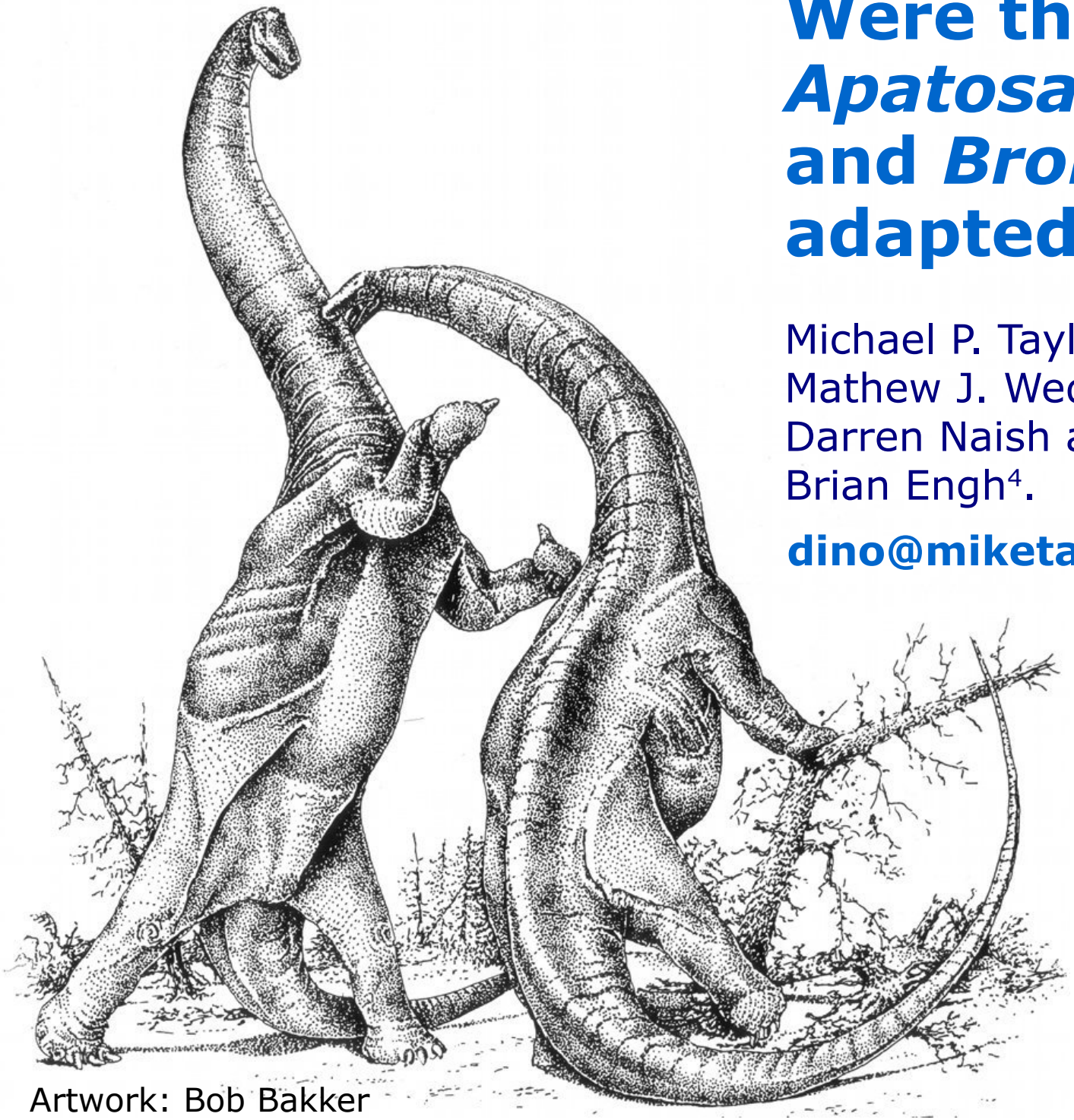
Were the necks of *Apatosaurus* and *Brontosaurus* adapted for combat?

Michael P. Taylor[1*],
Mathew J. Wedel[2],
Darren Naish and[3]
Brian Engh[4].

dino@miketaylor.org.uk



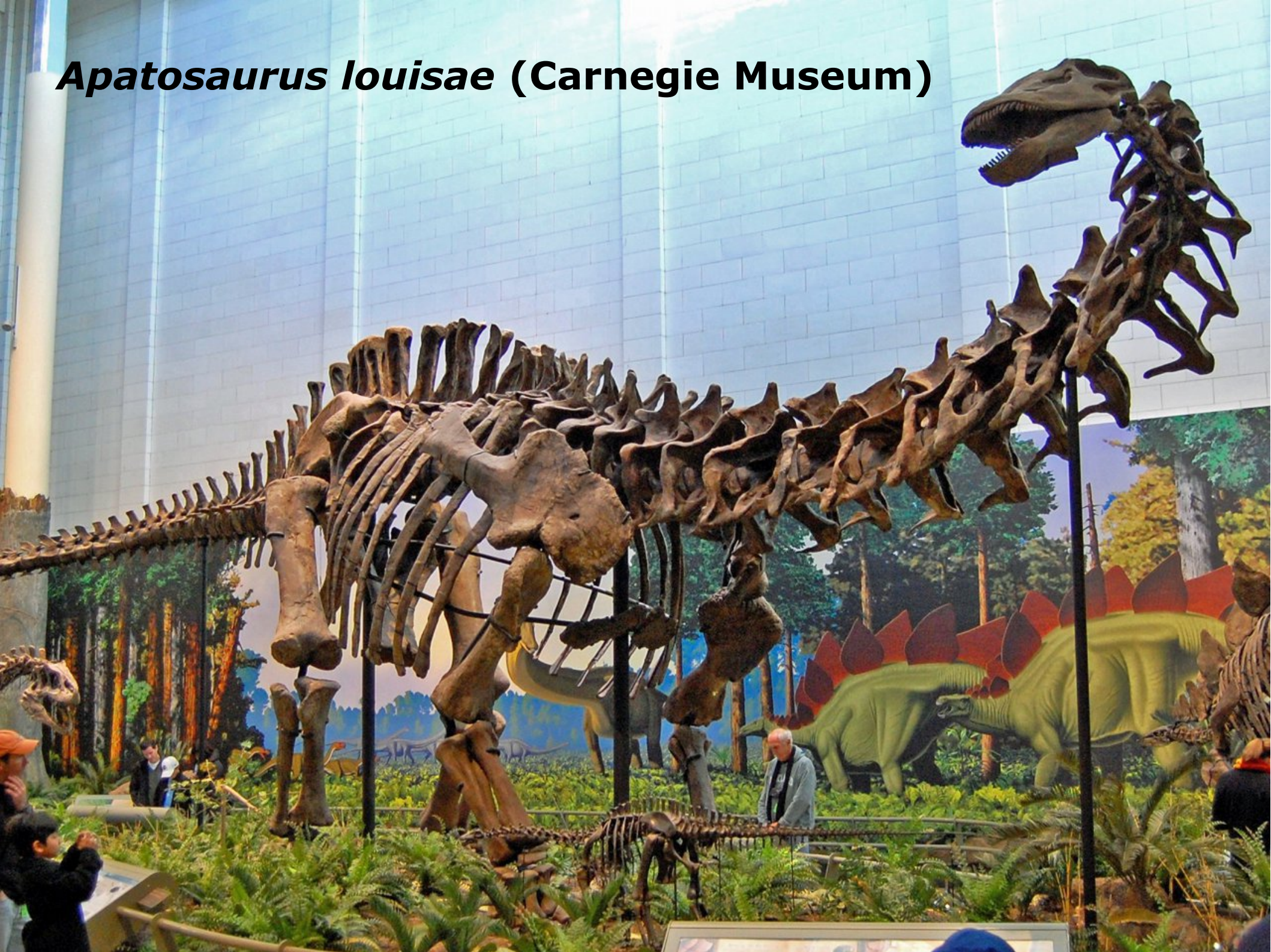
Artwork: Bob Bakker

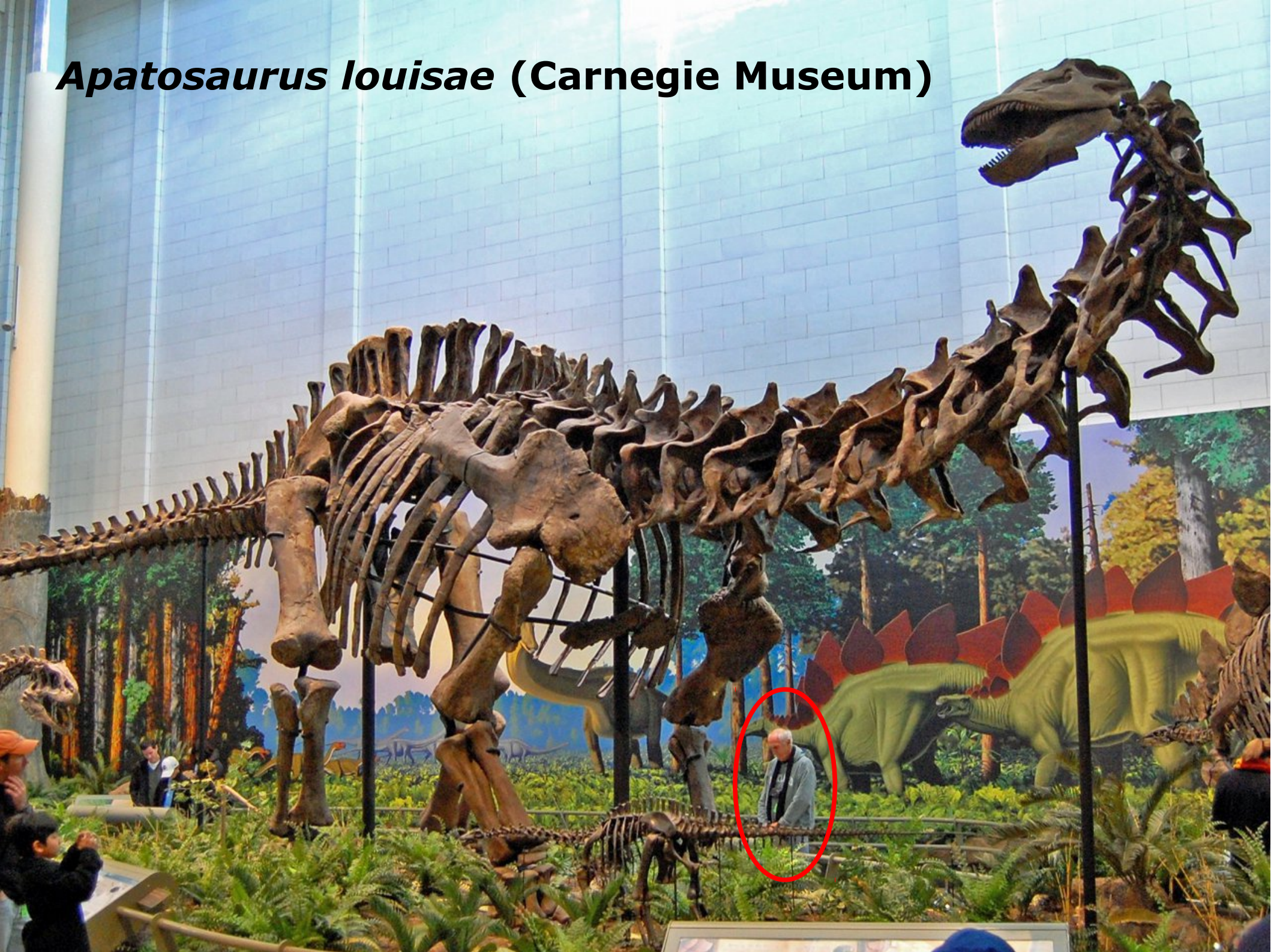
[1]Department of Earth Sciences, University of Bristol, UK.

[2]College of Osteopathic Medicine of the Pacific and College of Podiatric Medicine, Western University of Health Sciences, Pomona, California, USA.

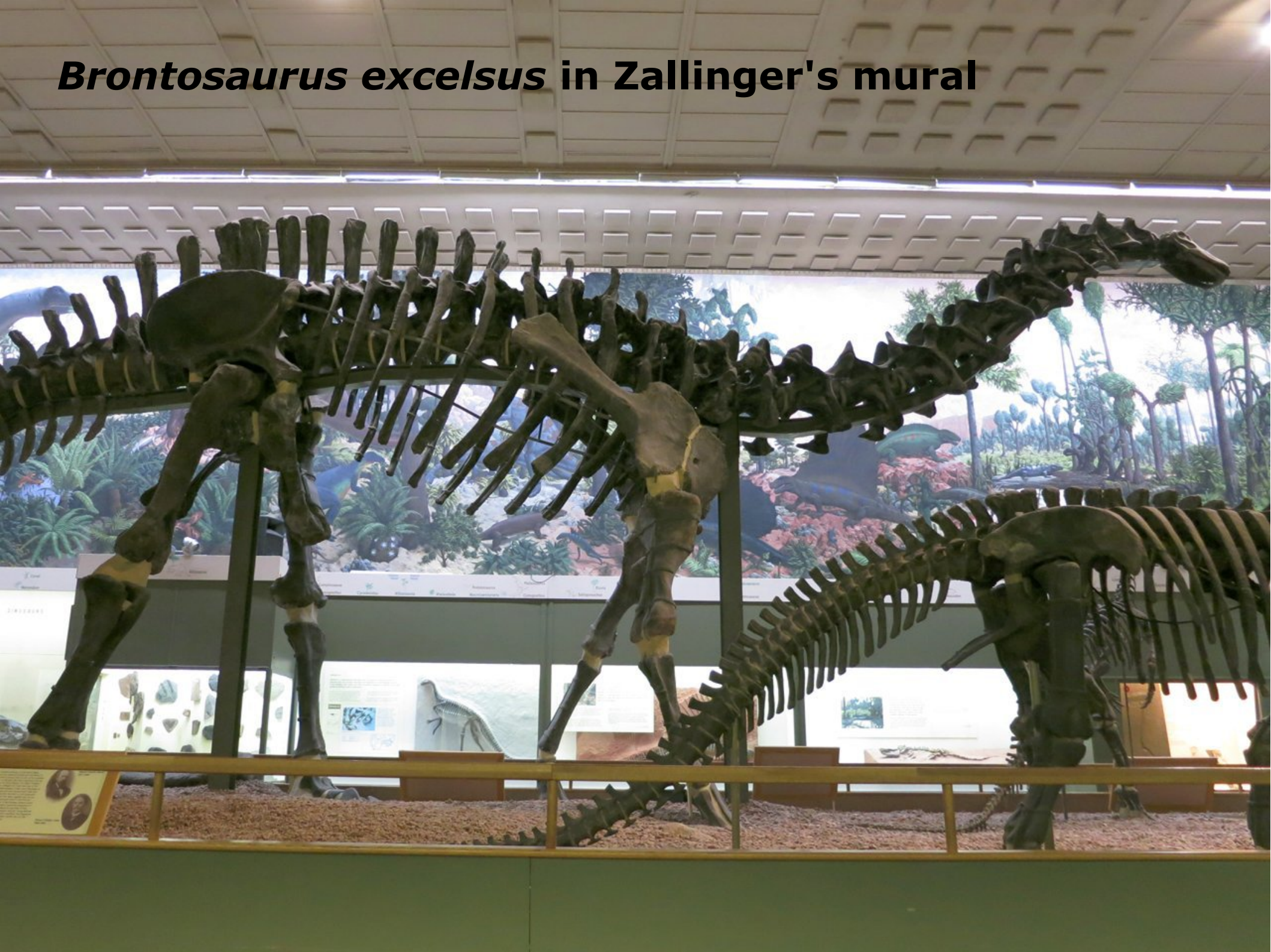
[3]National Oceanography Centre, Southampton, University of Southampton, UK.

[4]1522 Charles Avenue, Arcata, California 95521, USA.

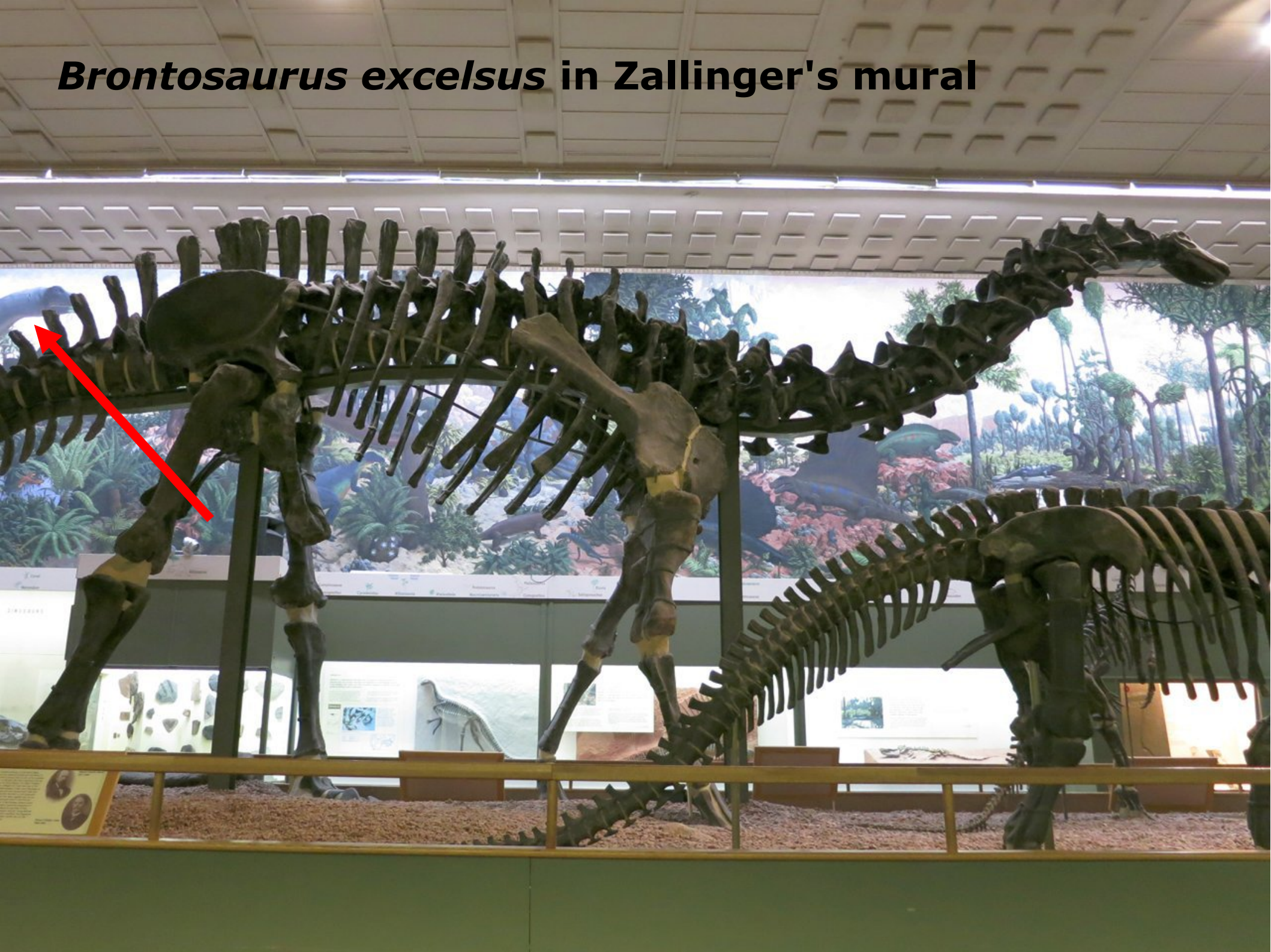

Apatosaurus louisae (Carnegie Museum)


Apatosaurus louisae (Carnegie Museum)

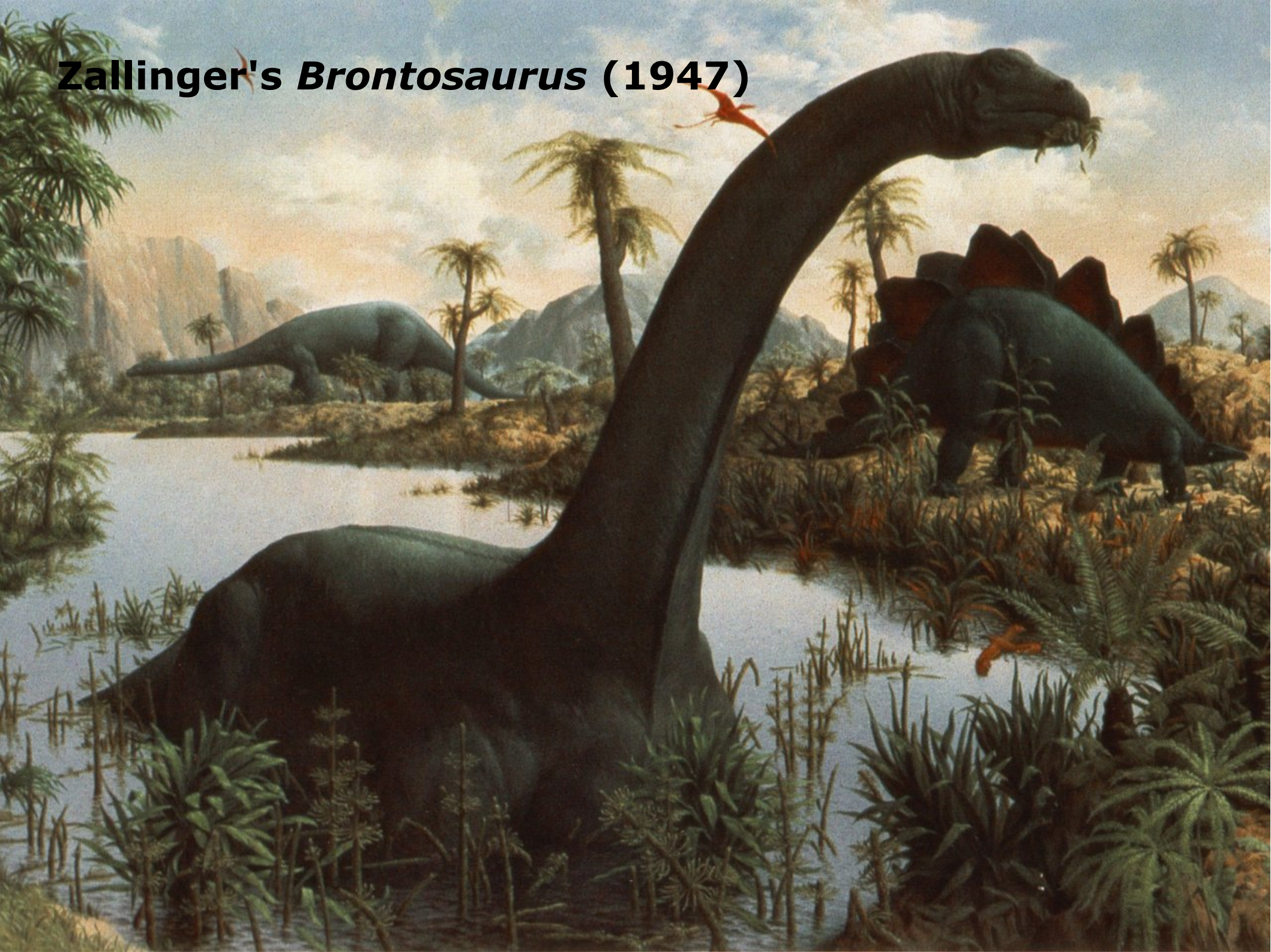
Brontosaurus excelsus in Zallinger's mural



Brontosaurus excelsus in Zallinger's mural



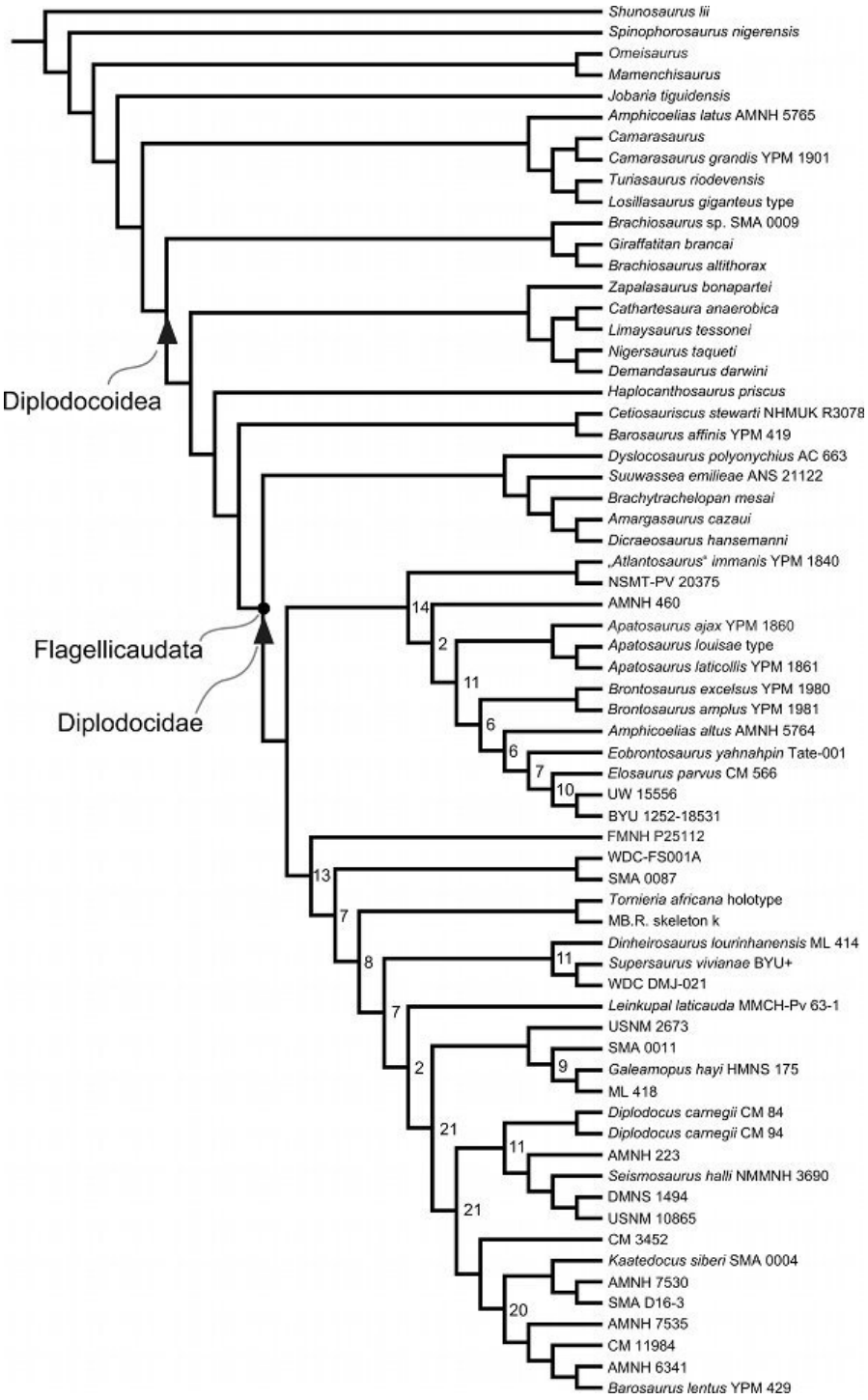
Brontosaurus excelsus in Zallinger's mural


Zallinger's *Brontosaurus* (1947)


Knight's *Brontosaurus* (1897)

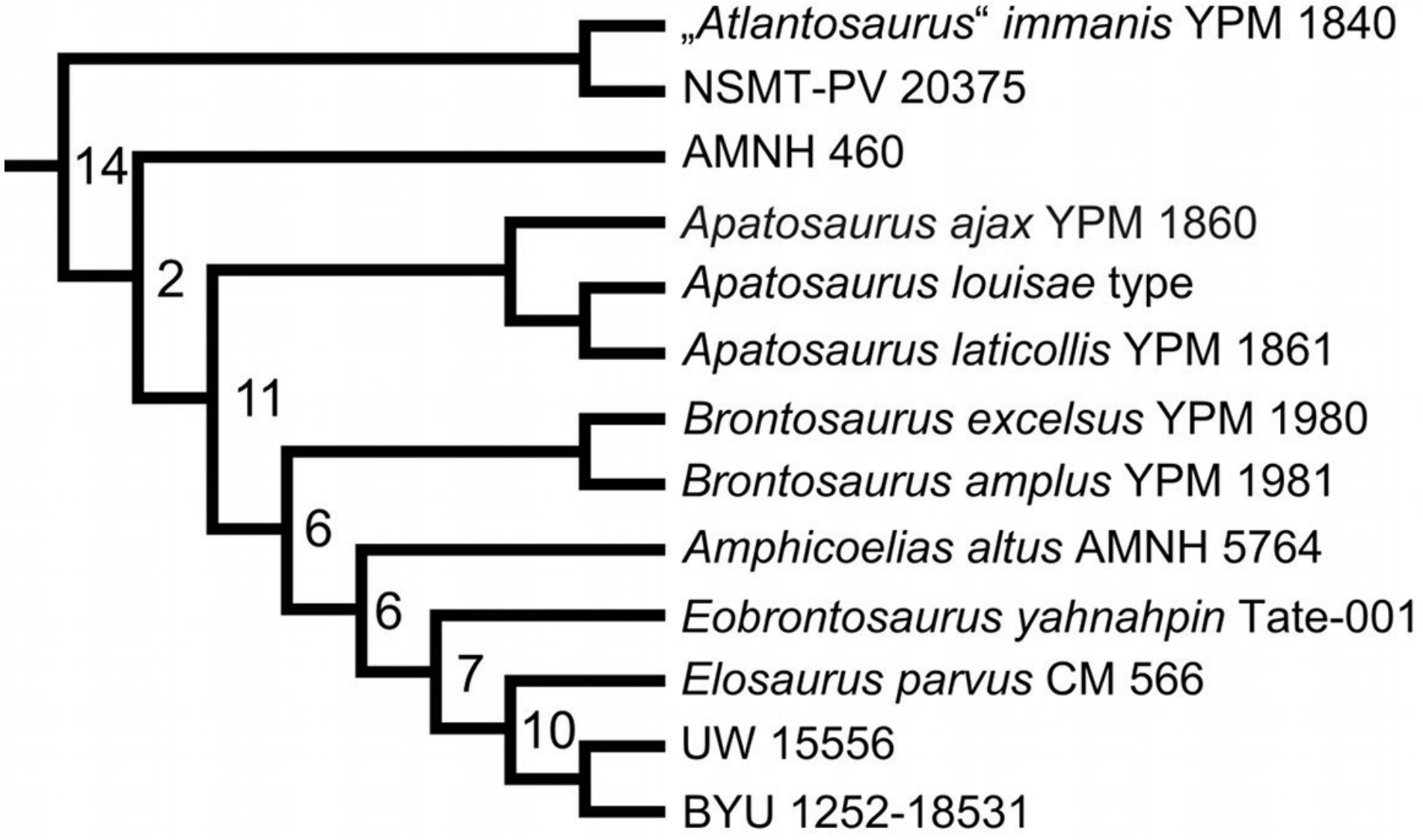
What exactly is an apatosaurine?

Tschopp et al. (2015), Figure 115. Reduced consensus tree obtained by equal weighting. Fifteen OTUs were deleted a posteriori. Numbers at the nodes indicate the number of changes between the two branches departing from the node (for the apomorphy count).



What exactly is an apatosaurine?

Tschopp et al. (2015), Figure 115.
Reduced consensus, apatosaurine section.



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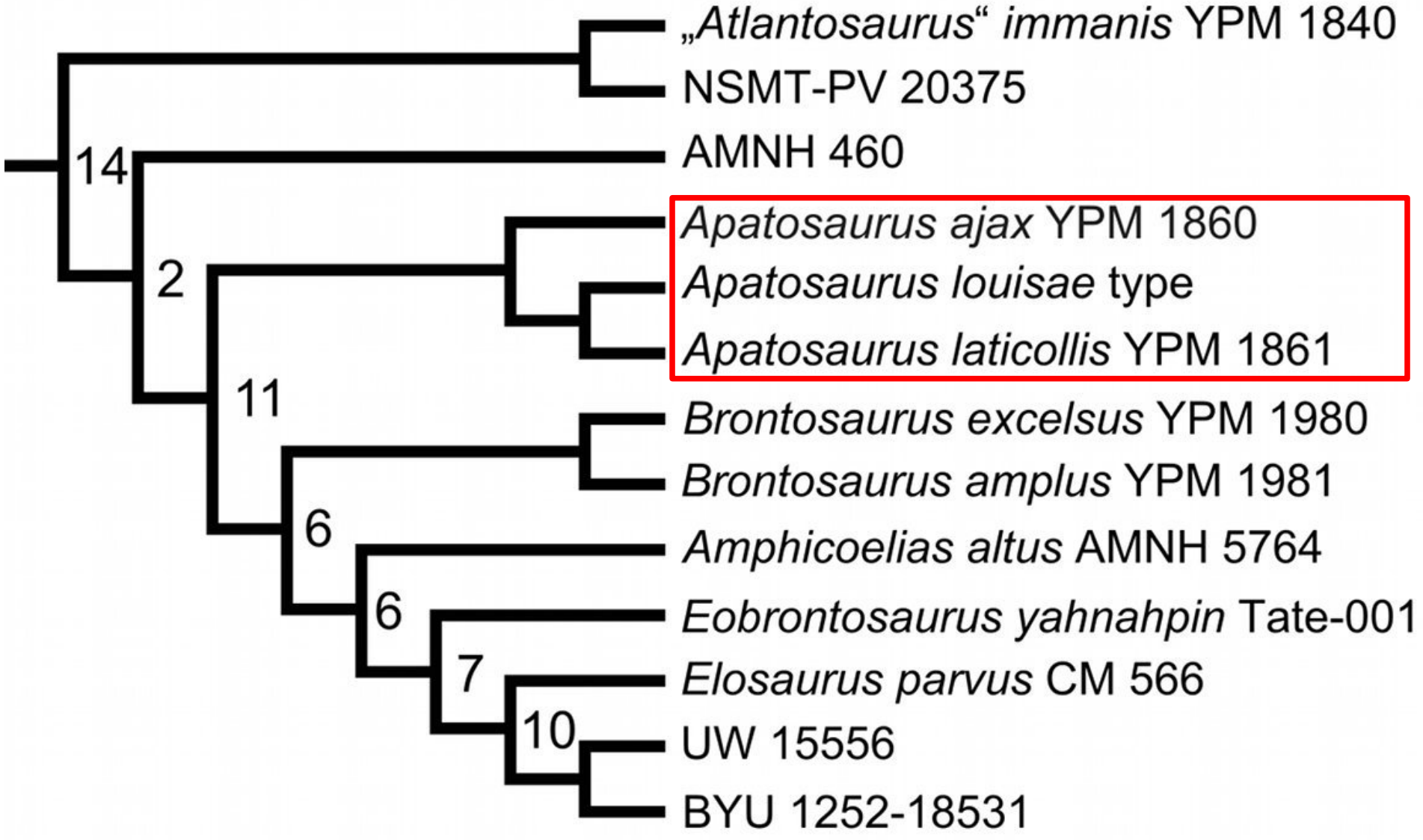

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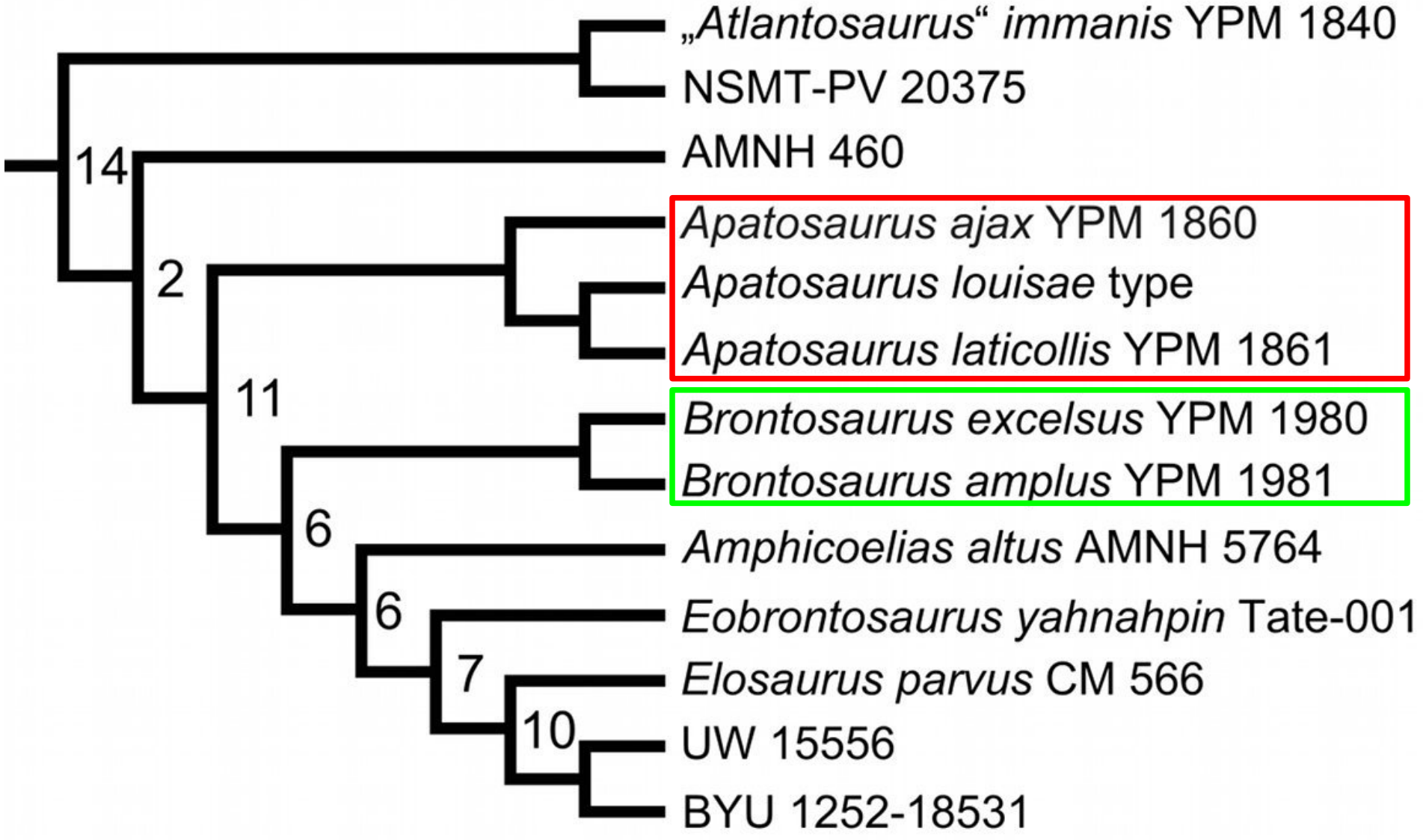

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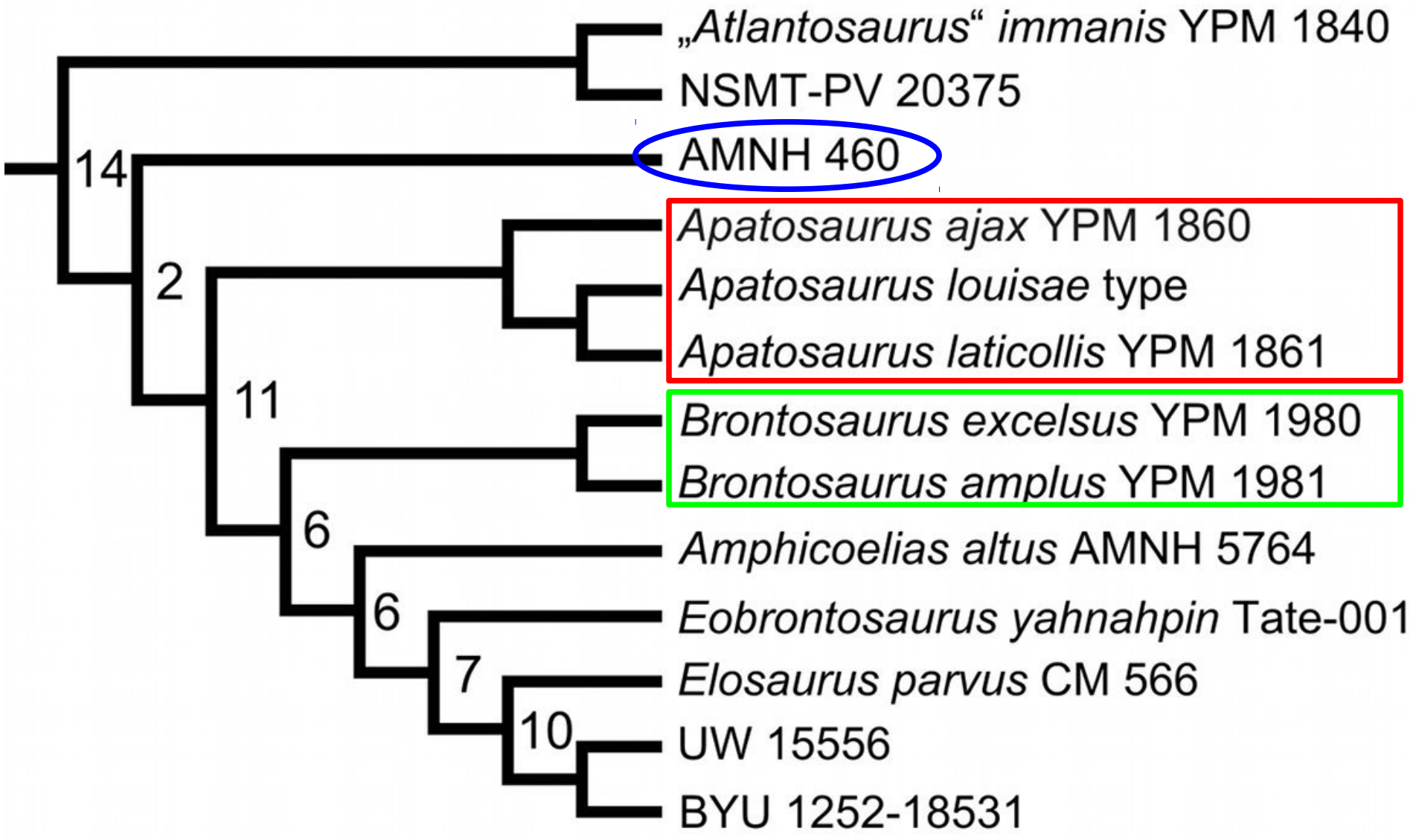
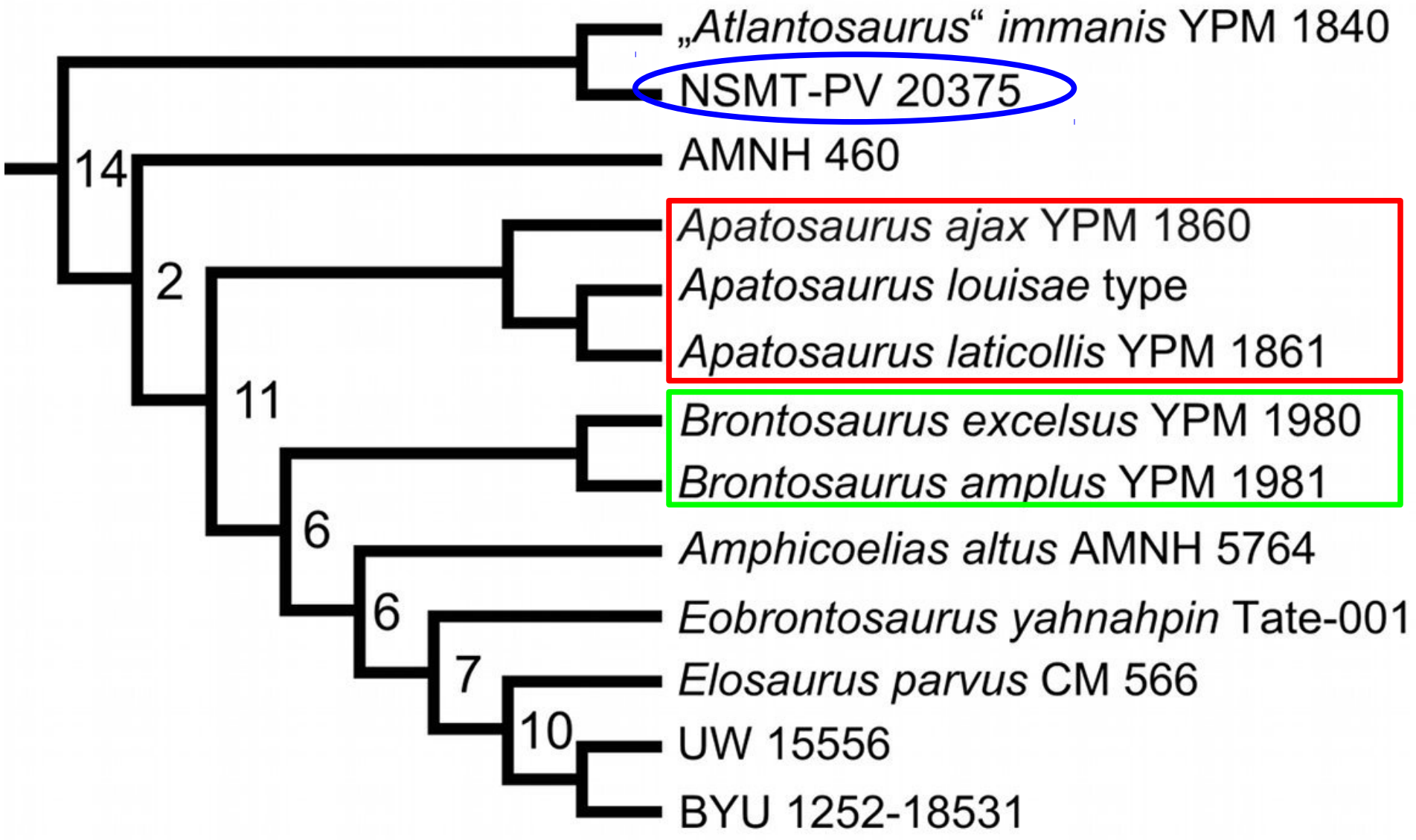
Reduced consensus, apatosaurine section.

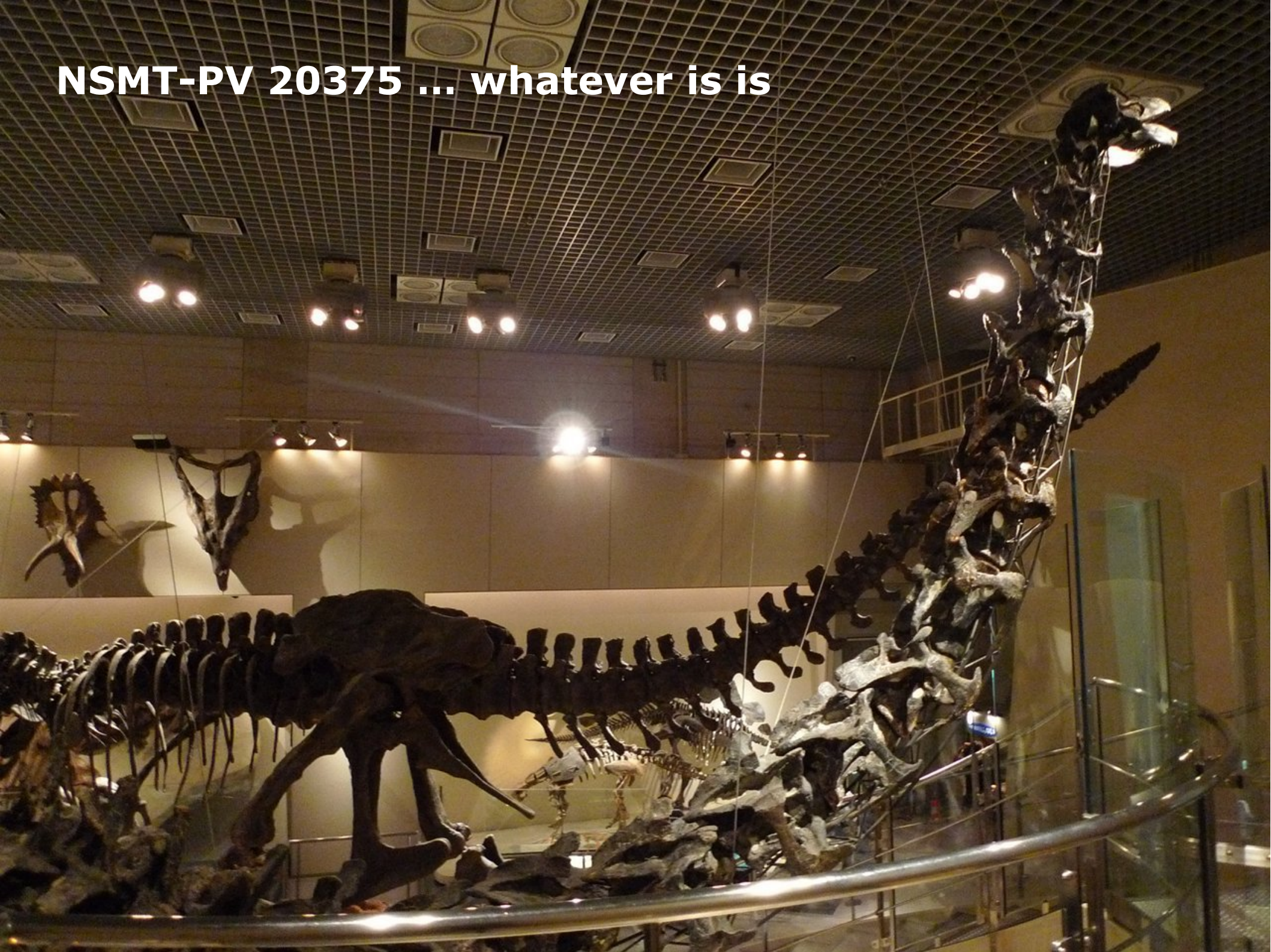


AMNH 460 … whatever it is

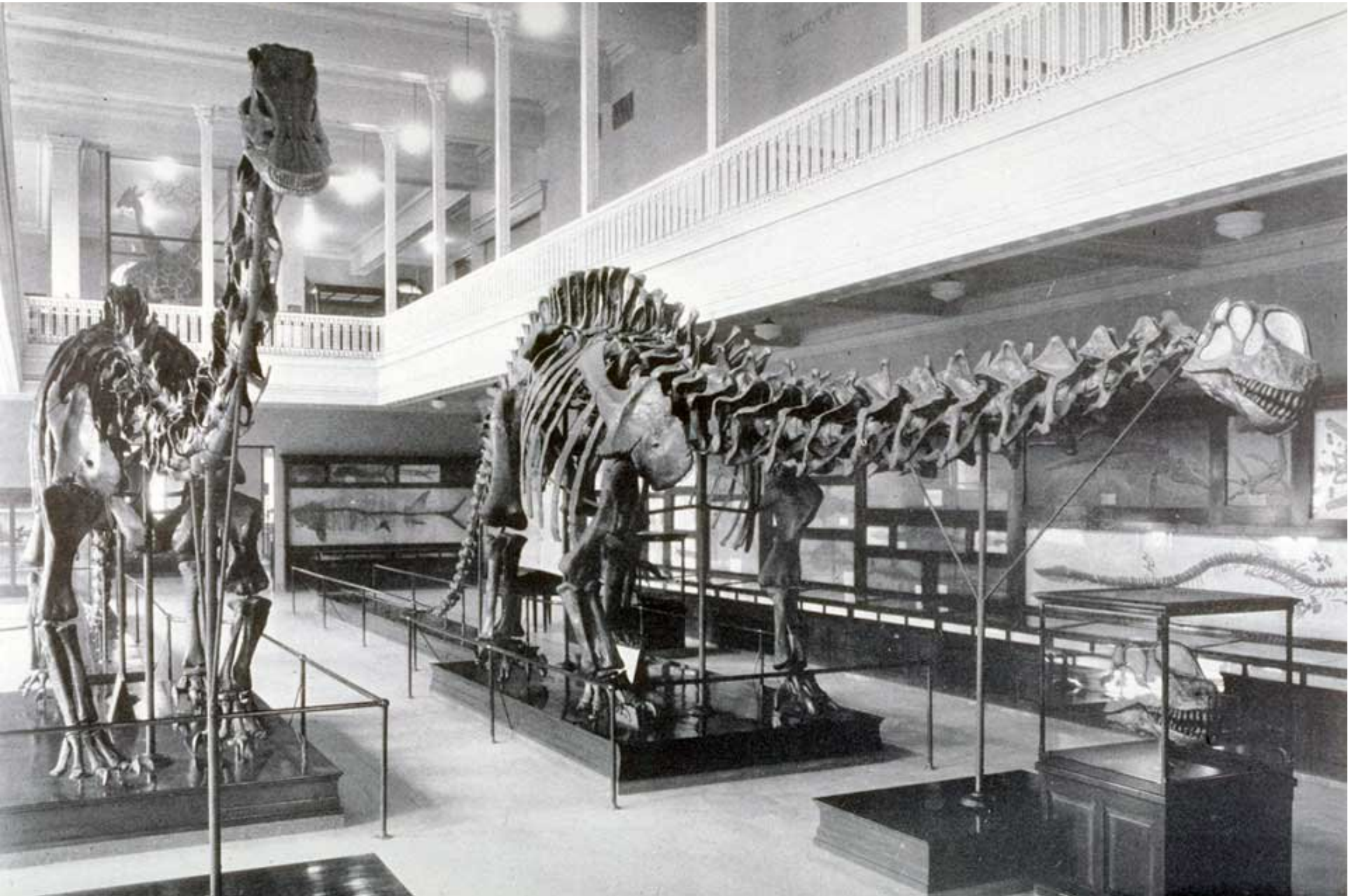
What exactly is an apatosaurine?

Tschopp et al. (2015), Figure 115.
Reduced consensus, apatosaurine section.




NSMT-PV 20375 ... whatever is is

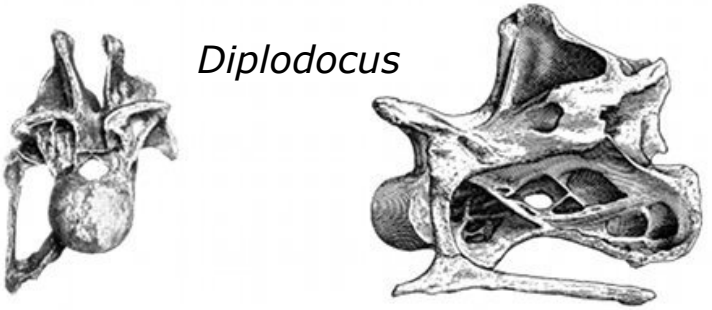
Diplodocus and *Apatosaurus* (Carnegie Museum)



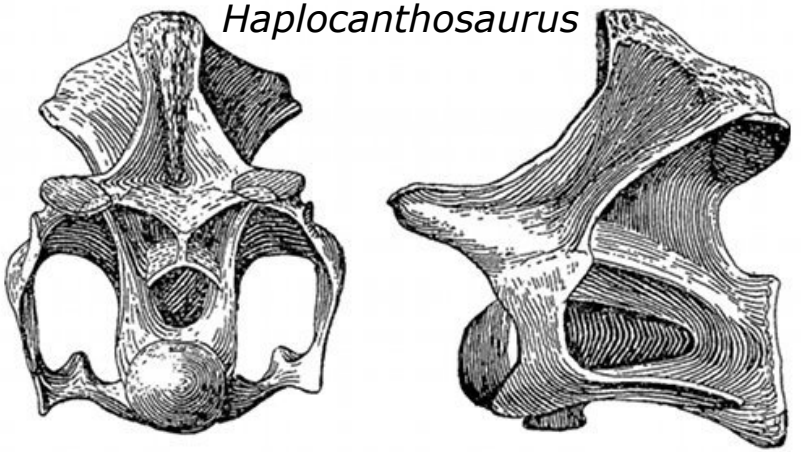
Diplodocus and *Apatosaurus* (Carnegie Museum)

Kaatedocus

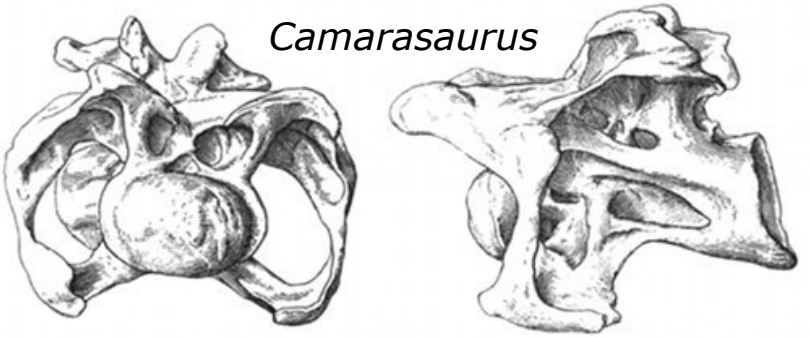
Diplodocus



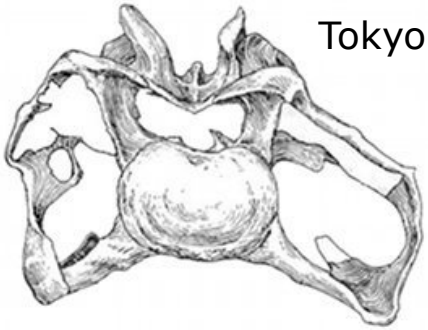
Haplocanthosaurus

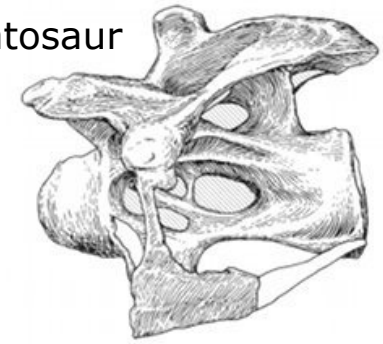


Camarasaurus



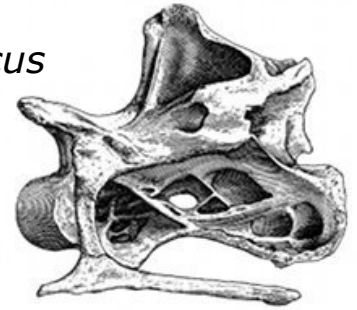
Tokyo apatosaur



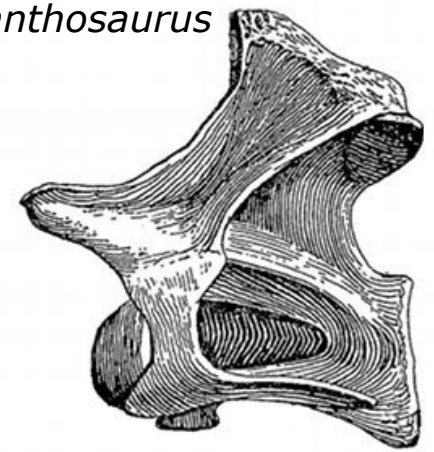


Kaatedocus

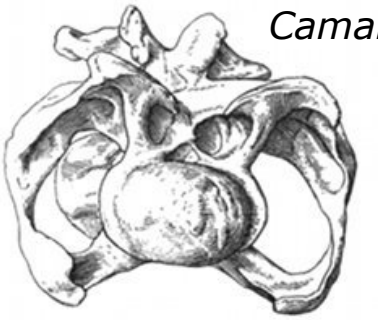
Diplodocus

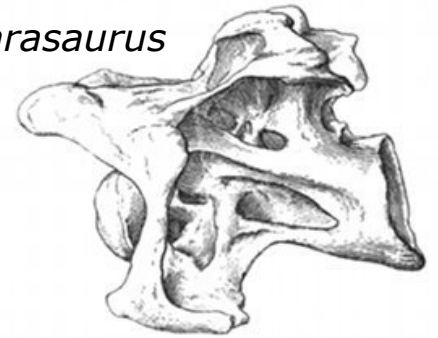


Haplocanthosaurus

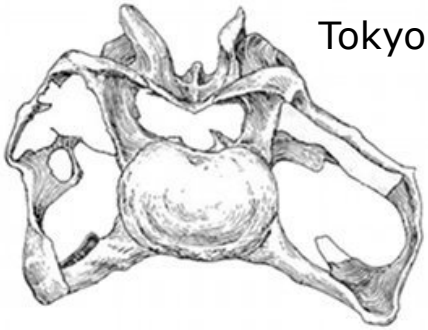


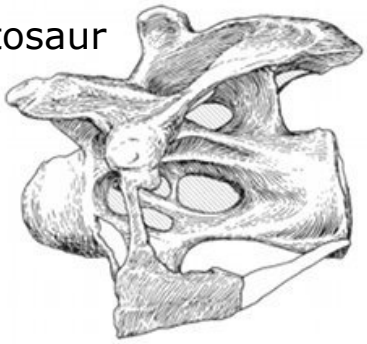
Camarasaurus



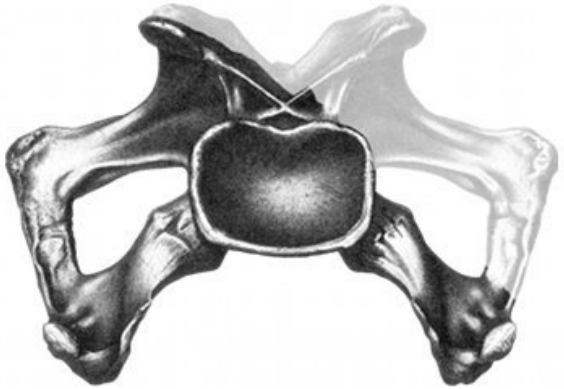


Tokyo apatosaur



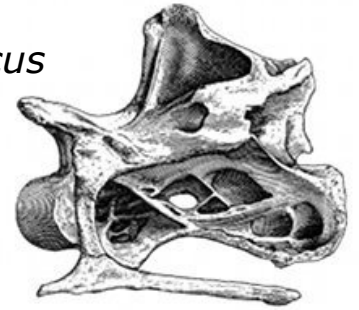


Apatosaurus ajax

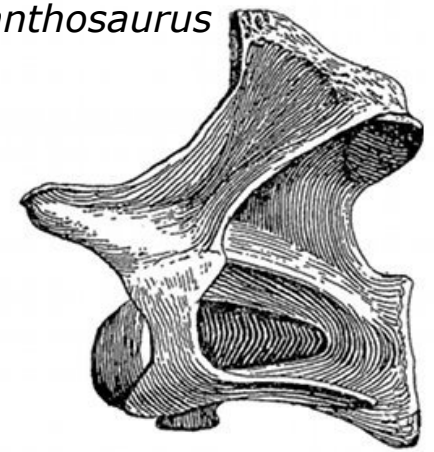


Kaatedocus

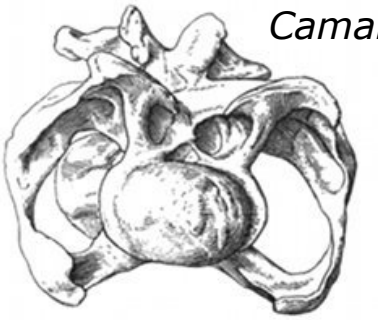
Diplodocus

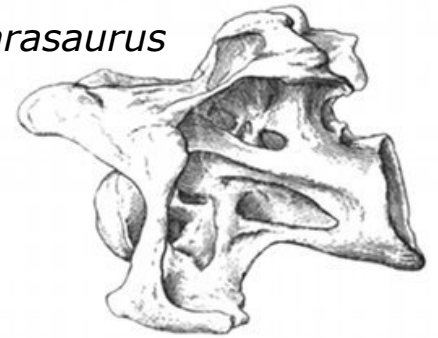


Haplocanthosaurus



Camarasaurus





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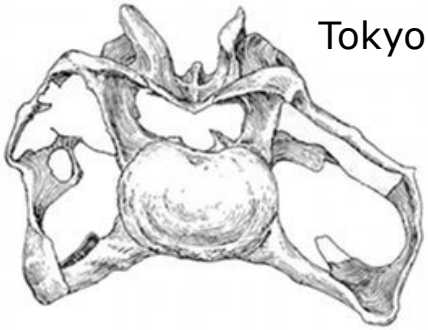
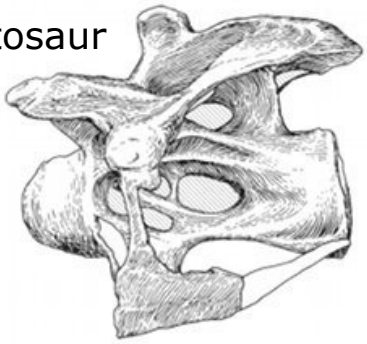
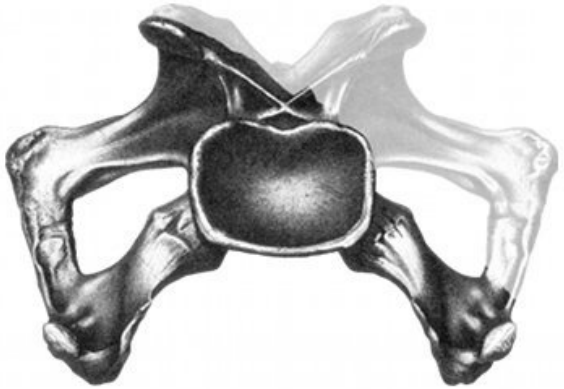
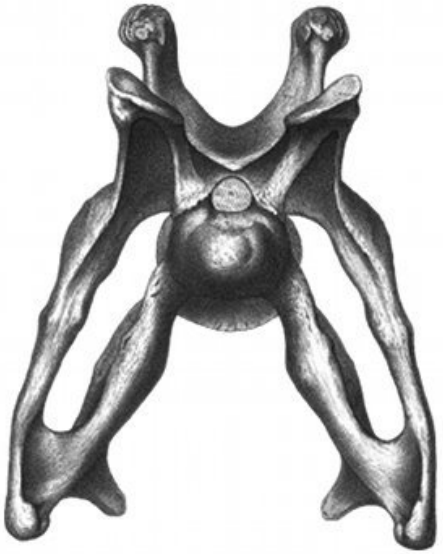




Apatosaurus ajax

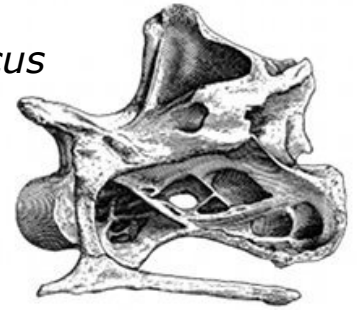


Brontosaurus excelsus

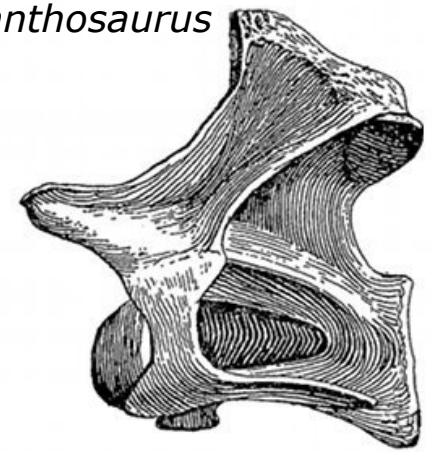


Kaatedocus

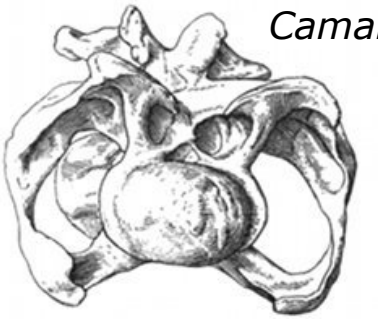
Diplodocus

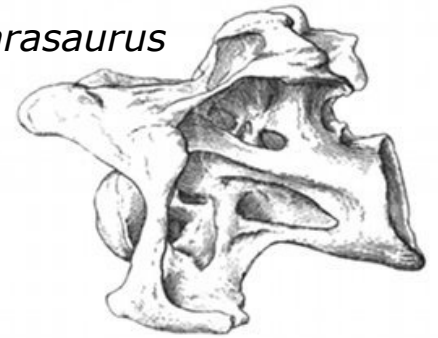


Haplocanthosaurus



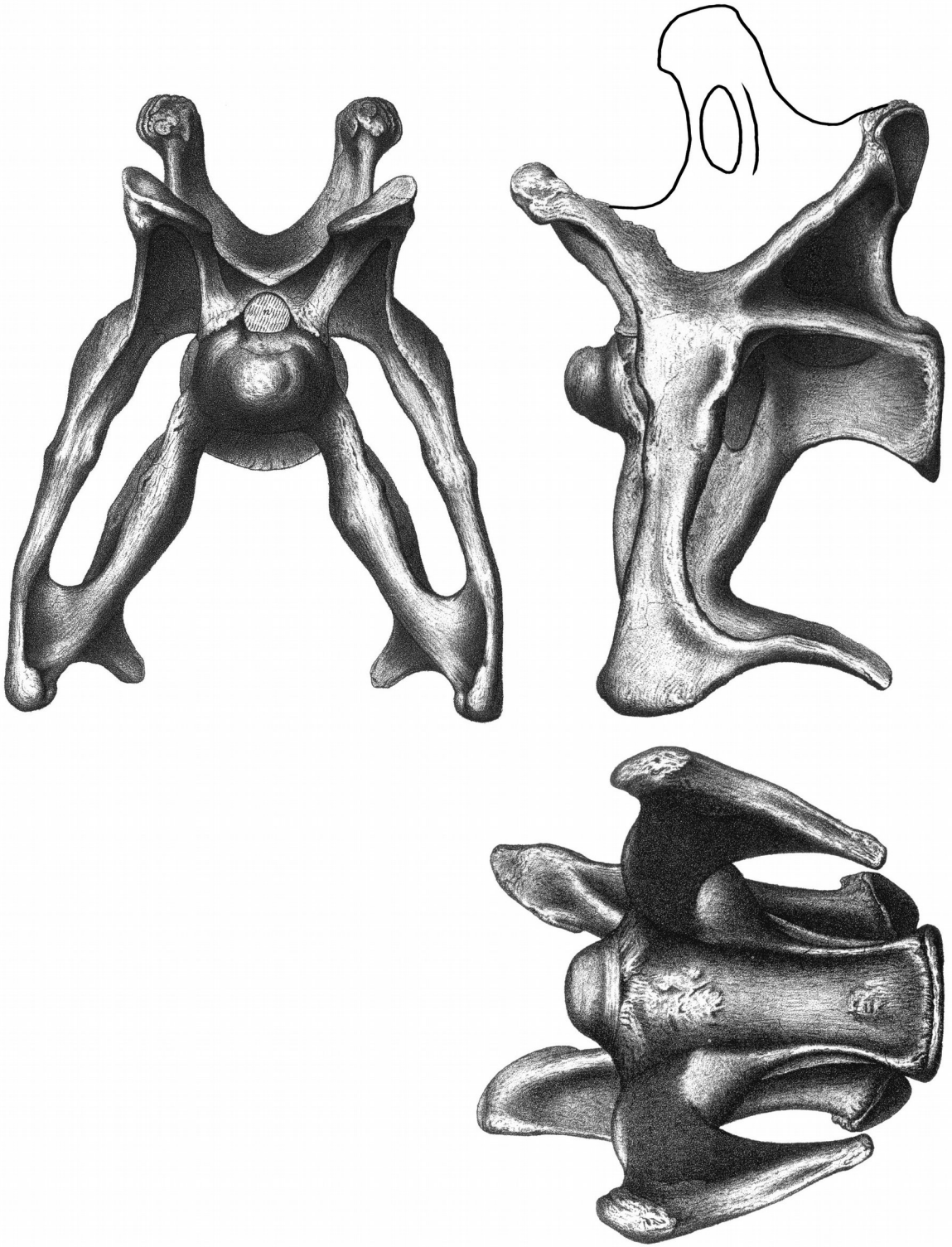
Camarasaurus





Brontosaurus excelsus
holotype
YPM 1980

Cervical ?8

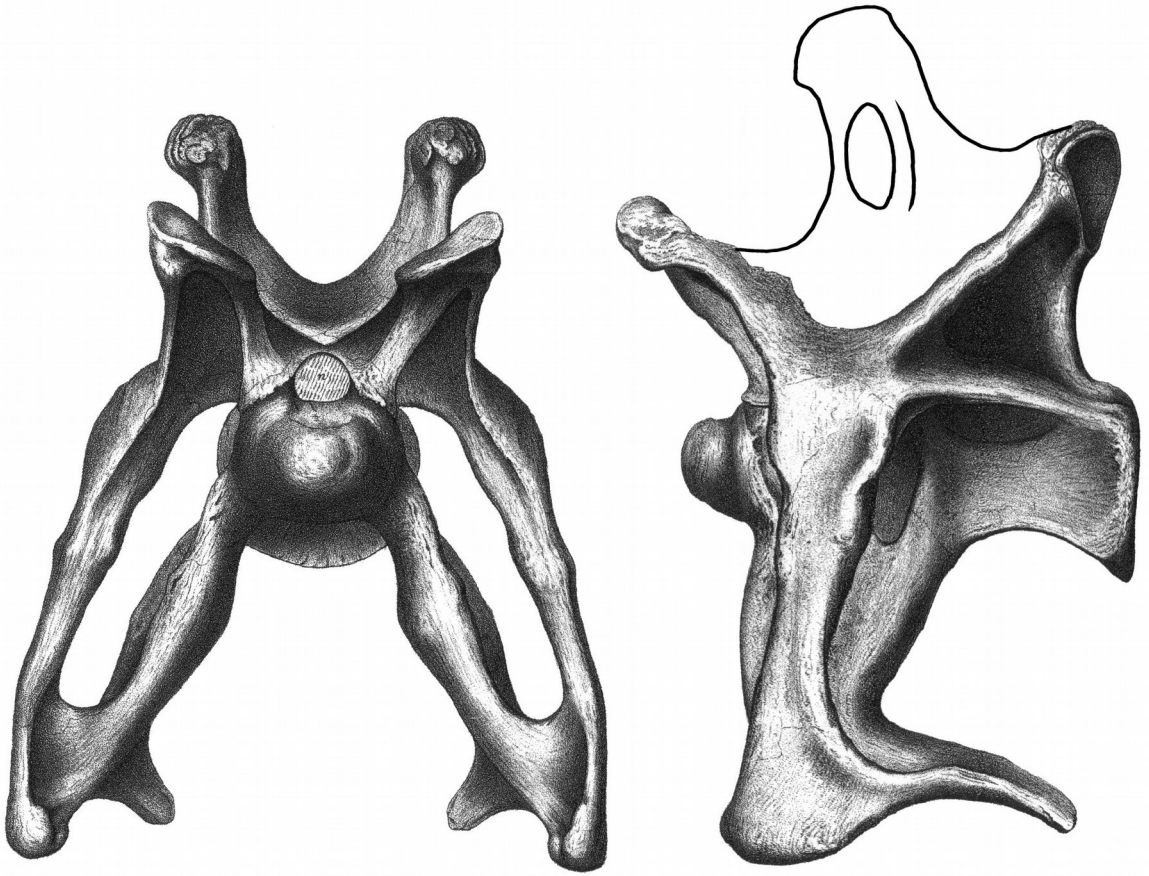


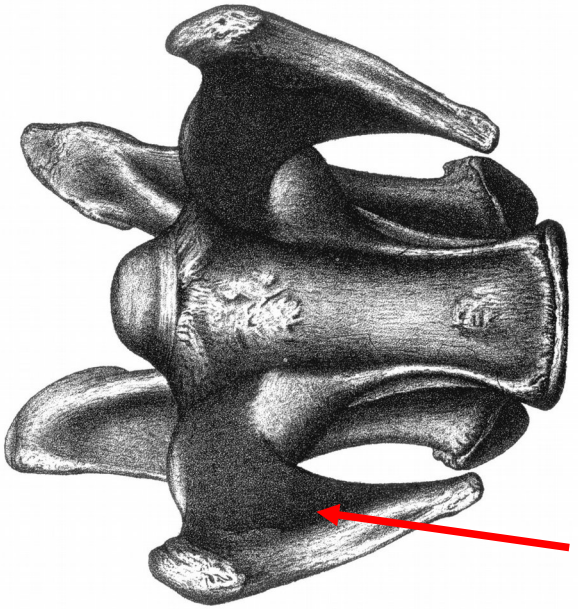
STAR WARS THE CLONE WARS

Umbaran starfighter

Brontosaurus excelsus
holotype
YPM 1980

Cervical ?8

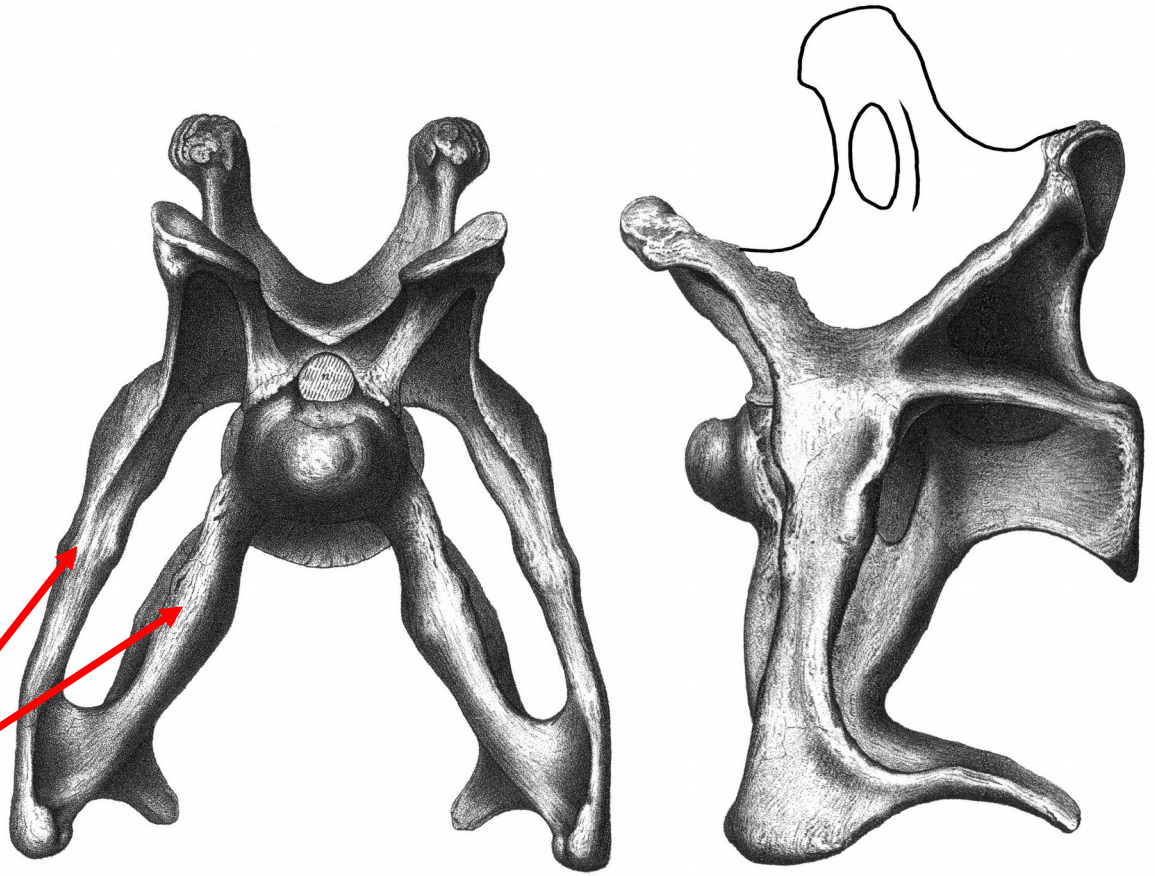




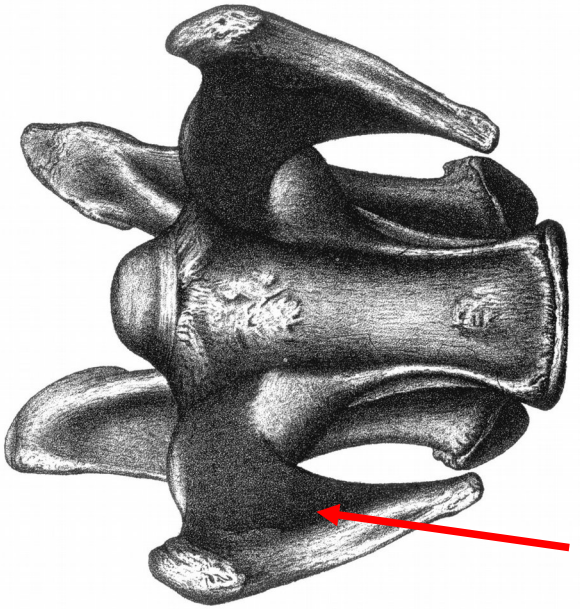
Cervical ribs robust

Brontosaurus excelsus holotype YPM 1980

Cervical ?8



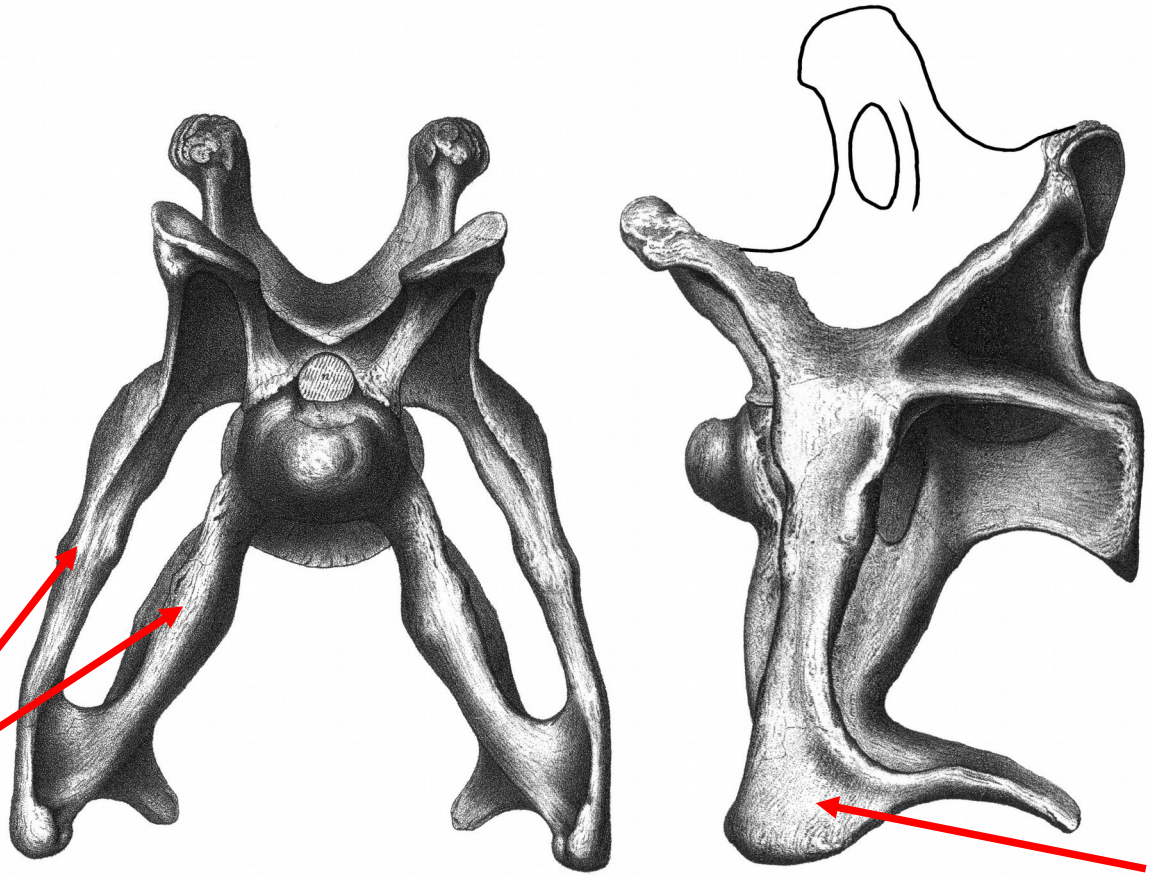
Diapophyses and parapophyses robust



Cervical ribs robust

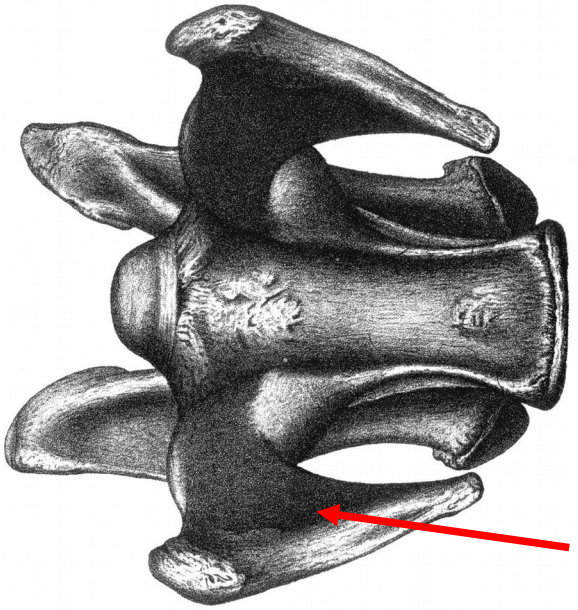
Brontosaurus excelsus holotype YPM 1980

Cervical ?8



Diapophyses and parapophyses robust

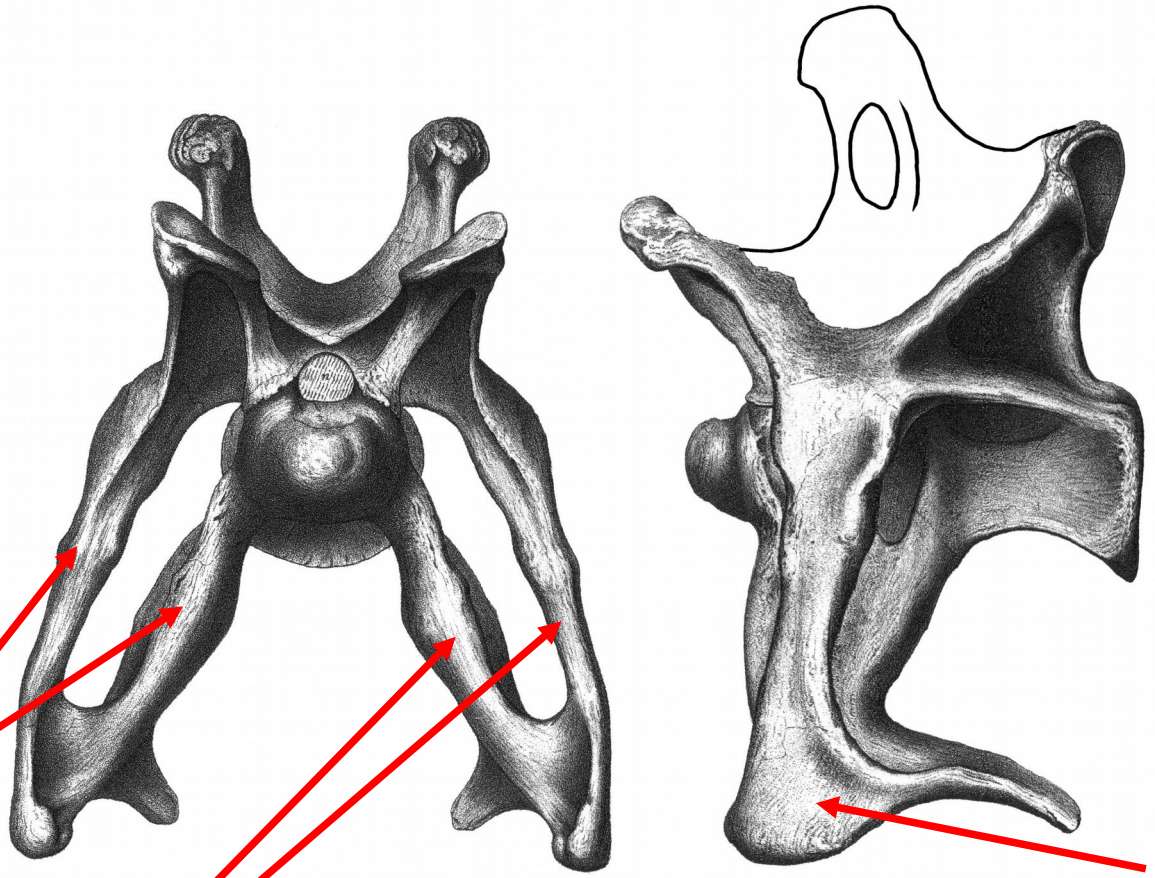
Cervical ribs displaced ventrally



Cervical ribs robust

Brontosaurus excelsus holotype YPM 1980

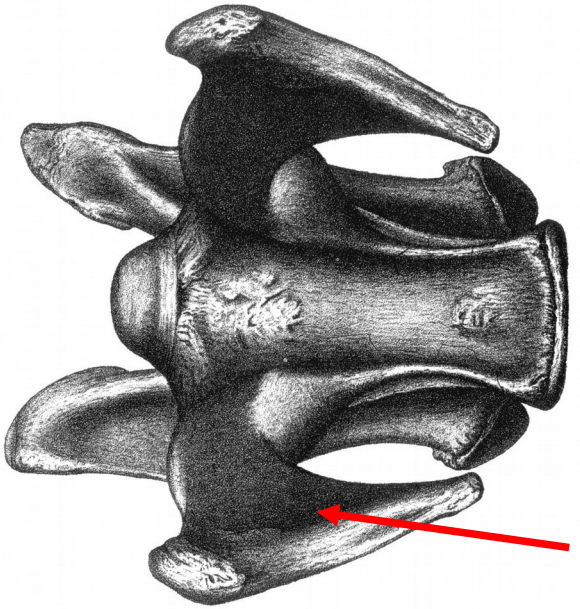
Cervical ?8



Diapophyses and parapophyses robust

Cervical ribs displaced ventrally

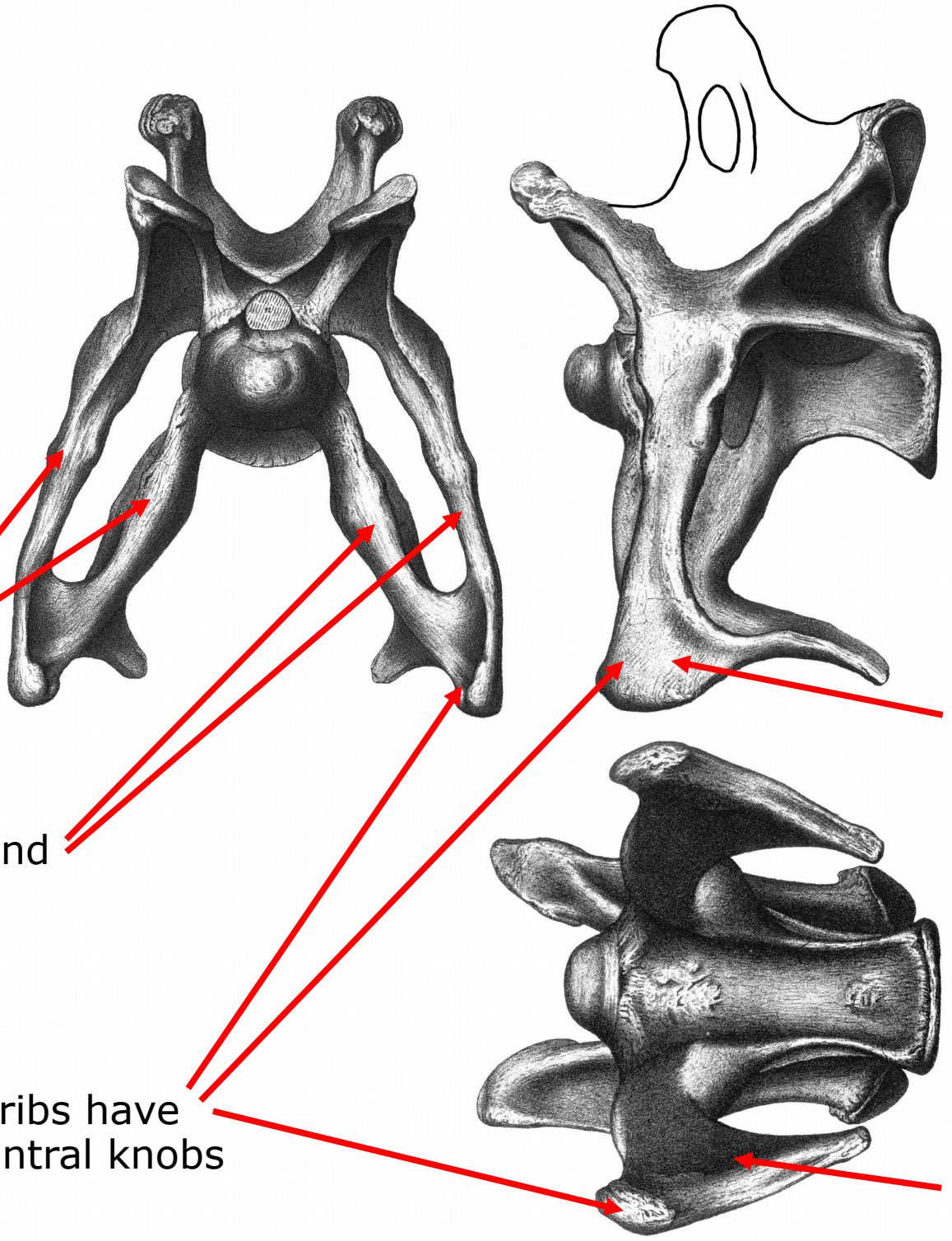
Diapophyses and parapophyses project ventrolaterally



Cervical ribs robust

Brontosaurus excelsus holotype YPM 1980

Cervical ?8



Diapophyses and parapophyses robust

Diapophyses and parapophyses project ventrolaterally

Cervical ribs have anteroventral knobs

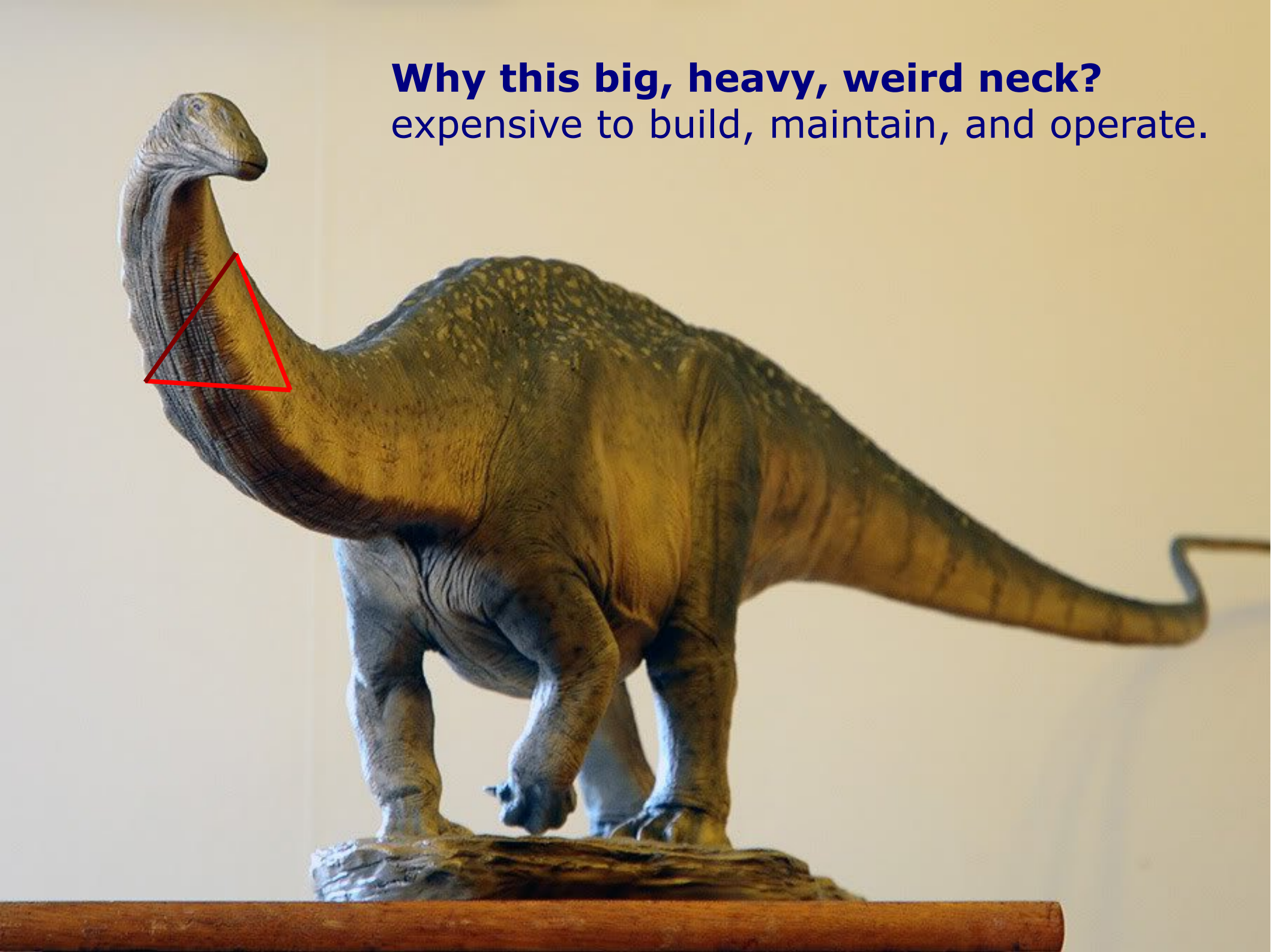
Cervical ribs displaced ventrally

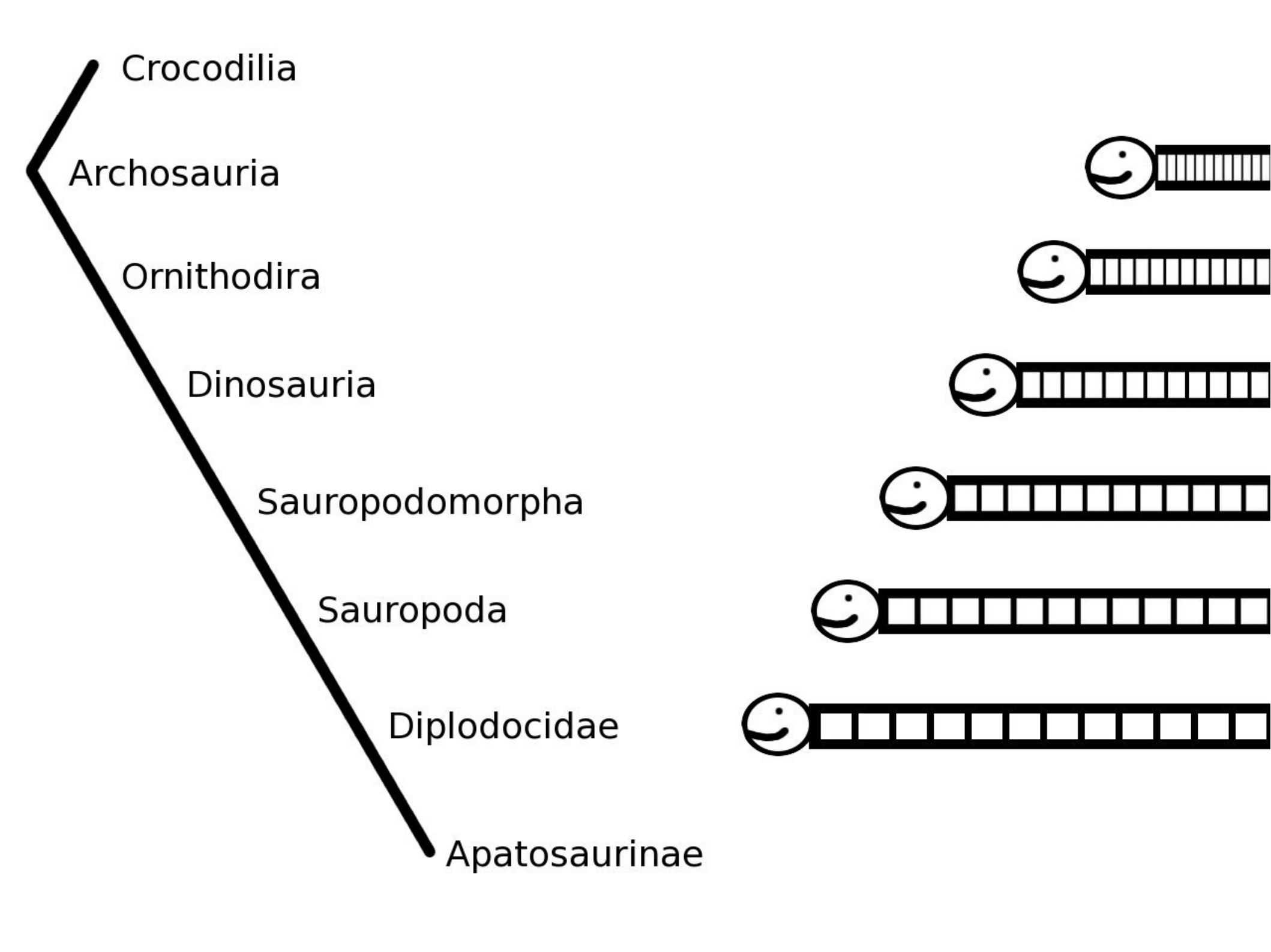
Cervical ribs robust

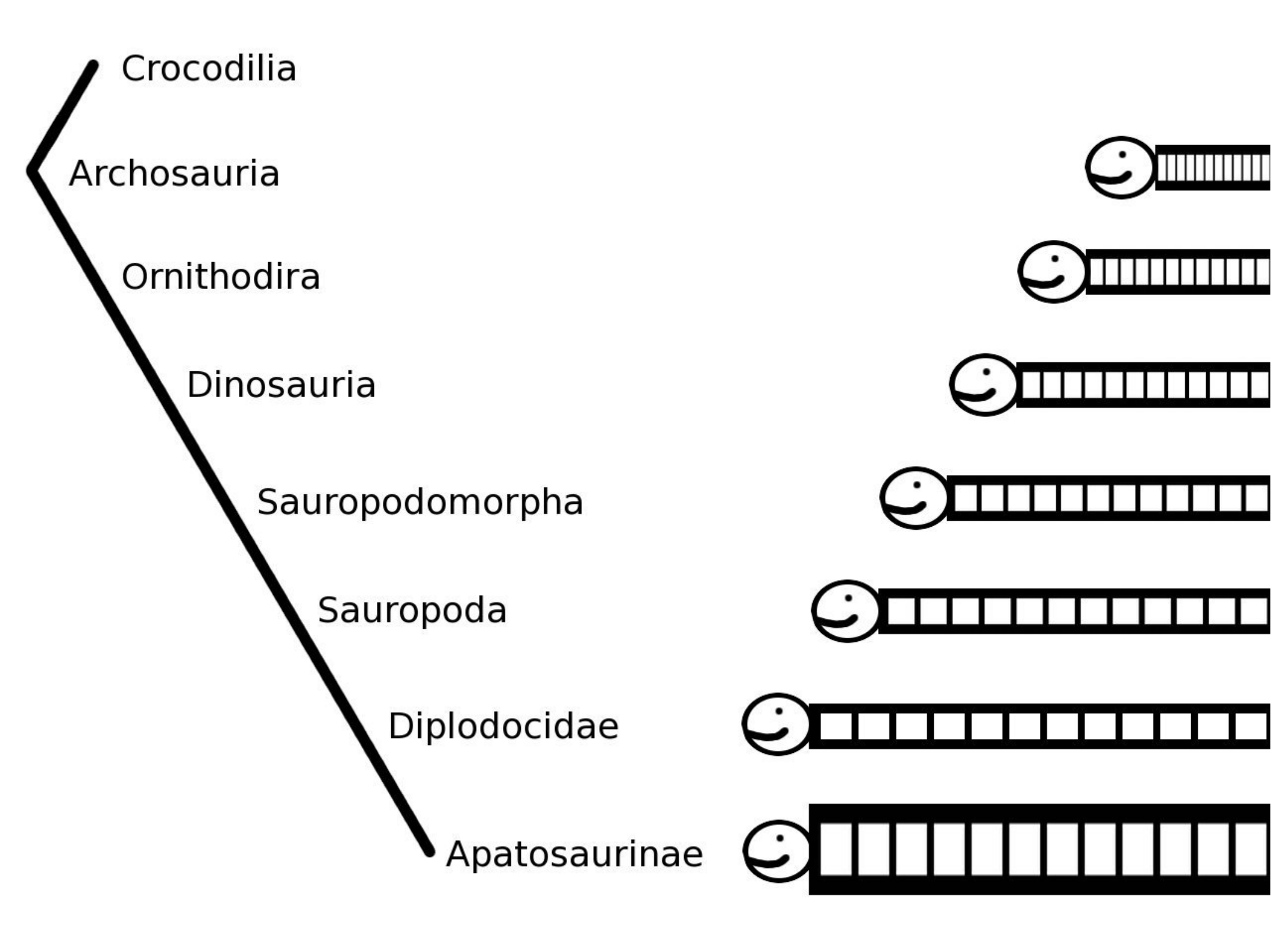

Knight's *Brontosaurus* (1897)


Nestlé
No artificial colours


SWISS MILK CHOCOLATE WITH HONEY AND ALMOND NOUGAT
TOBLERONE
OF SWITZERLAND
NET WT. 400g
25g
132 kcal


Why this big, heavy, weird neck?
expensive to build, maintain, and operate.


Crocodilia
Archosauria
Ornithodira
Dinosauria
Sauropodomorpha
Sauropoda
Diplodocidae
Apatosaurinae


Crocodilia
Archosauria
Ornithodira
Dinosauria
Sauropodomorpha
Sauropoda
Diplodocidae
Apatosaurinae

Taylor and Wedel (2013a:26) just gave up

PeerJ

Apatosaurus presents a final riddle regarding cervical ribs. Even among diplodocids, it had extraordinary cervical ribs: very short, very robust, and positioned very low, far below the centra on extremely long parapophyses (Figs. 7.1 and 7.2), so that the neck of *Apatosaurus* must have been triangular in cross-section. What function can the ribs have evolved to perform? They were much too short to have functioned efficiently in horizontal or vertical stabilization, and in any case seem over-engineered for these functions. It is tempting to infer that the autapomorphies of the neck in *Apatosaurus* are adaptations for some unique aspect of its lifestyle, perhaps violent intraspecific combat similar to the "necking" of giraffes. Even if this were so, however, it is difficult to see the benefit in *Apatosaurus excelsus* Marsh, 1879a of cervical ribs held so far below the centrum – an arrangement that seems to make little sense from any mechanical perspective, and may have to be written off as an inexplicable consequence of sexual selection or species recognition.

Outline

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Taylor and Wedel (2013a:26) just gave up

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Apatosaurus presents a final riddle regarding cervical ribs. Even among diplodocids, it had extraordinary cervical ribs: very short, very robust, and positioned very low, far below the centra on extremely long parapophyses (Figs. 7.1 and 7.2), so that the neck of *Apatosaurus* must have been triangular in cross-section. What function can the ribs have evolved to perform? They were much too short to have functioned efficiently in horizontal or vertical stabilization, and in any case seem over-engineered for these functions. It is tempting to infer that the autapomorphies of the neck in *Apatosaurus* are adaptations for some unique aspect of its lifestyle, perhaps violent intraspecific combat similar to the "necking" of giraffes. Even if this were so, however, it is difficult to see the benefit in *Apatosaurus excelsus* Marsh, 1879a of cervical ribs held so far below the centrum – an arrangement that seems to make little sense from any mechanical perspective, and may have to be written off as an inexplicable consequence of sexual selection or species recognition.

Outline

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No sex, please, we're sauropods

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The long necks of sauropods did not evolve primarily through sexual selection

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Keywords
sexual selection; dinosaurs; sauropods; giraffes; necks; feeding; behaviour; ecology.

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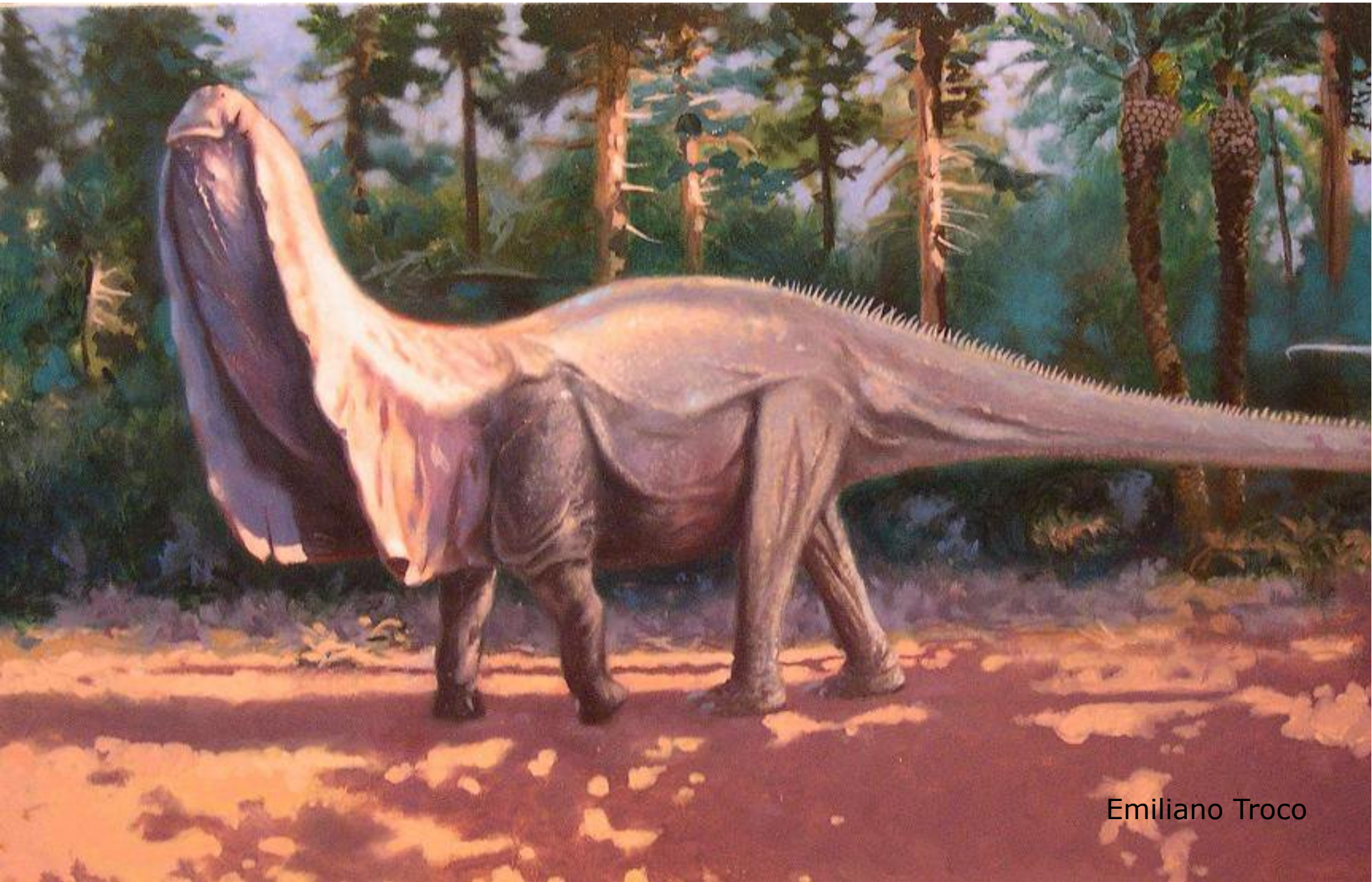
Abstract

It has recently been argued that the elongate necks of sauropod dinosaurs evolved primarily through selection for their use as sexual and dominance signals, and not as an adaptation for accessing a large 'feeding envelope' as traditionally thought. Here we explore this idea and show that all six arguments that have been advanced in support of the sexual selection hypothesis are flawed: there is no evidence for sexual dimorphism in the necks of sauropods; neither is there any evidence that they were used in dominance displays; long necks provided significant survival benefits in allowing high browsing and energetically efficient grazing; their fitness cost was likely less than has been assumed; their positive allometry through ontogeny is uninformative given that ontogenetic allometry is common in animals; apparent lack of correlation between neck and leg length across phylogeny is

But apatosaurs are different




But apatosaurs are different
John Conway

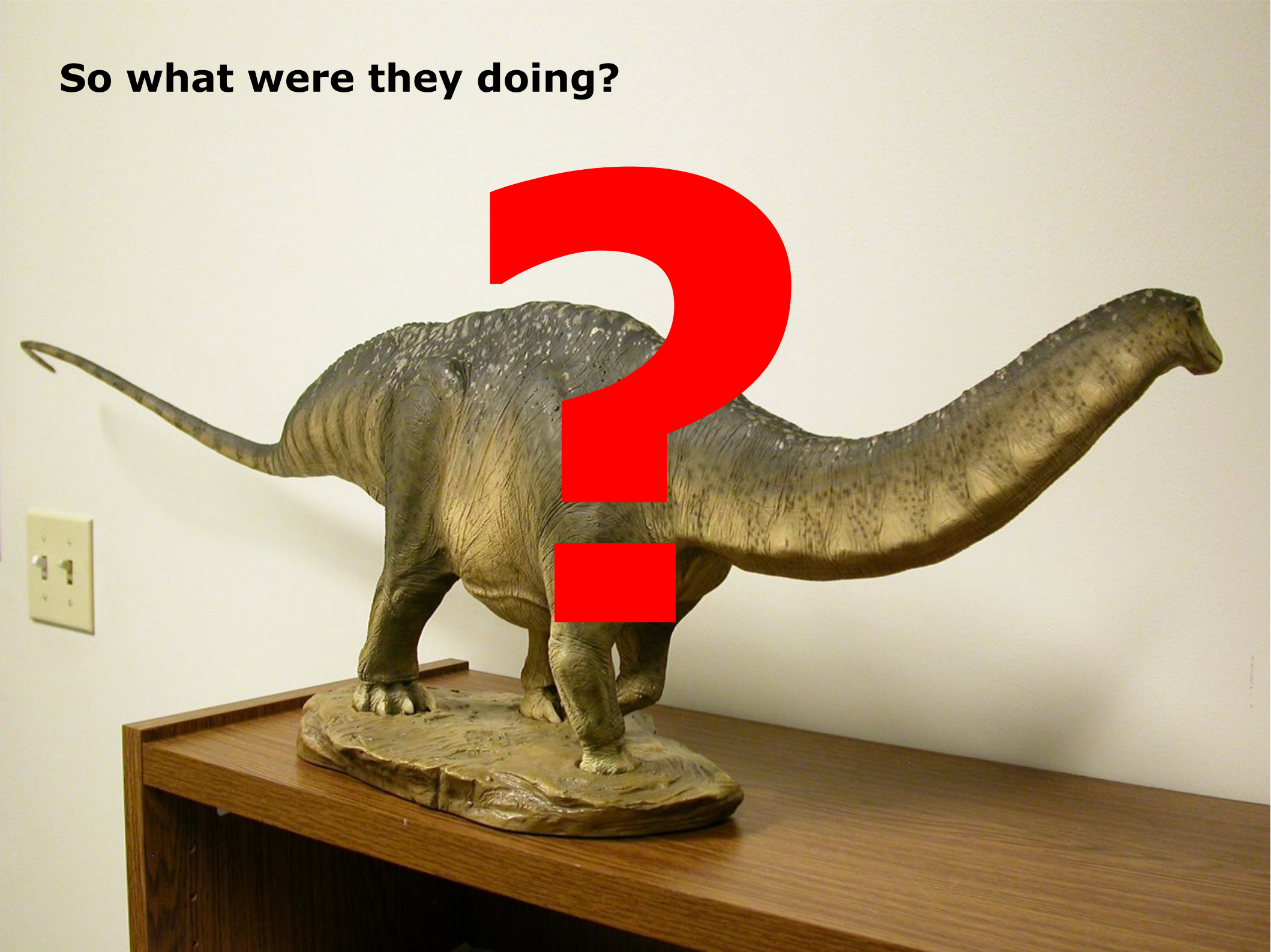
Sexual combat like necking giraffes?

Giraffes have crass, uncharismatic,
Highly fused mammalian skulls ...

… Whereas apatosaurs have elegant, fragile skulls

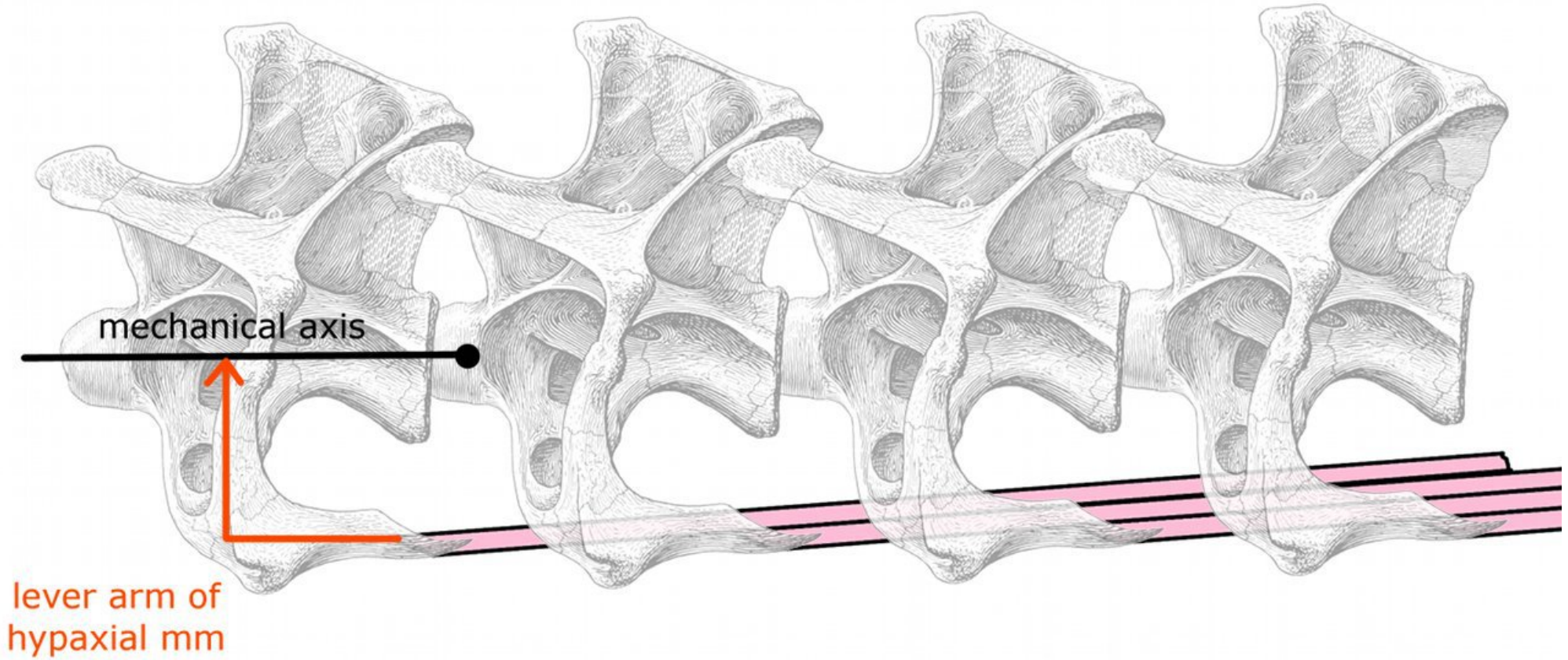
Sexual combat like necking giraffes?

So what were they doing?



1. Ventral displacement of cervical ribs

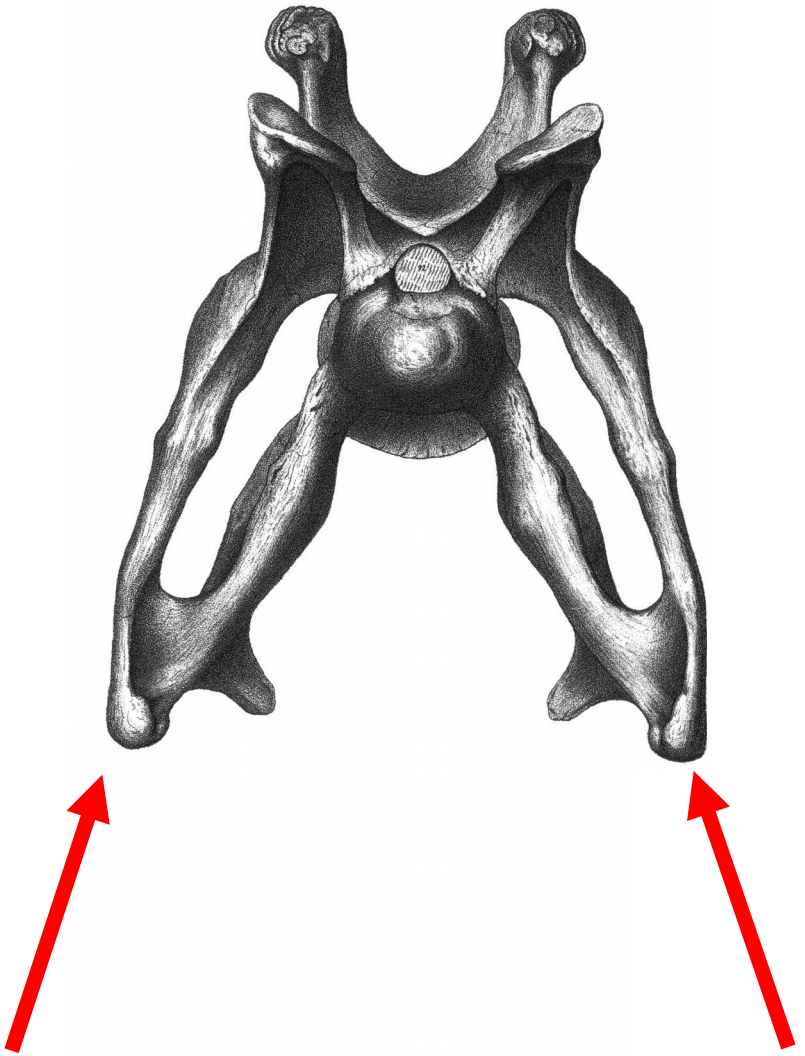
Improved mechanical advantage of hypaxial muscles.



Stronger ventral movements of the neck

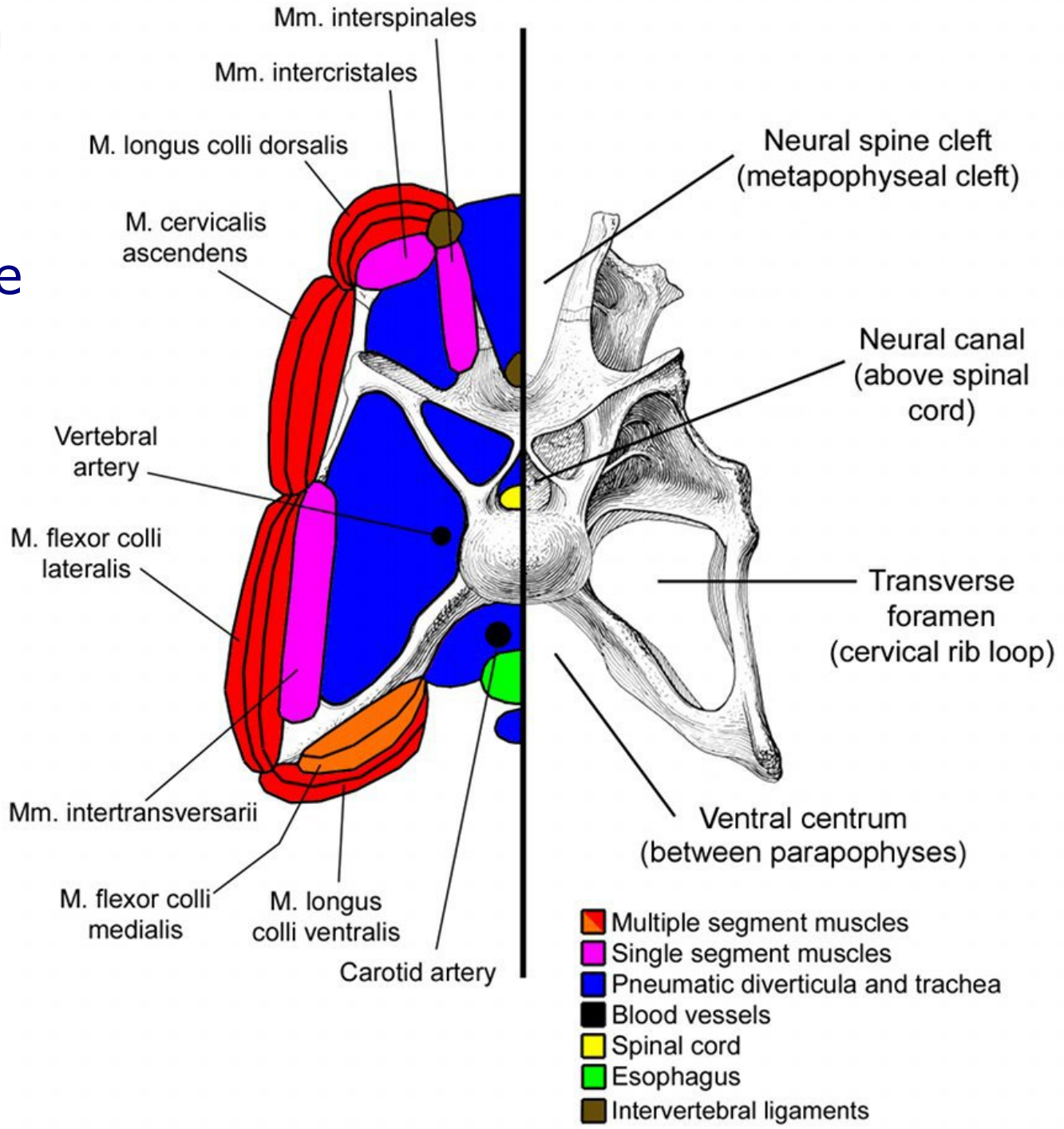
2. Ventrolaterally directed parapophyseal rami

Oriented to resist ventral impacts



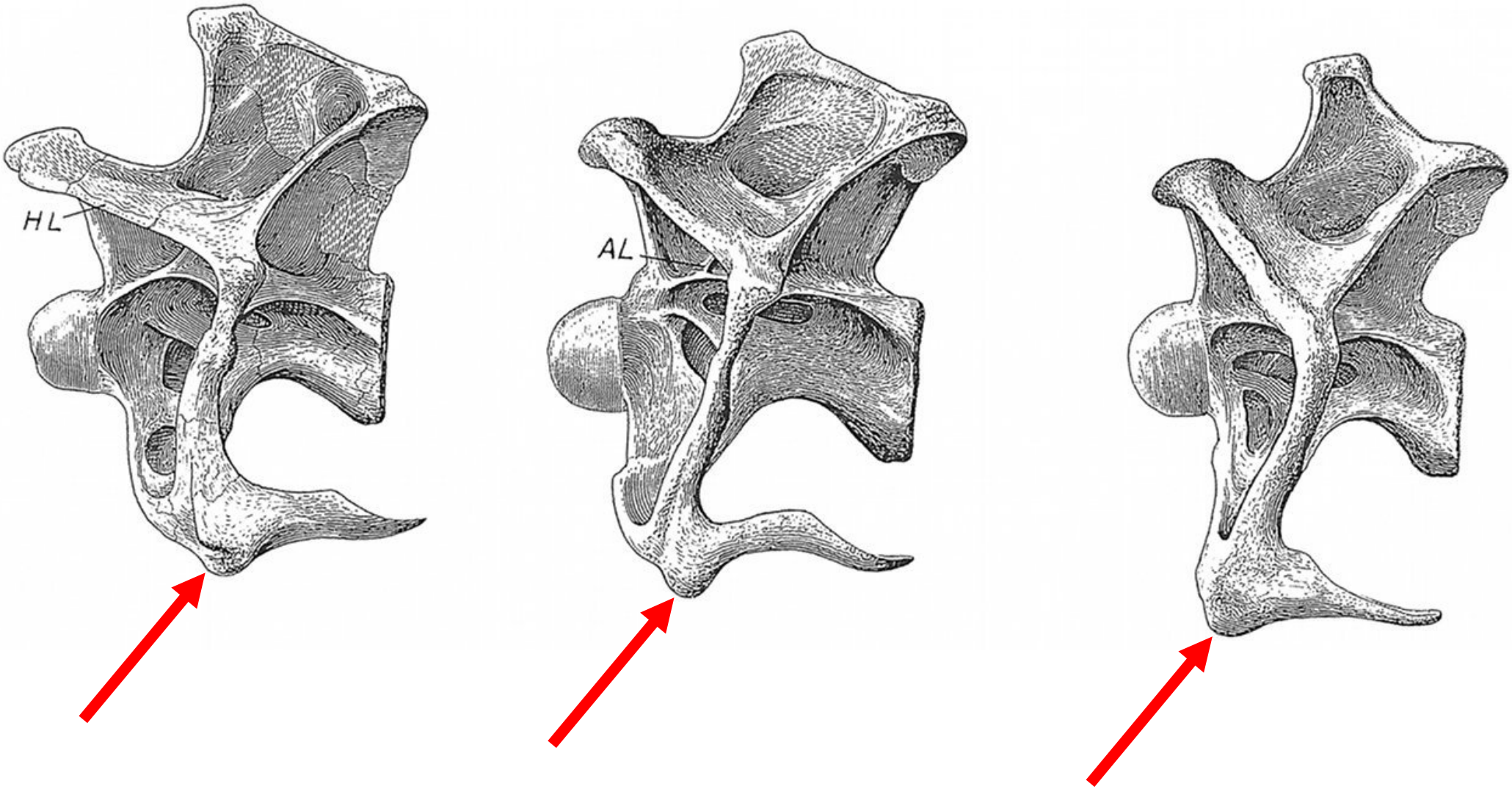
3. Ventral trough between the cervical ribs

Provided soft-tissue protection for the trachea, oesophagus, and major blood vessels.



4. Ventrolateral processes on the cervical ribs

Apatosaurus louisae holotype CM 3018 cervicals 10–12. (Gilmore 1936:plate XXIV)



Ventral midline callosities on ostrich torsos

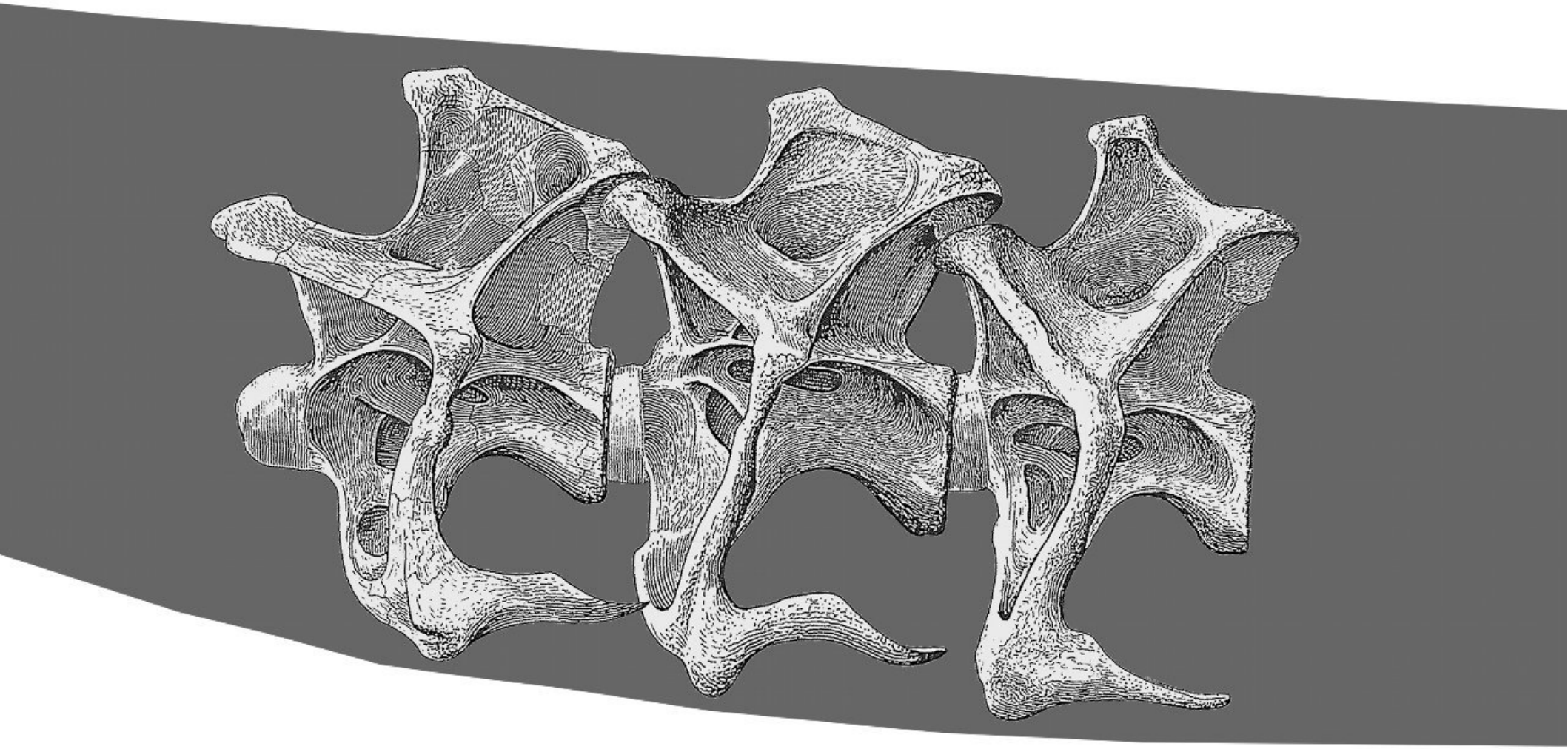
Slack (2002: figure 4)

(Note the hilarious three-toed ostrich feet)

Nature Reviews | Genetics

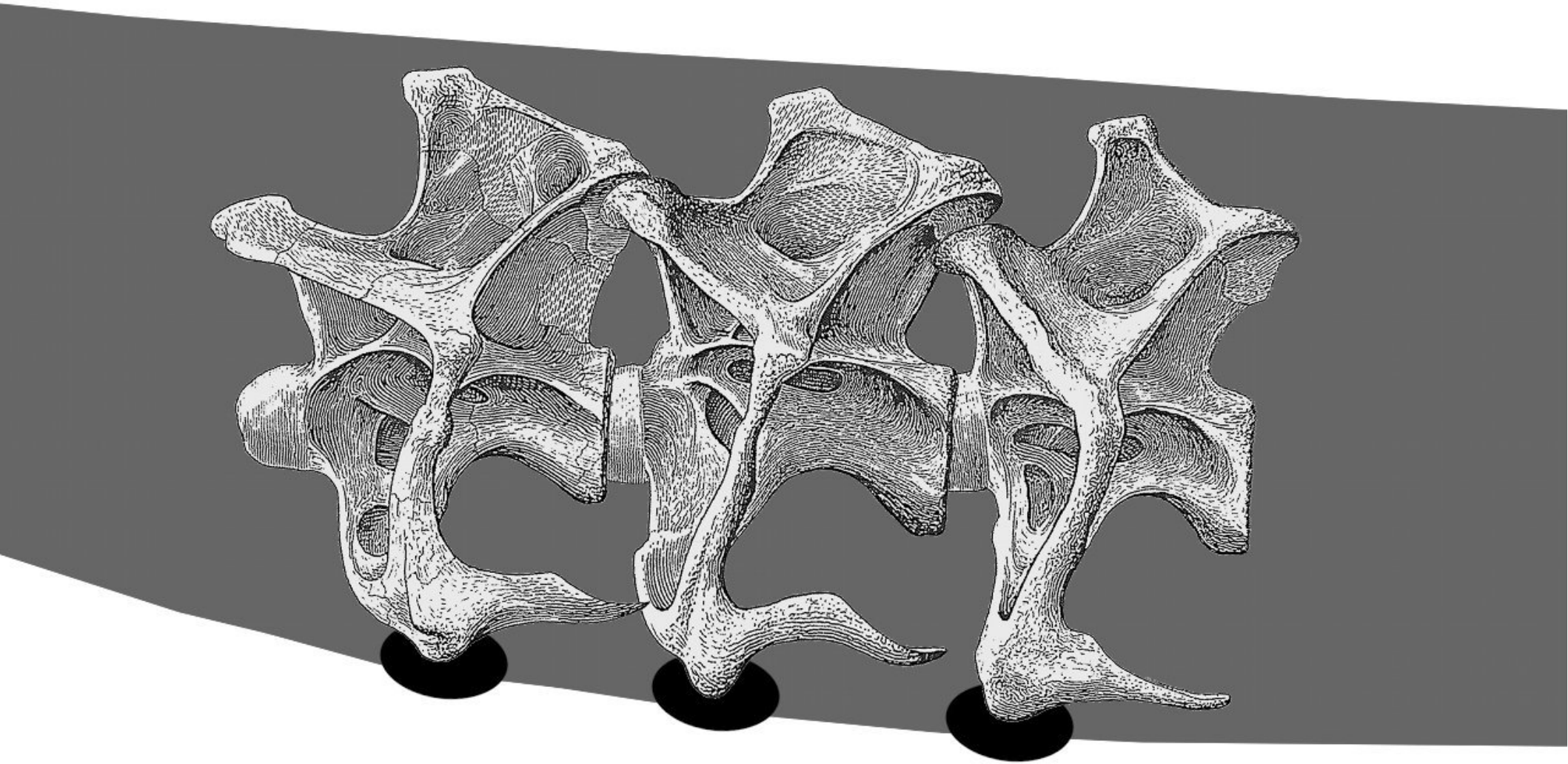
4. Ventrolateral processes on the cervical ribs

Maybe instead of this ...

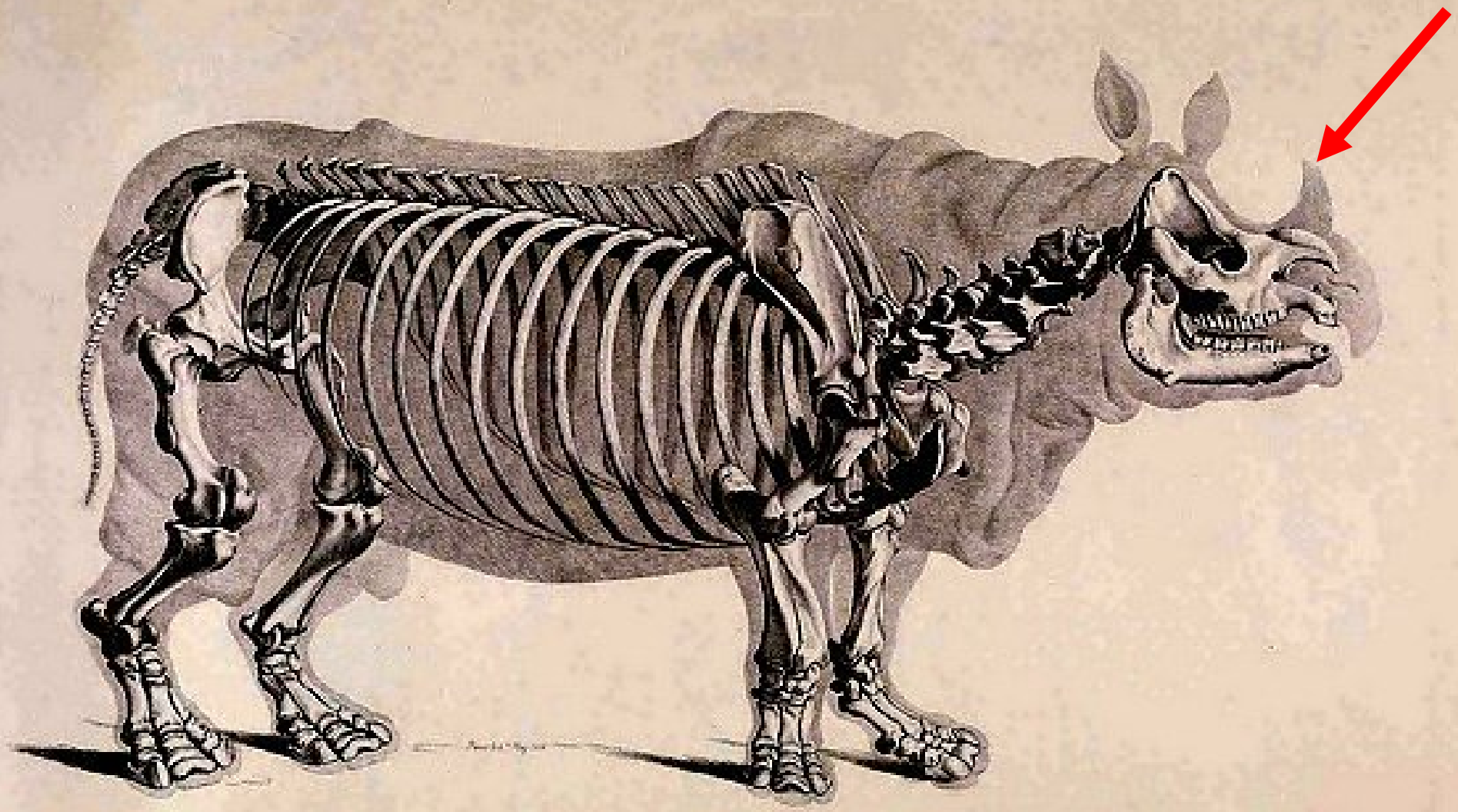


4. Ventrolateral processes on the cervical ribs

… this?



Keratinous horn in rhinoceroses



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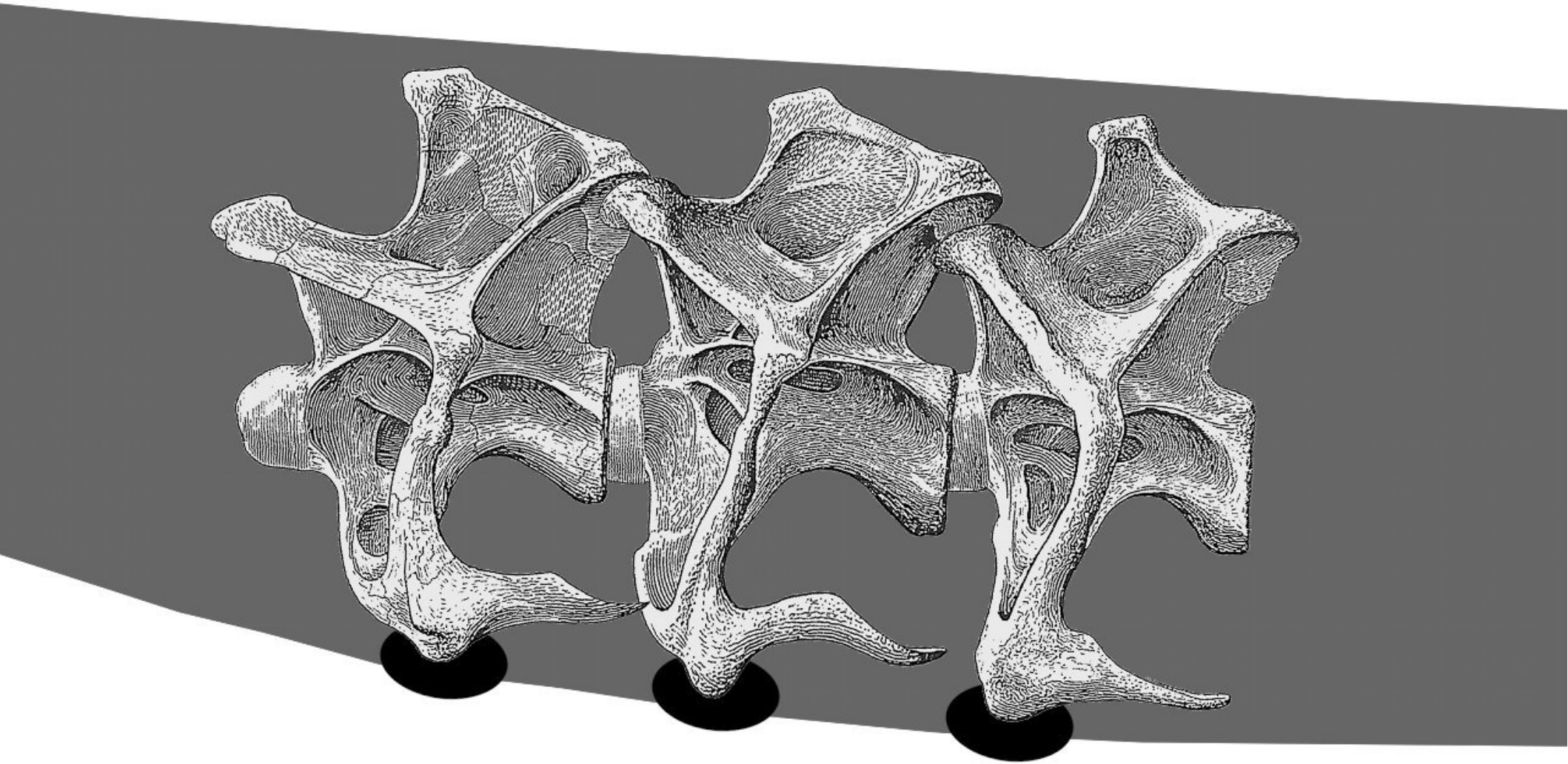

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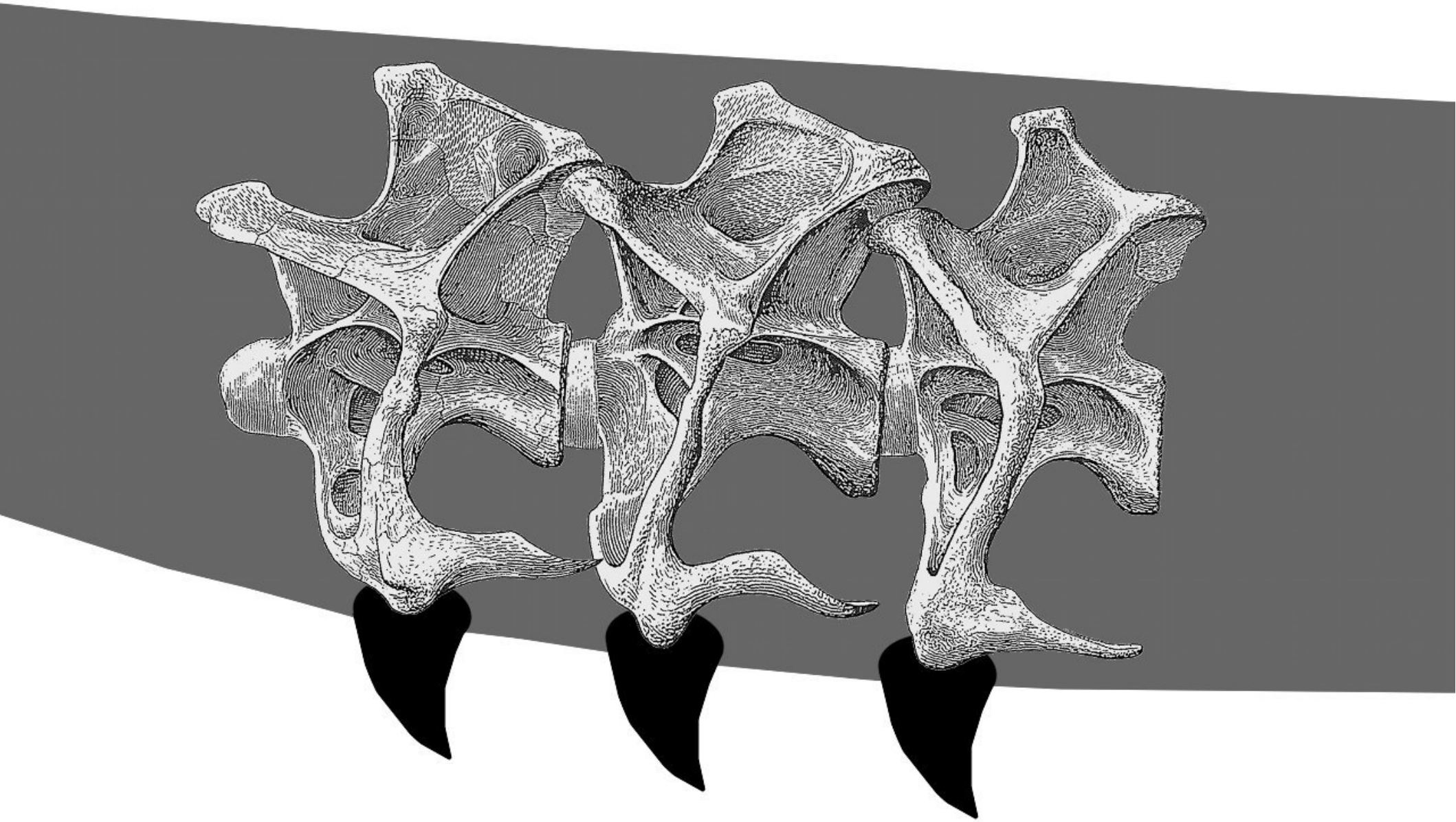

Summary

1. Ventral displacement of cervical ribs
   - Improved mechanical advantage of hypaxial muscles.
   - Stronger ventral movements of the neck

2. Ventrolaterally directed parapophyseal rami
   - Oriented to resist ventral impacts

3. Ventral trough between the cervical ribs
   - Provided soft-tissue protection for the trachea, blood vessels.

4. Ventrolateral processes on the cervical ribs
   - Calloused lumps or spikes on ventral surface

⇒ **combat by crashing necks ventrally.**


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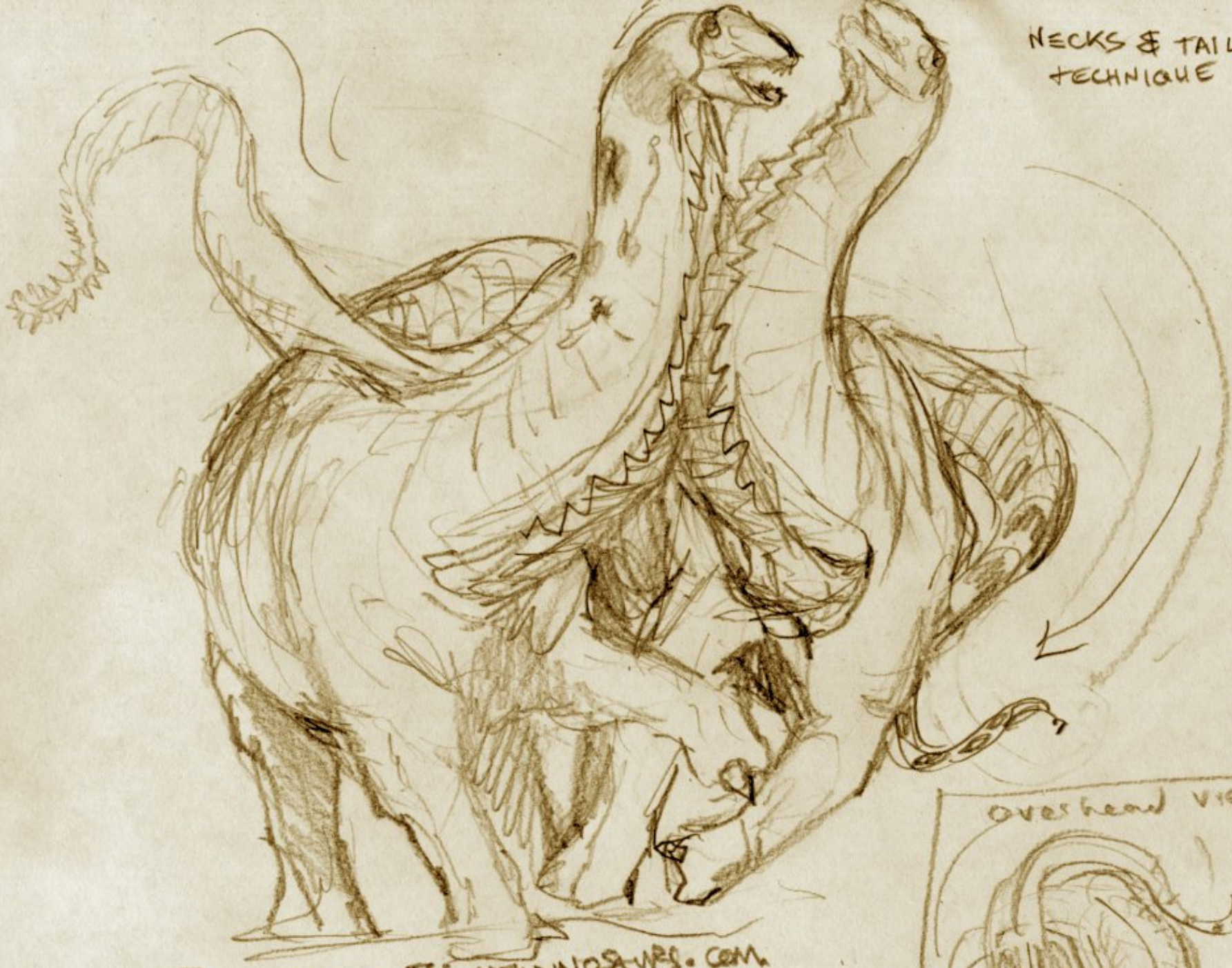

overhead view!

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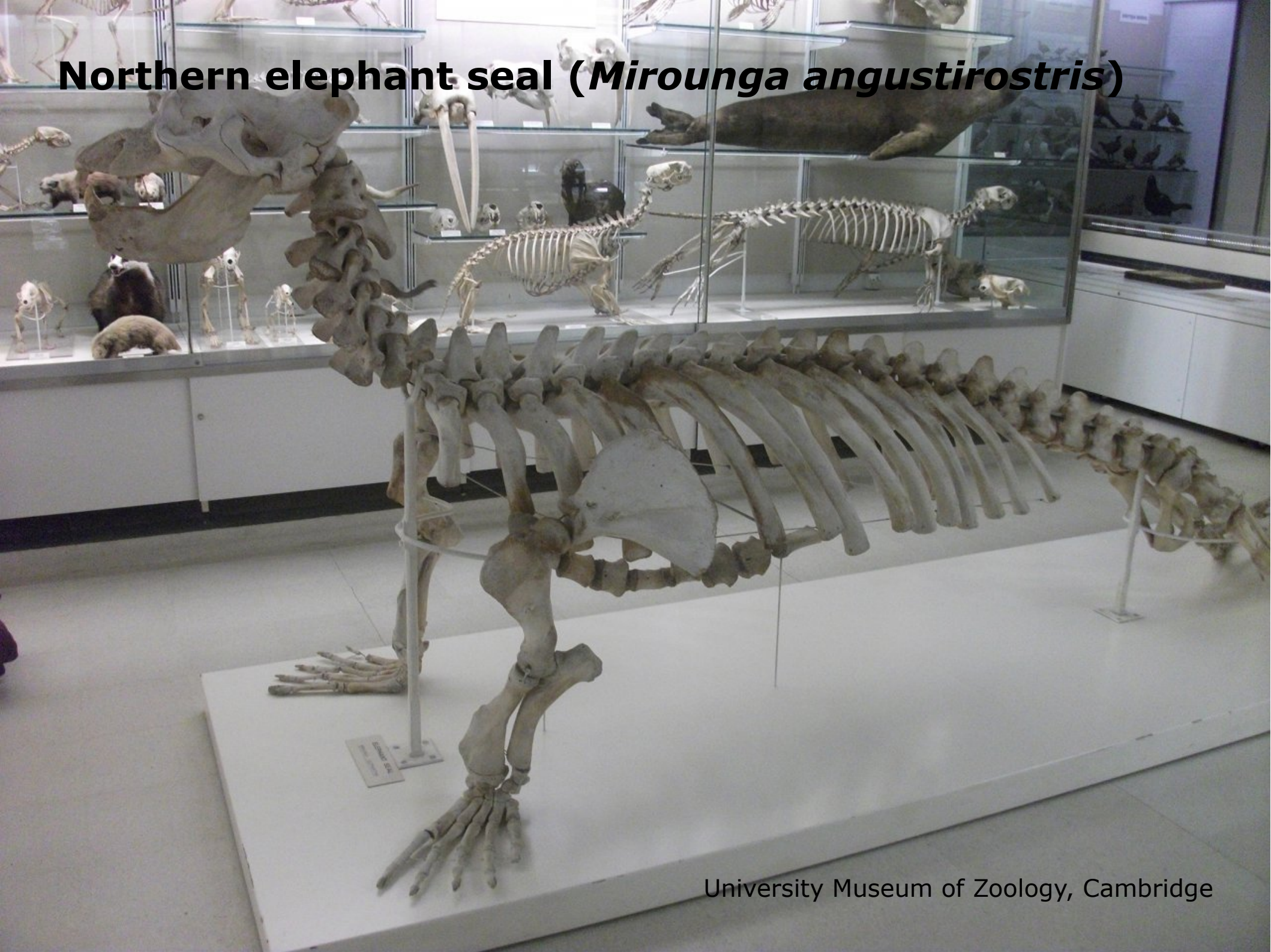
Male southern elephant seals (*Mirounga leonina*)

Male northern elephant seals (*Mirounga angustirostris*)


Male northern elephant seals (*Mirounga angustirostris*)

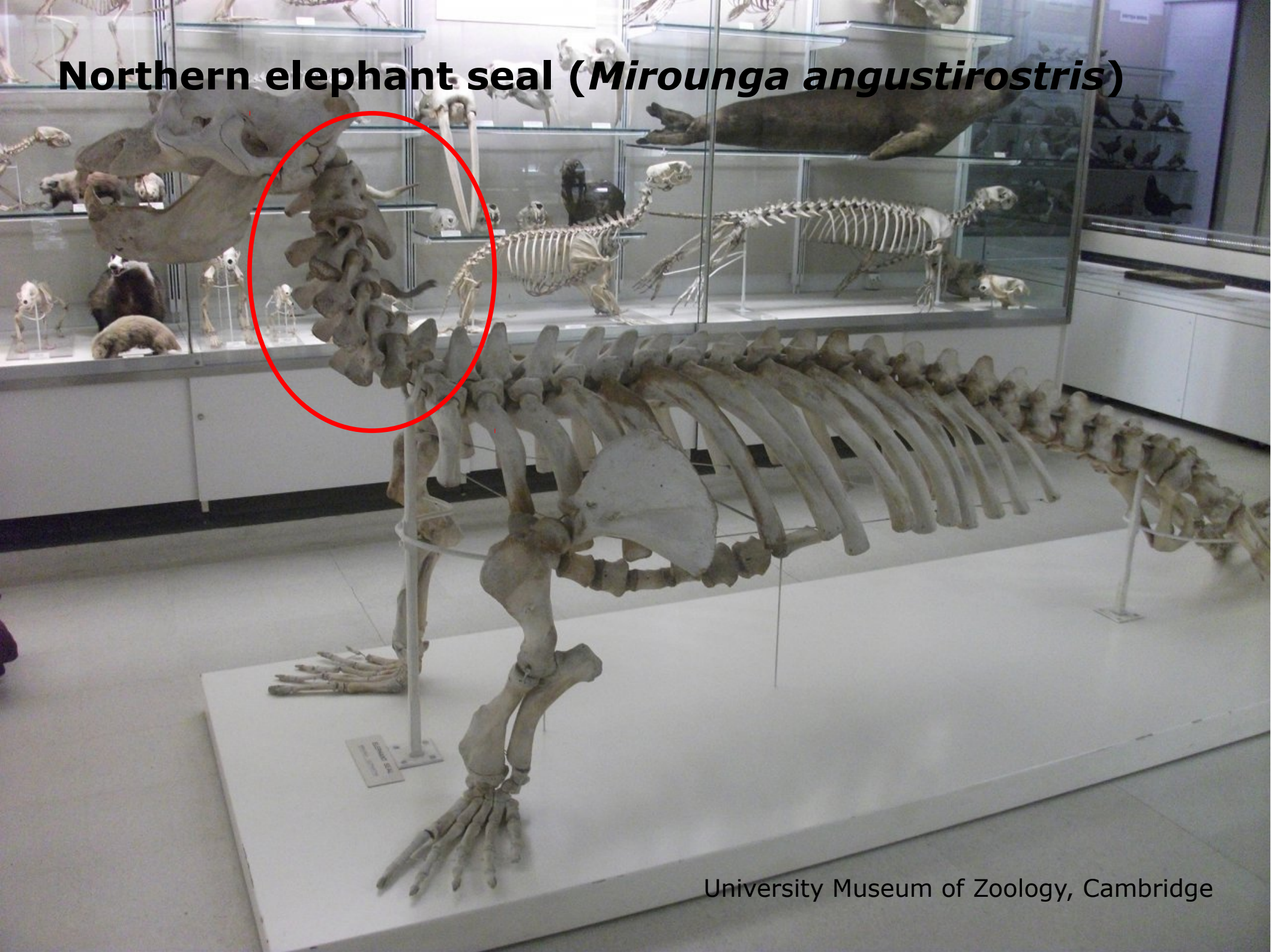
Male southern elephant seal (*Mirounga leonina*)

Northern elephant seal (*Mirounga angustirostris*)



University Museum of Zoology, Cambridge

Northern elephant seal (*Mirounga angustirostris*)



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Sea lion (*Zalophus californianus*)

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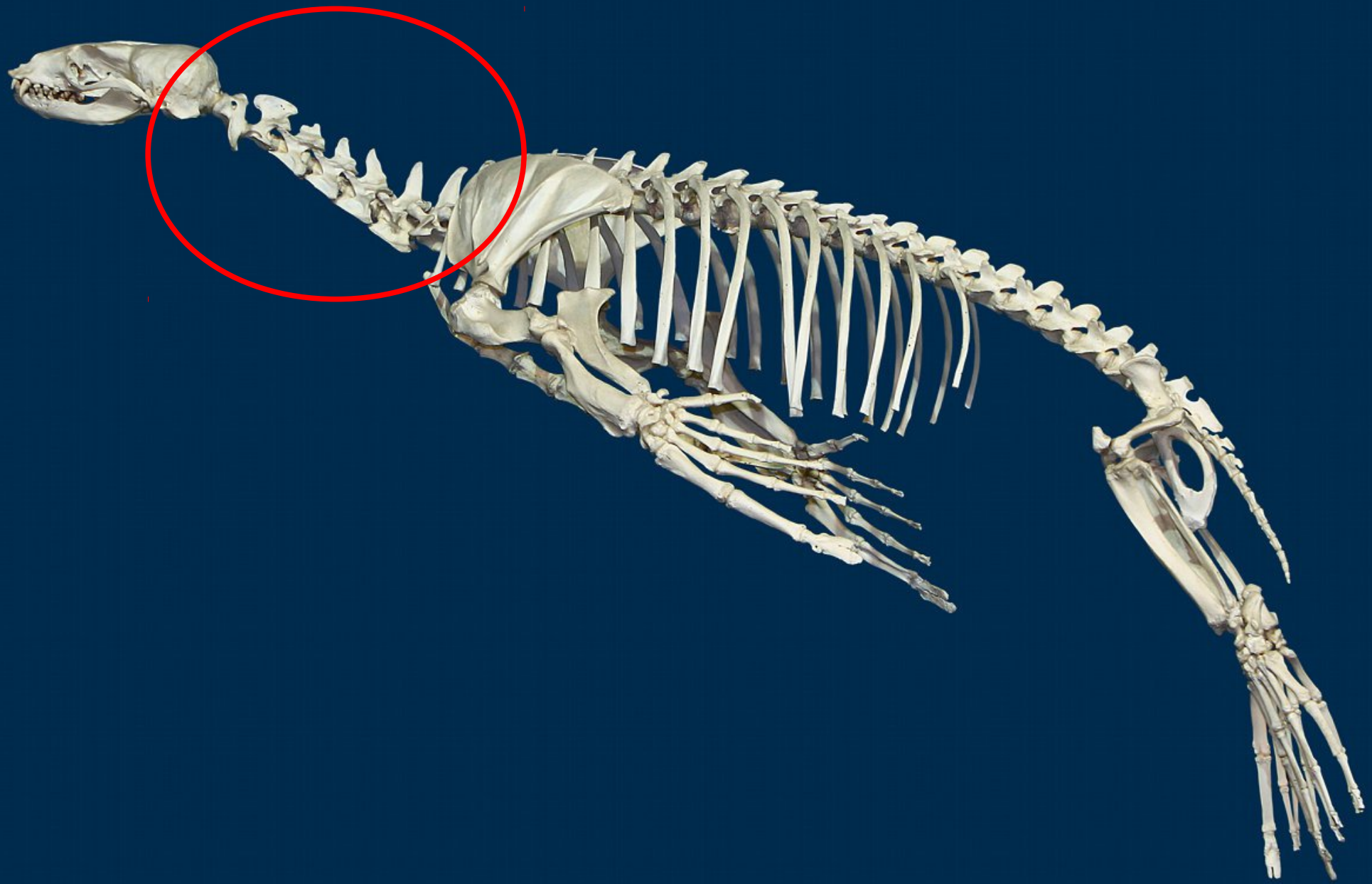


Huge soft-tissue envelope

Extremely inexact analogue


Brian Engh