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Article XVI.—TYRANNOSAURUS, UPPER CRETACEOUS CARNIVOROUS DINOSAUR. (SECOND COMMUNICATION.)

By Henry Fairfield Osborn.

Plate XXXIX.

This great carnivorous Dinosaur of the Laramie was contemporary with and undoubtedly the chief enemy of the Ceratopsia and Iguanodontia. As described in a previous bulletin[1] this animal was first recognized as a new form from remains found in the true Laramie of Hell Creek, Dawson County, northern Montana. In the preliminary description another large carnivorous Dinosaur found in Wyoming was considered, on what appeared to be good and sufficient grounds, a distinct form and described as *Dynamosaurus*. The separation of these two forms now proves to have been an error.

Continued excavations in the summer of 1905 brought to light many additional parts of the type of *Tyrannosaurus*, and during the past winter the remains of the type of *Dynamosaurus* have been carefully worked up. The two animals are found to be generically if not specifically identical. Taken together, with a third individual discovered in Montana in 1905, they afford knowledge of a considerable part of the skull and of practically the entire skeleton excepting the bones of the fore arm and manus and the caudal vertebræ.

I am indebted to Mr. Barnum Brown of the American Museum staff for his very able and energetic field work and intelligent supervision of the Museum work, which overcoming all difficulties, have finally brought all the parts of this extraordinary animal together. Mr. Barnum Brown has also coöperated with me in all the details of description and measurement. Messrs. Paul Miller and Peter Kaison have faithfully assisted in the difficult work of preparation.

The type of *Tyrannosaurus* consists of superbly preserved bones in an excessively hard matrix, while the type of *Dynamosaurus* consists of extremely fragile bones in a soft and treacherous matrix.

Materials. — The materials now at hand include the following three individuals:

(1) Type of *Tyrannosaurus rex* (Amer. Mus. No. 973), including the jaws, portions of the skull, vertebræ, shoulder girdle, abdominal ribs, pelvis, and hind limbs. (2) Type of *Dynamosaurus imperiosus* (Amer. Mus. No. 5866), cervical vertebræ, certain dorsal vertebræ,

[1] Henry Fairfield Osborn. Tyrannosaurus and other Cretaceous Carnivorous Dinosaurs. Bull. Amer. Mus. Nat Hist., Vol. XXI, 1905, pp. 259–265, Oct, 4, 1905.

ribs, dermal plates, and portions of pelvis and limbs. Mingled with these remains were found part of the frill of a specimen of *Triceratops* and part of a jaw of an Iguanodont; it is believed. however, that the dermal plates are part of the type individual, (3) Portions of right and left hind limbs (Amer. Mus. No. 5881); a slightly smaller individual than the type of *T. rex*, presenting some additional characters.

The following table shows the parts preserved in each specimen:

Parts Preserved	Type of *Tyrannosaurus rex*, No. 973	Type of *Dynamosaurus imperiosus*, No. 5866	Limbs No. 5881
Maxillary	L.		
Prefrontal	R. and L.		
Palatine		R. and L.	
Squamosal	L.		
Transverse	L.		
Dentary	R. and L.	R. and L.	
Surangular	L.		
Scapula	R.		
Humerus	L.		
Femur	L. and frag. R.	Frag. L.	L.
Tibia	R. and L.		R. and L.
Metatarsal I			L
" II	R.		R. and L.
" III	R.		
" IV	L.		R.
Ilium	R. and L.	frag. R.	
Ischium	R.	L.	
Pubis	R. and L.		
Sacrum	Complete	2 vert. and spine	
Atlas, C1		× hypocentrum	
Axis, C2		× "	
3, cervical		×	
4 "		×	
5 "		×	
6 "		×	
7 "		×	
8 "		×	
9 "	×	×	
10 Cervico-dorsal		×	
11 " "		×	
12 Dorsal	×	×	
13 "		Spine	
14 "		Spine	
15 "		Centrum	
16 "			
17 "			
18 "	×		
19 "	×		
20 "	×		
21 "	×		
22 "	×		
23 "	Centrum		
1 Sacral	×		
2 "	×		
3 "	×		
4 "	×		
5 "	×		

Summary of Characters.

The most surprising discovery is that of the existence of a complete series of abdominal ribs as represented in both skeletons and now determined to exist also in the Upper Jurassic or Lower Cretaceous *Allosaurus*.[1] Some of the characters indicate that this animal was a development on a very much larger scale of the *Allosaurus* type; others indicate that it belonged to a separate family of the Theropoda which if it shall prove to be distinct may be called **Tyrannosauridæ** Detailed comparison of these animals will be made subsequently by the writer. A summary of the principal characters is as follows:

1. Skull abbreviated, with two large antorbital openings, and a third smaller opening between the maxillaries and premaxillaries. Squamosal sending off a horizontal anterior bar.

2. Teeth, thirteen in the maxillaries and twelve to thirteen in the dentaries. A pair of reduced anterior cutting teeth in the dentaries, Teeth very broadly oval in section, transverse exceeding antero-posterior diameters, with serrate edges.

3. Dental alveoli in the maxillaries and dentaries expanded into triangular supporting plates on the inner side of the jaws.

4. Actual number of presacral vertebræ unknown, probably twenty-three; cervicals probably nine with broad neural spines; sacrals five, with coalesced spines forming a continuous plate.

5. Atlas and axis complex, apparently consisting of six separate elements, namely: *atlas* hypocentrum, two neurapophyses, and pleurocentrum (odontoid); *axis* hypocentrum and centrum.

6. Shoulder girdle with greatly reduced scapula and humerus.

7. Complete system of median and paired abdominal ribs resembling those of *Hatteria*.

8. Pelvic girdle consisting of elongate, compressed ilium, with elongate horizontal plate extending from anterior portion; pubes firmly coalesced in median portion, also at distal peduncle; ischia reduced in contact distally.

9. All known limb bones and longer girdle bones hollow.

10. Hind limbs greatly elongated, with large hollow cavities, femur longer than tibia. Three chief metatarsals partly coalesced, and reduced hallux.

It is impossible to separate the animals specifically at present; they may, therefore, be described together, referring to the numbers to distinguish the individuals on which the description is based.

[1] There is some reason to believe that in the Sauropoda also bones interpreted as belonging to the shoulder girdle may represent abdominal ribs.

Genus **Tyrannosaurus** *Osborn.*

Syn. *Dynamosaurus* OSBORN.

Tyrannosaurus rex *Osborn.*

The complete skeleton of this animal is restored on Pl. XXXIX. The height of the head in the standing position was 5.35 m. The skull was of relatively large size, of extremely robust structure. The neck was abbreviated but flexible, the cervical ribs being relatively short. In the standing position the body was balanced by the tail, only a few parts of which are known. There is little indication of much free movement between the dorsal vertebræ, the centra being of the amphiplatyan type, flat or feebly amphicœlian. The sacrals are firmly coalesced with each other and with the ilium as the centre of motion. The pubes are of extraordinary size, terminating inferiorly in an enormous peduncle. The hind limbs are provided with extremely muscular attachments, but they contain large hollow cavities and are relatively light. The feet, judging by the metatarsals and single phalanx preserved, were of huge size and provided with powerful claws.

1. THE SKULL.

The parts of the skull preserved are put in place (Fig. 1) by comparison with the skull of *Allosaurus* (Fig. 2). Our knowledge will fortunately be supplemented from a skull in the Carnegie Museum, which is perfectly preserved in the occipital region, and which, with other parts, will soon be described by Dr. W. J. Holland. In general the skull resembles that of *Allosaurus*, with greater massiveness and marked abbreviation, less elongate and of greater depth.

Maxillary. — The maxillaries are triangular in outline, enclosing the second antorbital foramen (2) and bounding chiefly the antorbital (1) foramen as well as the maxillo-premaxillary (3) foramen. The surface is convex, roughened, and pitted with numerous open canals and foramina, which are arranged in rows parallel with the dental series. Anteriorly and superiorly the lines of union with the premaxillaries, nasals, and prefrontals are distinguishable. On the inner side the dental alveoli extend downward into triangular plates which do not touch each other but are continuous with the walls separating the teeth and evidently functioned in their reinforcement. The maximum length of the maxillary is 690 mm.; its greatest depth, 410 mm.

Twelve teeth constitute the maxillary series. There was certainly one and possibly two small teeth in the premaxillary making thirteen to fourteen altogether. The maxillary teeth are ovate in

cross section. Nos. 1 and 2 of the maxillary series are of smaller size; Nos. 4, 5, and 6 are the largest of the series; the remainder diminish rapidly to No. 12, which was greatly reduced, judging from its small alveolus.

Prefrontal. — This massive ¬-shaped bone is formed by the union of two bars surmounted by the supraorbital protuberances as in *Allosaurus*. On the inner surface of the descending bar is a thin transverse plate separating the orbit from the antorbital fenestra.

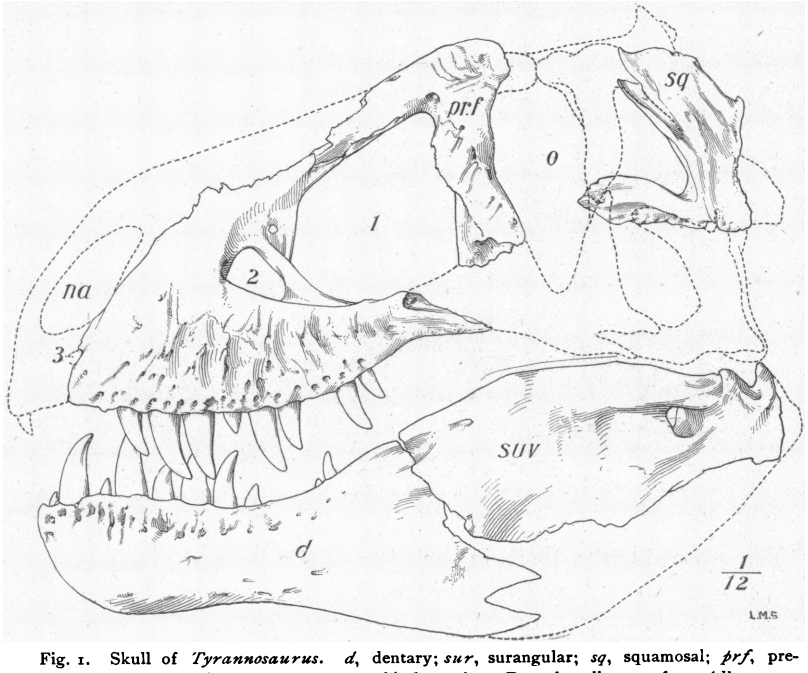


Fig. 1. Skull of *Tyrannosaurus*. *d*, dentary; *sur*, surangular; *sq*, squamosal; *prf*, prefrontal; *o*, orbit; *na*, anterior nares; 1, 2, 3, antorbital openings. Dotted outlines are from *Allosaurus*.

The length of the antero-posterior bar is 340 mm., of the vertical bar 350 mm.

Palatine. — A pair of thin flat plates (Amer. Mus. No. 5866) probably represent these elements, the main body of the plate extending forward and ending in an obtuse point which articulated with the maxillary, while a smaller process projected backward to unite with the pterygoids. The measurements are: length 355, width 225 mm.

Squamosal. — The squamosal exhibits a decided contrast with that of *Allosaurus* in the presence of the horizontal bar (possibly homologous with the depressed bar in *Allosaurus*) which appears to project forward

into the latero-temporal fenestra; below this bar is a rough border for union with the quadrato-jugal; its proximal end is deeply incised, apparently for the stapedial canal. A somewhat similar bar in *Allosaurus* extends downward and forward. The superior groove for the reception of the projecting process of the postorbito-frontal, the roughened area for the attachment of the paroccipital, the postero-inferior attachment of the paroccipital, and the inferior articular area for the quadrate, can be made out clearly.

Dentary. — The dentaries of both rami with nearly all the teeth finely preserved are shown in both specimens; the exterior surface is pitted by vascular foramina. The symphysial union was ligamentous. The dentary deepens decidedly below its junction with the surangular.

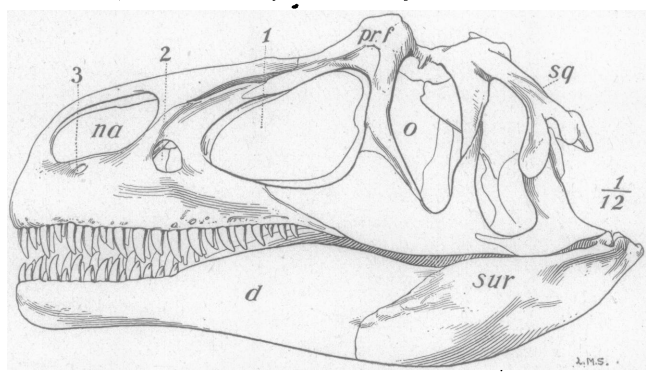


Fig. 2. Skull of *Allosaurus* in the American Museum of Natural History. To same scale as the skull of *Tyrannosaurus*.

There are thirteen teeth in each jaw of the type of *Tyrannosaurus*, and thirteen on one and fourteen on the other side in the jaws of Amer. Mus. No. 5866 (type of *Dynamosaurus*). The teeth are large, with the transverse exceeding the antero-posterior diameter, and points recurved. The anterior tooth, as in the four anterior teeth of *Allosaurus* and some of the anterior teeth of *Deinodon*, has a subtriangular form and is of greatly inferior size; the edges divide the tooth unequally into an anterior convex face representing two-thirds of its surface, and a posterior concave face. The second to fifth teeth are the largest of the series. The sixth to the thirteenth decrease gradually, so that the thirteenth could scarcely have been functional. As in *Allosaurus* the serrate edges do not equally divide any of the crowns, and change according to the position of the teeth; the anterior serrated edge gradually shifts forwards from the inner side to the anterior border of the tooth. In *Allosaurus* the teeth are more com-

pressed transversely, as is the case also in the Judith River *Deinodon.*

As in the maxillaries the inner border of the alveoli is strengthened by triangular dentary plates; at their base is a deep canal parallel to the alveoli. The dental foramen opens beneath the eighth tooth. In front of this, extending nearly the entire length of the dentary is an open shallow canal. Measurements: extreme length of dentary, 850; depth at middle section, 155; largest tooth, 125 mm.

Surangular. — The surangular is a broad plate, with an arched dorsal coronoid border overhanging the concave inner surface. Contracting posteriorly a heavy inner process expands to form the anterior buttress of the articular; just in front of this is the large

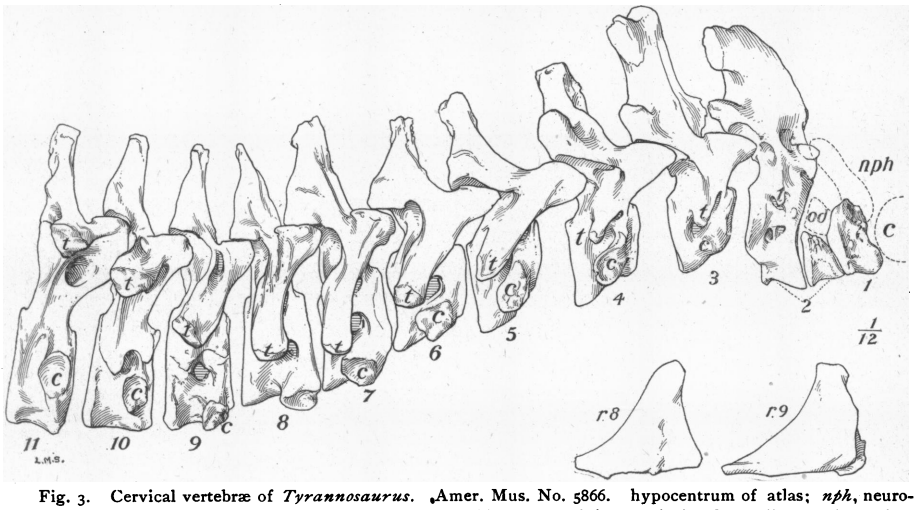


Fig. 3. Cervical vertebræ of *Tyrannosaurus.* Amer. Mus. No. 5866. hypocentrum of atlas; *nph*, neurophysis; *2* supposed axis with its hypocentrum; *od*, odontoid; *3*, *9* remaining cervicals; *r8*, *r9*, ribs found attached to ribs, *8–9*, *10–11*, cervico-dorsals; *c*, capitular facet; *t*, tubercular facets.

foramen homologous with that in *Allosaurus* and *Hatteria.* The measurements are: length 610, extreme depth 260.

2. The Vertebral Column.

The vertebral formula cannot be given precisely. It is estimated in the restoration (Plate XXXIX) that there were twenty-three presacrals, as in *Allosaurus.* The characters of most of the vertebræ can be precisely ascertained from the types of *Tyrannosaurus* and *Dynamosaurus.*

Cervicals. — The cervicals in No. 5866 were found partly articulated and in position (Fig. 3).

Some uncertainty exists as regards the atlas-axis complex,

because the vertebra interpreted as the *axis* (Fig. 2), which in *Allosaurus* lacks the odontoid process and is firmly coalesced with the axis, fails to show evidence of the sutural union between the lower portion of the centrum and the supposed hypocentrum.

The vertebra interpreted as the axis is extremely abbreviate as compared with that of *Allosaurus;* possibly because of partial crushing; it bore a slender two-headed rib, which is preserved.

The *atlas* is positively determined with its very shallow concavity for the cranial condyle (*c*), with attachment areas for the neural arches (*n p h*), with a definite articulation posteriorly for the hypocentrum of the axis (*h y*), and with a postero-superior concave surface for articulation of the odontoid.

Cervicals 3–9. — Of the cervical series Nos. 2 and 3 were in position, No. 4 was found in a separate block, Nos. 5–11 with the neural spines of Nos. 12, 13, were found articulated. The hypocentrum of the axis exhibits a plane anterior face with a roughened posterior face for close union with the centrum in the third vertebra. These cervicals are distinguished by: (1) broad depressed neural spines (Fig. 4), (2) gently opisthocœlous centra, (3) relatively short ribs which change from slender bars in C1–C3 into somewhat broadened triangular plates as preserved in C8 and C9, (4) the centra broad and short, deeply excavated laterally. The posterior faces are distinctly but gently concave, while the natural convexity of the anterior faces appears to have been altered by crushing.

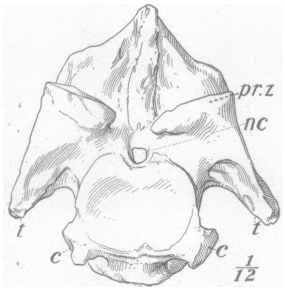


Fig. 4. Anterior view of mid-cervical vertebra, Amer. Mus. No. 5866.

In *Allosaurus* the cervicals are relatively elongate, more deeply opisthocœlous, with relatively narrow, erect neural spines, and more elongate ribs.

Cervico-dorsals, Nos. 10–11. — In these transitional vertebræ, which in *Allosaurus* have the same relations as in *Hatteria*, the space between the capitulum and tuberculum rapidly widens and it is provisionally inferred (Pl. XXXIX) that the ribs were more of the dorsal type, as in *Allosaurus*, but were not connected by cartilaginous ribs with the sternum. The faces of the centra are more plane, passing into the amphiplatyan type of the dorsals. The neural spines are narrower and more elevated.

Dorsals Nos. 12–23.—We proceed on the supposition that there

were eleven dorsals, the most anterior of which supported the sternum (see Plate XXXIX). Portions of several are preserved in the two specimens, as indicated by shading in the restoration (Pl. XXXIX). These vertebræ are characterized by high, stout spines, with rugose areas for ligamentous attachment, rather abbreviate centra excavated laterally by deep pits which almost completely traverse the centrum from the opposite sides. The zygopophyses are gradually approximated until in the posterior dorsals they form the characteristic wedge-shaped union, but apparently without hyposphen. The articular surfaces of the centra are partly amphiplatyan, with a characteristic slight anterior concavity in the upper

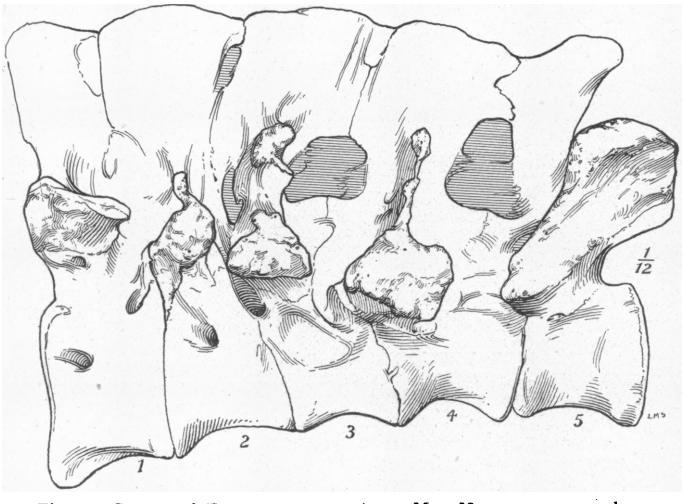


Fig 5. Sacrum of *Tyrannosaurus*. Amer. Mus. No. 973. *1–5*, sacrals 1–5.

portion of the face below the neural canal, similar to the same surfaces in *Allosaurus*.

Sacrals.—The sacrum is completely preserved in the type of *Tyrannosaurus*, consisting of five vertebræ with closely coalesced neural spines forming a continuous plate with three fenestrations between S2 and S5. The centrum of S1 was less firmly united than the others and was found entirely detached in the matrix, whereas the centra of S2 and S3 were most firmly coalesced and appear to correspond with the primary sacrum. The centrum of S4 is also firmly united. Viewed from the front sacrals 2 and 3 are wedge-shaped, narrowing inferiorly, while S1 is vertically extended, and S5 is more vertically oval. S1 exhibits a broad rugose attachment area facing

downward for articulation with the horizontal transverse plate of the ilium, whereas S2–5 exhibit rugose areas facing outward, that of S5 being greatly expanded.

Table of Measurements.

Vertebral Measurements of No. 5866.

	Height of vertebra including spine mm.	Transverse width of centrum mm.	Antero-posterior length of centrum mm.
Atlas H. C.		130	65
Axis	445	145	100 without hypocentr.
3	435	140	100
4	375	155	120
5	390	165	115
6	390	165	120
7	435	175	110
8	430	180	125
9	460	175	100
10	490	165	110
11	500	180	100

Vertebral Measurements of No. 973, Type.

18	580	225	130
19	600	240	145
2			
23		270	170

Sacrum of No. 973, Type.

	mm.
Length of centra antero-posteriorly	940
Length of spines antero-posteriorly	1000
Height of spines and centrum, anterior	740
Height of spines and centrum, posterior	630
Transverse width of anterior centrum	270
Transverse width of posterior centrum	235

3. Shoulder Girdle and Humerus.

With the type specimen (No. 973) are preserved the left humerus and right scapula, which indicate that the shoulder girdle and fore limb were even more reduced than in *Allosaurus*.

Scapula.—The scapula has the same general contour as that of *Allosaurus* but exhibits a more expanded inferior plate for attachment with the coracoid; as shown in Fig. 6, it is actually larger, but compared with the size of *Tyrannosaurus* as a whole it is relatively smaller than in *Allosaurus*. The measurements are: length of scapula 950, length of coracoid attachment 320 mm.

Humerus.—The humerus is so small that grave doubts were entertained as to its association with this animal. These were finally set aside for three reasons: (1) the humerus is hollow, proving that

it belonged to one of the Theropoda; (2) the head of the humerus fits into the glenoid cavity of the scapula; (3) while absurdly reduced as compared with the femur (Fig. 8) it nevertheless is provided with very stout muscular attachments, a powerful deltoid ridge, which proves that it served some function, possibly that of a grasping organ in copulation.

4. Pelvic Girdle and Hind Limb.

Ilium. — The ilium has the same elongate form as in *Allosaurus* with a similar general contour, but with still more compact union

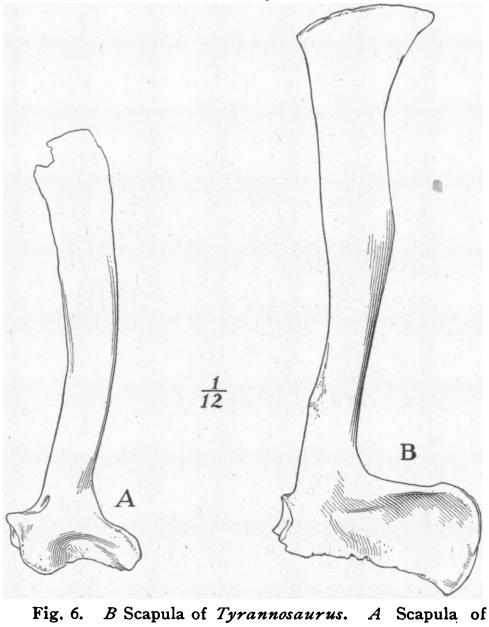


Fig. 6. *B* Scapula of *Tyrannosaurus*. *A* Scapula of *Allosaurus*.

with the sacrum. An important distinction is the broad plate which extends forward on the inner side of the ilium from the level of the pubic peduncle, especially for attachment with the first sacral vertebra; this is absent in *Allosaurus*. A wide plate extends backward and inward above the ischiadic peduncle for attachment with the processes of S_{4-5}; this is present in *Allosaurus*. The measurements are as follows:

	mm.
Extreme length	1515
Height above middle of acetabulum	530
Height above pubic peduncle	770
Width of acetabulum	590

Ischium.—As noted above, the ischium is in progress of reduction inferiorly. Below the junction with the ischiadic peduncle of the ilium (Fig 7) and with the posterior peduncle of the pubis it sends forwards a hook-like process and backwards a process, and then contracts into a long, round, diminishing bar, which united with the opposite ischium for the last 320 millimeters of its length but was not

Fig. 7. Pelvis of *Tyrannosaurus*. Amer. Mus. No. 73.

coössified. The extreme distal end is missing but there is no evidence of an expanded foot. The measurements are:

	mm
Length	1110
Across peduncles	360
Length of acetabulum boundary	160

Pubes. — The pubes are preserved complete in the type of *Tyrannosaurus*. They are massive bones with the proximal iliac articulations set closer together than in *Allosaurus*. They are separated below the junction with the ilium by an elliptical opening equal to one-third of their length; they are then united for a short distance; the middle sections again separate; the distal third is again firmly united and expands anteriorly and posteriorly into the broad foot (Fig. 7)

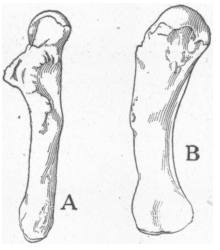


Fig. 8. Humerus of *Tyrannosaurus*. Amer. Mus. No. 972. To same scale as femur (Fig. 9). *a*, external view; *b*, posterior view.

Femur. — The femur is relatively larger than that of *Allosaurus* but resembles it somewhat closely in form and in the areas of muscular attachment. The greater trochanter has relatively a greater

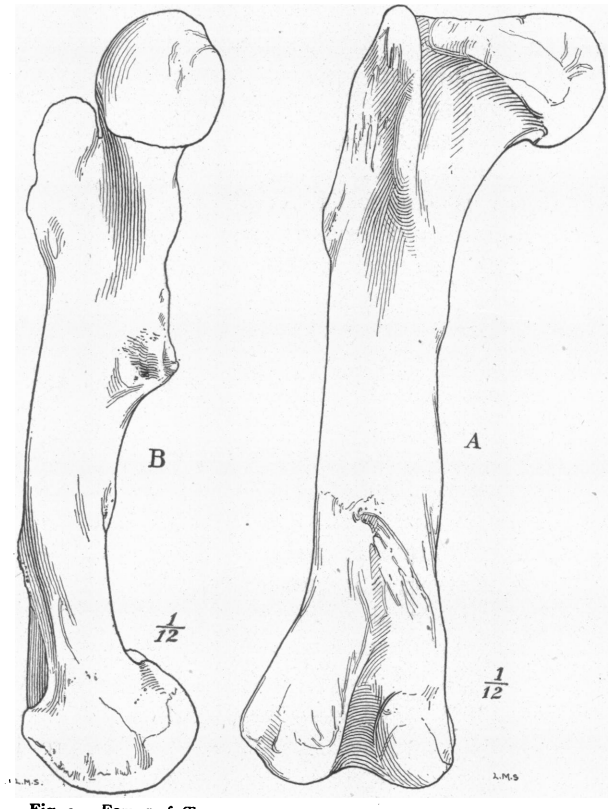


Fig. 9. Femur of *Tyrannosaurus*. Amer. Mus. No. 973. *a*, posterior view; *b*, internal view.

development. The articular head of the femur is clearly defined;

a very characteristic feature is that when placed in the acetabulum the planes of the articular head are set at an angle of 45° to the axis of the vertebral column, proving that the femora at the distal extremities were approximated, bringing the hind feet close together at the ground.

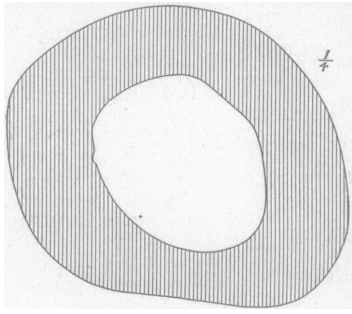


Fig. 10. Section of femur of *Tyrannosaurus*. Amer. Mus. No. 973.

The petrified bone is remarkably light for its size, weighing only 180 lbs. when cleaned of all matrix; seventeen inches of the middle portion of the shaft is hollow, containing a cavity (Fig. 10) four inches in diameter. The total length is 1300 mm.; the mid-diameter of the shaft is 180; the diameter of the head, 200, the greatest transverse width of the condyles, 340 mm.

Tibia. — The tibia is relatively larger than that of *Allosaurus* but with similar contours and similar attachments; twenty-five inches of the shaft is hollow, with a cavity two to three inches in diameter. The total length is 1140 mm. or 160 mm. less than that of the femur.

Pes. — The pes is composed of three very elongate and massive metatarsals exhibiting a more powerful and less mobile arrangement of the metatarsals, because they show sutural attachments but not actual coalescence in the middle portion of the shaft, as represented in Fig. 11. Mts. III was considerably the longest and largest of the series and firmly buttressed between II and IV; the distal ends of Mts. II and IV turn outward. Mts. I was evidently composed of proximal and distal osseous segments as in *Allosaurus;* of these only the distal segment is preserved, indicating a retroverted, bird-like position of the claw. The chief measurements are as follows:

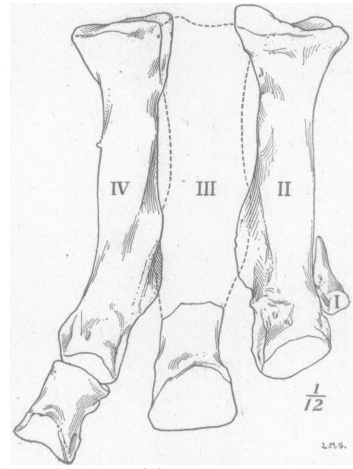


Fig. 11. Right pes of *Tyrannosaurus*. Amer. Mus. No. 973.

	mm.
Mts. II, length	615
" IV "	600
" III width of distal end	140

5. The Thorax.

Ribs. — A considerable number of thoracic ribs are preserved with No. 5866, but they have not as yet been fully worked out. The general form is represented in Pl. XXXIX. The probabilities are that the ribs extended back beneath the anterior crest of the ilium as in *Allosaurus* and in the Sauropoda.

Abdominal ribs. — One of the most surprising characters discovered in this fossil is the presence of an abdominal series of ribs, consist-

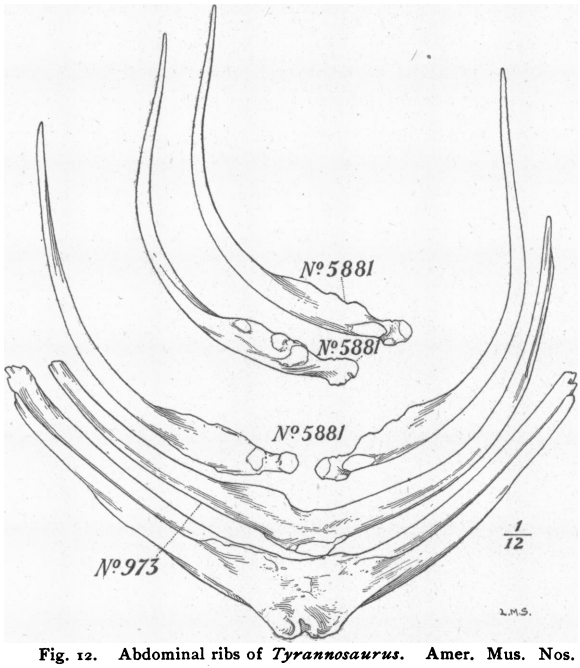


Fig. 12. Abdominal ribs of *Tyrannosaurus*. Amer. Mus. Nos. 973 and 5881.

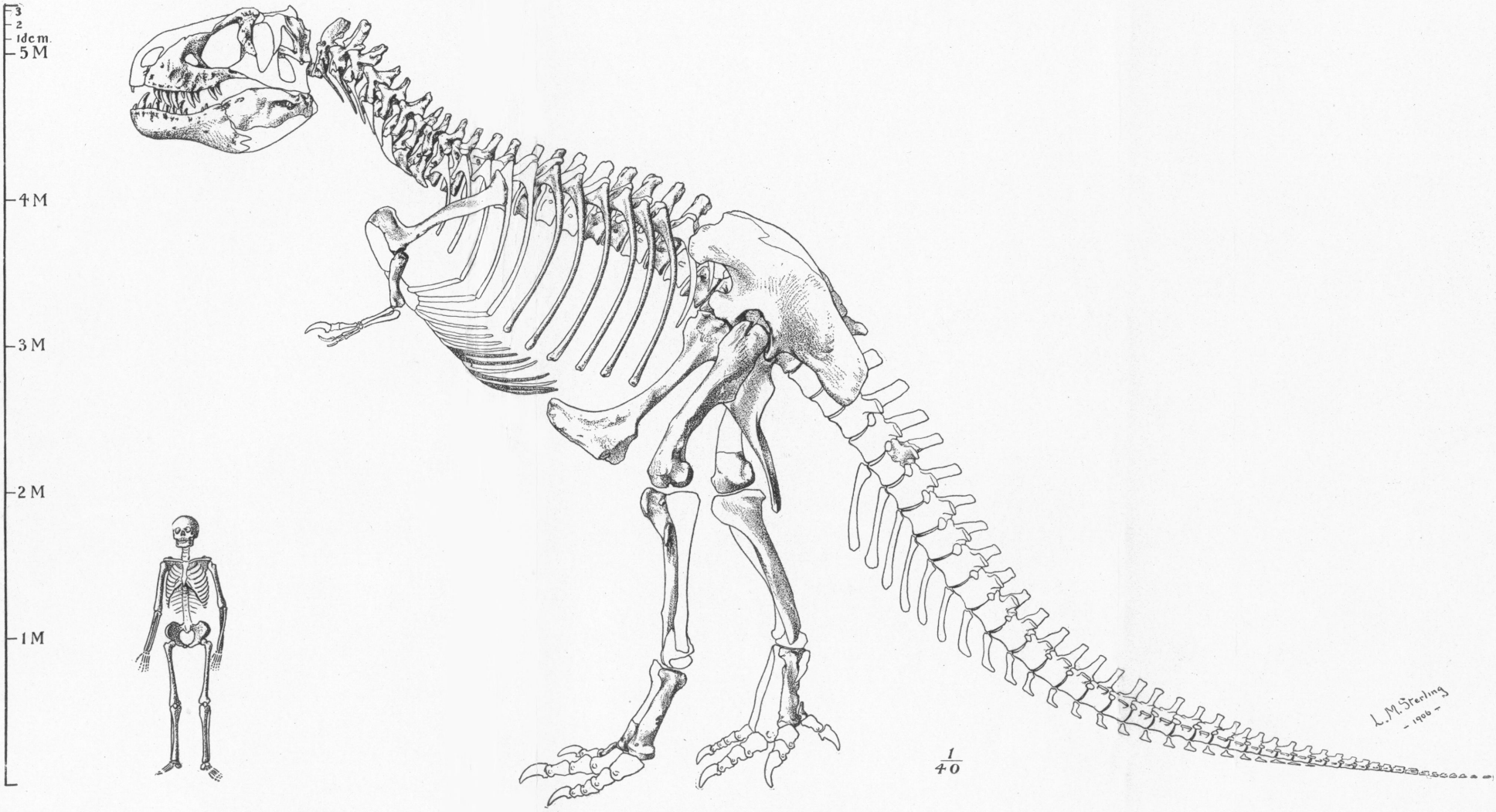
ing of double-pointed central ribs and single-pointed short lateral ribs, as in *Sphenodon*. As shown in Fig. 12 the ribs are asymmetrical and sometimes double. They mostly exhibit a double anterior and posterior rough surface attachment to the preceding and succeeding ribs. The median arched part of the rib extended forward and the free ends pointed backward.

6. The Dermal Armor.

Many dermal plates were found with the individual No. 5866

originally described as *Dynamosaurus;* they were used in defining *Dynamosaurus*. Some doubt as to their association with this carnivorous Dinosaur is caused by the presence of a fragment of a frill of *Triceratops* and a portion of the jaw of an Iguanodont. These plates were, however, found with ribs that can certainly be assigned to the carnivorous Dinosaur, because they exhibit no resemblances to the ribs of the Sauropoda or Iguanodontia. The plates are irregular in form and size, ranging from half an inch to six inches in length, the small ones rounded and the larger ones flattened with sometimes a raised central ridge curved to form part of the dermal line or crest. The largest plates are about half an inch thick.

Despite the evidence cited above it is difficult to imagine why this carnivorous Dinosaur should be protected by any form of dermal armature, unless possibly against attacks by members of its own family.



RESTORATION OF TYRANNOSAURUS REX.
From the type skeleton, Amer. Mus. No. 973. Many of the vertebræ belong to No. 5866.