extremity of the left parapophysis (pl. 10, fig. 10) is missing. The outward and downward projecting parapophyses are inclined more strongly forward than on the preceding lumbar; these processes are also slightly shorter and wider than those on the eighth lumbar. No bony excrescences are present.

Tenth lumbar.—This lumbar (USNM 23794; pl. 9, fig. 10) lacks the roof of the neural arch, both metapophyses and the neural spine. The dorsoventrally compressed parapophyses (pl. 11, fig. 10) are approximately as wide (75 mm.), but are slightly shorter than those of the preceding lumbar and are deflected less obliquely downward from horizontal. A portion of the extremity of the left parapophysis (pl. 10, fig. 11) is missing; the right process is complete. Decrease of the transverse diameter (23 mm.) has been gradual. A sharp-edged median longitudinal ridge is present on the ventral surface of the centrum and a similar less elevated ridge extends the length of the floor of the neural canal.

Eleventh lumbar.—This lumbar was dislodged from the vertebral column prior to the accumulation of the protective overlying sediments and was not found associated with the skeleton.

Twelfth lumbar.—This lumbar (USNM 23794; pl. 9, fig. 11) lacks the roof of the neural arch, both metapophyses, the neural spine, and all except the basal portions of both the parapophyses. The length, width, and height of this lumbar exceeds the corresponding dimensions of all the preceding lumbars. Posteriorly on the right side of the centrum (pl. 11, fig. 11) above the parapophysis, a rather large, bony excrescence projects backward about 30 mm. beyond the posterior epiphysis. A sharp-edged median longitudinal ridge is present on the ventral surface of the centrum; a similar longitudinal ridge, however, is not developed on the floor of the neural canal.

CAUDAL VERTEBRAE

Thirteen caudal vertebrae (USNM 23794), lying consecutively in a row, that have their epiphyses firmly ankylosed to the centrum, were associated with this skeleton. At least one small terminal caudal is missing. The lengths of the three anterior caudals are approximately equal; the length of the centrum diminishes more abruptly behind the sixth caudal. The terminal caudals are more noticeably compressed anteroposteriorly.

The distance between the dorsoexternal edges of the metapophyses progressively diminishes from the first to the sixth. Behind the second caudal the height of the neural spine rapidly decreases. Shortening of the transverse process terminates in the short flange-like thickened condition present on the sixth caudal. This transverse process is perforated at the base medially on the fourth, fifth, and sixth caudals. A vertical aqueduct on the lateral portion of the centrum of the seventh, eighth, and ninth caudals serves the same function for passage of the segmental blood vessels on their upward course.

On the first caudal a short remnant of the ventral keel on the posteriormost lumbar is retained in the median ventral longitudinal haemal groove; posterior, but no anterior, haemal tubercles are present. Anterior and posterior pairs of haemal tubercles, separated by the median ventral longitudinal haemal groove, are present on the third, fourth, fifth, and sixth caudals. On each side of the centrum of the seventh and eighth caudal, the anterior and posterior haemal tubercle is connected by a thickened longitudinal bony connection which is perforated medially by a foramen for passage of the segmental blood vessels. Behind the eighth caudal, the lateral portion of the centrum is pierced vertically by an aequeduct for passage of these blood vessels. The seventh may be regarded as the transitional caudal since it has a reduced but complete roof for the neural arch over the neural canal.

The total length of this consecutive series of thirteen caudals, including the cartilaginous intervertebral disks, did not exceed 1270 mm. (50 inches). See table 14 for measurements of the caudal vertebrae.

First caudal.—On this vertebra (USNM 23794) a pair of ventral posterior haemal tubercles contribute the lateral limits of the median longitudinal haemal depression which rather unusually is divided at the middle of its length by a longitudinal ridge. No anterior haemal tubercles are present. The broad neural spine (pl. 11, fig. 12) is broken off distally, but is inclined backward. Both metapophyses are missing. The thin pedicles of the

Table 14.—*Measurements (in mm.) of the caudal vertebrae, USNM 23794*

	Ca. 1	*Ca. 2*	*Ca. 3*	*Ca. 4*	*Ca. 5*	*Ca. 6*	*Ca. 7*	*Ca. 8*	*Ca. 9*	*Ca. 10*	*Ca. 11*	*Ca. 12*	*Ca. 13*
Anteroposterior diameter of centrum	137	136	136	131	123	118	108	96	72	53	45	41	39
Transverse diameter of centrum anteriorly	133	137	130	137	140	132	110	103	98	95	82	69	65
Vertical diameter of centrum anteriorly	116	118	117	121	120	119	118	111	102	89	73	63	56
Minimum anteroposterior length of pedicle of neural arch	84	65	71	59	78	71	71	–	–	–	–	–	–
Transverse diameter of neural canal, anteriorly	18	12	14	17	16	18	12	9	11	–	–	–	–
Vertical diameter of neural canal, anteriorly	31	28	23	21	9	13	12	–	–	–	–	–	–
Distance between ends of transverse processes	267±	244±	214	196	174	138	–	–	–	–	–	–	–
Dorsal edge of metapophysis to ventral face of centrum, anteriorly	180±	180	180[h]	181[h]	168[h]	161[h]	141[h]	125[h]	–	–	–	–	–
Tip of neural spine to ventral face of centrum, posteriorly	258±[h]	237[h]	205[h]	187[h]	168[h]	161[h]	145[h]	–	–	–	–	–	–
Transverse diameter of centrum, posteriorly	–	139	137	137	127	108	102	99	96	–	–	–	–
Vertical diameter of centrum, posteriorly	125	123	126	124	124	120	115	106	95	–	–	–	–

[h] – including haemapophyses.

neural arch extend most of the length of the centrum. Both transverse processes (pl. 13, fig. 1), which lack their extremities, were obviously shorter than those of the twelfth lumbar. The neural canal (pl. 12, fig. 1) is quite narrow. Posteriorly on the right side, commencing at the level of the transverse process and extending upward to the neural arch, a very large bony excrescence extends backward more than 45 mm. beyond the posterior epiphysis.

Second caudal.—Distinct paired anterior haemal tubercles are not developed on the ventral surface of the centrum (USNM 23794); the posterior pair of rather large tubercles are separated by a wide (30 mm.) haemal groove, but no remnant of the longitudinal ridge present on the preceding caudal persists. The left transverse process (pl. 13, fig. 2) is short and broad; the right process is broken off at the base. The left metapophysis (pl. 12, fig. 2) which is complete, projects more outward than upward, and extends forward beyond the level of the anterior face of the centrum. The backward inclined neural spine (pl. 14, fig. 1) is shorter and the neural canal narrower than the preceding caudal.

Third caudal.—The right metapophysis is broken off, but otherwise this caudal (USNM 23794) is complete. The elongate posterior haemal tubercles are separated by the broad longitudinal open groove which also extends forward between the smaller anterior haemapophyses. As compared with the second caudal, the transverse processes (pl. 13, fig. 3) are shorter, more expanded anteroposteriorly and truncated distally. On their upward course from the ventral haemal groove, the segmental vascular vessels (pl. 14, fig. 2) pass in front of the shallow notch at the anterobasal angle of the transverse process and thence follow a broad shallow groove that extends obliquely backward on the lateral surface of the centrum to the posterior end of the neural canal. The distally truncated backward slanting neural spine is reduced in height as is the narrow neural canal.

Fourth caudal.—Except for the missing apical portion of the neural spine this caudal (USNM 23794) is well preserved. An aproximately equal development of the anterior and the posterior pair of haemal tubercles, and an increase in the width of the median ventral longitudinal haemal groove occurs first on this caudal. The separation on each side of the anterior from the posterior haemal tubercle by a long deep notch or gap provides the pathway for the segmental blood vessels on their upward course on the lateral surface of the centrum through the foramen that pierces the base of the short, broad transverse process (pl. 13, fig. 4) medially and thence obliquely to the posterior end of the neural canal. The low pedicles of the neural arch (pl. 12, fig. 4) support the thickened metapophyses which do not project forward beyond the anterior face of the centrum. The neural spine (pl. 14, fig. 3) has diminished in height as well as in anteroposterior diameter.

Fifth caudal.—The contour of both ends of the centrum (USNM 23794; pl. 12 fig. 5) is almost hexagonal. The ends of the short transverse processes (pl. 13, fig. 5) are obliquely truncated from the anteroexternal angle to the posteroexternal angle. Both of these processes are pierced medially at the base for the passage of the segmental blood vessels (pl. 14, fig. 4) which on each side pass through the open notch between the anterior and the posterior haemal tubercles and dorsally reach the neural canal through the foramen in the pedicle of the neural arch. The median ventral longitudinal haemal groove is broad and deep. The neural canal is diminished to a transversely oval passage. The thick metapophyses are directed obliquely upward and outward; the neural spine is low.

Sixth caudal.—On this caudal (USNM 23794) the profile of the posterior end of the centrum is almost ovoidal in contrast to the hexagonal anterior end (pl. 12, fig. 6) and also is somewhat narrower. The segmental blood vessels (pl. 14, fig. 5) follow the same upward course from the gap between the anterior and posterior haemal tubercles through the foramen at the base of the abbreviated transverse process (pl. 13, fig. 6) to the foramen in the pedicle of the neural arch. The median ventral longitudinal haemal groove is deep but narrower than on the preceding caudal.

Seventh caudal.—Ventrally (USNM 23794) on each side the anterior and posterior haemal tubercles (pl. 14, fig. 6) are united by a thickened osseous connection which is pierced by a foramen for passage of the segmental blood vessels. Above this foramen these blood vessels on their upward course pass through a vertical aqueduct in the lateral portion of the centrum to reach on the left side the foramen in the pedicle of the neural arch. This dorsal foramen is obliterated in the right pedicle. The median ventral longitudinal haemal groove is deep. A thin and very low neural spine (pl. 13, fig. 7) extends almost the full length of the roof of the neural arch. This roof is lacking on the caudals behind this vertebra. A thick longitudinal ridge marks the position of the transverse process on the preceding caudals.

Eighth caudal.—This caudal (USNM 23794; pl. 13, fig. 8) resembles the seventh caudal in having the anterior and posterior haemal tubercles united by a thick osseous connection perforated medially for the passage of the segmental blood vessels from the deep ventral longitudinal haemal groove. These vessels continue their course upward through the vertical aqueduct in the lateral portion of the centrum, and presumably reach the posterior end of the open neural canal. The metapophyses (pl. 12, fig. 8) are reduced to low, thickened elongate knobs. The neural canal is an open elongated groove. A reduced longitudinal ridge (pl. 14, fig. 7) marks the position of the transverse process on the preceding caudals.

Ninth caudal.—Absence of haemapophyses (USNM 23794; pl. 12, fig. 9) and a further shortening of the centrum characterize this caudal (pl. 13, fig. 9). Except for the elongated central orifice of the vertical aqueducts of the segmental blood vessels, the ventral longitudinal haemal groove is almost obliterated. One additional orifice on each side completes the normal three ventral orifices of the vertical aqueducts that pierce the centrum and enable the segmental blood vessels to emerge dorsally through two foramina in the deep open neural groove. On the small terminal caudals of Recent mysticetes, the neural canal is not covered by the roof of the neural arch and chevron bones are not attached; these anteroposteriorly compressed caudals serve as a base for the attachment of the fibrous caudal flukes.

Tenth caudal.—A depressed but flattened anterior end (pl. 12, fig. 10) and a convex posterior end of the anteroposteriorly compressed and somewhat circular centrum are the most obvious distinguishing features of this caudal (USNM 23794). The dorsal pair of orifices (pl. 13, fig. 10) for the vertical vascular aqueducts, separated by an interval of 5 mm., open into a short ovoidal cavity. Ventrally there are three smaller orifices for the segmental blood vessels, each lateral one being 24 mm. distant from the central orifice.

Eleventh caudal.—The centrum of this caudal (pl. 12, fig. 11; USNM 23794) has become more quadrangular in outline, the anterior end is depressed, and the posterior end convex. A rather broad longitudinal groove is present on each lateral surface. Dorsally, the two orifices of the vertical vascular aqueducts (pl. 13, fig. 11) are closely approximated in a small (width, 7 mm.) circular cavity. The usual three small ventral openings are present.

Twelfth caudal.—Viewed from in front, the profile of this caudal (USNM 23794; pl. 12, fig. 12) is definitely quadrangular, the lateral longitudinal groove (pl. 14, fig. 11) is narrower, and both ends are depressed. The dorsal and ventral orifices of the vertical aqueducts for the segmental blood vessels are not materially different from those of the eleventh caudal.

Thirteenth caudal.—This anteroposteriorly compressed caudal (USNM 23794; pl. 14, fig. 12) differs from the preceding caudal in being smaller, but otherwise lacks distinguishing features.

At least one small terminal vertebra was not represented in this caudal series.

CHEVRONS

Three chevron bones were found intermingled with other skeletal elements of this mysticete, the largest of which was articulated with the third caudal (table 15). All three have strong haemal spines and large articular facets on the transversely widened dorsal ends of the lateral lamina. The haemal canal of all three chevrons is smooth, without any indication of a median longitudinal ventral ridge.

Table 15.—*Measurements (in mm.) of the chevrons, USNM 23794*

	Ch. 3	*Ch. 6*	*Ch. 7*
Vertical diameter of chevron	117	75	58
Greatest anteroposterior diameter of haemal spine at extremity	94	66	65
Anteroposterior diameter of articular facet on right lateral lamina	58	—	49
Least distance between internal (median) margins of opposite articular facets	13	—	none

The third chevron (USNM 23794; pl. 1, fig. 2) has a large elongated haemal spine, whose free ventral edge curves convexly downward from the anterior end of the haemal canal to its nearly straight vertical posterior edge. The right articular facet is shorter and wider than the left, which is more strongly attenuated as its anterior end.

The next largest chevron (USNM 23794; pl. 1, fig. 3) is incomplete, the posterior half of the right lamina and most of the left lamina are broken off. This chevron has a short, broad haemal spine, truncated horizontally, ventrally and a small obtuse anterobasal projection. The vertical diameter of the haemal canal below the edge of the articular facet is 22 mm. as contrasted to the 41 mm. depth of the canal of the third chevron. The anterior half of the right articular facet is similar in shape to that of the third chevron. The measurements of the haemal canal suggest that this may be the sixth chevron.

The smallest (USNM 23794; pl. 1, fig. 4) of these three chevrons has a somewhat shorter, ventrally thickened haemal spine and a narrower anterobasal projection than the larger, more rounded posterobasal projection. The small haemal canal is higher (15 mm.) than wide (10 mm.). Above the haemal canal the elongated ovoidal articular facets are in contact medially. This is tentatively identified as the seventh.

RIBS

Eleven pairs of ribs were associated with this skeleton (USNM 23794). No trace of a twelfth pair of ribs was found at the site of excavation. The lack of a roughened area on the beveled obliquely truncated extremity of the transverse process of the twelfth dorsal vertebra seemingly suggests but does not necessarily confirm the absence of a twelfth pair of ribs.

The capitulum at the vertebral end of the first to eighth pair of ribs, inclusive, is lodged mainly in the protuberant posterior facet on the dorsoexternal face of the centrum of the preceding vertebra. The tuberculum of each of the eight anterior pairs of ribs articulates with the facet at the extremity of the diapophysis. The rather robust neck of the ribs in the eight anterior pairs progressively diminishes in length from the second (the longest) to the eighth. On the first rib, the vertebral end is strongly compressed anterposteriorly and the distance between the vertebral margin of the tuberculum and the external margin of the capitulum is short (right, 20 mm.). The single head of the ninth, tenth, and eleventh ribs is asymmetrical, and articulates solely with the facet at the extremity of the transverse process (parapophysis).

As a result of curvature the anterior face of the shaft near the vertebral end imperceptibly becomes the external face toward the distal end on all the ribs behind the first pair; this face is more convex than the posterointernal face.

The first rib is the shortest and most strongly compressed anteroposteriorly, and also most abruptly curved inward at the ventral or sternal end of all the ribs. This rib most certainly had a ligamentary attachment to the sternum. Behind the first pair the ribs progressively increase in length (in a straight line) to the fifth and sixth pairs and then decrease to the eleventh pair. The distal or sternal ends of the second, third, and fourth ribs on the right side, and the second, third, fourth, fifth, and sixth on the left side are truncated and rugose, possibly for attachment of some ligamentary connection with sternal ribs. The manubrium is much too small to provide a base for attachment of so many ribs. All other ribs are attenuated toward the ventral or distal end and presumably terminated freely in the mass of abdominal muscles. See table 16 for measurements of the ribs.

First rib.—The distal end of the shaft is broken off on both the right and left ribs (USNM 23794; pl. 15, fig. 1). On the right rib the small ovoidal capitular facet is separated from the much larger tubercular facet by a short interval (20 mm.). Both of these facets are malformed on the left rib. The shaft of these ribs is markedly compressed anteroposteriorly from the vertebral to the sternal end, and also strongly curved. Since the seventh cervical and the diapophysis of the first dorsal were not recovered with this skeleton, the articular relations of this first rib are uncertain.

Second rib.—On the right side, this long rib (USNM 23794; pl. 15, fig. 2) is complete; the vertebral end of the left rib is broken off. This rib is considerably larger than the first rib; its rugose sternal end is compressed but not reduced in width and presumably was attached to the sternum by a ligament. The flattened capitular facet is located at the end of the anteroposteriorly compressed neck and is separated by an interval of 55 mm. from the concave articular surface of the tuberculum. No angle is developed on the shaft external to the tuberculum; the curvature is regular, the external edge being thicker than the internal.

Third rib.—The third pair of ribs (USNM 23794; pl. 15, fig. 3) are more curved and longer than the second, the right and left measuring, respectively, 637 and 636 mm.; the shaft is strongly compressed toward the sternal end. The sternal end of the shaft is rugose and pitted, and not appreciably narrower than the widest portion of the shaft. At the vertebral end of the neck, the distance between the large ovoidal capitular facet and the narrow elongated tubercular facet (left, length, 60 mm.) is reduced to 18 mm., although

Table 16.—*Measurements (in mm.) of ribs, USNM 23794*

	R.1	*L.1*	*R.2*	*L.2*	*R.3*	*L.3*	*R.4*	*L.4*	*R.5*	*L.5*	*R.6*	*L.6*
Greatest length, capitulum to extremity in a straight line	227+	314+	521	477+	637	636	698	705	728	725	705	715
Articular face of capitulum to external margin of tubercular facet	86	–	97	–	92	94	84	86	79	83	82.5	77
Shaft, greatest width	44	47	50	42	51	50	45	43	40	43	38	39

	R.7	*L.7*	*R.8*	*L.8*	*R.9*	*L.9*	*R.10*	*L.10*	*R.11*	*L.11*	*R.12*	*L.12*
Greatest length, capitulum to extremity in a straight line	697	706	710+	692	650	662	558+	540+	494+	588		
Articular face of capitulum to external margin of tubercular facet	74	77	–	–	–	–	–	–	–	–		
Shaft, greatest width	38	39	34.5	34	36	33	32	31	35	34		

the distance between the capitulum and the external margin of the tuberculum is very slightly less than on the second rib.

Fourth rib.—The length of the ribs of the fourth pair (USNM 23794; pl. 15, fig. 4) has increased (right, 698 mm.; left, 705 mm.) ; the width of the curved shaft has become more uniform from end to end, and the articular area of the tuberculum has been reduced. Although the distance (30 mm.) from the capitular facet to the inner (vertebral) margin of the tubercular facet has increased, this end of the rib is actually shorter than on the third rib. Although longer, the shaft of this rib is actually narrower than the third; its compressed sternal end is likewise rugose and pitted. As compared with the external edge the internal edge of the shaft is less noticeably compressed.

Fifth rib.—No indication of an angle external to the tuberculum is present on the outer surface of the shaft of either rib (USNM 23794; pl. 15, fig. 5). The end-to-end curvature of the shaft is about the same as that of the preceding rib. At the vertebral end of the shaft the tuberculum is a saddle-like depression separated from the more nearly circular capitular facet by an interval of 15 mm. Shortening of the neck and a narrowing of the shaft have accompanied elongation of this rib (right, 728 mm.; left, 725 mm.). The attenuated sternal end of the right rib is deeply pitted, presumably for attachment of a ligament; this end of the shaft of the left rib is attenuated but otherwise normal.

Sixth rib.—A slight indication of an angle 120 mm. external to the tuberculum is present on the outer surface of the shaft of the left rib; (USNM 23794; pl. 15, fig. 6). Each of these ribs is slightly shorter (right, 705 mm.; left, 715 mm.) than the preceding, although the end-to-end curvature is about the same. The attenuated sternal end of the left rib is deeply pitted, but the sternal end of the left is normal. The saddle-like tubercular facet is separated by an interval of not more than 15 mm. from the convex capitular facet. The length of the neck is approximately equal to that of the preceding rib. The outer surface of this rib is slightly convex and the internal is flattened.

Seventh rib.—The ribs of the seventh pair (USNM 23794; pl. 15, fig. 7) are slightly shorter than the sixth, the right and left ribs measuring, respectively, 697 and 706 mm.; the curvature of the shaft is quite similar. A definite angle is developed 140 mm. external to the tuberculum on the left but not on the right rib. On this left rib the oval articular face of the knob-like capitulum is located at the extremity of the more noticeably constricted and shortened neck; the capitulum of the right rib is much smaller and lacks projecting edges. The tuberculum on both ribs is an ill-defined irregularly depressed surface. A slight enlargement attributable to osteophytosis has deformed the left rib about 315 mm. distant from the articular face of the capitulum. The sternal ends of both ribs are compressed and gradually attenuated.

Eighth rib.—A definite angle is present 240 mm. external to the articular face of the capitulum on the outer surface of the left but not on the right rib (USNM 23794; pl. 15, fig. 8). The vertebral end of each rib in this pair is quite unlike any of the preceding ribs; the neck is dorsoventrally compressed and attenuated to the small terminal capitulum. The ill-defined tuberculum is located on an elevation at the commencement of the neck. The shaft of the eighth rib is also more slender and much less compressed than that of the seventh rib, but is attenuated at the sternal end.

Ninth rib.—The right and left ribs of the ninth pair (USNM 23794; pl. 15, fig. 9) measure, respectively, 650 and 662 mm. in a straight line; the shaft of each rib is less curved, particularly near the vertebral end, than the eighth rib. The articular area on the vertebral end of the rib is exceedingly nodular and irregularly excavated.

Tenth rib.—Both ribs of the tenth pair (USNM 23794; pl. 15, fig. 10) have their distal ends broken off and lost. Both ribs have the vertebral end dorsoventrally compressed and widened for the elongated articular surface. The shafts of these ribs are slightly curved and are less compressed than the preceding ribs.

Eleventh rib.—The narrow articular head of each of the eleventh ribs (USNM 23794; pl. 15, fig. 11) is ovoidal in outline, pitted, and roughened for the ligament that serves for attachment to the extremity of the transverse process of the eleventh dorsal. The left rib, which measures 588 mm. in a straight line, may either have been fractured 190 mm. above the compressed distal end or malformed by osteophytosis.

STERNUM

Recent Mysticeti possess a sternum consisting of a broad flattened presternum, which is extended posteriorly into a xiphioid process in some species; but no mesosternal segments have been observed and, consequently, only the first pair of ribs are attached to the presternum. The sternum of these Recent mysticetes varies from heart-shaped, longitudinally oval, to trilobate. Although it is generally accepted that the sternum does not provide a satisfactory basis for discriminating closely allied species of Recent Mysticeti, evidence now exists that two Miocene genera have a sternum of almost identical shape.

The thin sternum (USNM 23794; pl. 1, fig. 5) of this Choptank cetothere is definitely cordiform in outline, measuring 99 mm. in width and 91 mm. in length, and the apparent downward bowing when viewed from below is attributable to the convex fore and aft curvature of the ventral surface of this bone. The entire bone is rugose, the texture of the exposed surface being granulated. The indentation of each side may represent the area of attachment of the sternal end of the first rib. The heart-shaped sternum of the Miocene *Cetotherium klinderi* figured by Brandt (1873, pl. 5, figs. 13A, 13B) differs from this Choptank sternum in having an acute posterior end and in lacking the lateral indentation. True (1904, p. 258, fig. 85) has figured a heart-shaped sternum of a North Atlantic *Balaena glacialis*, but observes that a lack of uniformity among the several recorded specimens is not surprising.

2. THE VERTEBRAE OF A SECOND MIOCENE CHOPTANK CETOTHERE

A subsequent tendency toward a rather gradual shortening of the neck seems to be indicated by a comparison of the relative cervical lengths of Miocene cetotheres with Recent balaenopterid mysticetes. The cervical length of this Miocene Choptank cetothere constituted about 5.6 percent of the total skeletal length. Reduction of the cervical length attributed to the mechanical squeezing of the neck between the head and the thorax by water pressure from in front while swimming as advocated by Winge (1918, pp. 62–63; 1921, p. 5) requires further consideration. On a purely mechanical basis it would appear more probable that such pressure would have tended to narrow the skull and possibly to elongate the neck.

Among these Calvert and Choptank cetotheres fusion of the cervical vertebrae, involving the coalescence of the opposing centra and the pedicles of the neural arches, occurs first between the axis and the third cervical (USNM 11976, 23794). Reduction in the length of the centra is manifested first on the third cervical. Increase in the length of the centra behind the axis is gradual to and including the first dorsal and on some cetothere skeletons the second dorsal as well. The chief dorsal neck muscles are regarded as an integral part of the musculature of the trunk, and function as such during swimming.

Among Recent balaenopterids, the anterior pairs of ribs have reduced or lost their articular connections with the centra of corresponding dorsal vertebrae; and the neck, between the tuberculum and the capitulum of the rib, has been shortened. Eight anterior pairs of ribs of these cetotheres have definite articular relations with these anterior dorsals. On these dorsals a well-defined articular facet, located at the posterodorsal angle of the external face of the centrum below the floor of the neural canal, articulates with the capitulum of the following rib, and the end of the diapophysis (upper transverse process) articulates with the tuberculum. Each lateral transverse process (parapophysis) projecting horizontally outward from the centrum on the posterior dorsal vertebrae has a single headed rib attached by ligaments to its extremity. On the posteriormost dorsal the transverse processes rival in size and length the corresponding processes of the lumbars and are regarded as serially homologous. The neural spines increase in height and width (in an anteroposterior direction) toward the posterior end of the dorsal series; these neural spines are longer and often broader in the lumbar region.

Atrophy of the hind limb and the accompanying degeneration of the pelvis had been effected in some at least of the cetotheres before the close of the Miocene. Retrogressive remodeling of the innominate bones of the middle Miocene (Astoria fm.) *Cophocetus oregonensis* (Packard and Kellogg, 1934, pp. 58–59, figs. 22–24) had proceeded so far that the acetabulum was obliterated, yet the elongated ilium resembled the balaenopterid type. There is no visible indication that the pelvic bone retained a functional contact with any vertebra. Sacral vertebrae that normally in land mammals possess flattened areas on their transverse processes for a ligamentous attachment of the pelvis are not recognizable as such and they (the sacrals) have assumed the shape and characteristics of vertebrae either in front or behind.

The caudal vertebrae are distinguished by a ventral articulation with a chevron bone which serves to protect the caudal arterial and venous trunks that follow the haemal groove on the under side of each centrum. Four or five modified terminal caudals are embedded in the caudal flukes of Recent mysticetes and the corresponding cetothere caudals are similarly degenerate. The anterior caudals have robust centra, diminishing in size toward the more obviously anteroposteriorly compressed centra of the terminal vertebrae and of these the first six or seven have strong neural arches that support neural spines and metapophyses. Neural spines progressively reduced in height and width (in an anteroposterior direction), large metapophyses spreading obliquely upward and outward, but not interlocking with the vertebra in front, and diminishing neural canals also characterize the anterior caudals. Shortening of the transverse processes terminates in the flange-like condition of the sixth caudal. On the small anteroposteriorly compressed terminal caudals, the neural canal is not covered by the roof of the neural arch and chevrons are not attached ventrally.

Comparison with skeletons of Recent balaenopterids shows that the caudal vertebrae of these cetotheres possess the requisite structural features to support the musculature and tendons required to manipulate effectively a terminal organ of propulsion. The cetothere tail obviously was strongly muscled and employed as a propelling organ by up-and-down or side-to-side strokes, or possibly with a sculling motion. The strongly muscled cetothere tail with a terminal flattened horizontal fluke would function as the primary specialized organ to propel the whale forward, upward or downward in a nearly straight line. The pectoral flippers serve in steering and balancing.

The cordiform shape of the small sternum (pl. 1, fig. 5) of a Choptank cetothere indicates that it had become reduced or atrophied and consequently has lost most of its functional relationship with the ribs in the thorax.

Halicetus,[2] new genus

Type-species.—*Halicetus ignotus*, new species.

Diagnosis.—Atlas not unusually thickened and a vestigial hyapophysial process present. Odontoid process of axis short, acutely pointed. Pedicles of neural arch of third to seventh cervicals short and rather wide; neural canal relatively high, not unusually widened; roof of neural canal arched. Neural spines of dorsals progressively increasing in anteroposterior width and height toward posterior end of series, almost vertical on anterior dorsals in contrast to slight backward inclination of posterior dorsals. Neural spine of eleventh lumbar shorter but broader than on first lumbar; metapophyses of lumbars and posterior dorsals thin, deep vertically. Transverse processes of first to fourth caudals anteroposteriorly widened toward extremity. Posterior process of periotic greatly enlarged anteroposteriorly; bulbous anterior process rugose and porous internally, elsewhere irregularly creased or wrinkled longitudinally; dorsal rim of circular internal acoustic meatus projects internally (cerebrally) beyond slit-like depression for aperture of vestibular aqueduct and the cochlear aqueduct orifice; transverse and vertical diameters of excavation behind stapedial fossa for extension of air sac system approximately equivalent.

[2] *Halos*, sea, in allusion to life in the sea.

Halicetus ignotus, new species

Type-specimen.—USNM 23636. Skull when excavated badly fractured and individual bones detached; both tympanic bullae; both periotics; seven cervical vertebrae; 12 dorsal vertebrae; 3 lumbar vertebrae; 12 caudal vertebrae; rib fragments. Collector, Richard Warren, April 1964.

Horizon and locality.—In shell layer of sandy zone 19, about 14 feet above beach level, 1.9 miles (10,000 feet) south of Calvert Beach Run (U.S.G.S. Cove Point sheet, 1943), Calvert County, Maryland. Choptank formation, middle Miocene.

SKULL

TYMPANIC BULLA

Both tympanic bullae (USNM 23636) were associated with the periotics attached to the squamosal portions of the type skull. The left bulla is the best preserved although both lack the anterior and posterior pedicles. Except for a more accentuated roughening of the dorsal surface of the involucrum by development of wider transverse ridges as well as the greater width of the anterior eustachian outlet of the tympanic cavity, the bulla of this mysticete resembles in several respects the corresponding auditory bone of *Pelocetus calvertensis* (Kellogg, 1965, fig. 4, p. 12), not only in size. Viewed from the external side, the ventral profile of this bulla (pl. 16, fig. 5) is slightly arched, the posterior end being markedly convex and the anterior end obliquely truncated in a dorsoventral direction. The large elongated sigmoid process is twisted at a right angle to the long axis of the bulla, its bluntly rounded extremity being bent backward.

See table 17 for measurements of the left tympanic bulla.

The basal portion of the slender processus gracilis (anterior process of Ridewood, 1922, p. 241, fig. 10) of the malleus remains fused to this bulla in the groove

Table 17.—*Measurements (in mm.) of left tympanic bulla, USNM 23636*

Greatest length	65
Greatest width	40
Greatest depth of bulla on external side, ventral face to tip of sigmoid process	52.5

321-614 O—69——3

in front of the sigmoid process; the anterior pedicle has been broken off at the level of the free outer edge of the overarching outer lip. A deep narrow groove intervenes between the sigmoid process and Beauregard's conical apophysis; the latter is a short bluntly rounded process separated by a notch from the thin external portion of the posterior pedicle. The major basal portion of this posterior pedicle projected from the involucrum.

The involucrum attains its maximum width (pl. 16, fig. 4) behind the projecting sigmoid process and becomes abruptly narrowed in front of the level of the attachment of the processus gracilis. Viewed from the ventral side (pl. 16, fig. 3) this bulla is characterized by an oblique truncation at both ends; the anterior widening of the tympanic cavity is reflected in the increased width of the anterior end of the bulla which is also greater than the posterior end.

PERIOTIC

The type-skull was so badly crushed and broken up prior to excavation that reconstruction has not been attempted. Disintegration of the bone has destroyed the original contact surfaces of the larger pieces of the basicranium.

The posterior process of the right periotic (USNM 23636) was firmly lodged between the exoccipital and the base of the postglenoid process of the squamosal before the periotic was detached. This posterior process (pl. 16, fig. 1) is elongate and markedly enlarged toward its distal end, the greatest vertical diameter (84 mm.) exceeding the anteroposterior diameter (55 mm.) near the terminal end, although the posterior surface of this process seems to have been abraded before the exoccipital was detached. A well-defined deep and curved groove for the facial nerve traverses the ventral surface of this process from its base to its extremity. The pars cochlearis is extended into the large recess behind the pterygoid fossa.

The external denser pars labyrinthica and its forward continuation, the anterior process, are both creased externally and lodged as usual in the cavity on the internal face of the squamosal. A ventrointernal projection or lip from the pars labyrinthica overlaps the adjacent surface of the squamosal and is possibly abnormal although developed on both periotics. The transverse diameter of the thick anterior process is rapidly diminished from the level of the pars cochlearis to its blunt anterior end.

The pars cochlearis (pl. 16, fig. 1) is inflated and its external face overhangs the fenestra ovalis. Viewed from the ventral side, its cerebral profile is modified by the projecting dorsal rim of the internal acoustic meatus; its convex posterior face descends abruptly below the fenestra rotunda in contrast to the pronounced flattening of the ventral surface anteriorly.

Behind the epitympanic orifice of the Fallopian aqueduct, a narrow raised rim separates the fenestra ovalis from the groove for the facial nerve. The small fossa for the stapedial muscle is rugose. Between the base of the anterior pedicle of the bulla, which is fused to the anterior process, and the epitympanic orifice of the Fallopian aqueduct is a shallow depression for lodging the head of the malleus. The small fossa incudis is located on a narrow ledge projecting inward below the groove for the facial nerve.

The circular internal acoustic meatus (pl. 16, fig. 2) is relatively small, and the upper portion of its rim projects inward at least 15 mm. beyond the level of the cerebral orifice of the vestibular aqueduct located in a deep slit-like depression. The cerebral orifice of the cochlear aqueduct is small. A thin osseous partition separates the large orifice of the Fallopian aqueduct, located at the anterointernal edge of the pars cochlearis, from the centrally located internal acoustic meatus. The cerebral face of the pars labyrinthica above and in front of the internal acoustic meatus is depressed, rugose and somewhat nodular.

Dorsal to the thin shelf projecting outward above the fenestra rotunda and behind the stapedial fossa, a smooth surfaced excavation, presumably for lodging an extension of the air sac system, extends across the posterior face of the pars cochlearis.

See table 18 for measurements of the right periotic.

TABLE 18.—*Measurements (in mm.) of right periotic, USNM 23636*

Greatest dorsoventral depth of periotic, from most inflated portion of tympanic face of pars cochlearis to most projecting point of cerebral face	63
Distance between epitympanic orifice of Fallopian aqueduct and extremity of anterior process	75
Length of posterior process, distance from external end to outer wall of groove for facial nerve	95
Distance from external end of posterior process to anterior end of anterior process (in a straight line)	179

VERTEBRAE

All the vertebrae of this skeleton (USNM 23636) have the epiphyses firmly ankylosed to the centra and with few exceptions all have their processes preserved. Relatively minor distortion resulting from crushing is observable on a few vertebrae. This skeleton is represented by 7 cervicals, 12 dorsals, 3 lumbars, and 12 caudals, each series being arranged when found in close natural contact with the preceding and succeeding vertebrae. The lumbar series comprised at least 12 lumbars of which the first and the two at the hinder end were excavated in their natural sequence with the adjacent part of the vertebral column.

The total length of this skeleton, including the skull (estimated length, 1525 mm.; 60 inches), from extremity of the rostrum to and including the terminal caudal did not exceed 19 or 20 feet.

CERVICAL VERTEBRAE

All cervical vertebrae are free and the epiphyses are firmly ankylosed to their centra. Atlas not unusually thickened with short neural spine; short, blunt transverse processes; and almost vestigial hyapophysial process. Axis has a short threesided neural spine; odontoid process is short, acutely pointed; the broad transverse processes are elongated, attenuated distally, turned downward and bent backward; and the foramen transversarium is reduced to a small opening. Upper and lower transverse processes of third cervical elongated and united externally to enclose a large cervical extension of the thoracic retia mirabilia; anterior face of centrum is broadly elliptical, bluntly rounded laterally; and neural spine short. Extremities of upper and lower transverse processes of fourth cervical are not united distally to completely enclose the foramen transversarium; neural spine short, compressed from side to side, and triangular in outline. Extremities of upper and lower transverse processes of fifth cervical are separated by a rather wide gap; neural spine short, similar in configuration to that of fourth cervical. Contour of anterior face of centrum of sixth cervical nearly subcordate; upper slender transverse process is curved downward and backward to its attenuated extremity; no vestige persists of lower transverse process; neural spine is higher, attenuated distally. The diapophysis of the seventh cervical terminates distally in an elongated facet for articulation with the head of the anterior limb of the assumed bifurcated first rib; no vestige of the lower transverse process persists.

The lower transverse processes (parapophyses) are not developed on either side of the sixth and seventh cervical vertebrae. The presence of an articular facet at the extremity of each upper transverse process (diapophysis) of the seventh cervical vertebra points either to the persistence of a separate cervical rib, or to a cervical rib ankylosed to the first rib, the head of the latter articulating with the diapophysis of the first dorsal vertebra.

When the first rib is subdivided at its vertebral end by a deep cleft into two distinct heads, the anterior limb of this double-headed rib articulated with the end of the upper transverse process (diapophysis) of the seventh cervical vertebra and the posterior limb articulated only with the diapophysis of the first dorsal vertebra. The presence of a bifid first rib seems to be normal in occurrence in the Recent *Balaenoptera borealis*. This forked or bifurcated condition of the vertebral end of the first rib has been reported also for other Recent Mysticeti. The cervical rib may enther persist free or be ankylosed with the first rib, and in the latter condition the vertebral end of the first rib is bifurcated by a cleft of varying depth. Turner (1871), however, concluded that the presence of a double-headed first rib has not necessarily any specific importance.

The total length of the seven cervical vertebrae comprising the neck, including cartilaginous intervertebral disks, is 365 mm. (14½ inches). See table 19 for measurements of the cervical vertebrae.

TABLE 19.—*Measurements (in mm.) of the cervical vertebrae, USNM 23636*

	Atlas	*Axis*	*C.3*	*C.4*	*C.5*	*C.6*	*C.7*
Anteroposterior diameter of the centrum	73	70[od]	40	43	45	44	45
Transverse diameter of centrum anteriorly	196.5	–	104	96	96.5	96	97
Vertical diameter of centrum, anteriorly			76.5	82	82	83	80.5
Tip of neural spine to ventral face of centrum, anteriorly	135	166	141	150	154	158	169
Greatest vertical diameter of neural canal, anteriorly	71	42	38	35	35	35	34
Greatest transverse diameter of neural canal, anteriorly	45	56	49	50	56	55	53
Greatest distance between outer ends of diapophyses	196.5		225	208	216	245	239
Greatest distance between outer ends of parapophyses		235	243	238	167		
Least anteroposterior diameter of right pedicle of neural arch	60	34	24.5	22.5	23	23	18.5
Greatest transverse diameter of centrum, posteriorly		107	100	97.5	96	97	98
Greatest vertical diameter of centrum, posteriorly		73	81	82	83	82	77.5

[od] Including odontoid process.

Atlas.—Not unusually thick, with broad (anteroposteriorly) neural arch; anterior facets (pl. 17, fig. 1) for articulation with occipital candyles of skull deeply concave, widest near middle of height and slanting obliquely outward from internal to external margins, the two facets separated ventrally by a narrow shallow groove (trough). On each side, the neural arch (neurapophysis) is pierced ventrally near its anterior border by a vertebra-arterial foramen (pl 18, fig. 1) which opens externally into a ventrally directed groove. Neural spine thick and short, with adjacent surface of arch rugose and pitted. Transverse process on each side short, blunt, almost three-sided in shape. Neural canal large. The two opposite posterior facets (pl. 17, fig. 2) for articulation with the axis are broad, their external margins set off from the lateral surface of the centrum. The hyapophysial facet below the neural canal is short, acuminate, and vestigial. Between opposite posterior facets and below the neural canal is the broad upward and forward sloping surface for articulation with the odontoid process of the axis. A broad downward and backward slanting articular surface, for the reception of the forward projecting angle of the neural arch of the axis, occupies the posterior border of the neural arch medially.

Additional measurements of USNM 23636 are as follows: Greatest distance between outer margins of anterior articular facets, 150 mm.; greatest distance between outer margins of posterior articular facets, 151 mm.; greatest vertical diameter of right anterior articular facet, 101 mm.; greatest vertical diameter of right posterior articular facet, 79 mm.

Axis.—Characterized in part by large rugose three-sided neural spine (pl. 17, fig. 3) arising from top of neural arch. Transverse processes elongated, dorsoventrally widened on basal half, attenuated distally, directed downward but strongly bent backward. Foramen transversarium on transverse process for cervical extension of thoracic retia mirabilia reduced to a small opening (passage) less than the diameter of a pencil; a rather deep cavity or depression on the posterior face (pl. 17, fig. 4) of each process occupies the area where a larger opening originally was located. The width of the neural canal exceeds its height. The rather rugose anterior facets for articulation with the atlas are somewhat flattened, the vertical diameter of each exceeding its transverse diameter. The odontoid process is short, acuminate. The anterior median angle of the neural arch is extended forward noticeably beyond the level of the anterior facets to articulate with or rest on an opposing surface on the posterior median border of the neural arch of the atlas. The neural arch is massive, its lateral surfaces unusually rugose and sculptured. The floor of the neural canal is shallowly concave; the wide ventral surface of the centrum is roughened by a number of irregular small excrescences. The broadly elliptical posterior face of the centrum is flattened, shallowly concave medially. The greatest distance (USNM 23636) between outer margins of anterior articular facets is 153 mm.

Third cervical.—The anterior face of the centrum is broadly elliptical, bluntly rounded laterally, wider than those of the following cervicals and shallowly depressed medially, but the anteroposterior diameter of the centrum (pl. 18, fig. 3) is less. The transverse diameter of the neural canal (pl. 17, fig. 5) exceeds its vertical diameter. The pedicles of the neural arch are short and thick (minimum transverse diameter, 37 m.), and support the prezygapophysial facets which are largely destroyed. The postzygapophysial facets are elongated, almost flat and project at least 10 mm. beyond the level of the posterrior face of the centrum. The neural arch is lightly constructed and is very rugose dorsally; the neural spine is short. The upper rather slender transverse process (diapophysis) projects outward and backward and is united distally with the end of the stronger parapopyhysis, enclosing the large transverse foramen for the cervical extension of the thoracic retia mirabilia. The lower transverse process or parapophysis is broader near the base than the upper process, its posterior surface being rounded: it projects outward with a twist, the distal end being bent nearly vertical, almost at right angles to its basal portion and is likewise bent backward.

Fourth cervical.—The broadly elliptical anterior face of the centrum is flattened and its posterior face is shallowy depressed medially. The width of the neural canal exceeds the vertical diameter. The pedicles of the neural arch (pl. 17, fig. 7) are very short and support ovoidal prezygapophysial facets which project forward beyond the level of the anterior face of the centrum. The oblique postzygapophysial facets are elongated and also project backward beyond the level of the posterior face of the centrum. A short triangular neural spine (pl. 18, fig. 4) rises from the top of the neural arch. The extremities of the diapophyses and parapophyses are not united distally to completely enclose the foramen transversarium for accommodation of the cervical extension of the thoracic retia mirabilia. Each thin diapophysis is dorsoventrally compressed on the basal half of its length but is bent downward and attenuated distally, the extremity of the right process being separated from the end of the corresponding parapophysis by a gap of at least 7 mm., and by 17 mm. on the left side.

The distal ends of the thicker parapophyses are curved upward and backward.

Fifth cervical.—As contrasted with the fourth cervical, the vertical diameter of the anterior face of the centrum has increased, the neural canal is wider, and the opening for the cervical extension (pl. 17, fig. 6) of the thoracic retia mirabilia is less completely closed. The pedicles (right, minimum transverse diameter, 38 mm.) of the neural arch are short, but occupy more of the dorsoexternal face of the centrum. Each pedicle supports a wide (right, maximum width, 23 m.) concave prezygapophysial facet, which projects forward beyond the level of the anterior face of the centrum. The postzygapophysial facets are also wide and slope obliquely downward from external to internal margins. A short neural spine (pl. 18, fig. 5) rises from the top of the neural arch. The slender diapophyses which project outward, but curve downward and backward, arise partly from the pedicle of the neural arch and partly from the dorsoexternal portion of the centrum anteriorly. The left diapophysis is longer than the right. Each short parapophysis or lower transverse process projects outward and curves upward and backward; the increase in width is gradual on the basal two-thirds of its length, but the distal end is attenuated. The extremities of the upper and lower transverse processes are separated by a gap, and thus do not completely enclose the foramen transversarium. The ventral surface of the centrum is depressed on each side of the low longitudinal median ridge.

Sixth cervical.—The contour of the anterior face of the centrum (pl. 17, fig. 8) has become more nearly subcordate and the transverse diameter continues to exceed the vertical. The pedicles (right, minimum transverse diameter, 40 mm.) of the neural arch are short and wide but the major support to each diapophysis is contributed by the dorsoexternal portion of the centrum anteriorly. Each pedicle supports an elongate concave prezygapophysial facet which projects forward beyond the level of the anterior face of the centrum. The postzygapophysial facets are ovoidal but slope less noticeably downward from external to internal margins; they project backward beyond the level of the posterior face of the centrum. The neural spine (pl. 18, fig. 6) is short. The dimensions of the neural canal do not differ materially from those of the fifth cervical. Each slender diapophysis projects outward and curves downward and backward to its attenuated extremity. No vestige of the parapophysis or lower transverse process persists. On each side of the low median longitudinal ridge the concavely depressed ventral surface merges with the similarly depressed lateral face.

Seventh cervical.—The anterior face of the centrum (pl. 17, fig. 9) is subcordate. The median longitudinal ridge on the ventral face of the centrum is much narrower and more prominent than the corresponding broad ridge on the preceding cervical. The pedicles of the neural arch are low and support the forward projecting elongated concave prezygapophysial facets which are not symmetrical. The inward slanting postzygapophysial facets are elongated. The neural spine (pl. 18, fig. 7) is slender, triangular in outline, with subacuminate apex. The diapophyses are dorsoventrally widened at the base and project outward from the dorsoexternal portion of the centrum anteriorly. Each diapophysis terminates distally in an elongated facet (40 x 15 mm.) for articulation with the head of the anterior or cervical limb of the bifurcated first rib. Each diapophysis is compressed in an anteroposterior direction and slopes obliquely downward from upper to lower margin. No vestige of the ventral transverse process is present.

DORSAL VERTEBRAE

All of the epiphyses on the cervical, dorsal, lumbar, and caudal vertebrae associated with these skeletal remains were firmly ankylosed to their respective centra, an indication of physical maturity. All of the dorsal vertebrae were found during excavation in their original undisturbed sequence. The centra increase in length from the first to the twelfth and on all the transverse diameter exceeds the vertical diameter of the anterior end. The profiles of both ends of consecutive dorsal centra are modified from a transversely widened subcordate anteriorly to a less noticeably dorsoventrally compressed subcordate posteriorly. On each side of the centrum of the first to eighth dorsals inclusive, below the level of the floor of the neural canal and adjacent externally to or on the edge of the posterior epiphysis of the centrum, there is an articular facet for reception of the capitulum of the following rib. On the anterior border of the next following centrum adjacent to this posteroexternal facet a narrower articular surface is formed for the hinder border of the head of the same rib.

The neural canal decreases in width from the first to twelfth dorsals. On the anterior eight dorsals the pedicles of the neural arch are massive and wide. The diapophyses progressively increase in width on the eight anterior dorsals and, on all, these processes arise in part from the pedicle of the neural arch and in part from the dorsoexternal portion of the centrum anteriorly. The parapophyses of the ninth to twelfth dorsals, inclusive, project outward from the lateral surface of the centrum. The neural spines increase in height from the first to the twelfth dorsals. The width of the gap between the prezygapophysial facets decreases from the anterior to the posterior end of the dorsal series.

On the first to seventh dorsal vertebrae, the articular facet on each metapophysis is horizontal and flat, although an anteroposterior crest delimiting the outer edge of the prezygapophysial facet progressively increases in prominence. On the eighth dorsal this crestlike development culminates in the shift in the inclination of each metapophysis from horizontal to vertical. From this dorsal vertebra to the hinder end of the lumbar series these side to side compressed metapophyses progressively increase in size and rise higher above the level of the floor of the neural canal.

The total length of the consecutive series of twelve dorsal vertebrae, including the cartilaginous intervertebral disks, did not exceed 1015 mm. (40 inches). See table 20 for measurements of the dorsal vertebrae.

First dorsal.—In dimensions the centrum of the first dorsal is not materially unlike the seventh cervical. The tip of the subtriangular neural spine (pl. 18, fig. 8) rises 53 mm. above the roof of the neural canal; the width (47 mm.) of this canal exceeds its height (35 mm.). The short pedicles of the neural arch support the prezygapophysial facets, which are elongated and extended forward beyond the level of the anterior face of the centrum. A gap of 65±mm. separates the prezygapophysial facets anteriorly. The postzygapophysial facets are large and are concavely curved from side to side. The diapophyses (pl. 20, fig. 1) are dorsoventrally widened, concavely depressed on anterior face and convex on posterior face, and slope obliquely backward from upper to lower edge. Each diapophysis, which projects outward and slightly forward, arises in part from the pedicle (right, minimum transverse diameter, 49 mm.) of the neural arch and in part from the dorsoexternal portion of the centrum anteriorly. The distal end of each process is expanded dorsoventrally (vertical, 39× transverse, 12 mm.) to form the elongated facet for articulation with the tuberculum of the posterior limb of the bifid first rib. A large half-moon-shaped and deeply concave facet with markedly elevated margins for reception of the capitulum of the second rib is located on the posteroexternal angle of the centrum. On each side of the rather broad median longitudinal ridge the concavely depressed ventral surface of the centrum merges with the similarly depressed lateral face.

Second dorsal.—The base of the rather broad diapophysis (pl. 20, fig. 2) arises in part from the pedicle of the neural arch and in part from the dorsoexternal angle of the centrum anteriorly, and projects outward and slightly forward. In cross-section this upper transverse process is compressed in a dorsoventral direction and the obliquely directed ovoidal facet (length, 42×25 mm.) on its extremity for reception of the tuberculum of the second rib is roughened by the presence of many irregularly spaced pits, presumably for attachment of a cartilaginous connection. The pedicles of the neural arch are low and broad; the minimum transverse diameter of the right pedicle is 45 mm. The tip of the at-

Table 20.—*Measurements (in mm.) of the dorsal vertebrae, USNM 23636*

	D.1	*D.2*	*D.3*	*D.4*	*D.5*	*D.6*	*D.7*	*D.8*	*D.9*	*D.10*	*D.11*	*D.12*
Anteroposterior diameter of centrum	47. 5	51	61	65. 5	71	74	80	89	96	100	104	107
Transverse diameter of centrum, anteriorly	98	99	102	101. 5	104	106	108	108. 5	103	102. 5	101	98
Vertical diameter of centrum, anteriorly	78	75. 5	74	74. 5	73. 5	73	74. 5	75. 5	81	84. 5	85	90. 5
Minimum anteroposterior length of pedicle of neural arch	20	28	27. 5	31	38	46	54	60	65	67	69	71±
Transverse diameter of neural canal, anteriorly	46	47	48	50	47	46	48	44	40	40	39	36
Vertical diameter of neural canal, anteriorly	38	38	39	40	36	33	28	34	38	36	35	37
Distance between ends of transverse processes	215	197	185	187	180	164±	164±	174. 5	193	234	312±	380±
Dorsal edge of metapophysis to ventral face of centrum, anteriorly	85	89	90	95	95	100	105	112	133	141	145	150
Tip of neural spine to ventral face of centrum, posteriorly	166	190	205	219	235±	238	255±	270	285	298	323±	335
Transverse diameter of centrum, posteriorly	106[f]	112[f]	114[f]	119[f]	122[f]	123[f]	119[f]	108. 5[f]	105	102	101	101. 5
Vertical diameter of centrum, posteriorly	75	73	71	72	74	73	75	79	83	85	89	93

[f] Including posterior capitular facet.

tenuated neural spine (pl. 18, fig. 9) rises 85 mm. above the roof of the neural canal. Both prezygapophysial facets are incomplete internally but were obviously elongated and extended forward beyond the level of the anterior face of the centrum. A narrow half-moon-shaped articular surface on the anterior border of the lateral face of the centrum represents an enlargement of the capitular facet on the posteroexternal angle of the centrum of the first dorsal. The large deep capitular facet on the posteroexternal angle of the centrum for reception of the capitulum of the third rib is similar in shape and size to the corresponding facet on the first dorsal. The median longitudinal ridge is broad; the ventral and lateral surfaces of the centrum resemble closely the first dorsal. The anterior and posterior faces of the centrum are transversely widened and broadly subcordate.

Third dorsal.—The transverse processes (diapophyses) are slightly broader, shorter and directed less forward than those of the second dorsal, expanded at the extremity to provide a large facet (length, 47 mm.; vertical diameter, 28 mm., greatest on anterior half of its length and also attenuated posteriorly), and are extended forward noticeably beyond the level of the anterior face of the centrum. The thickened basal portion of this diapophysis (pl. 20, fig. 3) arises from the transversely widened pedicle of the neural arch (right, minimum width, 41 mm.) and the dorsoexternal portion of the centrum anteriorly. The pedicle of the neural arch is robust and rather short. Prezygapophysial and postzygapophysial facets are largely destroyed. Neural spine is (pl. 18, fig. 10) wider than that of the second dorsal, and rises 99 mm. above the roof of the neural canal. Anterior face of the centrum is transversely widnened but more subcordate in outline. A more crest-like median ventral longitudinal ridge separates shallower depressed ventral and lateral surfaces. A large posteroexternal facet for capitulum of the fourth rib and a reduced narrow demifacet on the anteroexternal border adjacent to the capitular facet on the second dorsal are present.

Fourth dorsal.—A slight increase in the length (65.5 mm.) of the centrum as well as in the height (110 mm.) of the neural spine (pl. 18, fig. 11) above the roof of the neural canal characterizes this vertebra. The robust transverse processes (diapophyses) do not differ materially from those of the third dorsal, each being projected outward, but less extended forward beyond the level of the anterior face of the centrum. The extremity of each diapophysis (pl. 20, fig. 4) is expanded to provide a large concave pitted facet (length, 50 mm.; vertical diameter, 31 mm., greatest on anterior half of its length and attenuated posteriorly) for the tuberculum of the fourth rib. The main axis of this facet is almost horizontal. The broad basal portion of each diapophysis arises from the transversely widened pedicle of the neural arch (right, minimum width, 40 mm.) and from the dorsoexternal portion of the centrum anteriorly. The prezygapophysial facets are almost flat and are located on the low, bluntly pointed metapophyses. A gap of 90 mm. separates the prezygapophysial facets anteriorly. The postzygapophysial facets are elongated, rather broad and slope obliquely from internal to external margins. The neural spine is materially broader at the base than that of the third dorsal and more narrowed distally; it rises 110 mm. above the roof of the neural canal. The subcordate anterior face of the centrum is transversely widened but flattened dorsally. A narrow median ventral longitudinal ridge separates the concavely excavated ventral and lateral surfaces of the centrum. A large protuberant posteroexternal facet for the capitulum of the fifth rib and a much narrower demifacet on the anteroexternal border adjacent to the capitular facet on the third dorsal are well developed.

Fifth dorsal.—The fifth dorsal is characterized by rather widely separated prezygapophysial facets (95 mm. anteriorly), which are elongated (40 ± mm.) and shallowly concave. The robust transverse processes (diapophyses) are essentially similar to those of the fourth and each projects forward beyond the level of the anterior face of the centrum. The rugose facet (length, 48 mm.; vertical diameter anteriorly, 29 mm.) for the tuberculum of the fifth rib on the expanded extremity of each diapophysis is concavely excavated in a horizontal direction and slopes downward and inward from the dorsal to ventral margins. As on the fourth dorsad, the broad basal portion of each diapophysis arises from the transversely widened pedicle of the neutral arch (right, minimum width, 35 mm.) and from the dorsoexternal portion of the centrum anteriorly. The low bluntly pointed metapophyses project noticeably beyond the level of the anterior face of the centrum. The elongated postzygapophysial facets are very narrow and project backward beyond the level of the posterior face of the centrum. The width of the neural spine (pl. 18, fig. 12) has increased. The contour of the anterior face of the centrum (pl. 20, fig. 5) does not differ materially from that of the fourth dorsal, but the median ventral longitudinal ridge is less prominent although it separates the deeply excavated lateral surfaces of the centrum. The posteroexternal facet for the capitulum of the sixth rib is as strongly protuberant as on the preceding dorsal, although the anteroexternal demifacet is barely discernible.

Sixth dorsal.—The narrowing of the gap (85 mm.) anteriorly between the prezygapophysial facets is continued on this dorsal. This dorsal has a slightly wider neural spine (pl. 19, fig. 1) which rises at least 130 mm. above the roof of the neural canal. The robust transverse processes (diapophyses) are as wide as on the preceding dorsal, although slightly shorter and each projects forward beyond the level of the anterior face of the centrum. The rugose ovoidal facet on the extremity of each diapophysis (length, 47 mm.; vertical diameter anteriorly, 26 mm.) for the tuberculum of the sixth rib is concave horizontally and slopes obliquely downward and inward from the dorsal to ventral margins. The basal portion of each diapophysis arises from the thickened pedicle (minimum transverse width, 32 mm.) and from the dorsoexternal portion of the centrum anteriorly. The low blunt metapophyses project strongly beyond the level of the anterior face of the centrum; each is traversed anteroposteriorly by a rounded ridge which delimits externally the prezygapophysial facet. The narrow elongated prezygapophysial facets are deeply concave from side to side. The postzygapophysial facets are very narrow and project strongly backward beyond the level of the posterior face of the centrum. The contour of the anterior face of the centrum (pl. 20, fig. 6) is similar to that of the fifth, but the median ventral longitudinal ridge on the centrum is less prominently developed, although the lateral surfaces continue to be deeply excavated. The posteroexternal facet for the capitulum of the seventh rib is quite protuberant and the anteroexternal demifacet persists.

Seventh dorsal.—The vertical diameter (27 mm.) of the neural canal anteriorly on this dorsal is less than that of any other dorsal. An increase in the length (81 mm.) of the centrum as well as in its width anteriorly (108 mm.) is not unusual in this portion of the dorsal series. Thick pedicles (right, minimum transverse diameter, 34 mm.) of the neural arch give origin to the transverse processes (diapophyses) which project outward horizontally and extend forward beyond the level of the anterior face of the centrum. The rugose facet on the extremity of each diapophysis for the tuberculum of the seventh rib is elongated (length, 52 mm.; vertical diameter medially, 24 mm.), shallowly concave from end to end, and its articular face is more nearly vertical. The low, flattened, anteriorly rounded and forward projecting metapophyses are traversed anteroposteriorly by a prominent crest which delimits externally each prezygapophysial facet. Each prezygapophysial facet is very narrow anteriorly but increases in width and concaveness toward the base of the neural spine. The postzygapophysial facets are very narrow and extend backward beyond the level of the posterior face of the centrum. The neural spine (pl. 19, fig. 2) is broader than that of the preceding dorsal and rises 150 $\pm$ mm. above the roof of the neural canal. The contour of the anterior face of the centrum (pl. 20, fig. 7) is similar to that of the sixth, but the median ventral longitudinal ridge on the centra of the anterior dorsals is not developed. The lateral surfaces of the centrum are deeply excavated. The posteroexternal facet for the capitulum of the eighth rib is situated mainly on the posterior face of the prominent protuberance. The anteroexternal demifacet is larger than on the sixth.

Eighth dorsal.—On this dorsal one observes the accentuation of the previously developing anteroposterior crest which has now culminated in the shift of each metapophysis from horizontal to vertical. This development permits the pair of metapophyses to limit the side to side movement of the postzygapophyses of the preceding dorsal. Each broad transverse process (diapophysis) projects outward from the transversely widened (40 mm.) robust pedicle of the neural arch and from the dorsoexternal portion of the centrum anteriorly and is bent upward, extending very slightly beyond the level of the anterior face of the centrum. The rugose facet for the tuberculum of the eighth rib on the extremity of each diapophysis is elongated (length, 54 mm.; vertical diameter anteriorly, 21 mm.), subcrescentic in outline and deeply excavated medially. The backward projecting postzygapophysial facets are quite narrow and closely approximated. The neural spine (minimum width, 74 mm.) is broader (pl. 19, fig. 3) than that of the preceding dorsal, abruptly truncated at the extremity, and rises 160 mm. above the roof of the neural canal. The contour and width of the anterior face (pl. 20, fig. 8) of the centrum are similar to the seventh dorsal. No vestige of the median ventral longitudinal ridge is discernible on the centrum and the lateral surfaces are even more strongly excavated. The posteroexternal protuberance for articulation with the capitulum of the ninth rib is reduced in size as contrasted with that of the seventh, and the anteroexternal demifacet is similar to that of the seventh dorsal.

Ninth dorsal.—In contrast to those on the eighth dorsal, the greatly enlarged metapophyses now rise 48 mm. above the floor of the neural canal, and the gap between them is 54 mm. Each metapophysis is compressed from side to side, obtusely pointed anterodorsally, extended forward beyond the level of the anterior face of the centrum, and contributes the outer wall of the rather narrow prezygapophysial facet. On the first to eighth dorsals, inclusive, the transverse process (diapophysis) projects outward mainly from the more or less massive pedicle of the neural arch and maintains its elevation above the dorsal face of the centrum. On the ninth dorsal, however, the bent upward transverse process (parapophysis) projects outward solely from the dorsoexternal surface of the centrum. At the extremity of each parapophysis is an elongated facet (length, 47 mm.; vertical diameter, 16 mm.), strongly concave from end to end for the head of the ninth rib. The distance between the ends of the parapophyses is 194 mm. and this distance progressively increases to the end of the dorsal series. The narrow backward projecting postzygapophyses are markedly reduced in extent. The neural spine (pl. 19, fig. 4) has increased in width (minimum 78 mm.) and projects more upward than backward; it rises 176 mm. above the roof of the neural canal and its distal extremity is horizontally truncated. The pedicles of the neural arch are quite thin (minimum transverse width, 9 mm.); the minimum length of each is 65 mm. A noticeable change in the contour (pl. 21, fig. 1) and dimensions of the anterior face of the centrum occurs on the ninth dorsal (vertical diameter, 81 mm.; transverse diameter, 103 mm.). No vestige of the median ventral longitudinal ridge is present on this centrum, the lateral and ventral surfaces being equally depressed.

Tenth dorsal.—This dorsal has a higher and wider neural spine (minimm width, 84 mm.; pl. 19, fig. 5) and it rises 186 mm. above the roof of the neural canal. Longer, horizontally widened and dorsoventrally compressed transverse processes (parapophyses), longer centrum, and a narrower (36 mm.) neural canal also distinguish this dorsal from the ninth dorsal. Each parapophysis (pl. 21, fig. 2) projects outward and obliquely upward from the upper portion of the lateral surface of the centrum, but the bifurcated or deeply indented distal end is probably abnormal. The posterior end of this distal facet for the head of the tenth rib is roughened, although the head of this rib may most probably have been attached for the most part in the anterior indenture. The thin pedicles of the neural arch have a slightly greater anteroposterior length than on the ninth. The large metapophyses project obliquely upward and extend forward beyond the level of the anterior end of the centrum; they rise 54 mm. above the floor of the neural canal. The prezygapophysial facets are almost vestigial. The postzygapophysial facets, although damaged, were obviously very narrow. The contour and dimensions of the subcordate anterior face of the centrum is similar to the ninth.

Eleventh dorsal.—Rather slender, dorsoventrally compressed and backwardly curved parapophyses (pl. 21, fig. 3) which project outward from near the middle of the height of the lateral surface of the centrum characterize this vertebra. The left transverse process is missing. The anterior edge of the right parapophysis is thin, the posterior edge thickened and rounded, and the relatively small ovoidal (length, 34 mm.; vertical diameter, 15 mm.) distal facet for the head of the eleventh rib is located posteriorly on the distal end. The thin pedicles of the neural arch slightly exceed in anteroposterior diameter (69 mm.) those on the tenth dorsal. The metapophyses are larger and less widely separated than on the tenth dorsal. Neither prezygapophysial nor postzygapophysial facets are discernible. The neural spine (minimum width, 84 mm., pl. 19, fig. 6) is horizontally truncated at the distal end, is slanted slightly backward, and rises 208 mm. above the roof of the neural canal.

Twelfth dorsal.—The roughened rounded end of the right parapophysis indicates that the head of the twelfth rib was attached there. This right parapophysis lacks portions of the anterior border, but sufficient remains to suggest the original contour of this dorsoventrally compressed transverse process. The left transverse process is not preserved. The large laterally compressed metapophyses rise 58 mm. above the floor of the neural canal and were separated by a 38 mm. gap; they project forward noticeably beyond the level of the anterior end of the centrum. Portions of the broad neural spine (pl. 19, fig. 7) are missing and hence the original height is uncertain. The extremity, however, was slightly convex. The length of the centrum (108 mm.) exceeds that (104 mm.) of the eleventh as does the vertical diameter (90.5 mm.) of the anterior end. The transverse diameter of the neural canal (pl. 21, fig. 4) diminishes toward the first lumbar on most of the dorsal vertebrae.

LUMBAR VERTEBRAE

Assuming that the lumbar series comprised twelve vertebrae, an estimate based on progressive increase in the length of the centra from the first to twelfth indicates a total length of 1550 mm. (61 inches).

The bowed outward portion of the vertebral column between the first and eleventh lumbars fell to the base of the slope facing Chesapeake Bay at some time during the process of continued weathering and erosion. Tidal action resulted in disintegration and dispersal of the fallen bone fragments prior to discovery of the remainder of the partially exposed skeleton. At the time of excavation the first lumbar was found in contact with the twelfth dorsal and the last two lumbars in a similar relation with respect to the first in the consecutive series of caudals.

An incipient development of the median longitudinal keel is observable on the ventral surface of the centrum of the first lumbar and on the eleventh and twelfth this keel is low, rounded, and not prominent. The neural spines decrease in height from first to last and presumably were as wide on those missing between the first and eleventh as on the latter. Large elongated and laterally compressed metapophyses were developed on the lumbars. The neural canal diminished in height from the first to the last lumbar. The configuration of the transverse process was altered from the elongated and relative narrow process of the first lumbar to the broad subspatulate form on the last lumbar and the length reduced about one third. See table 21 for measurements of the lumbar vertebrae.

First lumbar.—This vertebra was found in normal sequential contact with the hindermost vertebra in the consecutive series of twelve dorsal vertebrae. Thus there can be no doubt as to its position in the vertebral series. It was damaged when found and a narrow gap exists between the upper portions of the pedicles of the neural arch and their bases. The right metapophysis was detached and the left transverse process was missing. The most obvious alteration in this first lumbar is the backward inclination of the neural spine (pl. 19, fig. 8) which rises 212 mm. above the roof of the neural canal and is horizontally truncated distally. The anterior border of the neural spine is, however, eroded; its extremity may possibly have been slightly expanded. The backward projecting portion of the neural arch extended beyond the level of the posterior face of the centrum.

Table 21.—*Measurements (in mm.) of the lumbar vertebrae, USNM 23636*

	L.1	*L.11*	*L.12*
Anteroposterior diameter of centrum	111	135	138
Transverse diameter of centrum, anteriorly	101	115	117
Vertical diameter of centrum, anteriorly	92.5	105	108
Minimum anteroposterior length of pedicle of neural arch	70±	67	69
Transverse diameter of neural canal, anteriorly	35	21	19
Vertical diameter of neural canal, anteriorly	38	28	28
Distance between ends of transverse processes	415±	345±	335
Dorsal edge of metapophysis to ventral face of centrum, anteriorly	153	169±	170
Tip of neural spine to ventral face of centrum, posteriorly	340	315	295
Transverse diameter of centrum, posteriorly	101	113	119
Vertical diameter of centrum, posteriorly	93	108	114

The centrum is approximately the same length (110 mm.) as that of the twelfth dorsal and the contour of the anterior end (pl. 21, fig. 5) is quite similar. The lateral and ventral surfaces of the centrum are deeply concave. No distinct median longitudinal ventral keel is developed on the centrum and no visible longitudinal ridge is discernible on the depressed floor of the neural canal.

The dorsoventrally compressed transverse process, which projects outward from the external face of the centrum at essentially the same level as that of the twelfth dorsal, is constricted near the base, widened beyond the middle of its length, and then the anterior border is obliquely truncated toward its narrowed extremity. It exhibits a tongue-like enlargement on its anterior border. The left transverse process is essentially complet except for the outer edge.

The base of each thin (compressed from side to side) pedicle of the neural arch occupies approximately two-thirds of the length of the dorsal face of the centrum. They support the large metapophyses which rise at least 60 mm. above the dorsal rim of the anterior epiphysis and are separated anteriorly by a gap of 37 mm.; they also extend well beyond the level of the anterior face of the centrum. The metapophyses are compressed from side to side and project upward and forward from the neural arch beyond the level of the anterior face of the centrum. Neither pre- nor post-zygapophysial facets are present. The transverse diameter (35 mm.) of the neural canal anteriorly is approximately equivalent to that of the twelfth dorsal.

Eleventh lumbar.—This lumbar was found immediately preceding the twelfth lumbar which was itself in contact with the first caudal, when this portion of the skeleton was excavated. The outer half of the right dorsoventrally compressed transverse process was missing, but the left process (pl. 22, fig. 3) is sufficiently complete to indicate the original shape. This process projects outward almost horizontally and is inclined slightly forward; its distal half is widened anteroposteriorly. The broad (minimum width, 96 mm.) neural spine (pl. 22, fig. 1) rises 170 mm. above the roof of the neural canal and is truncated distally. The backward projecting dorsal portion of the neural arch extends beyond the level of the posterior face of the centrum.

The base of each pedicle of the neural arch occupies about four-sevenths of the length of the dorsal face of the centrum. These thin pedicles support the large side-to-side compressed metapophyses which rise 63 mm. above the dorsal rim of the anterior epiphyses, and barely project forward beyond the level of the anterior face of the centrum. Neither pro- nor post-zygapophysial facets are present. The vertical diameter (27 mm.) of the neural canal (pl. 22, fig. 5) anteriorly exceeds its transverse diameter (21 mm.).

The centra of the last two lumbars are larger and longer than that of the first lumbar which appears to be normal for these Miocene cetotheres. The length of this lumbar is 136 mm. The contour of the anterior end of the centrum tends to approach that of the first caudal, including an increase in the transverse (115 mm.) and vertical (105 mm.) diameters. A low ventral longitudinal keel is present between the concave depressions on the ventral surface.

Twelfth lumbar.—The dimensions of the centrum have increased very slightly over those of the eleventh. The metapophyses, however, are more noticeably obliquely inclined upward and outward, the neural spine is shorter, and the width of the transverse process is increased. These broad transverse processes (pl. 22, fig. 4) project outward, slightly downward and are inclined a little forward.

The width of the neural spine (pl. 22, fig. 2) has decreased; it rises 153 mm. above the roof of the neural canal and the backward projecting dorsal portion of the neural arch continues to extend beyond the level of the posterior face of the centrum. The length (69 mm.) of the thin pedicle of the neural arch exceeds that (67 mm.) of the pedicle of the eleventh lumbar. These pedicles support rather long (length, 76 mm. at dorsal edge) metapophyses which are more noticeably spread apart (distance between dorsoexternal edges, 72 mm.) than on preceding lumbar, project forward beyond level of anterior face of centrum, and rise 61 mm. above the dorsal rim of the anterior epiphyses. Neither pre- nor postzygapophysial facets are present. The vertical diameter (27 mm.) of the neural canal (pl. 22, fig. 6) anteriorly exceeds its transverse diameter (19 mm.).

The end profiles of the centrum are not subcordate; the dimensions of the posterior end are approximately the same as those of the anterior end of the first caudal. A prominent longitudinal keel separates the opposite portions of the central surface of the centrum.

CAUDAL VERTEBRAE

All twelve of these caudal vertebrae (USNM 23636) have the epiphyses firmly ankylosed to the centra. In so far as our present knowledge goes, it would appear that two and possibly three of the terminal caudals are not represented in this series. Sixteen caudal vertebrae were present in the skeleton of the middle Miocene (Helvetian) *Mesocetus hungaricus* (Kadic, 1907, p. 75). At least one (USNM 16667) of the Calvert cetotheres possessed 14 caudals. The centrum of the first caudal is slightly longer than the twelfth lumbar behind the first the centra progressively decrease in length toward the terminal end of this series. The interval between the dorsal edges of the opposite metapophyses progressively diminishes behind the third caudal. Behind the second caudal the height of the neural spine rapidly diminishes. The shortening of the transverse process terminates in the short flange-like condition present on the sixth caudal.

On the first caudal a pair of ventral posterior haemal tubercles (haemapophyses) replace the ventral keel of the lumbar vertebrae and constitute the lateral limits of the haemal groove which on succeeding caudals becomes more excavated with the increased development of these paired tubercles. The anterior pair of haemal tubercles are ill defined and weakly developed on the three anterior caudals; the posterior pair of haemal tubercles increase in size from the first to the third caudal. On the fifth, sixth, seventh, and eighth caudals on each side of the longitudinal haemal groove, the anterior and posterior haemal tubercle are united by a continuous osseous connection through which the vascular branches emerge laterally in a medially located orifice. These segmental blood vessels pass through a perforation at the base of the transverse process on each side on their upward course. Behind this caudal the centra of the terminal caudals are pierced dorsoventrally on each side by a vertical aqueduct for the passage of these segmental blood vessels.

Including a 4 mm. allowance for the cartilaginous intervertebral disks, this consecutive series of twelve caudals and two additional terminal caudals provide a fairly accurate estimated length of 1370 mm. (54 inches) for the tail. See table 22 for measurements of the caudal vertebrae.

First caudal.—The neural spine of the first caudal is considerably shorter than that of the posteriormost lumbar rising 142 mm. above the dorsal rim of anterior epiphysis and the length of the centrum is slightly greater. The centrum (pl. 23, fig. 1) is deeply hollowed out laterally, both above and below the transverse processes. Haemal tubercles (haemapophyses) separated by a broad longitudinal open groove or channel are developed at the posterior end of the ventral surface of the centrum for articulation with the chevron bone. The anterior haemal tubercles are rudimentary, if present. Relatively minor widening (125 mm.) modifies the circular contour of the posterior end of the centrum. Both ends are somewhat flattened. The transverse processes (pl. 24, fig. 1) are broad (minimum anteroposteri-

TABLE 22.—*Measurements (in mm.) of the caudal vertebrae, USNM 23636*

	Ca.1	*Ca.2*	*Ca.3*	*Ca.4*	*Ca.5*	*Ca.6*	*Ca.7*	*Ca.8*	*Ca.9*	*Ca.10*	*Ca.11*	*Ca.12*
Anteroposterior diameter of centrum	142	139	139	135	130	120	112	101	87	57	48	45
Transverse diameter of centrum, anteriorly	116	123	116	114	120	116	115	102	90	77	78	63
Vertical diameter of centrum, anteriorly	113	118	116	113	116	115	110	105	96	74	63	53
Minimum anteroposterior length of pedicle of neural arch	76	68	66	66	67	71	69	43	27	–	–	–
Transverse diameter of neural canal, anteriorly	19	20	20	17	15	14	9	7	4	–	–	–
Vertical diameter of neural canal, anteriorly	26	24	20	12	7	7	5	5	–	–	–	–
Distance between ends of transverse processes	325	310	270	216	188	147	115	–	–	–	–	–
Dorsal edge of metapophysis to ventral face of centrum, anteriorly	165	173	170	165	165	145	131	114	–	–	–	–
Tip of neural spine to ventral face of centrum posteriorly	280	248	299	186	138	136	–	–	–	–	–	–
Transverse diameter of centrum, posteriorly	125	120	120	121	121	108	103	95	87	78	72	61
Vertical diameter of centrum, posteriorly	123	119	118	118	117	114	107	102	87	72	62	48

or diameter, 69 mm.), expanded distally and abruptly truncated, dorsoventrally, flattened, and directed outward and slightly forward. The neural canal, (pl. 25, fig. 1) is narrow (19 mm.) anteriorly, and also reduced in height (26 mm.). The outer half of the right transverse process is broken off. The thin pedicles of the neural arch have increased in length (76 mm.), but decreased in height. The low, but long (88 mm.) metapophyses are directed more outward than upward (distance between dorsoexternal edges, 92 mm.) and rise 53 mm. above the floor of the neural canal.

SECOND CAUDAL.—The paired posterior haemal tubercles are not strongly developed on the ventral face of the centrum and are, however, separated by a broad shallow open groove or channel for the caudal artery. The anterior haemapophyses are slightly developed. The transverse processes are noticeably widened distally and irregularly truncated; the anterior and posterior edges of these processes are thin (minimum anteroposterior diameter, 70 mm.).

The lateral surfaces of the centrum (pl. 23, fig. 2) above and below the transverse processes are deeply hollowed out, and the posterior end is slightly more convex than the more flattened anterior end. The transverse and vertical diameters of the neural canal (pl. 25, fig. 2) are reduced. The pedicles of the neural arch (length, 68 mm.) support the large metapophyses (length dorsoexternal edge of right, 86 mm.) which are more upturned distally than those of the first caudal, and rise 58 mm. above the dorsal rim of anterior epiphysis; the distance between the dorsoexternal edges is 107 mm.

The neural spine (pl. 24, fig. 2) has decreased in width and height, but rises 108 mm. above the roof of the neural canal; this spine is obliquely truncated distally.

THIRD CAUDAL.—This caudal is characterized by elongate transversely compressed posterior haemal tubercules, separated by a deep open groove or channel for the caudal artery, and rather small, low anterior haemal tubercules. The sides of the centrum, both above and below the transverse processes are deeply hollowed out, and the posterior end of the centrum is slightly more convex than the anterior end. As compared to those of the second caudal, the transverse processes (pl. 24, fig. 3) are shorter, more noticeably expanded distally and abruptly truncated (minimum anteroposterior diameter, 70 mm.). The neural canal is narrow and rather long.

The pedicles of the neural arch (length, 66 mm.) support large metapophyses (length dorsoexternal edge of left, 78 mm.) which are strongly upturned distally, and rise 58 mm. above the dorsal rim of anterior epiphysis; the distance between the opposite dorsoexternal edges is 111 mm.

The neural spine (pl. 23, fig. 3) has decreased noticeably in height, but rises 82 mm. above the roof of the neural canal and is obliquely truncated distally. The reduction of the neural canal is continued.

FOURTH CAUDAL.—The relatively long, laterally compressed pair of posterior haemal tubercules are separated by a deep open groove or channel for the caudal artery. The anterior pair of haemal tubercules are rather thick and less elongated. The lateral surfaces of the centrum are deeply hollowed out, both above and below the transverse processes. Both ends of the centrum are somewhat convex. The transverse processes (pl. 24, fig. 4) are shortened, obliquely truncated distally (minimum anteroposterior diameter, 69 mm.), and directed outward and slightly forward. Neither process is perforated.

The rather thick pedicles of the neural arch (length, 67 mm.) support transversely thickened metapophyses (length dorsoexternal edge of right, 74 mm.) which are strongly upturned distally and rise 50 mm. above the dorsal rim of anterior epiphysis; the distance between the dorsoexternal edges is 102 mm.

The neural spine (pl. 23, fig. 4) is broader (84 mm.) but shorter than that of the third caudal, and rises 70 mm. above the roof of the neural canal.

Fifth caudal.—Ventrally on each side of the centrum, the anterior and posterior haemal tubercles are united by a continuous osseous strip which borders completely the open groove or channel for the caudal artery, an ascending branch of which emerges laterally through a rather large orifice (width, 19 mm.) and continues upward on the external face of the centrum in front of the anterior notch at the base of the transverse process. The lateral surfaces (pl. 23, fig. 5), both above and below the transverse processes, are deeply hollowed out; both ends of the centrum are slightly convex. The transverse processes (pl. 24, fig. 5) are short, obliquely truncated distally, the anterior angle projecting outward farther than the posterior angle. The thick metapophyses (length right, 62 mm.) are directed upward and outward, but cannot clasp the posterior median angle of the neural arch of the preceding caudal. These metapophyses rise 44 mm. above the dorsal rim of the anterior epiphysis; the distance between the dorsoexternal edges is 92 mm. The thick pedicle (length, 66 mm.) of the neural arch is approximately the same length as that of the fourth caudal. The thin neural spine is vestigial, reduced to a thin longitudinal ridge, and the neural canal small (pl. 25, fig. 5).

Sixth caudal.—Ventrally on each side the anterior and posterior haemal tubercles are united by a somewhat thickened osseous connection and as on the preceding caudal a branch of the caudal artery emerges laterally through a large foramen. On its upward course, however, this arterial branch passes through the perforation in the greatly shortened transverse process (pl. 23, fig. 6). The lateral surfaces of the centrum are deeply hollowed out above and below the transverse process; the anterior end of the centrum is flattened and the posterior end is slightly convex. The transverse processes (pl. 24, fig. 6) are very short, obliquely truncated distally and perforated at the base. Each thickened pedicle of the neural arch is low, and the transverse diameter of the neural canal (pl. 25, fig. 5) exceeds the vertical. The left pedicle is perforated near the posterior end of the roof of the neural arch. The thick metapophyses (length, 48 mm.) rise 31 mm. above the dorsal rim of the anterior epiphysis; the distance between the dorsoexternal edges is 75 mm. The thin and very low neural spine extends irregularly the length of the roof of the neural arch.

Seventh caudal.—On each side the transversely widened anterior and posterior haemal tubercles are united by a much thicker osseous connection (pl. 23, fig. 7), each of which is perforated medially to permit the passage of a branch of the caudal artery which on its upward course passes through a foramen in the base of the ridge-like thickened transverse process. The ventral open groove or channel for the caudal artery is deep. The lateral surfaces of the centrum above and below the transverse processes are hollowed out; both ends of the centrum are more flattened than convex. Each low pedicle of the neural arch extends most of the length of the dorsal surface of the centrum, and is pierced medially at the base by a small foramen. The oval neural canal (pl. 25, fig. 7) is very small and the neural spine is low. The markedly reduced oval knob-like metapophyses (length, 36 mm.) rise 29 mm. above the dorsal rim of the anterior epiphysis; the distance between the dorsoexternal edges is 59 mm.

Eighth caudal.—This caudal resembles the seventh in having the anterior and posterior haemal tubercles (pl. 23, fig. 8) united by a thick osseous connection, perforated medially for the passage of a branch of the caudal artery. This vascular branch likewise continues its upward course through the perforation in the very low and thick basal remnant of the transverse process. The lateral surfaces of the centrum are less noticeably hollowed out; the posterior end of the centrum is slightly more convex than the anterior end. The metapophyses (pl. 25, fig. 8) are reduced to small, low, oval knobs. A low, thin neural spine (length, 36 mm.) persists on the short (length, 42 mm.) roof of the neural arch. The roof of the neural arch completely encloses the small neural canal, no larger than the diameter of a pencil.

Ninth caudal.—The anterior end (pl. 25, fig. 9) of this caudal is higher than wide; the lateral surfaces of the centrum are much less hollowed out, and the posterior end is slightly convex and the anterior end is flattened. A tendency exists for the posterior end of these terminal caudals to become smaller than the anterior end as well as more convex. The centrum is pierced dorsoventrally by a large vascular aqueduct on each side external to the low, thickened pedicle of the neural arch; their closely approximated ventral orifices are located in a deep elongated haemal groove or channel.

No vestige of either transverse process persists. The roof of the very small neural arch, although short (27 mm.), is complete, and the low lateral pedicles are broad. A small foramen at the base of the right pedicle (pl. 23, fig. 9) about halfway of its length provides a vascular passage to the neural canal from the lateral vertical aqueduct.

Tenth caudal.—This vertebra is characterized by the marked foreshortening (pl. 23, fig. 10) of the centrum (length, 57 mm.) and the reduction of the lateral ridges bounding the ventral haemal channel for the caudal artery. A very short bone isthmus (length, 5 mm.) bridges the very narrow neural canal. The centrum is pierced dorsoventrally by two vascular aqueducts, the two large orifices of which are located in an oval depression on the ventral face of the centrum. Dorsally, each of these aqueducts has two or more orifices located on each side of the narrow partially roofed-over neural canal. The anterior end of (pl. 25, fig. 10) of the centrum is flattened and the posterior end is convex. The dorsal and ventral surfaces of this caudal have deep scratches made by shark teeth.

Eleventh caudal.—The anterior end (pl. 25, fig. 11) of the centrum although depressed medially is somewhat flattened, and the posterior end is convex. The centrum of this caudal is smaller and shorter (pl. 23, fig. 11) than that of the tenth and no remnant persists of the neural arch. The vertical vascular aqueducts that pierce the centrum medially have two dorsal orifices and three ventral orifices. The pair of vertical vascular aqueducts, separated by a 14 mm. interval, open dorsally into a shallow oval cavity. Ventrally a wider interval (31 mm.) separates the two largest orifices and about halfway between them is a much smaller orifice.

The ventral and dorsal surfaces are deeply incised or scratched by shark teeth.

Twelfth caudal.—The smallest of these terminal caudals also has the anterior end of the centrum (pl. 23, fig. 12) strongly depressed medially and the posterior end convex. On the flattened dorsal face of the centrum two orifices of the vertical vascular aqueducts are separated by an interval of 10 mm. and ventrally by an interval of 23 mm. Viewed from in front the outline of this caudal is quadrangular; its lateral surfaces being grooved longitudinally about the middle of their height. The posterior and ventral surfaces are deeply incised and mutilated by shark teeth; pieces have been bitten out of the right and dorsal sides of the vertebra. A split tooth of a tiger shark (*Galeocerdo*) is embedded in the gashed dorsal surface of this caudal.

CHEVRONS

Six chevron bones (USNM 23636) were excavated beneath the consecutive caudal vertebrae, seemingly at their normal location. The largest chevron lay beneath the fourth caudal and the smallest, apparently the terminal chevron, below the ninth caudal.

Inferentially one or two anterior chevrons may have exceeded the size of the chevron found beneath the fourth caudal. Anterior to the origin of the horizontal caudal flukes, the chevrons are attached on the skeletons of Recent mysticetes below the intervertebral space between two caudals. Assuming a similar method of attachment on this cetothere skeleton, not more than nine chevrons were present. Five of these chevrons have a definite haemal spine, whose anteroposterior diameter decreased toward the last one. All six chevrons have a "Y" profile when viewed from in front and have large articular facets on the horizontally widened dorsal ends of the lateral lamina. The minimum interval between these articular facets is decreased almost imperceptibly between the fourth and the seventh chevrons and although in the same direction the transverse diameter is diminished, no obvious shortening is observable in the length of the articular surface. The haemal canal of these chevrons is smooth without trace of a median ventral ridge, but it decreases in diameter toward the terminal chevron. See table 23 for measurements of the chevrons.

Table 23.—*Measurements (in mm.) of chevron bones, USNM 23636*

	4th	*5th*	*6th*	*7th*	*8th*	*9th*
Vertical diameter of chevron	108	78	73	61	40	29
Greatest anteroposterior diameter of haemal spine at extremity	92+	106	91	84	66	43
Anteroposterior diameter of combined articular facets on base of right lateral lamina	57	60	63	58	52	31
Least distance between internal margins of articular facets	13	9	11	11	7	7

Fourth chevron.—This chevron (pl. 20, fig. 9) is the largest of the six, but lacks the posterior end of the haemal spine, whose vertical diameter (70 mm.) exceeds the others. The bluntly pointed anterior projection probably was shorter than the more slender posterior end. The ovoidal transversely widened (28 mm.) articular facets are large (length, 57 mm.) attenuated anteriorly and rounded posteriorly.

Fifth chevron.—The anterior projection of the haemal spine on this chevron (pl. 20, fig. 10) is short and acuminate; the posterior projection is considerably elongated and there is a median indentation on the ventral edge. The wide (31 mm.) articular facets (length, 60 mm.) are attenuated anteriorly and rounded posteriorly.

Sixth chevron.—A median indentation on the ventral edge of the haemal spine as well as a short anterior projection and a rather deep posterior projection are the most obvious profile alterations (pl. 20, fig. 11). The articular facets (length, 63 mm.) are attenuated at both ends and somewhat narrower (28 mm.) than on the preceding chevron. Deep scratches by shark teeth, especially on the left side, are present on the haemal spine.

Seventh chevron.—Elongated (58 mm.) but narrower (24 mm.) articular facets, strongly attenuated at both ends, shorter anterior and posterior projections of the haemal spine and a much narrower haemal canal characterize this chevron (pl. 20, fig. 12).

Eighth chevron.—This chevron (pl. 20, fig. 13) is about half the size of the preceding, the haemal spine being markedly reduced; the posterior projection is short and distinct. The elongated (52 mm.), anteriorly and posteriorly attenuated, and transversely narrowed (20 mm.) articular facets enclose an even smaller haemal canal than that of the preceding chevron.

Ninth chevron.—This is the smallest (pl. 20, fig. 14) chevron of the six associated with this skeleton. The thick haemal spine lacks a projection at either end. Each articular facet is elongated (34 mm.), more noticeably attenuated at the anterior end than posteriorly, and separated from the opposite facet by a minimum interval of 7 mm.

Literature Cited

Brandt, Johann Friedrich
1873. Untersuchungen über die fossilen und subfossilen Cetaceen Europa's. Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 20, no. 1, viii+372 pp., 34 pls.

Cabrera, Angel
1926. Cetáceos fósiles del Museo de La Plata. Revista Mus. La Plata; Buenos Aires, vol. 29, pp. 369–370, figs.

Doran, Alban Henry Griffiths
1878. Morphology of the mammalian ossicula auditus. Trans. Linnean Soc. London, ser. 2 (Zool.), vol. 1, pt. 7, pp. 371–497, pls. 58–64.

Emlong, Douglas
1966. A new archaic cetacean from the Oligocene of northwest Oregon. Bull. Mus. Nat. Hist. Univ. Oregon, Eugene, no. 3, pp. 51, 15 figs. October 1966.

Fraser, Francis Charles, and Purves, Peter Ernest
1960. Hearing in cetaceans: Evolution of the accessory air sacs and the structure of the outer and middle ear in recent cetaceans. Bull. British Mus. (Nat. Hist.), Zoology, London, vol. 7, no. 1, 148 pp., 34 figs., 53 pls. September 1960.

Howell, Alfred Brazier
1930. Aquatic mammals, their adaptation to life in the water. Springfield, Ill., xii+338 pp., 53 figs.

Kadic, Ottokar
1907. Mesocetus hungaricus Kadic, eine neue Balaenopteridenart aus dem Miozän von Borbolya in Ungarn. Mitteil. Jahrbuche Kgl. Ungarischen Anstalt, Budapest, vol. 16, no. 2, pp. 21–91, 70 figs., 3 pls.

Kellogg, Remington
1934. The Patagonian fossil whalebone whale, *Cetotherium moreni* (Lydekker). Contr. Palaeont., Carnegie Inst. Washington, publ. 447, pp. 63–81, 2 figs., 4 pls. January 10, 1934.

1965. Fossil marine mammals from the Miocene Calvert formation of Maryland and Virginia, Pt. 1: A new whalebone whale from the Miocene Calvert formation. Bull. 247, U.S. Nat. Mus., pp. 1–45, figs. 1–28, pls. 1–21. October 15, 1965.

1968. Fossil marine mammals from the Miocene Calvert formation of Maryland and Virginia, Pt. 8: Supplement to description of *Parietobalaena palmeri*. Bull. 247, U.S. Nat. Mus., pp. 175–197, figs. 77–98, pls. 64–67. June 12, 1968.

Mchedlidze, Guram A.
1964. Nekotorye yoprosy biologii i ievolutsii Ketoobraziych Trelichnye Mlekopitaivschie. Doklady Sovetskich Paleontologov, 8 Problema [Internat. Geol. Congress, XXII Session, Report of Soviet Paleontologists, Problem 8, Tertiary mammals, 1964, pp. 37–46, figs. 9], Moscow.

Packard, Earl L., and Kellogg, Remington
1934. A new cetothere from the Miocene Astoria formation of Newport, Oregon. Carnegie Inst., Washington, publ. 447, pp. 1–62, 24 figs., 3 pls. January 10, 1934.

Ridewood, Walter George
1922. Observations on the skull in foetal specimens of whales of the genera Megaptera and Balaenoptera. Philos. Trans. Roy. Soc. London, ser. B., vol. 211, pp. 209–272, 16 figs. May 8, 1922.

True, Frederick William
1904. The whalebone whales of the western North Atlantic, compared with those occurring in European waters with some observations on the species of the North Pacific. Smithsonian Contr. Knowl., vol. 33, publ. 1414, vii+331 pp., 97 figs., 50 pls. June 1904.

Turner, William
1871. On the so-called two-headed ribs in whales and in man. Journ. Anat. and Physiol., vol. 5, pp. 318–362.

1892. The lesser rorqual (*Balaenoptera rostrata*) in the Scottish seas, with observations on its anatomy. Proc. Roy. Soc. Edinburgh, vol 19, pp. 36–75, 4 figs.

Van Beneden, Pierre Joseph
1886. Description des ossements fossiles des environs d'Anvers, Part 5: Cétacés. Genres: Amphicetus, Heterocetus, Mesocetus, Idiocetus & Isocetus. Ann. Mus. roy. d'Hist. nat. Belgique, Bruxelles, ser. Paléontologique, vol. 13, 139 pp., 75 pls.

Winge, Herluf
1921. A review of the interrelationships of the Cetacea. Smithson. Misc. Coll., vol. 72, no. 8, publ. 2650, pp. 1–97. July 3, 1921. (A translation of Udsigt over Hvalernes indbyrdes Slaegtskab. Vidensk. Meddel. fra den naturh. Foren. i Kjøbenhavn, vol 70, pp. 59–142, by Gerrit S. Miller, Jr., August 29, 1918).

Kellogg, Remington. 1969. "Cetothere skeletons from the Miocene Choptank Formation of Maryland and Virginia. I. The skeleton of a Miocene Choptank cetothere." *Bulletin* 294, 1–40. https://doi.org/10.5962/bhl.part.9097.

View This Item Online: https://www.biodiversitylibrary.org/item/33313
DOI: https://doi.org/10.5962/bhl.part.9097
Permalink: https://www.biodiversitylibrary.org/partpdf/9097

Holding Institution
Smithsonian Libraries and Archives

Sponsored by
Smithsonian

Copyright & Reuse
Copyright Status: NOT_IN_COPYRIGHT

This document was created from content at the **Biodiversity Heritage Library**, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at https://www.biodiversitylibrary.org.

This file was generated 10 February 2024 at 17:12 UTC