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PARASAUROLOPHUS WALKERI

A NEW GENUS AND SPECIES OF CRESTED TRACHODONT DINOSAUR

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PARASAUROLOPHUS WALKERI

A NEW GENUS AND SPECIES OF CRESTED TRACHODONT DINOSAUR

Discovery

The specimen herein described was found in 1920 by an expedition from the University of Toronto in the bad lands of the Belly River formation on the Red Deer river, Alberta. The actual discovery was made by Mr. L. W. Dippell on the middle branch of the coulée below Sand creek at an elevation of 125 feet (aneroid) above the river. The excavation of the skeleton and its subsequent mounting in the Royal Ontario Museum of Palaeontology was done under the supervision of Mr. Levi Sternberg.

The skeleton was lying on its left side with some of the bones of the right or upper side in an indifferent state of preservation; in consequence, the mount has been prepared to show the left or under side. The whole of the anterior part including both fore limbs is well preserved, but the tail and hind limbs with the exception of one femur are wanting. The posterior ends of the ischia were also absent, but have been restored in the mount. No other restoration has been attempted.

General Description

The animal is evidently a representative of the *Trachodontidae* and of the sub-family *Saurolophinae* or crested type with footed ischia. It is characterized by a low-set and heavy body and by a very remarkable type of crest which seems to justify the creation of a new genus for its reception. Its affinities are undoubtedly with *Saurolophus* from the Edmonton; hence, the proposed generic name, *Parasaurolophus*. The specific name is given for Sir Edmund Walker, Chairman of the Board of Trustees of the Royal Ontario Museum.

The skeleton as mounted is shown by a carefully prepared drawing (Plate I) and by a photograph (Plate II). The anterior part is shown on a larger scale in Plate III. In all these figures it is apparent that the left side of the head has been sheared downwards. The drawing (Plate IV) indicates the head as it would probably appear in true lateral aspect. Some allowance must be made for the difficulty involved in this reproduction; in fact, I am now of the opinion that the supraorbital region has not been sufficiently foreshortened vertically. The general size of the animal is indicated by the following measurements:

GENERAL MEASUREMENTS

Tip of nose to anterior end of ilium	12 ft. 5 in.
Tip of nose to posterior end of ilium	15 ft. 9½ in.
Tip of nose to posterior rim of 41st centrum	16 ft. 9 in.

A comparison of numerous measurements indicates an animal somewhat smaller than *Saurolophus osborni*, for which Brown has estimated a total length of 32 feet.[1]

The resemblance to *Saurolophus* is very apparent in the head in which the crest assumes an elongated spike-like character rather than the plate-like appearance of such forms as *Corythosaurus* and *Stephanosaurus*. The structure of the premaxilla and of the external nares, however, suggests affinities with *Corythosaurus* and the lachrymal bone seems to be unique in its relationships. The size of the head, also, disregarding the crest, is very much less than in *Saurolophus*.

The body seems to be very like that of *Saurolophus*—massive and low-set. The pelvic girdle with the decurved anterior process of the ilium and the greatly expanded prepubis is strikingly similar to that of *Saurolophus*. The fore limb shows more differences in proportion: the humerus is almost exactly one-half the length of the femur, while in *Saurolophus* the proportion is considerably greater. In that genus, moreover, the radius and humerus are about equal in length, while in *Parasaurolophus* the radius is considerably shorter than the humerus.

[1]*Am. Mus. Nat. Hist.*, Vol. XXXI, Art. XIV, 1912; *ibid.*, Vol. XXXII, Art. XIX, 1913.

DETAILED DESCRIPTION

HEAD

The left side of the head, which is exposed in the mount, has been sheared downwards, thus increasing its apparent depth: in the drawing (Plate IV) an attempt has been made to place the parts in proper relationship. In general the lower and lateral parts of the head conform to the usual trachodont arrangement, but the superior margin is truly extraordinary as it is continued backward in a gently convex line to a greater distance than the total length of the head proper.

This posterior prolongation or crest is a stout structure of considerable thickness and depth the details of which will be given later. It can scarcely be doubted that this crest is analogous to that of *Saurolophus*, but it is much more massive and directed less upwards than in that genus.

The general measurements of the head (I) are given below with those of *Saurolophus osborni* (II) for comparison.

COMPARATIVE MEASUREMENTS OF HEAD

	I	II
Tip of premaxillary to paraoccipital process	810 mm.	1200 mm.
Tip of premaxillary to posterior of crest, measured along superior surface	1733	
Ditto, measured in straight line	1596	
Postorbital notch to anterior point of premaxillary	675	
Width of premaxillaries at widest part	170	380
Length in front of teeth	270	500
Length of quadrate	280	350
Length of mandible	640	1050
Length of crest from notch behind the orbit to posterior end	875	
Width at postorbital rim, probably not exceeding	200	
Height from inferior edge of articular in straight line at right angles to inferior line of mandible to superior margin	530	
Height ditto to superior margin of squamosal	330	

It will be seen from these measurements that the head, exclusive of the remarkable crest, is very much smaller than in *Saurolophus*; in fact, the proportions are more like those of *Corythosaurus*, in which the quadrate is of the same length (280 mm.) and the mandible nearly the same (669 mm.). In *Stephanosaurus*, likewise, the measurements of the critical elements of the head are very similar—275 mm. for the quadrate, and 645 mm. for the mandible.

Premaxillary—The premaxillaries form the characteristic duck-bill as in other genera of trachodonts: they are excavated in wide narial depressions anterior to the nares proper. This depression is floored throughout as in *Corythosaurus*, and there is a complete internarial septum. Whether this septum is formed by ascending processes from the premaxillaries or whether it is part of the nasal, it is impossible to say on account of the state of preservation of the parts. The only suture visible is a median one in the internarial bar. This can be traced forward a little in advance of the transverse line joining the anterior margins of the two narial depressions. Here it forks, turns outwards, and is lost. There is indistinct evidence that it turns back again and cuts the anterior margin of the narial depression about one-third of the distance across that opening. This arrangement is distinctly different from that in *Saurolophus*, where ascending processes from the premaxillaries separate the nasals along the mid-line of the internarial bar.

Posteriorly also a distinct suture between premaxillary and nasal cannot be deciphered with certainty; it is possible, however, that a suture runs backward from the posterior point of the narial opening, turns outwards and then forward, and terminates at the deep suture above the maxillary. If this line is really the premaxillary-nasal suture, it indicates a condition somewhat like that of *Prosaurolophus*. The most posterior point of this supposed suture is 460 mm. from the middle point of the beak and the termination on the premaxillary-maxillary suture 360 mm. from the same point.

It must be understood that the above sutures are very uncertain and that, as far as real evidence goes, the whole of the superior surface of head and crest is composed of premaxillaries. Maximum width of premaxillaries at duck-bill, 170 mm.; width of contracted part behind duck-bill, 125 mm.; width of narial opening, 80 mm.; tip of premaxillary to posterior suture with nasal (?), 460 mm.

Nasal—As already stated the sutures with the pre-maxillary are problematical; it is reasonable, however, to assume that the nasals occur, and if so, they must form the major part of the superior surface of the head and of the crest. A median sutural line can be observed superiorly, and a deeply incised suture separates the nasal (and pre-maxillary) from the maxillary and from the bone which forms the lower half of the crest, and which is herein provisionally regarded as the frontal.

Crest (Plate IV; Plate V, Fig. 1; text Figs. 1 and 2)—If the interpretation above is correct the crest is formed of nasals and frontals; it fades imperceptibly into the superior surface of the head proper; inferiorly it may be said to terminate at a notch behind the orbit which it is proposed to call the *postorbital notch*. The length from this notch to the inferior-posterior end is 875 mm. and to the superior margin 200 mm. The latter figure is doubtless too high as it makes no allowance for the downward shearing which the skull has suffered.

Posteriorly the crest is subquadrate in cross section, but farther forward it is drawn out to a keel inferiorly; just behind the postorbital notch it is sub-trapezoidal owing to a widening of the inferior surface. The distal part is expanded rather abruptly for a distance of about 20 mm. from the end. The posterior surface of this expansion is strikingly flat, is inclined downwards and backwards from the axis of the crest, and measures 90 mm. transversely and 110 mm. vertically. Laterally, this terminal expansion is sharply defined against the nasal, but less distinctly against the frontal. On the superior surface a median suture is plainly discernible almost to the extreme end. The strongly marked lateral sutures (Plate V, Fig. 1) do not reach the extreme end, but terminate in or near two deep pits. The inferior of these pits is larger than the other and is situated a little more anteriorly. This pit is so deep that it can not be separated from its fellow of the opposite side by more than 25 mm. The superior pit is smaller and seems to pass through the terminal expansion as a sort of slit-like opening.

On the lateral aspect of the nasal, 170 mm. from the end, is a deep pit which is continued backwards as a narrow sulcus to the depression marking the anterior edge of the swollen extremity. Above and posterior to this pit is a well marked corrugated tuberosity 55 mm. in length. A similar but smaller tuberosity lies below the sulcus at this point.

A natural fracture crosses the crest 360 mm. from the end: this break has enabled us to ascertain the character of the cross section (Figs. 1 and 2). The crest is composed

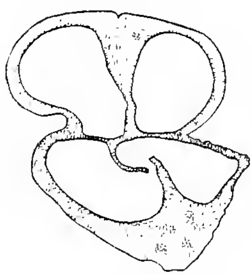


FIG. 1

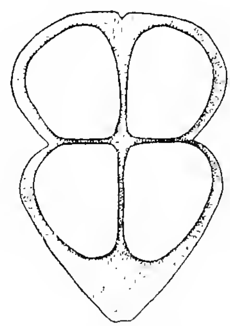


FIG. 2

Figure 1. Cross section of crest about 360 mm. from end, crushed as found. One-third natural size.

Figure 2. Cross section of crest about 360 mm. from end, restored. One-third natural size.

apparently of four tubes of very thin bone not more than 5 mm. thick except at the superior and inferior points of junction. The lower line of junction, particularly, is considerably thickened and drawn down to a hatchet-like edge. The bones are coalesced as no sign of sutural union is visible.

The appearance of the cross section is indicated in Figure 1, while Figure 2 is constructed to show the probable cross section of the crest when free from distortion. If this figure is correct the depth of the crest, 360 mm. from the end, is 130 mm., the superior diameter, 90 mm., and the inferior diameter, 85 mm.

In considering this remarkable structure, the question naturally arises as to the character of these hollow bones in life. Were they filled with organic tissues or were they open air passages? The external nares seem to lead directly into the upper pair of tubes, but nothing is known as to the internal nares. This interesting question could probably be answered by a longitudinal sawing through the skull, but we have been unwilling to injure the specimen so seriously.

Concerning the function of the crest itself, Brown is of the opinion that in *Saurolophus* it bore a frill and that this frill was probably continuous with a frill on the dorsal vertebral spines. There can be little doubt that a similar structure was present in *Parasaurolophus*, and we have reason to believe that a muscular or ligamental union existed between the crest and the dorsal vertebrae as will be more fully considered later.

Maxillary—This bone shows the ordinary well-marked sutures with the premaxillary and with the jugal: its relation to the lachrymal, however, is open to question. The actual suture with the premaxillary is 110 mm. long and with the lachrymal (?) 40 mm. long. There are 31 strongly carinated teeth visible in a length of 240 mm.

Lachrymal and prefrontal (Plate V, Fig. 2)—The identification and relationship of these bones is extremely doubtful, but it is certain that this genus is remarkably different from any other trachodont in the arrangement of the bones of this part of the head. A detailed drawing (Plate V, Fig. 2) has been prepared of this part of the head to show the sutures as far as they can be made out. Posterior to the maxillary, and overlapping it, is a quadrangular to subtriangular bone which it seems necessary to interpret as a lachrymal. Its suture with the jugal is distinct and it is separated from the nasal (premaxillary?) by a deep pit which extends forward above the maxillary and backward between the nasal and the frontal almost to the end of the crest. Supero-posteriorly there is a distinct suture with the bone behind, but infero-posteriorly there is more doubt. While it can not be stated with certainty there seems to be a small triangular bone separating the infero-posterior margin of the lachrymal from the jugal: this bone we are inclined to regard as the prefrontal.

If the interpretation above is correct the lachrymal in *Parasaurolophus* is unique among the dinosaurs: in no other case is it so far forward or is it excluded from the orbital rim.

The distinctness of the little bone which we have called the prefrontal is very doubtful; it may be merely a process of the jugal, as the occurrence of a suture along its inferior border is open to question. As in the case of the lachrymal the exclusion of the prefrontal from the orbital rim is remarkable.

If this little bone is a mere process of the jugal, the anterior part of the bone to be described later as the frontal may be the prefrontal. No suture is visible above the orbit, but the bone in this region is in a poor state of preservation, and the absence of a suture cannot be stated with certainty. This interpretation will doubtless appeal to many anatomists, as it leaves the prefrontal, at least, in the normal position above the orbit and forming part of the orbital rim.

Frontal—This bone is unusually conspicuous as it forms the whole of the lower half of the crest, and, apparently at least, the whole of the supraorbital rim. As already stated, however, the anterior part of this bone may possibly represent the prefrontal. The suture with the postfrontal is distinct and as indicated in the drawing.

Postfrontal—This bone is normal in character and position: its sutures with the frontal and with the squamosal are distinct.

Jugal—This bone is of normal type: it is apparently not in contact with the quadrate, but as the superior point of the quadratojugal and contiguous parts of the jugal have suffered some abrasion it is possible that the separation of the jugal from the quadrate is less pronounced than shown in the figure. The postorbital process is very slender, and there is a very pronounced spur-like and somewhat elevated point fitting into a recess at the suture with the frontal (prefrontal ?). A deep pit occurs at the base of the upwardly directed process or separate triangular bone which we have considered, possibly at least, to be the prefrontal. Length from supero-posterior to infero-anterior point, 237 mm. Suture with quadratojugal, 95 mm.

Orbit—This aperture is oval with the greater diameter strongly inclined backwards from the line of the teeth; maximum length, 170 mm., maximum width, 105 mm.

Lateral temporal fossa—This vacuity is long and narrow: 195 mm. by 50 mm.

Quadrate—The quadrate is 280 mm. long and concave posteriorly. The external width at the upper end is 45 mm.; just above the suture with the quadratojugal it is 65 mm., and at the narrow part above the lower end, 40 mm. It is deeply excavated for the quadratojugal.

Quadratojugal—The visible part of this bone is very narrow: its height is 95 mm. and its maximum external width, 25 mm. As already stated it is somewhat doubtful if it entirely separates the jugal from the quadrate.

Squamosal and paraoccipital process—The squamosal forms a deep cotylus for the quadrate and sends down a long process at the rear of the lateral temporal fossa: it forms the external part of the paraoccipital process for two-thirds of its length, the rest of this structure being formed by the exoccipital as in other trachodonts.

Parietals—These bones meet in a narrow longitudinal edge between the supratemporal fossae for a length of about 50 mm. Anteriorly the superior margin turns abruptly upwards for 35 mm. to the inferior surface of the crest. Here the bones flange outwards and backwards in overlapping sutures on the inferior surface of the frontals. Laterally they sweep around and form the anterior margins of the supratemporal fossae. They seem to terminate laterally in points between the frontals and postfrontals (*i.e.*, within and behind the postorbital notch, not shown in figure).

Supratemporal fossa—This opening is small and hidden under the crest: owing to the sloping character of the margins, exact measurements are difficult to make, but it may be said to be about 95 mm. long and 50 mm. wide.

The *mandible* is of the usual trachodont type: the extreme length is 640 mm., and the depth from the alveolar margin to the inferior edge at the first tooth is 104 mm. From the first tooth to the anterior point on midline is 200 mm.

Predentary—This bone is small and overlaps the dentary with prominent suture. Width, 280 mm.; length, 130 mm. on midline from anterior point to line joining the posterior prongs.

Dentary—The dentary is of the ordinary type, rather strongly decurved anteriorly. The length on the inferior margin from articulation with predentary to articulation with surangular is 455 mm., and from the posterior prong of the predentary to the same point, 390 mm. Thirty-one teeth are visible in a distance of 240 mm. Still more may occur, but if so they are hidden under the coronoid process. There is evidence of at least three rows. Seven prominent foramina occur on the external surface of this bone as shown in the figure. The coronoid process is prominent and directed slightly forward: it is 50 mm. wide at midlength. Its total height cannot be ascertained as it is partially hidden under the jugal, but it rises at least 190 mm. above the inferior margin of the mandible and 90 mm. above the alveolar margin.

Surangular—The upward extension of this bone lies beneath the coronoid process with its margin almost parallel with the posterior margin of the process: the bones are separated by a deep sulcus. The suture with the dentary runs irregularly down and back to the inferior edge of the mandible.

Angular and articular—The sutures of these bones with each other and with the surangular are not visible. From the inferior point of the suture between the surangular and dentary to the posterior tip of the articular is 115 mm.

The strong flexure of the neck and the displacement of the anterior vertebrae have revealed the foramen magnum, which is small and apparently low in position. The other features of the posterior aspect of the skull are not well shown, but present nothing differing from the usual trachodont arrangement.

VERTEBRAL COLUMN

The vertebral column consists of 13 cervicals, 17 dorsals, 7 sacrals, and 6 caudals preserved. The vertebrae of the sacral region are not sufficiently exposed in the mount to state definitely how many are coalesced. The actual conditions are shown in the photograph (Plate VI). It is apparent that the vertebral centra shown in Plate I are very largely restored.

Cervicals (Plate VII, Figs. 1, 2, 3)—The total length of the thirteen cervicals measured along the line of the diapophyses is about 1190 mm. A more accurate measurement is 670 mm. along the ventral side from the posterior rim of the 7th to the posterior rim of the 13th vertebra.

The cervical centra are strongly opisthocoelous. Cervical ribs are present, but owing to the neck having been forced between the mandibles the anterior cervical ribs do not appear. The most striking feature of the neck is the remarkably strong and prominent postzygopophyses.

The *atlas* is not well exposed: the length of the neural arch is 70 mm. and the maximum diameter across the two arches is 110 mm.

The *axis* carries the usual prominent plate-like neural spine, which is 85 mm. long on the midline. The total length to the posterior point of the postzygopophysis is 145 mm., and the width between the external surfaces of the two zygopophyses is 80 mm. The postzygopophysial facette is 38 mm. long.

The first apparent neural spine after that of the axis is the ninth, which is only about 10 mm. high. Posteriorly the spines increase in size as follows: 10th, 35 mm.; 11th, 40 mm.; 12th, 50 mm.; 13th, not measurable.

The first measurable cervical rib is the fifth which is long and slender, 105 mm. from diapophysis to tip. The sixth is shorter, and less pointed: its length is not measurable. The seventh to tenth inclusive are flatter, broader, square at the end, and of about equal length—90 mm., 100 mm., 90 mm., 85 mm. The eleventh to thirteenth are more pointed. The eleventh is 90 mm. long and the thirteenth 120 mm. The twelfth is not well preserved.

The diapophyses of the cervical vertebrae are well developed: that of the axis is small and uncertain, that of the 7th vertebra is 60 mm. long.

The postzygopophyses are very strongly developed. From the eighth to the thirteenth they are curved downward and carry a well-marked facette. The curvature of the postzygopophyses ceases abruptly with the first dorsal. The lengths measured along the curve are approximately as follows: 3rd, 50 mm.; 5th, 70 mm.; 6th, 80 mm.; 8th, 85 mm.; 9th, 85 mm.; 10th, 90 mm.; 11th, 90 mm.; 12th, 100 mm.; 13th, 110 mm.

Plate VII shows the eighth, ninth, and tenth cervical vertebrae from the left lateral, dorsal, and ventral points of view.

Dorsal vertebrae—There are apparently 17 dorsal vertebrae carrying ribs. The centra are decreasingly opisthocoelous posteriorly: the size of the centra is not measurable, but the posterior ones are approximately 80 mm. long, 150 mm. high, and 72 mm. wide.

The first dorsal spine is distinctly more pointed than the last cervical, and the spines gradually increase in length posteriorly: they are rather variable in shape, and the posterior ones are closely set and both broad and long. The fifth, sixth, and seventh show a remarkable modification which will be referred to later.

The postzygopophysis of the first dorsal is distinctly shorter than that of the last cervical, being only about 80 mm. long as compared with 110 mm. The second dorsal postzygopophysis is only 50 mm. and the 16th is quite small.

The diapophyses are prominent, long, and somewhat variable in shape: measurements are given in the table below.

The ribs are very heavy when compared with those of such genera as *Corythosaurus* or *Kritosaurus*. The fourth, fifth, and sixth ribs show distinct evidence of injury during the life of the animal. There is a distinct fracture observable in the fourth, and the fifth and sixth show swollen coalescences of broken parts.

MEASUREMENTS OF CERTAIN ELEMENTS OF THE DORSAL REGION

Dorsal vertebra, No.	Neural spine mm.		Diapophysis mm.			Rib length, mm.
	Length	Width at top	Length		Width	
1	160		130(?)	from centrum		360
2	165		120			590
3	170		120			840
4	...		135			970
5	180		135			1050
6	140		120	from base of neural spine		1130
7	140		110			1140
8	295	55	95		125	1115
9	290	85	100		100	918
10	305	85	95		80	685
11	305	85	100			400+
12	300	100	110			280+
13	285	95	120			275
14	270	80	150			245
15	275	75	120			198
16	280	80	120			105
17	...	..	180(?)			present but indeterminable

It will be observed from the above table and from a glance at the figure that the sixth neural spine is unusually wide and straight; that the fifth is pointed and inclined backwards so as almost to touch the sixth; and that the seventh, on the other hand, is inclined forward and is apparently in actual contact with the tip of the sixth. The sixth spine, in particular, and to some extent the seventh, bears at its tip a discoidal expansion or co-ossified separate bone about 100 mm. in diameter and 20 mm. thick. This pad of bone is rough and without distinct surface. At first we were inclined to regard it as the result of injury, more particularly as there is distinct evidence in the broken ribs already referred to of the animal having suffered an accident. There is another explanation, however, which appeals to us strongly, although at first one is tempted to regard it as fanciful. May it not be that the crest of the head was attached to this pad of bone by muscles or ligaments? It has already been suggested that the crested trachodonts bore a frill which extended down the neck and into the dorsal region. It is not hard to imagine that we have here an extreme case of the same sort of thing. If the abnormal flexure of the neck were removed and the head and crest placed in natural position, the end of the crest would be considerably above and in advance of this pad of bone on the sixth dorsal vertebra. That such connection between the crest and the vertebrae existed in life is further suggested by the very considerable difference between the seventh and eighth neural spines, the latter of which is more than twice as long as the former. Again, the dislocation of the column between the seventh and eighth vertebrae suggests an association of the anterior part with the head and implies a participation in the series of events in connection with the abnormal flexure of the neck whether before or after death.

Sacrum—It is quite impossible in view of the condition of the mount to state accurately the number of sacral vertebrae. There are at least six thoroughly fused centra and a seventh, partially united, which may be regarded as a sacro-caudal. The six anterior neural spines are high and wide like those of the posterior dorsals, but the seventh is narrower and resembles those of the undoubted caudals. The chief reason why this vertebra is regarded as a sacro-caudal is the length of the centrum, which is 120 mm., as compared with 90 mm. for the first true caudal.

MEASUREMENTS OF SACRAL VERTEBRAE

Sacral vertebra No.	Neural spines		Diapophysis
	Length, mm.	Width, mm.	Height from base of neural spine, mm.
1	310	90	140
2	310	90	160
3	305	80	150
4	310	85	150
5	330	80	145
6	370	....	200
7	405	65	170

Caudal vertebrae—Only four caudal vertebrae are perfectly preserved, but parts of the fifth and sixth are present: these have been restored in the mount, but are not referred to in the measurements given below.

MEASUREMENTS OF CAUDAL VERTEBRAE

Caudal vertebra No.	Length of centrum, mm.	Neural spine		Diapophysis Length, mm.	
		Length mm.	Width mm.	From base of sp.	From centrum
1	90	415	60	150	......
2	80	410	60	160	105
3	80	400	60	140	80
4	80	390	50	125	72

The 41st centrum, the only one measurable, is 80 mm. long, 150 mm. high, and 72 mm. wide.

PECTORAL GIRDLE

The girdle consists of the scapulae and coracoids as usual in the dinosaurs. Sternal bones were not found.

Scapula—This bone is unusually heavy and wide in the blade and it is firmly united with the coracoid. The photograph (Plate III) and the comparative measurements will serve to define it.[1]

COMPARATIVE MEASUREMENTS OF SCAPULA

	Parasaurolophus walkeri	Corythosaurus casuarius	Kritosaurus incurvimanus	Saurolophus osborni
Total length.....	940	890	776	900
Maximum width of blade......	248	200	189	220
Width at articular end.....	235		214	
Length of glenoid cavity......	125		110	
Width of glenoid cavity......	75		64	

It will be observed that the scapula is of greater length than that of *Saurolophus:* it is surpassed only by that of *Claosaurus annectens* (970 mm.). It shows a greater width of blade than any other form of which I can find a description.

Coracoid (Fig. 3)—Neither of the coracoids is well preserved: the left is in better condition and is shown, with considerable adjustment, in Figure 3. The bone is firmly united with the scapula and the foraminal notch is closed as in all trachodonts with the exception of *Kritosaurus*. The following rather uncertain measurements indicate the size of the bone. The glenoid cavity has a transverse width of

[1]Owing to disregard of an erratum slip accompanying Barnum Brown's paper on *Saurolophus osborni*, some of the measurements quoted in University of Toronto Studies, Geological Series, No. 11, are transposed. In the table on page 41 of that study, II should read *Saurolophus osborni*, III *Trachodon mirabilis*, and IV *Claosaurus annectens*.

80 mm. and a vertical width of 75 mm. From the infero-anterior point to the posterior of the articulation with the scapula is 185 mm. and from the margin of the glenoid

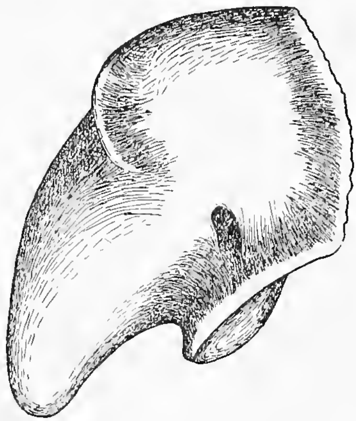


Figure 3. Left coracoid, external view. One-third natural size.

cavity to anterior edge of the bone, 105 to 110 mm. The upper portion of the twisted anterior margin is much more lobe-like than in the case of *Kritosaurus*.

FORE LIMB

Humerus (Figs. 4 and 5)—This bone is of the ordinary type, but it is remarkable for its short length and heavy character. This is the more noticeable in view of the great length of the scapula. The figures and the comparative measurements given herewith require little comment. The great radial crest with its upward aspect is rather striking.

COMPARATIVE MEASUREMENTS OF HUMERUS

	Parasaurolophus walkeri	Kritosaurus incurvimanus	Saurolophus osborni
Length	520	630	610
Width across radial crest	160	170	...
Length of radial crest	310	...	310
Girth of shaft	255	214	

COMPARATIVE MEASUREMENTS OF HUMERUS—*Continued*

	Parasaurolophus walkeri	Kritosaurus incurvimanus	Saurolophus osborni
Width across inner and outer tuberosities	200	160	
Width across condyles	150	...	
Thickness of outer condyle (ant.-post)	70(?)	80	
Thickness of inner condyle (ant.-post)	88	82	
Thickness of head	84	78	
Thickness of inner tuberosity	40	41	
Thickness of outer tuberosity	40	31	

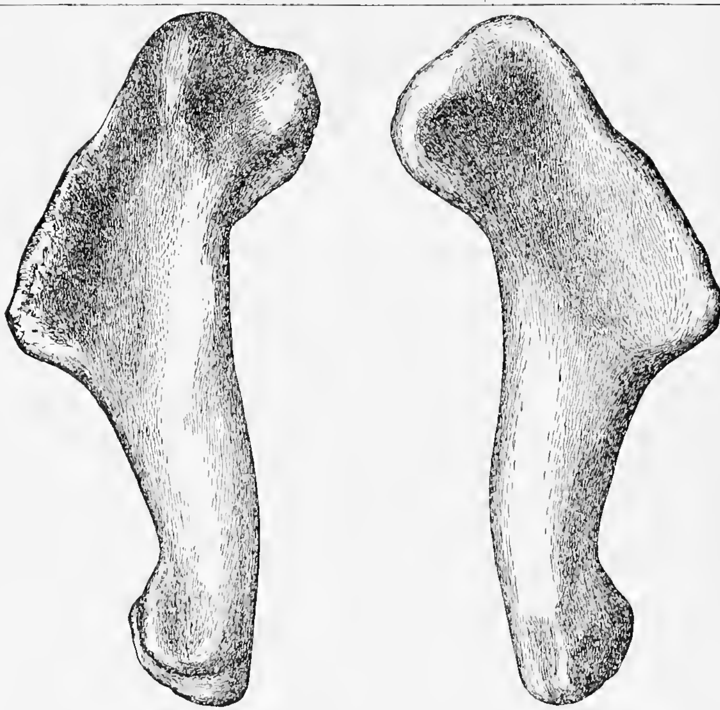


FIG. 4 FIG. 5

Figure 4. Left humerus, external view. One-sixth natural size.
Figure 5. Left humerus, internal view. One-sixth natural size.

Ulna (Figs. 6 and 7; Plate VIII, Figs. 1 and 2)—This bone requires little comment: it is quite the same as in other trachodonts. The proximal parts of both bones are rather badly crushed, rendering exact measurements difficult. The only significant features are indicated in the comparative measurements given below.

COMPARATIVE MEASUREMENTS OF ULNA

	Parasaurolophus walkeri	Kritosaurus incurvimanus	Saurolophus osborni
Length over olecranon..........	560	610	680
Minimum girth of shaft.........	180	158	

Radius (Plate VIII, Figs. 1 and 2)—This bone has the usual form of a long thin shaft expanded at both ends.

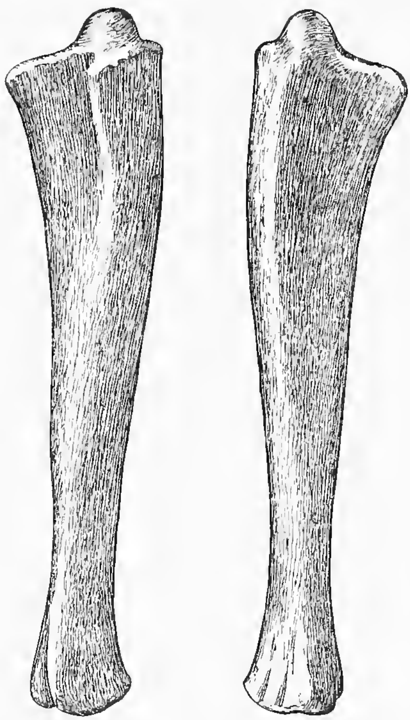


FIG. 6 FIG. 7

Figure 6. Left ulna, intero-anterior view. One-sixth natural size.
Figure 7. Left ulna, externo-posterior view. One-sixth natural size.

Neither bone was in the best of condition and, in consequence, a small allowance may be necessary in the figures given below: those for the left bone are the more reliable.

COMPARATIVE MEASUREMENTS OF RADIUS

	Parasaurolophus walkeri		Kritosaurus incurvimanus	Saurolophus osborni
	right	left		
Length	485	496	555	620
Girth of shaft, one-third from distal end	152	152	...	
Girth at middle	160	148	136	
Girth, one-third from prox. end	140	146		

Carpals—In both limbs a small carpal was found lying on the distal posterior edge of the ulna: a second carpal was not observed.

Manus (Plate VIII, Fig. 3; Plate IX, Figs. 1, 2, 3, and 4)—As in the case of the other elements of the fore limb the manus is short. Metacarpals III and IV are closely associated and longest; metacarpal II is somewhat shorter, but nevertheless closely associated with III and IV. Metacarpal V is much smaller and divergent. The phalangeal formula of trachodonts was discussed in a former paper.[1] Although the terminal phalanx of Digit V is lacking, there seems no reason to doubt that the formula for *Parasaurolophus* is the same as that for *Kritosaurus* as follows:

Digit II with three phalanges, the third a pointed hoof.
Digit III with three phalanges, the third a broader hoof.
Digit IV with three phalanges, no hoof.
Digit V with four phalanges, the terminal a small ovoid bone (this last phalanx is not preserved).

As in the case of *Kritosaurus*, phalanges II^2 and III^2 are triangular with the thin edge directed inwards: in the case of the latter of these bones, the triangular character is not so marked as in *Kritosaurus*.

[1] Parks, *University of Toronto Studies, Geol. Ser.*, No. 11, 1920.

Both feet are preserved intact with the exception of phalanx V^4 in both cases. While the bones are to some extent imperfect and deformed, there is, nevertheless, a certain amount of difference between the two feet which is not due to accidents after entombment. The most striking of these differences is the abnormally narrow distal end of metacarpal III in the left foot.

It has been thought better to illustrate the manus fully rather than to give detailed descriptions of the individual bones. The plates and the comparative measurements given below should suffice.

COMPARATIVE MEASUREMENTS OF METACARPALS

	Parasaurolophus walkeri	Saurolophus osborni	Kritosaurus incurvimanus	Trachodon mirabilis	Claosaurus annectens	Hypacrosaurus altispinus
	mm.	mm.	mm.	mm.	mm.	mm.
Metacarpal II, length	173	250	185	200	245	220
Metacarpal II, max. diameter proximal end	44		39			
Metacarpal II, max. diameter distal end	45		37			
Metacarpal III, length	208	330	226	220		265
Metacarpal III, max. diameter proximal end	54		49			
Metacarpal III, max. diameter distal end	60		50			
Metacarpal IV, length	195	330	225	215		280
Metacarpal IV, max. diameter proximal end	61		68			
Metacarpal IV, max. diameter distal end	57		51			
Metacarpal V, length	90	130	94	75		
Metacarpal V, max. diameter proximal end	48		52			
Metacarpal V, max. diameter distal end	32		35			

COMPARATIVE MEASUREMENTS OF PHALANGES

	Parasaurolophus walkeri	Kritosaurus incurvimanus
	mm.	mm.
Phalanx II¹, length	65	73
" proximal width	41	45
" distal width	45	42
Phalanx II², length	17	18
" width	31	25
Phalanx II³, length	58	64
" proximal width	34	37
" width of hoof	37	53
Phalanx III¹, length	38	57
" proximal width	58	51
" distal width	55	47
Phalanx III², length	15	21
" width	40	34
Phalanx III³, length	51	52
" proximal width	46	45
" width of hoof	52	58
Phalanx IV¹, length	54	66
" proximal width	48	52
" distal width	42	53
Phalanx IV², length	14	18
" width	33	34
Phalanx IV³, length	11	15
" width	17	21
Phalanx V¹, length	48	60
" proximal width	39	60
" distal width	34	
Phalanx V², length	30	32
" proximal width	28	
" distal width	27	
Phalanx V³, length	25	18
" width	25	
Phalanx V⁴, length	..	10

The relatively large size of the scapula has already been referred to: equally noteworthy is the relatively short fore limb in all its elements. The humerus is considerably shorter than in *Saurolophus osborni*, but somewhat longer than in *Trachodon* and *Claosaurus*. The ulna is very much shorter than in *Saurolophus*, and only in *Trachodon mirabilis* is a shorter one recorded. The same relationship holds for the radius. The radius is shorter than the humerus, while in *Saurolophus* it is slightly longer (*vide* preliminary description, p. 6).

If *Saurolophus osborni* be regarded as the nearest relative of the present species, a most striking difference is shown by the manus. *Saurolophus* appears from Brown's figures to have the longest manus of any trachodont; on the other hand, *Parasaurolophus* has the shortest.

Adding together the lengths of humerus, radius, and metacarpal III, we obtain the following figures for the lengths of the fore limbs exclusive of phalanges:

	mm.	
Parasaurolophus walkeri	1224	
Kritosaurus incurvimanus	1411	
Saurolophus osborni	1560	
Trachodon mirabilis	1161	
Claosaurus annectens	1345	(metacarpal II instead of III)
Hypacrosaurus altispinus	1545	

It will be observed that *Saurolophus* has the longest fore limb and that *Parasaurolophus* has the shortest with the exception of *Trachodon mirabilis*. These relationships would not be greatly changed even if allowance were made for difference in size of the animals. While the fore limb of *Parasaurolophus* is short, it is relatively stout and is supported by a scapula of extraordinary size. May it not be that this arrangement is a direct consequence of the supposed attachment of the crest to the vertebral column? Short fore limbs would seem to be a necessity in order to permit the animal to lower its head while eating.

PELVIC GIRDLE

The pelvic girdle is distinctly of the type described by Brown for *Saurolophus*.[1] It is deep and massive with decurved anterior process on the ilium and with expanded

[1] *Am. Mus. Nat. Hist.*, Vol. XXXIII, Art. XIX, 1913.

prepubis. A peculiar feature is that the ilium seems to form an overlapping union with the pubis instead of abutting against it as in other forms. After a careful examination, I am of the opinion that this arrangement is not due to deformation.

Ilium (Fig. 8, Plate VI)—This bone is very massive with stout ischiac peduncle above which the overhanging shelf is sharply defined and comes low down. The pubic peduncle

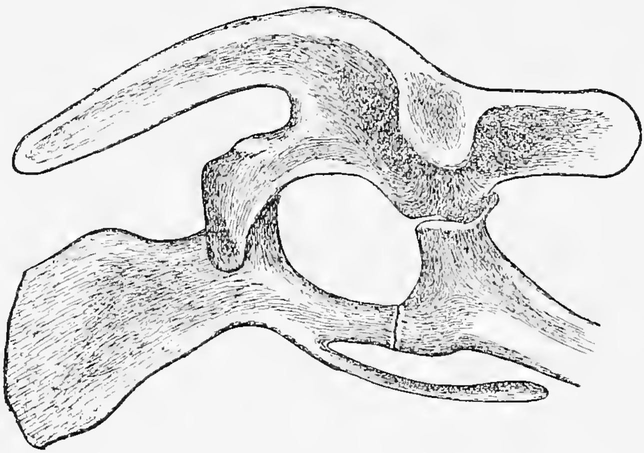


Figure 8. Left pelvic girdle, external view. One-twelfth natural size.

is unusually extended anteriorly, decurved at its anterior end and fastened to the pubis by an externally overlapping joint. Even if this manner of union is due to distortion, there can be no doubt as to the quite unique character of the anteriorly extended pubic peduncle.

Ischium (Fig. 8, Plate VI)—This bone seems to be less massive than the ilium and to present nothing of particular interest. Only the proximal portion is preserved, but the distal end has been restored with a "foot" in the mount.

Pubis (Fig. 8, Plate VI)—The prepubis is generally like that of *Saurolophus*, but has an outline sufficiently different to distinguish it. The anterior end is much less decurved and the narrow portion is relatively wider. It differs greatly from the prepubis of *Kritosaurus*, in which the upper and lower margins of the blade-like part are approximately parallel. The peculiar union with the ilium has been referred to above.

The postpubis is rather short and flattened towards the extremity. It seems to lie farther from the ischium than usual. The pubic notch is open. The acetabulum is elongated longitudinally.

COMPARATIVE MEASUREMENTS OF PELVIC GIRDLE

	Parasaurolophus walkeri	Saurolophus osborni	Kritosaurus incurvimanus	Trachodon mirabilis	Claosaurus annectene
Ilium, length in straight line	1015	1160	1013	1030+	1150
" length along superior margin	1120				
" length of anterior process	445	480			
Ischium, length	...	1200	1026	1090	
" width 300 mm. from proximal end	110				
" girth at this point	280				
Pubis, total length	894(?)	1150	1038	630	
" width of blade of prepubis	260	310	163	200	220
" preacetabular border to anterior end	516	590	519	360	450
" iliac union to anterior end of prepubis	636				

HIND LIMB

The only part of either hind limb preserved is the left femur.

Femur (Fig. 9, Plate VI)—This bone is of the ordinary type, and is sufficiently defined by the figures and the comparative measurements given below. The less prominent head in Figure 9, compared with that shown in Plate VI, Fig. 1, is due to the fact that the bone is thrown inwards distally, thus bringing the head into view. The figure is drawn in true projection.

COMPARATIVE MEASUREMENTS OF FEMUR

	Parasaurolophus walkeri	Saurolophus osborni	Kritosaurus incurvimanus	Trachodon mirabilis	Claosaurus annectens
Length, outer condyle to proximal end	1032	1150	1045	1040	1170
Width across trochanters	230		209		
Width of inner condyle	275		292		
Width of outer condyle	285		262		
Thickness at condyles	180		210		
Width of shaft above condyles	130				
Thickness of shaft above condyles	110				
Girth of shaft above condyles	410				
Width of head, antero-postero	185				
Length of 4th trochanter	290				
Height of 4th trochanter	100				
Thickness across head to midline between trochanters	265				

It will be observed that the lengths of the different femora do not greatly differ. The other measurements are not very reliable, as crushing in many cases seriously affects the proportions of different parts. For instance, it is unlikely that the figures given above for the widths of the inner and outer condyles are correct. Why should the inner condyle exceed the outer in width in *Kritosaurus* and the opposite condition maintain in *Parasaurolophus?*

While the pelvic girdles of trachodonts are distinctive for the different genera, it has not yet been established that the same holds true for the bones of the hind limb, which seem to be essentially so similar that only the greatest of detail will serve to differentiate the genera and species. The fore limb, on the other hand, indicates faithfully the specialization of the animal and is, in consequence, of greater value in the work of identification.

EPIDERMIS AND MUSCULATURE

Many ossified tendons were found in the course of preparation, but they were so broken and scattered that it was

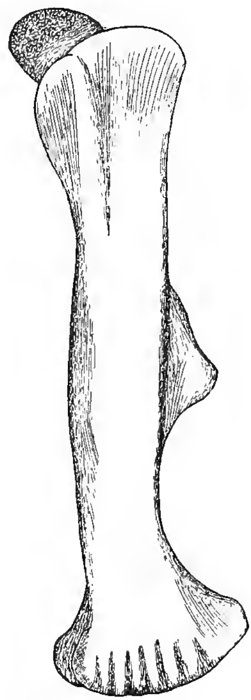


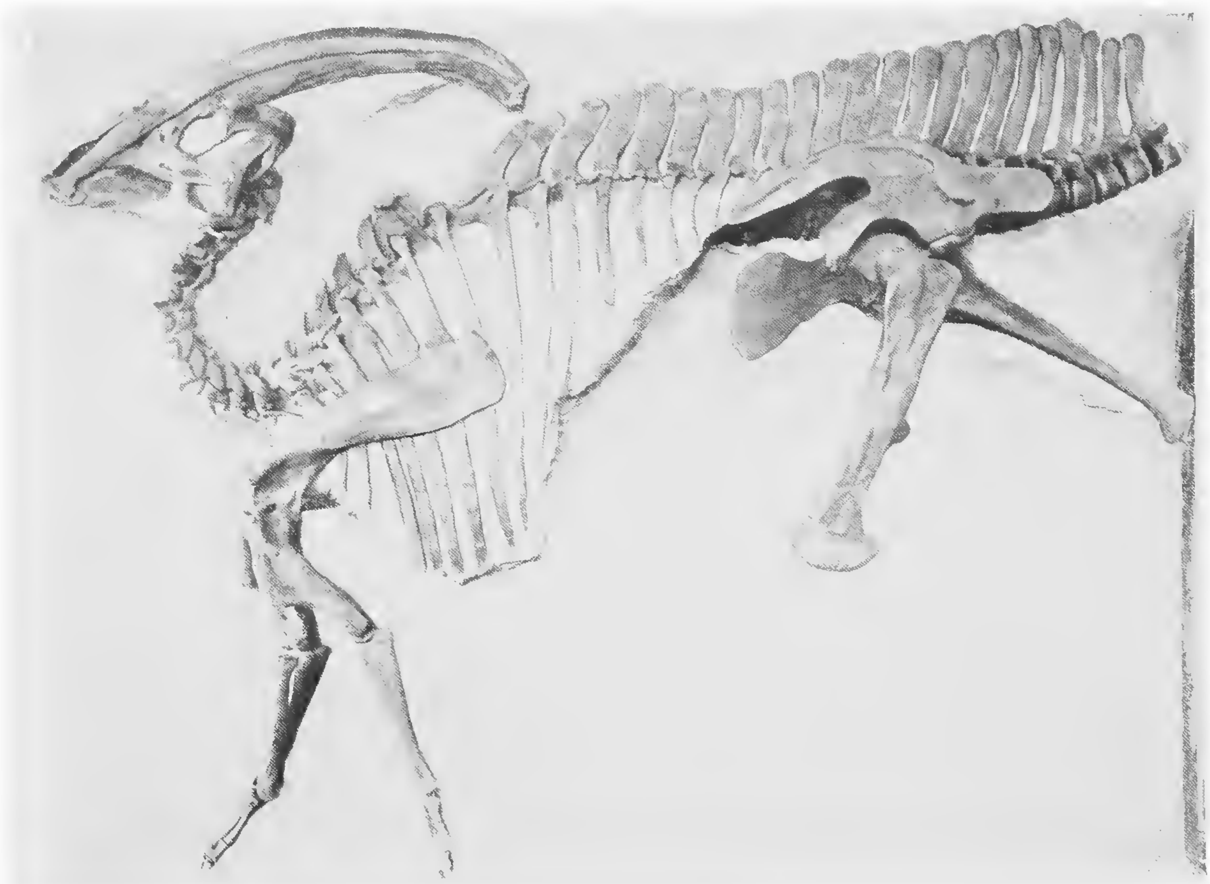
Figure 9. Left femur, external view. One-twelfth natural size.

impossible to save them. It was noticed that these tendons were not in close contact with the neural spines, as is generally the case.

Impressions of the skin also were found in several parts of the body: they all exhibited the usual tuberculated structure, but in no case revealed any of the acorn-like elevations seen in other trachodonts. Apparently the skin was uniformly tuberculated, but it is impossible to say that this condition maintained over the whole animal.

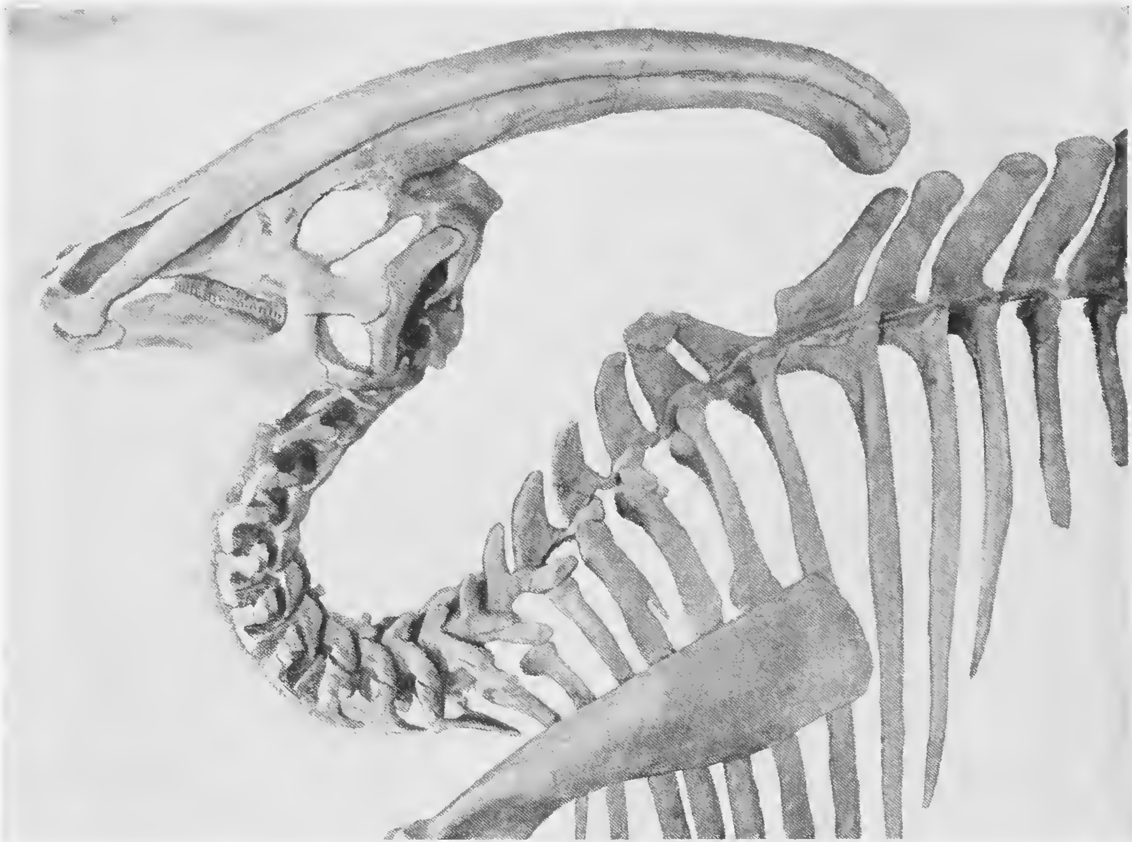
Parasaurolophus walkeri. Skeleton as found, with neck abnormally flexed and head sheared downwards. The centra of the vertebrae have been drawn in from general measurements. About 1/24 natural size.

PLATE II

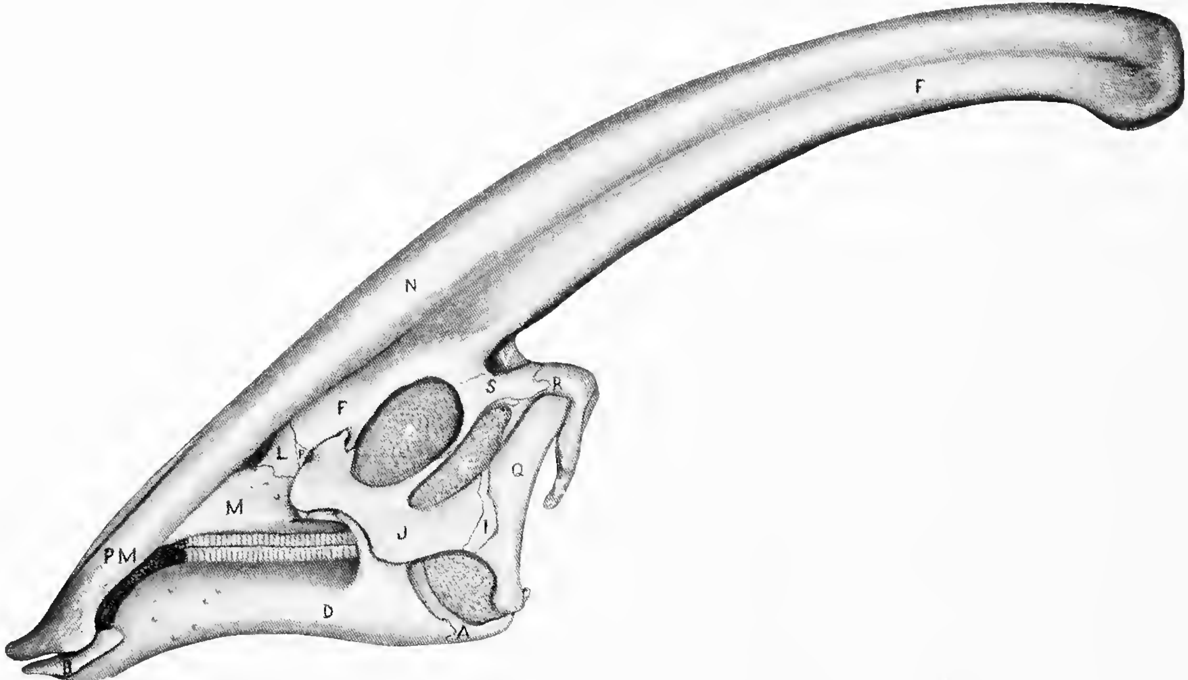


Parasaurolophus walkeri. The skeleton as mounted. The ends of the ischia and parts of the last caudal vertebrae have been restored. About 1/24 natural size.

PLATE III

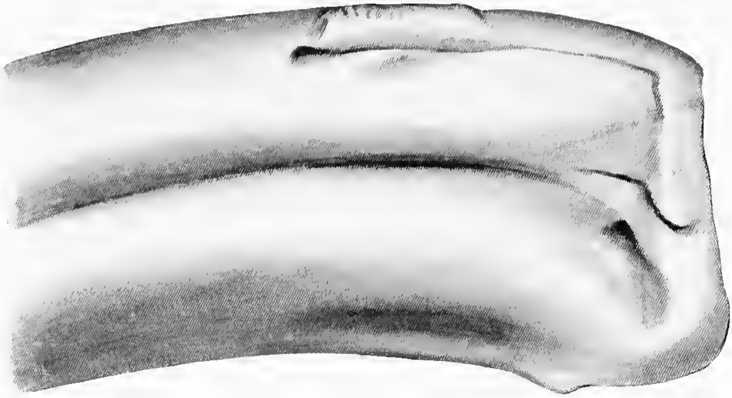


Parasaurolophus walkeri. Anterior part of mount. About 1/13 natural size.



Parasaurolophus walkeri. Left side of head with the distortion corrected. About 1/9 natural size.

A, surangular; B, predentary; D, dentary; E, exoccipital; F, frontal; I, quadrato-jugal; J, jugal; K, lateral temporal fossa; L, lachrymal (?); M, maxillary; N, nasal; O, orbit; P, prefrontal (?); PM, premaxillary; Q, quadrate; R, squamosal; S, postfrontal; V, parietal.



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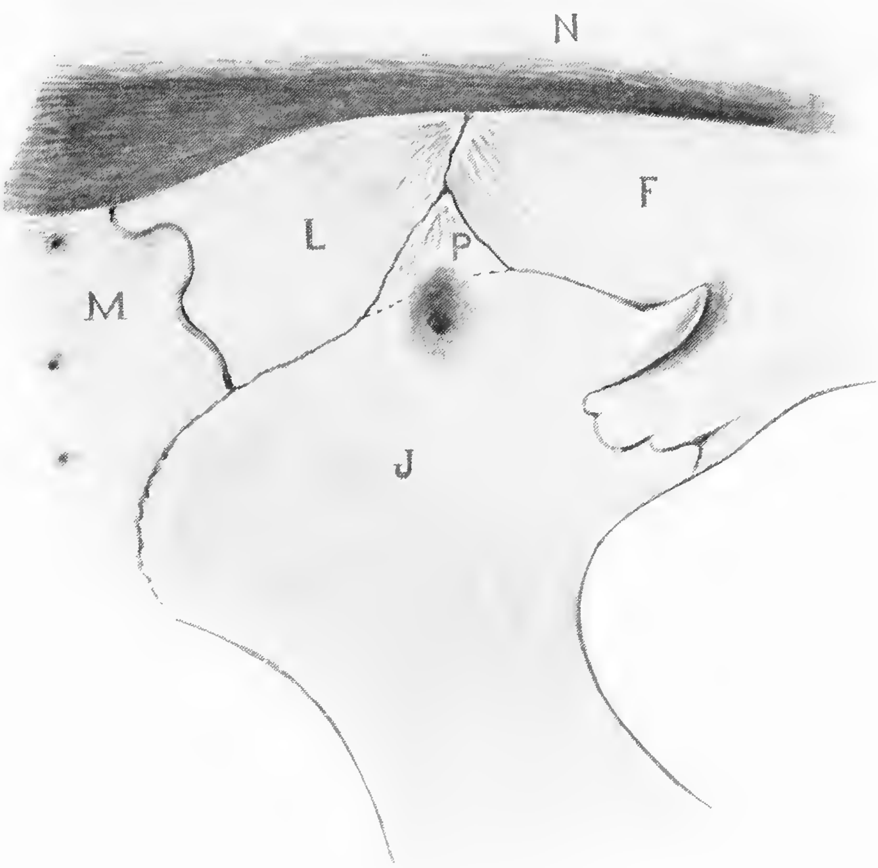


2

Parasaurolophus walkeri.

Figure 1. Detail of end of crest. About 9/20 natural size.

Figure 2. Detail of supra-preorbital region. About 2/3 natural size.

F, frontal; J, jugal; L, lachrymal (?); M, maxillary; N, nasal; P, prefrontal (?).

PLATE VI

Parasaurolophus walkeri. Sacral region. About 1/10 natural size.

Figure 1. Left lateral view.

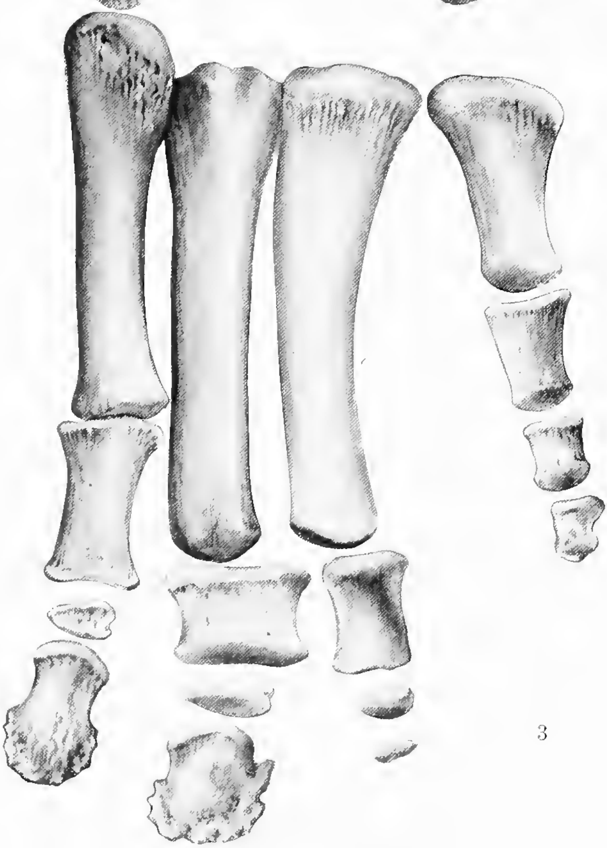
Figure 2. Dorsal view.

Figure 3. Ventral view.

Parasaurolophus walkeri. Eighth, ninth, and tenth cervical vertebrae. About 1/3 natural size.

1

2



3

Parasaurolophus walkeri.

Figure 1. Left radius and ulna, externo-posterior view. About 1/7 natural size.

Figure 2. Left radius and ulna, intero-anterior view. About 1/7 natural size.

Figure 3. Left manus, dissociated, anterior view. About 1/3 natural size.

PLATE IX

1

2

3

4

Parasaurolophus walkeri.

Figure 1. Right manus, anterior view. About 1/7 natural size.
Figure 2. Left manus, anterior view. About 1/7 natural size.
Figure 3. Left manus, posterior view. About 1/7 natural size.
Figure 4. Right manus, posterior view. About 1/7 natural size.

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