What do we mean by the directions “cranial” and “caudal” on a vertebra?

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This may seem like a boring subject

But like many boring things, it's necessary.

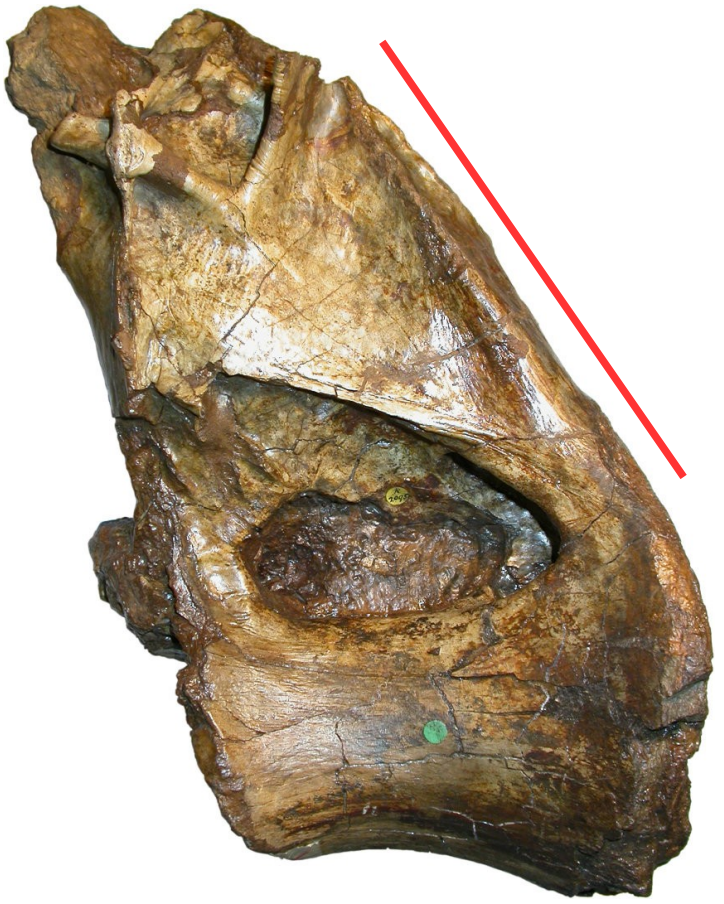
Xenoposeidon proneneukos NHMUK PR 2095

Diagnosis (from Taylor 2018):

1. Neural arch covers dorsal surface of centrum.
2. Neural arch slopes anteriorly 30°–35° relative to the vertical.
3. Sharp oblique lamina above lateral fossa forms ventral border of a broad, flat area.
4. Very large, teardrop-shaped anterior fossa.
5. Arched laminae form vaulted boundary of anterior fossa.

Xenoposeidon proneneukos NHMUK PR 2095

"Neural arch slopes anteriorly 30°–35° relative to the vertical."



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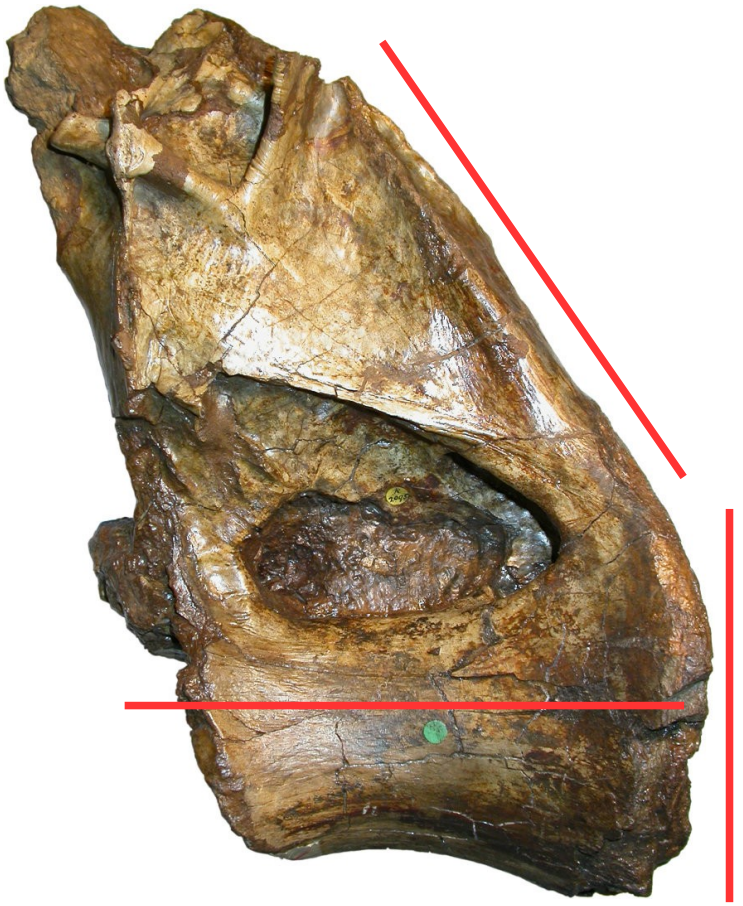

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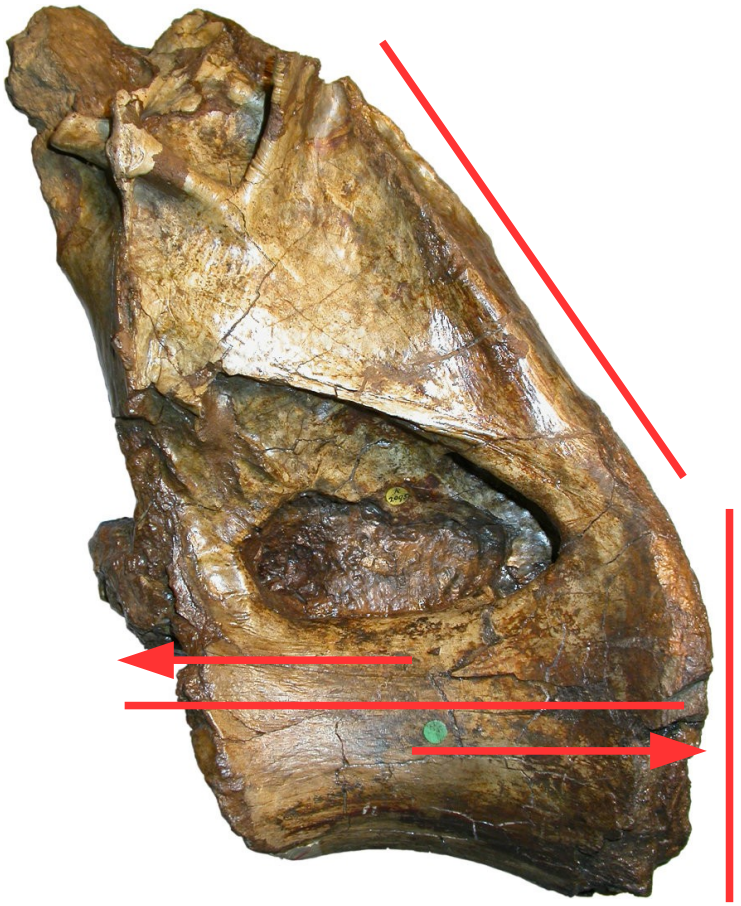

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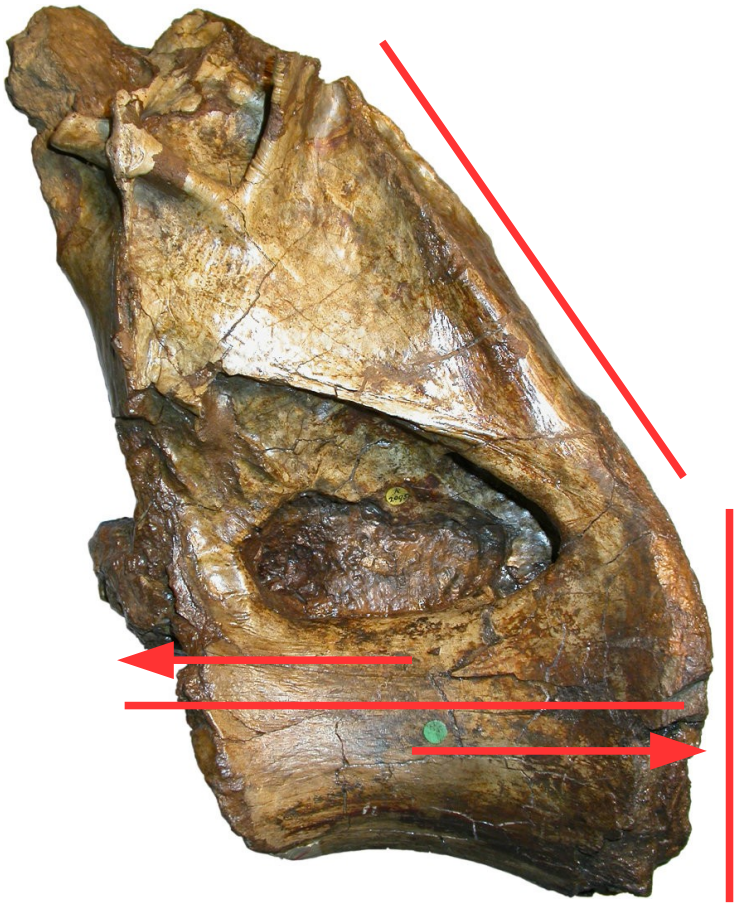

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"Neural arch slopes anteriorly 30°–35°
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How can we evaluate this unless we know what is "vertical"?

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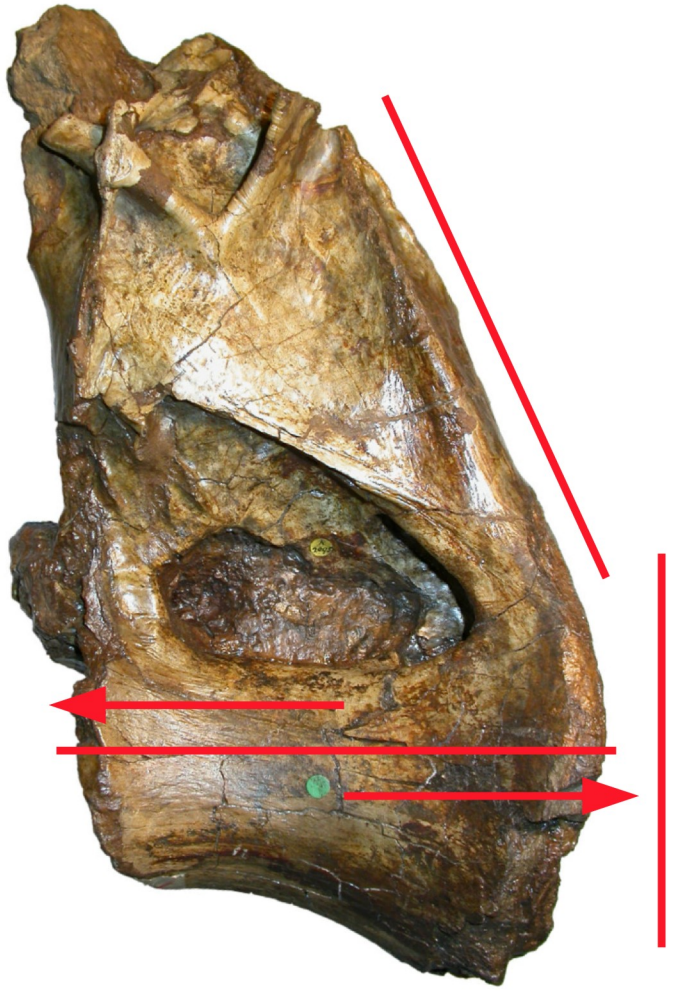
But what directions are those?

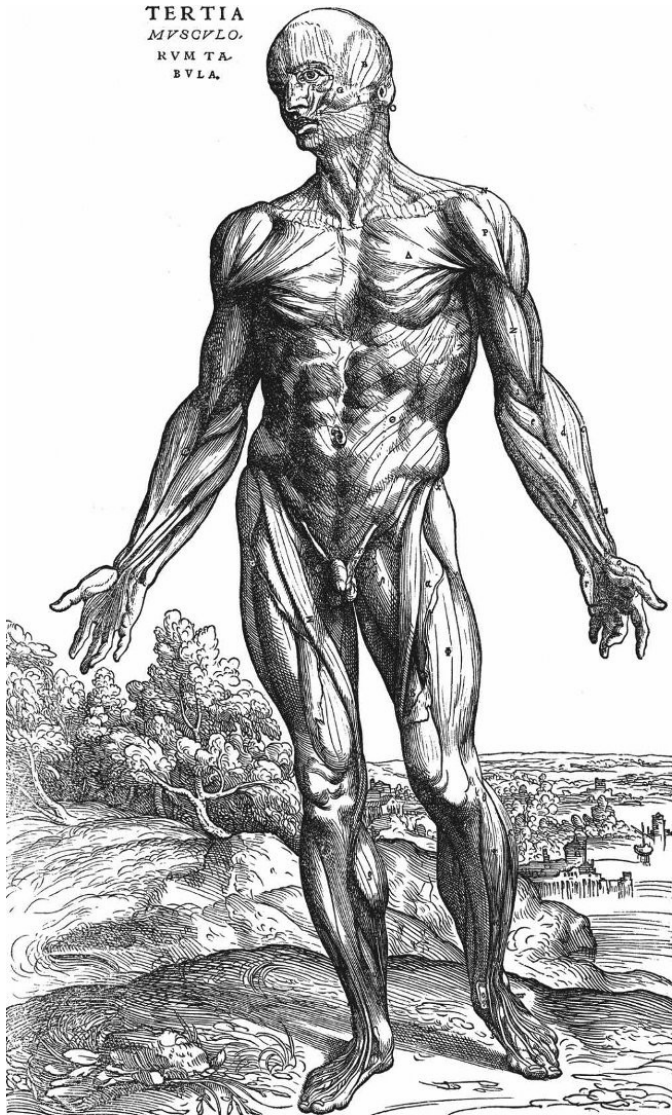
What if the vertebra should be rotated
10° "backwards"



A terminological note

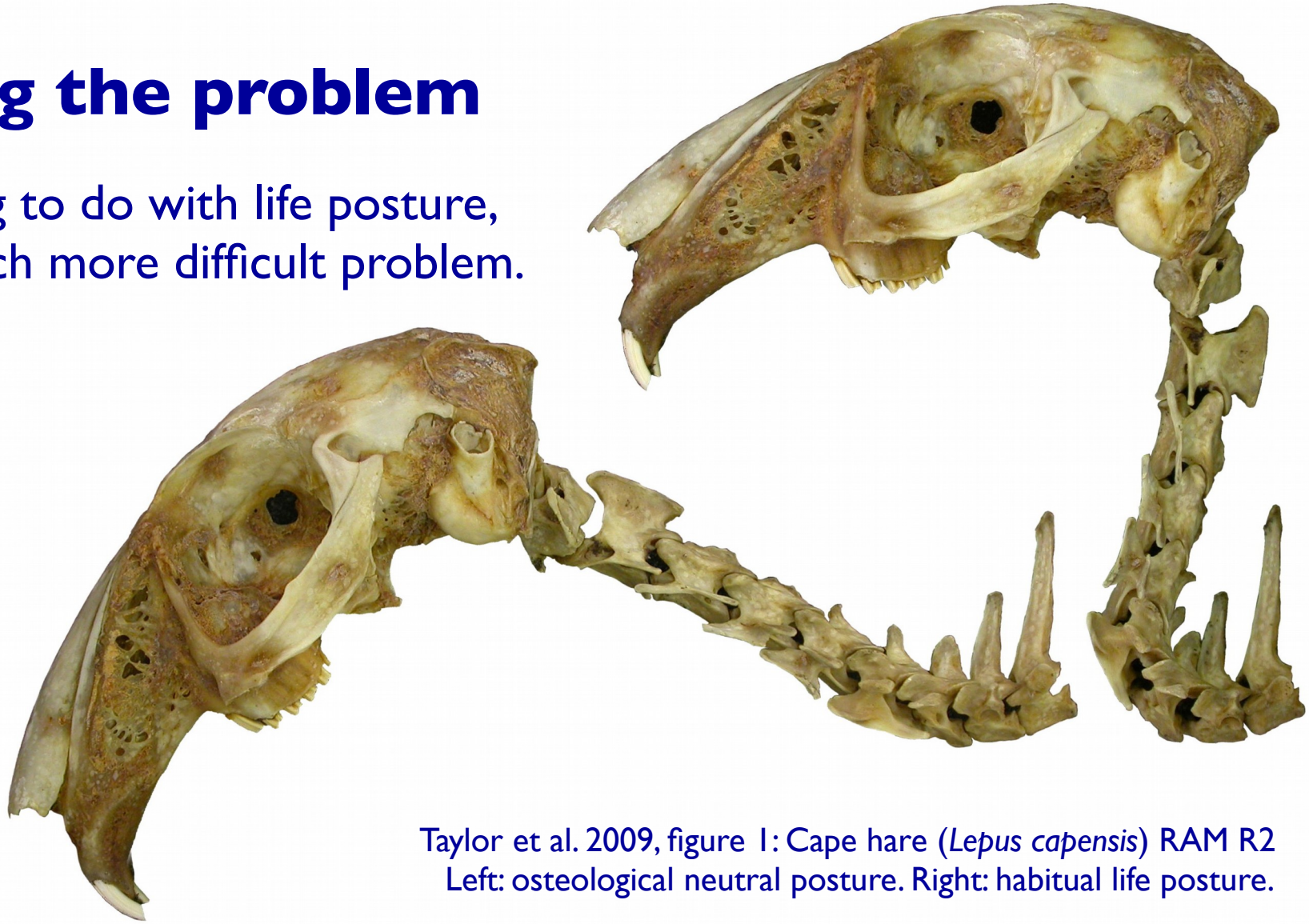
Usually, we prefer “anterior”/“posterior”.

But our goal here is truly universal definitions.



Clarifying the problem

This is nothing to do with life posture, which is a much more difficult problem.



Taylor et al. 2009, figure 1: Cape hare (*Lepus capensis*) RAM R2
Left: osteological neutral posture. Right: habitual life posture.

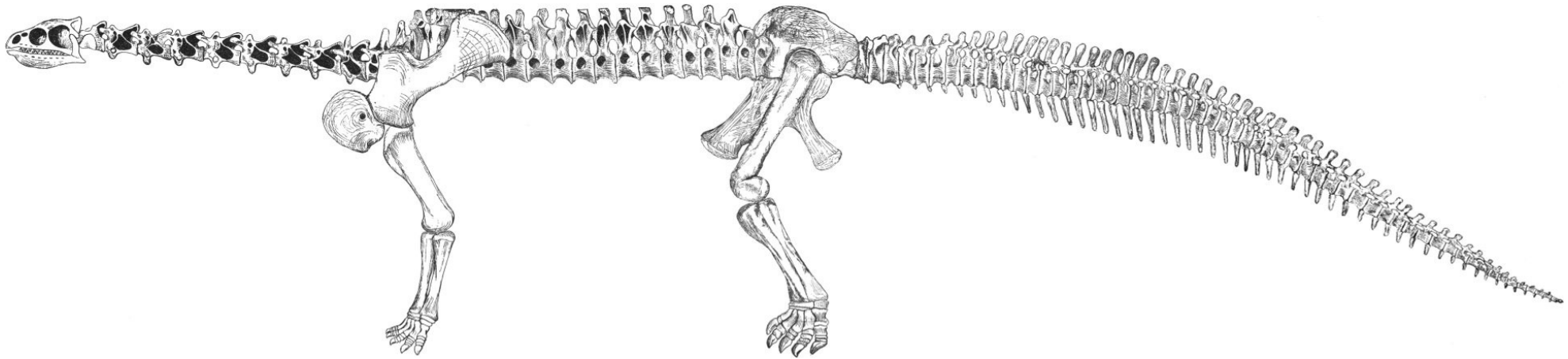
Clarifying the problem

We don't want a “horizontal”
that's upside-down!

Hemisected parrot (probably *Amazona ochrocephala*) in the Natuurhistorisch Museum of Rotterdam, from a post on *Love in the Time of Chasmosaurs*, 4 August 2012.

Clarifying the problem

We want an "ideal" horizontal.



Ryder's 1877 *Camarasaurus*

Consistency

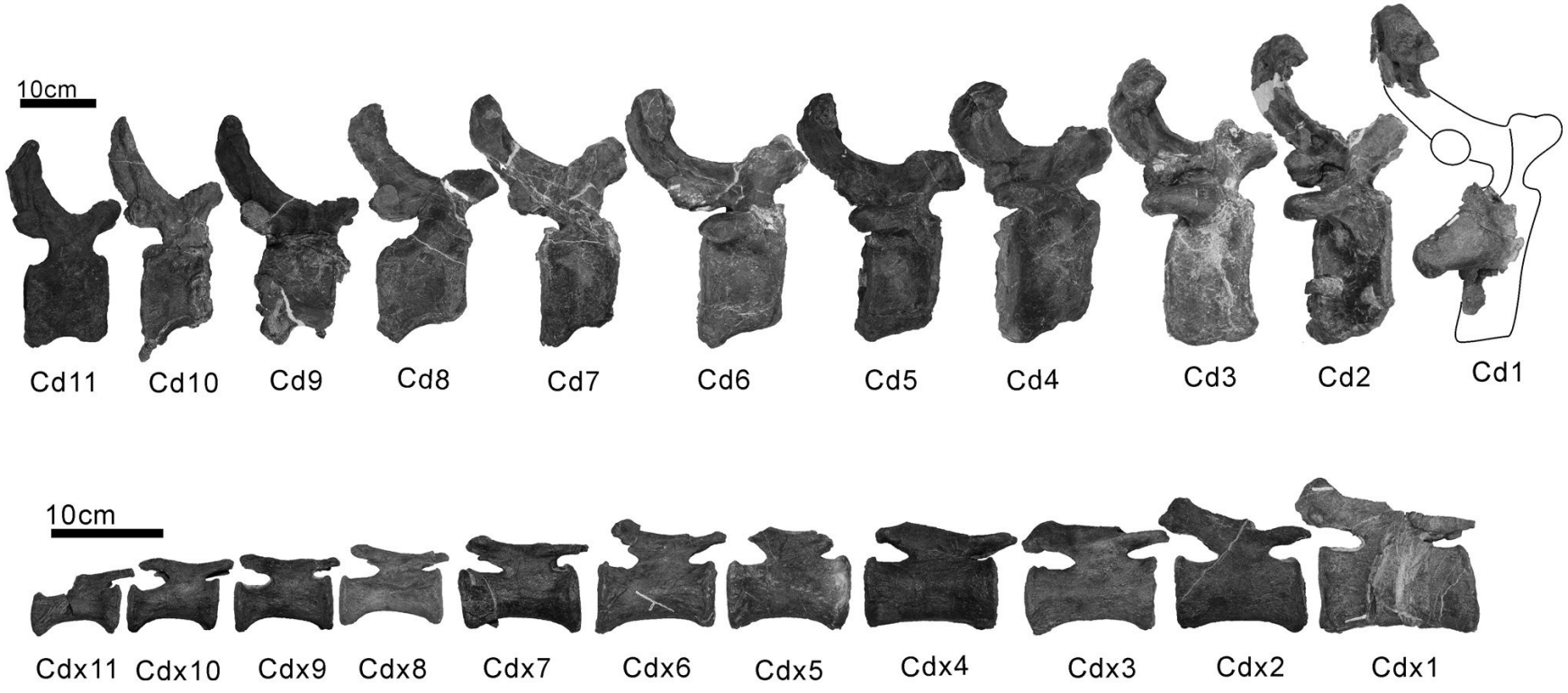
So that characters such as “Neural arch slopes cranially 30° relative to the vertical” become objective measurements rather than being disputable.

Consistency

For big animals like sauropods, vertebrae are usually oriented however they sit most easily on their pallets.

Consistency

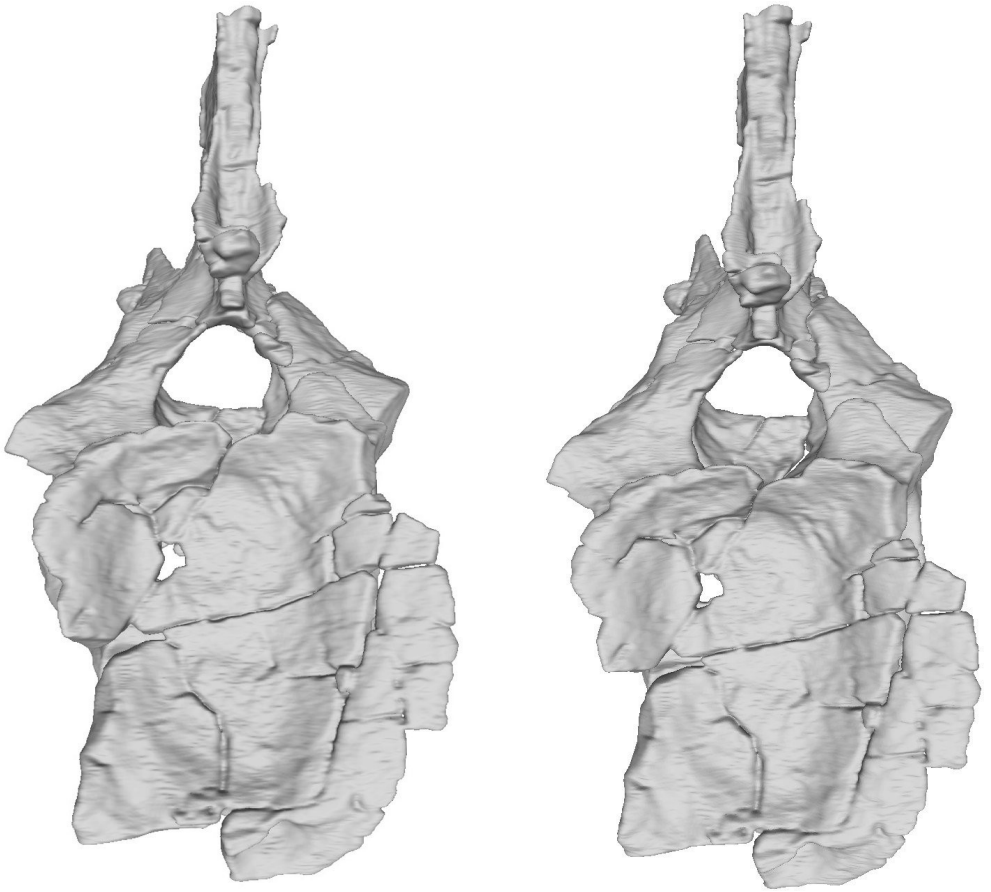
Differing vertebral shapes across taxa, and regions of the spinal column.



Saegusa and Ikeda (2104: fig. 8): *Tambatitanis amicitiae* holotype (MNHAH D-1029280) caudals, right lateral view

Consistency

There are biological questions that we can't answer unless the vertebra is correctly oriented: e.g., measuring cross-sectional area of the neural canal.



Haplocanthosaurus caudal ?3, MWC 8028

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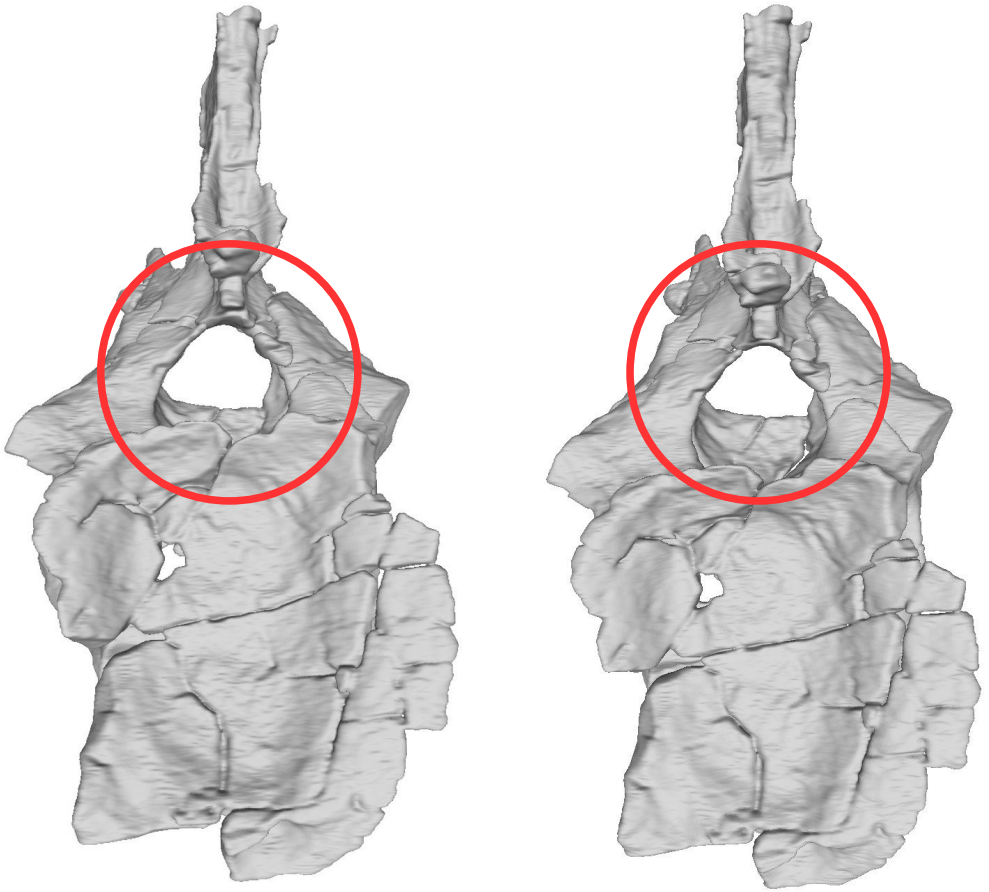


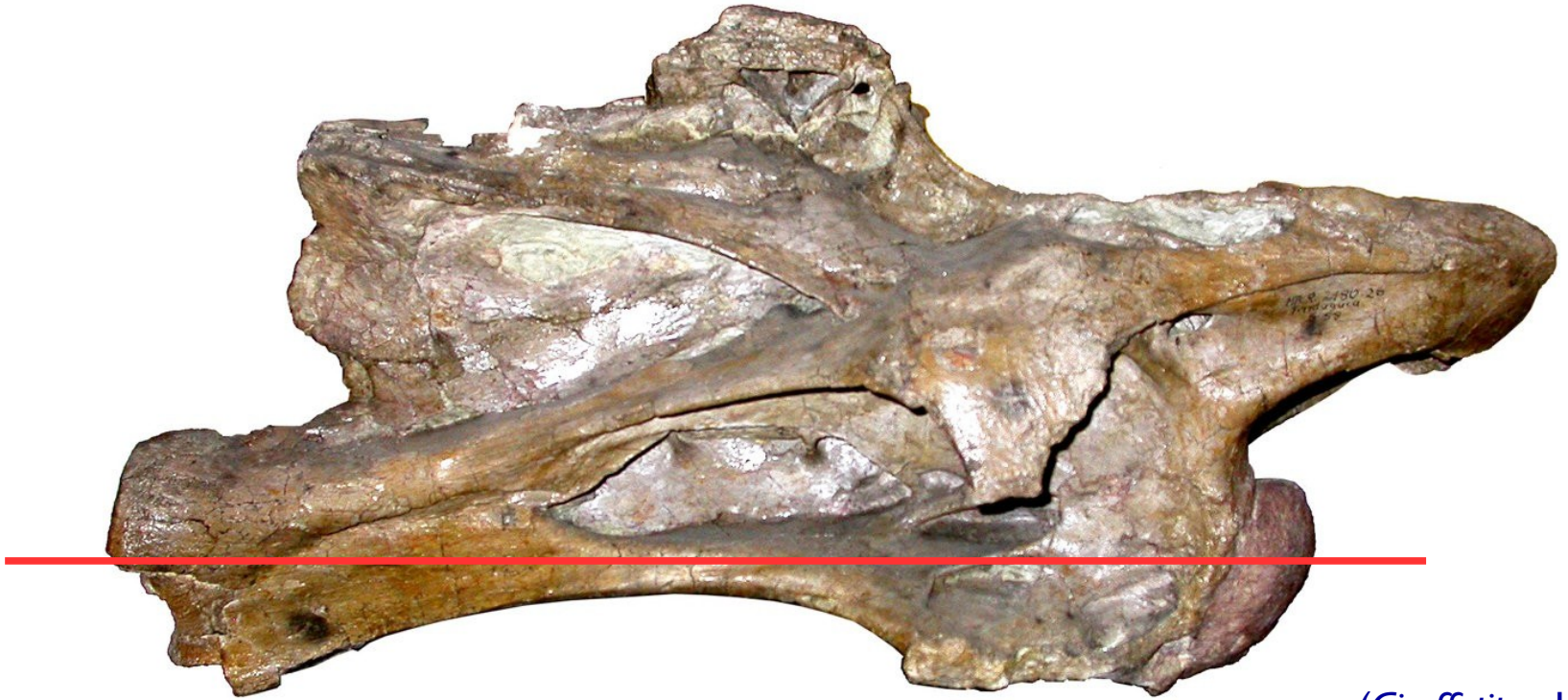
Haplocanthosaurus caudal ?3, MWC 8028

Four definitions of “horizontal”

1. Long axis of centrum is horizontal
2. Articular facets of centrum are vertical
3. Neural canal is horizontal
4. Similarity in articulation

1. Long axis of centrum is horizontal

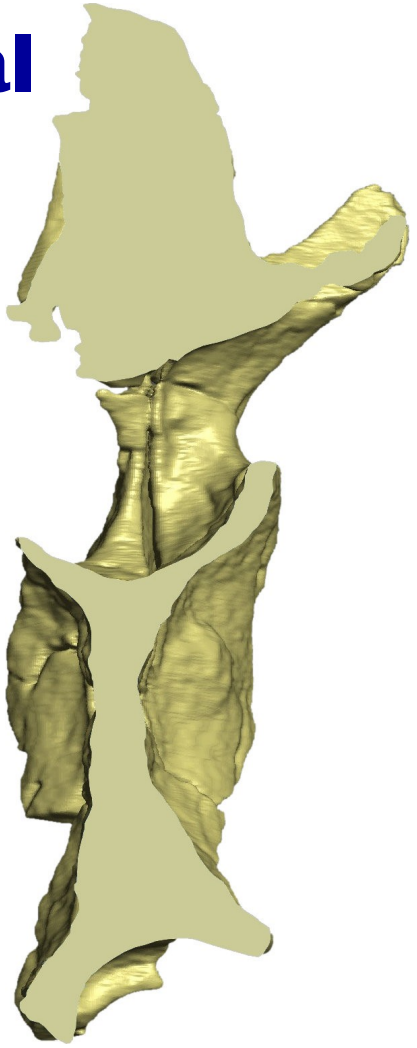
This is appealing for elongate vertebrae such as sauropod cervicals.



(*Giraffatitan* HMN SI cervical C5)

1. Long axis of centrum is horizontal

But it's difficult to determine for craniocaudally short vertebrae such as most caudals.



1. Long axis of centrum is horizontal

And where is “half height” at the front and the back?

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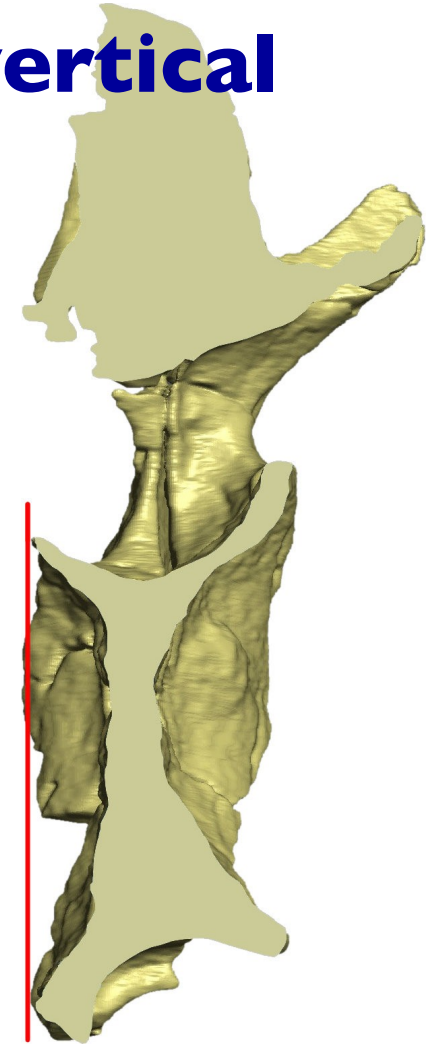
And where is “half height” at the front and the back?

2. Articular facets of centrum are vertical

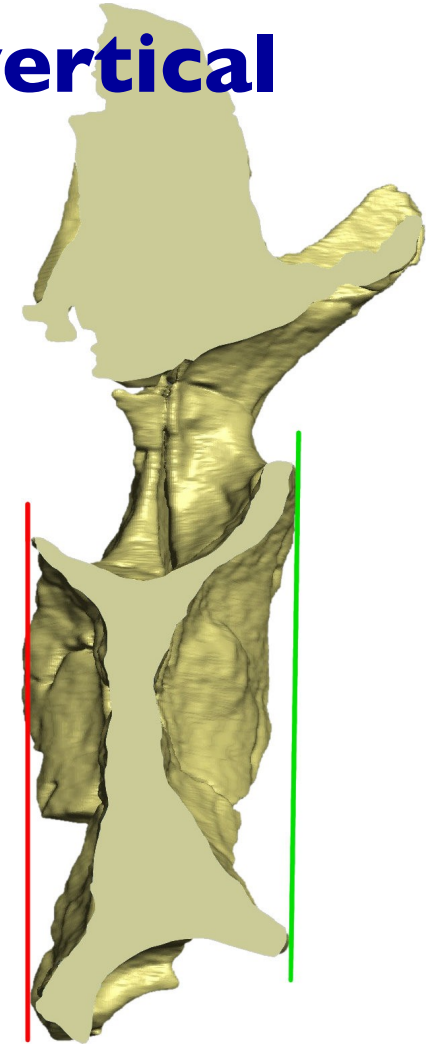
This is appealing for short, tall vertebrae.



2. Articular facets of centrum are vertical

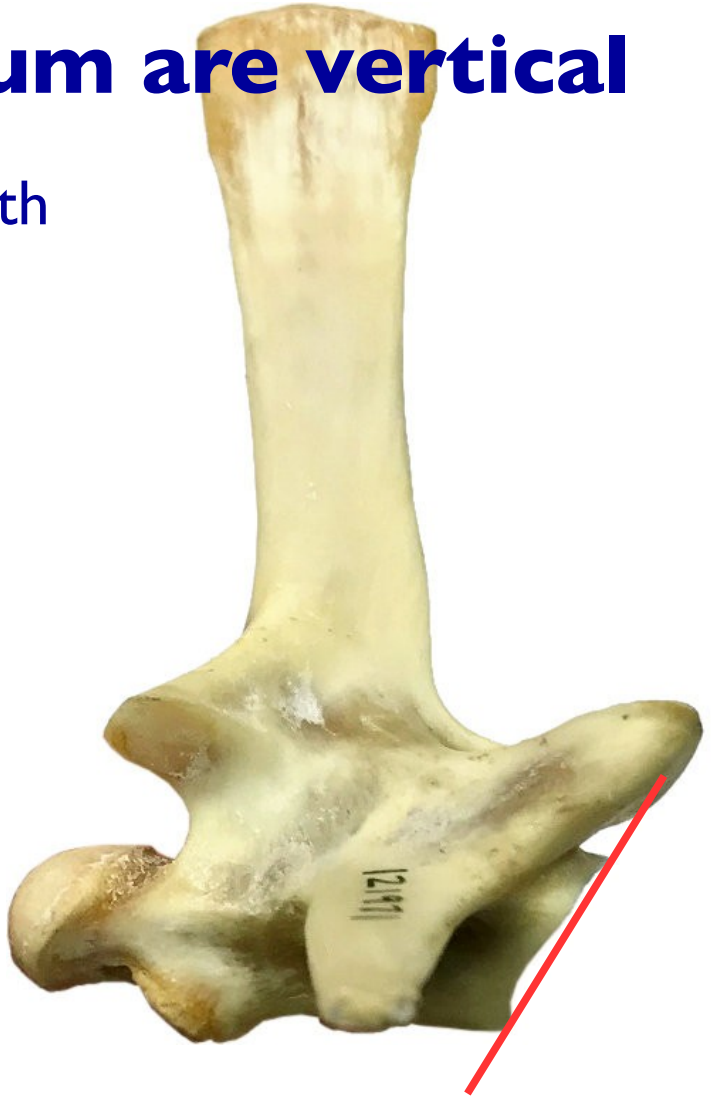
This is appealing for short, tall vertebrae.

But ambiguous when anterior and posterior facets are not parallel.



2. Articular facets of centrum are vertical

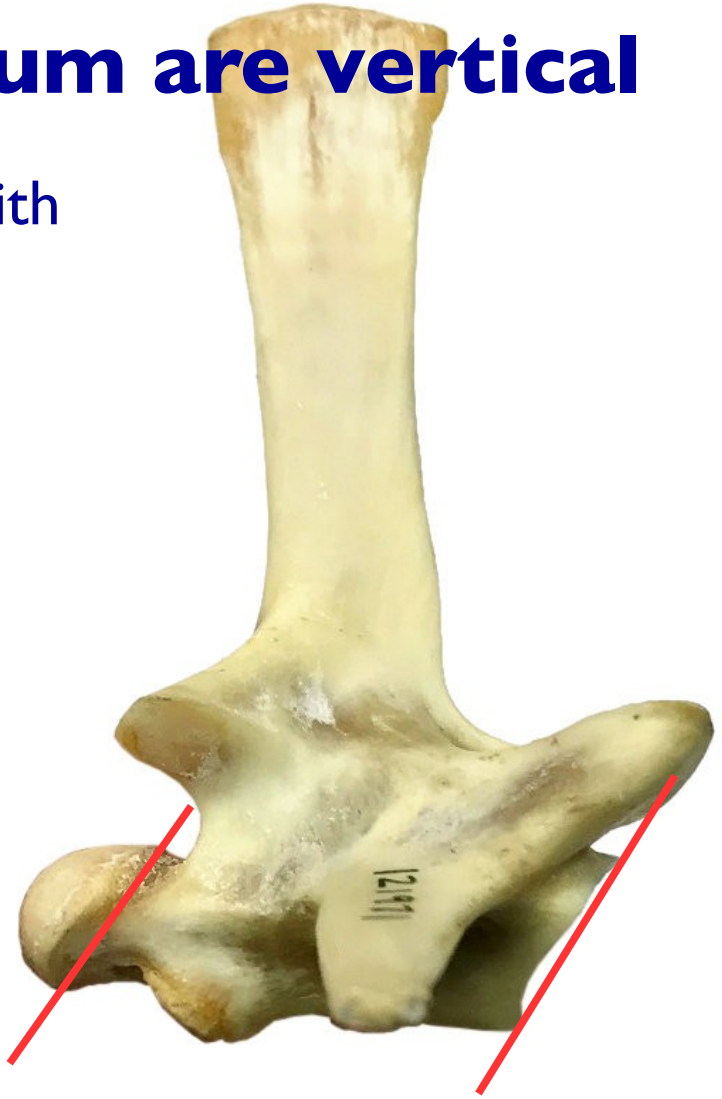
This is difficult to determine when dealing with facets that are concave.



Varanus komodoensis (Komodo dragon) caudal vertebra
LACM herp. 121971, right lateral view

2. Articular facets of centrum are vertical

This is difficult to determine when dealing with facets that are concave or (worse) convex.



Varanus komodoensis (Komodo dragon) caudal vertebra
LACM herp. 121971, right lateral view

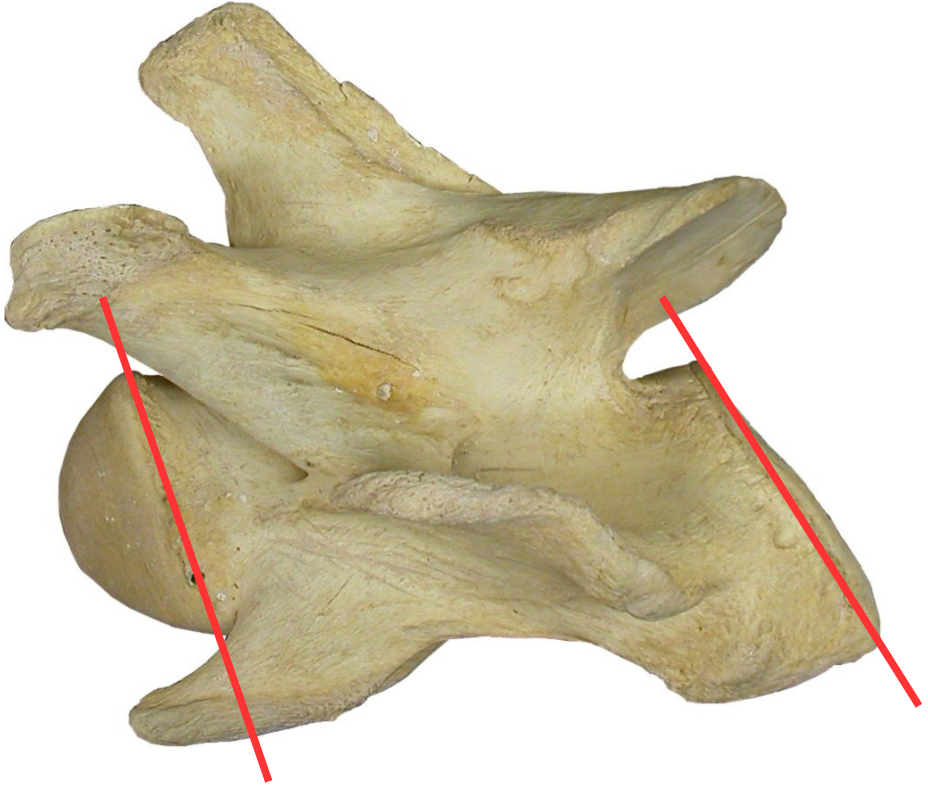
2. Articular facets of centrum are vertical

And would we *want* this vertebra oriented with the facets vertical?

Varanus komodoensis (Komodo dragon) caudal vertebra
LACM herp. 121971, right lateral view

2. Articular facets of centrum are vertical

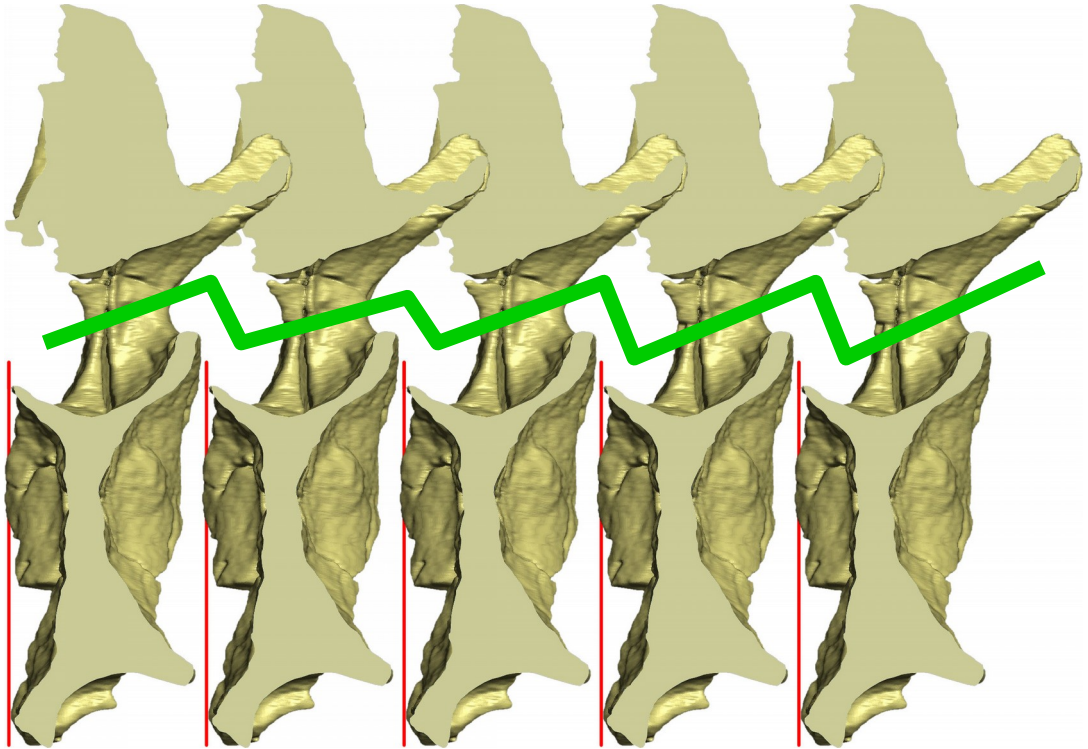
Ambiguous for "keystoned" vertebrae in which the facets are not parallel.



Giraffe *Giraffa camelopardalis*
FMNH 34426, cervical 7
in left lateral view

2. Articular facets of centrum are vertical

This interpretation of horizontality can make the neural canal jagged.



2. Articular facets of centrum are vertical

The spinal cord may curve in life, but it never kinks.

Sagittally bisected head and anterior neck of a horse
Veterinary school, Western University of Health Sciences.

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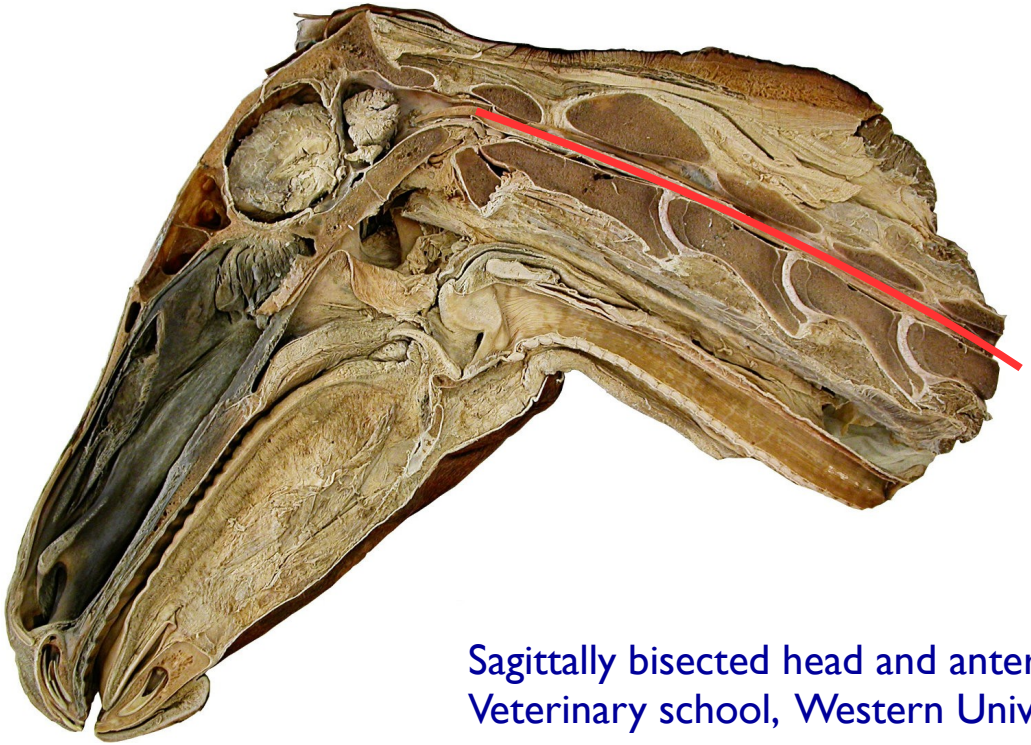
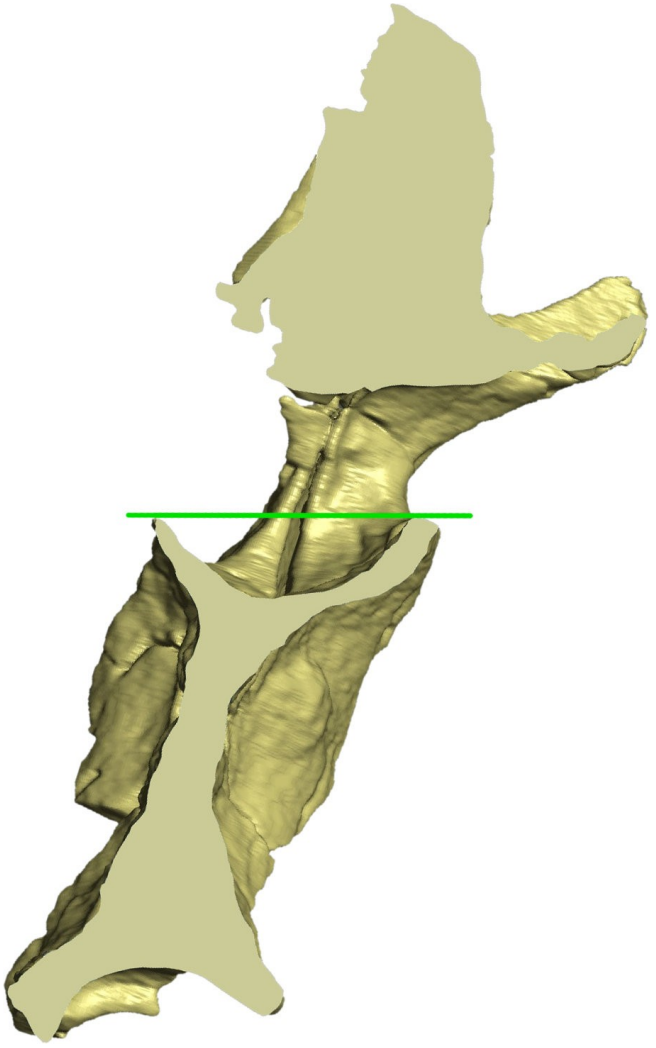


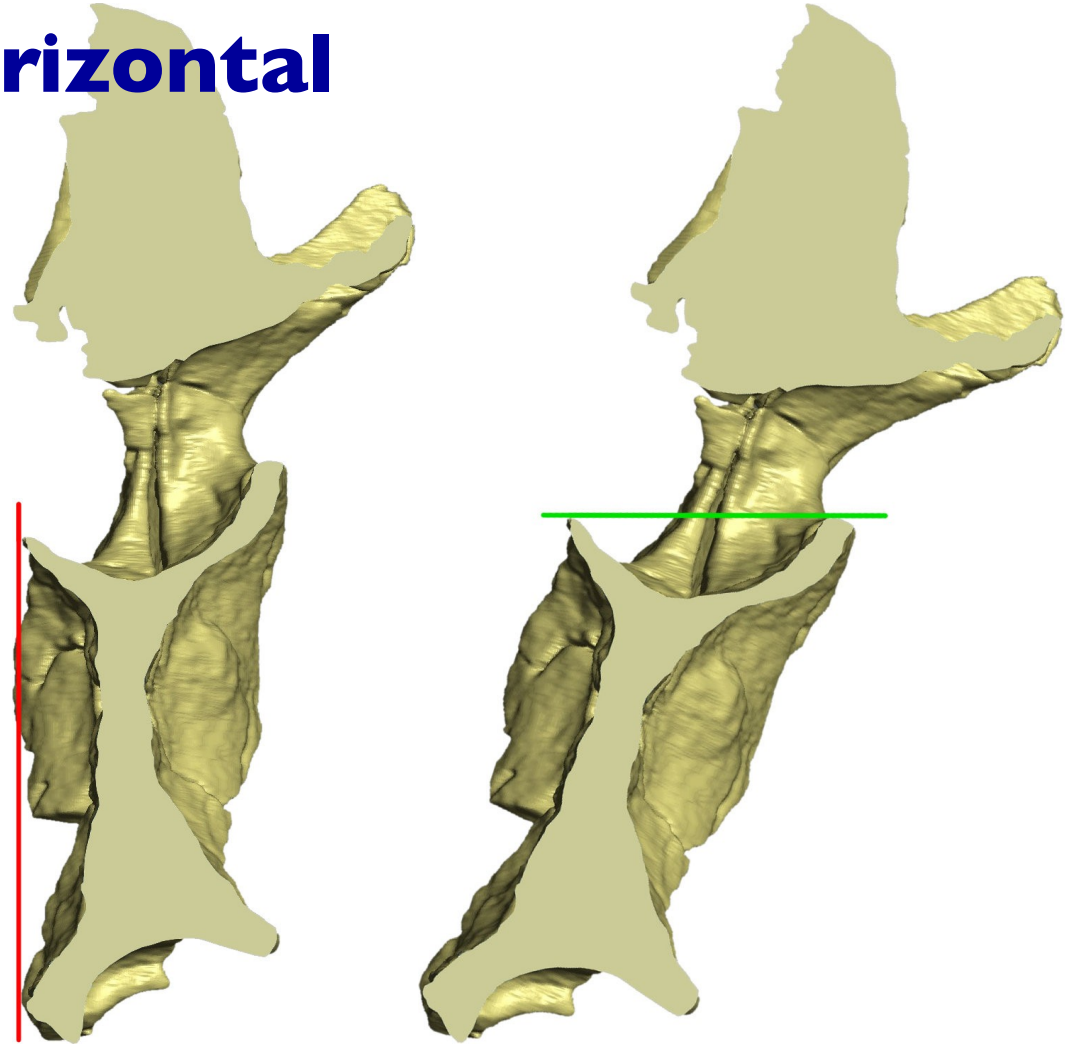
Sagittally bisected head and anterior neck of a horse
Veterinary school, Western University of Health Sciences.

3. Neural canal is horizontal



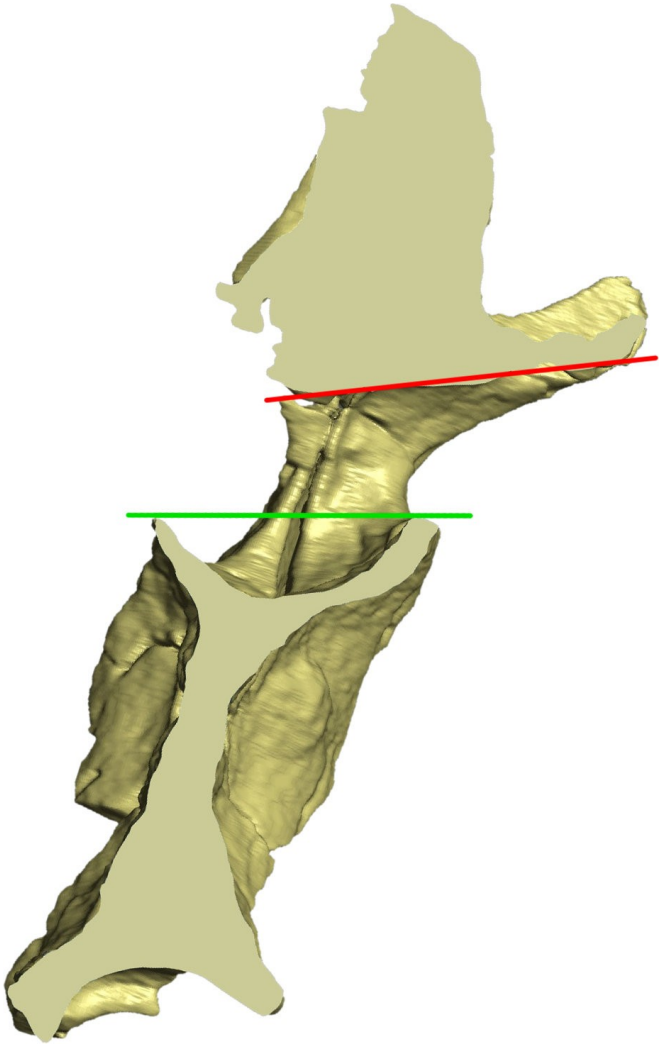
3. Neural canal is horizontal

Can be *very* different
from method 2.



3. Neural canal is horizontal

But ambiguous if dorsal and ventral margins of neural canal are not parallel.



3. Neural canal is horizontal

Low-tech levelling device.

Brachiosaur altithorax holotype
FMNH P 25107, caudals 1 & 2,
Right lateral view.

3. Neural canal is horizontal

This is anatomically informative, reflecting the developmental sequence. The vertebrae form around the spinal cord.

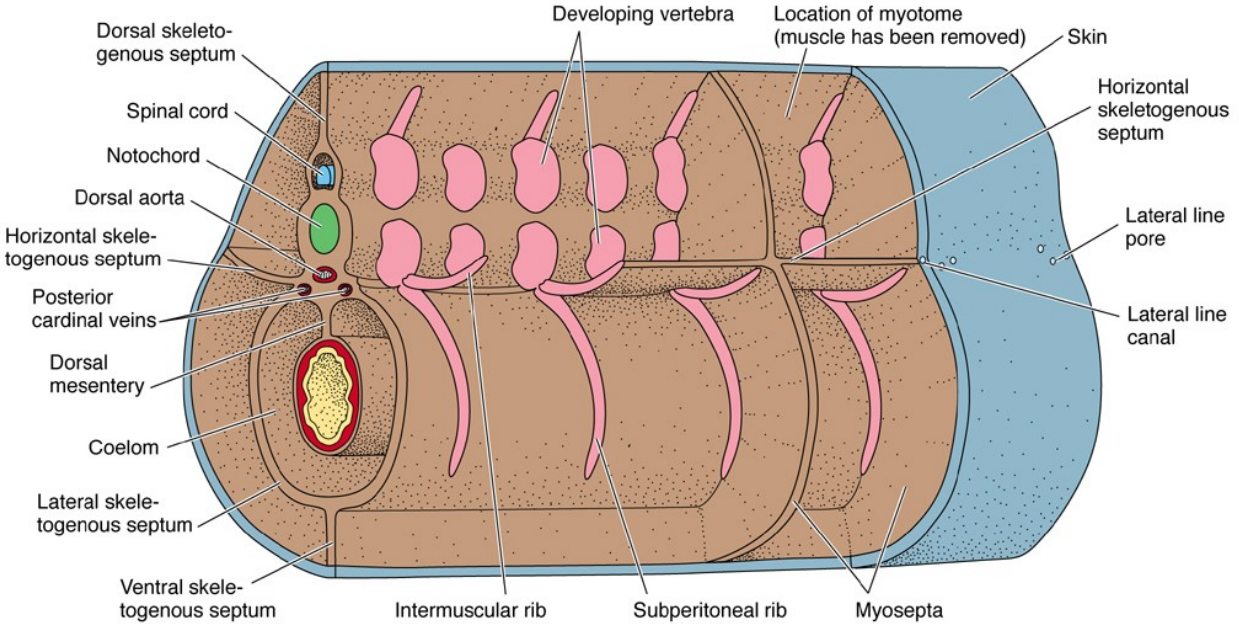


Fig. 8.3

Liem et al. (2001): fig 8.3.

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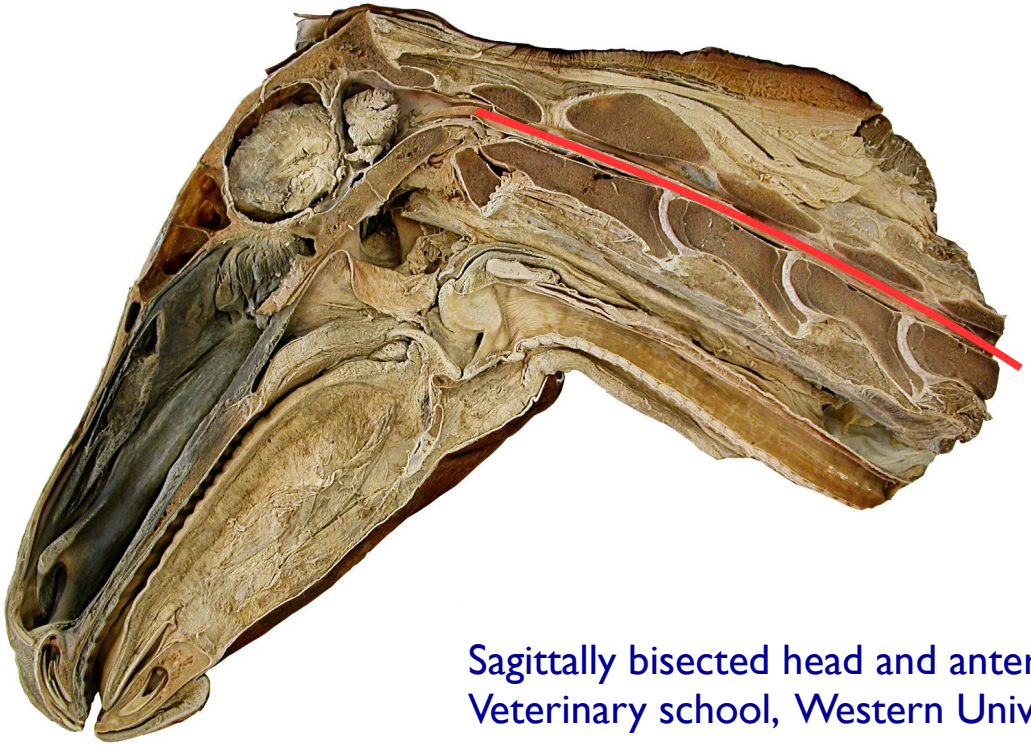


Sagittally bisected head and anterior neck of a horse
Veterinary school, Western University of Health Sciences.

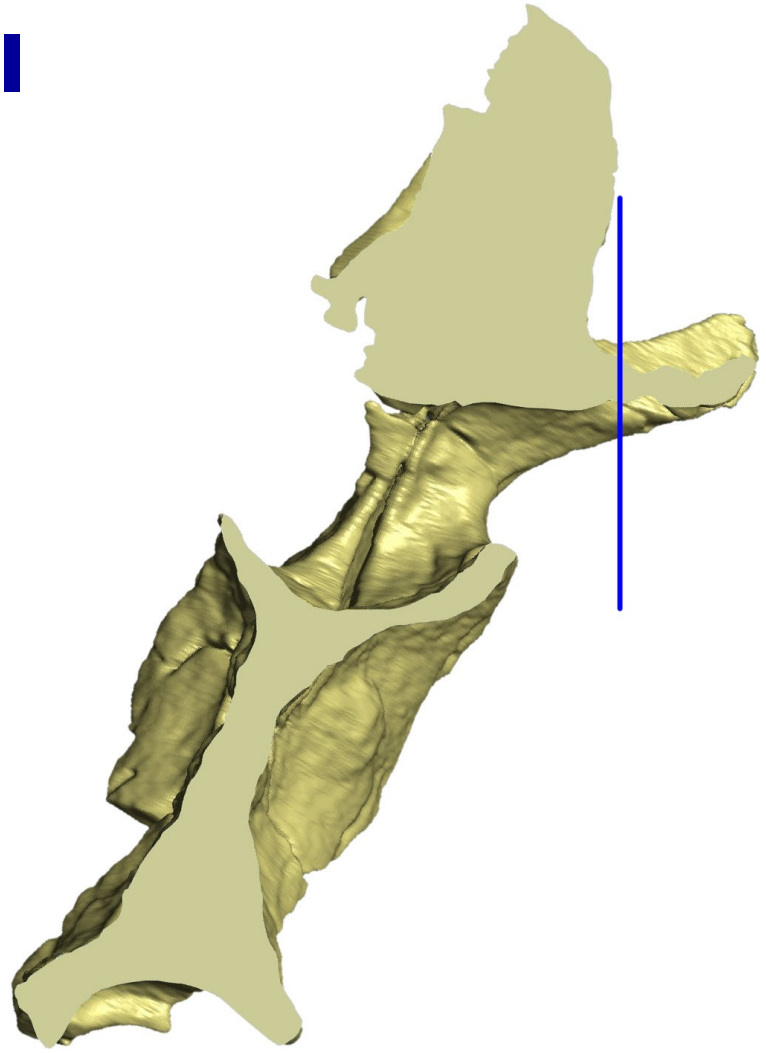
3. Neural canal is horizontal

But it's difficult to determine in vertebrae that have not been fully prepared or CT-scanned, and impossible to see in lateral view.

3. Neural canal is horizontal

But “horizontal” depends on where you think the start and end of the canal are.

Is the front here?



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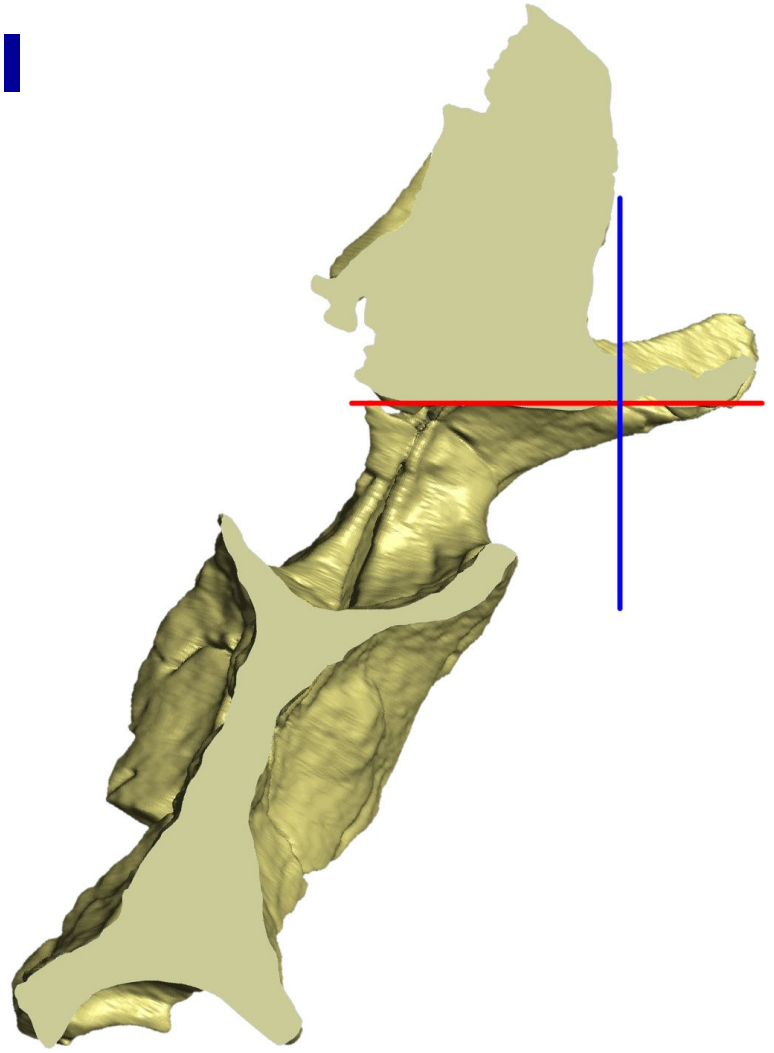

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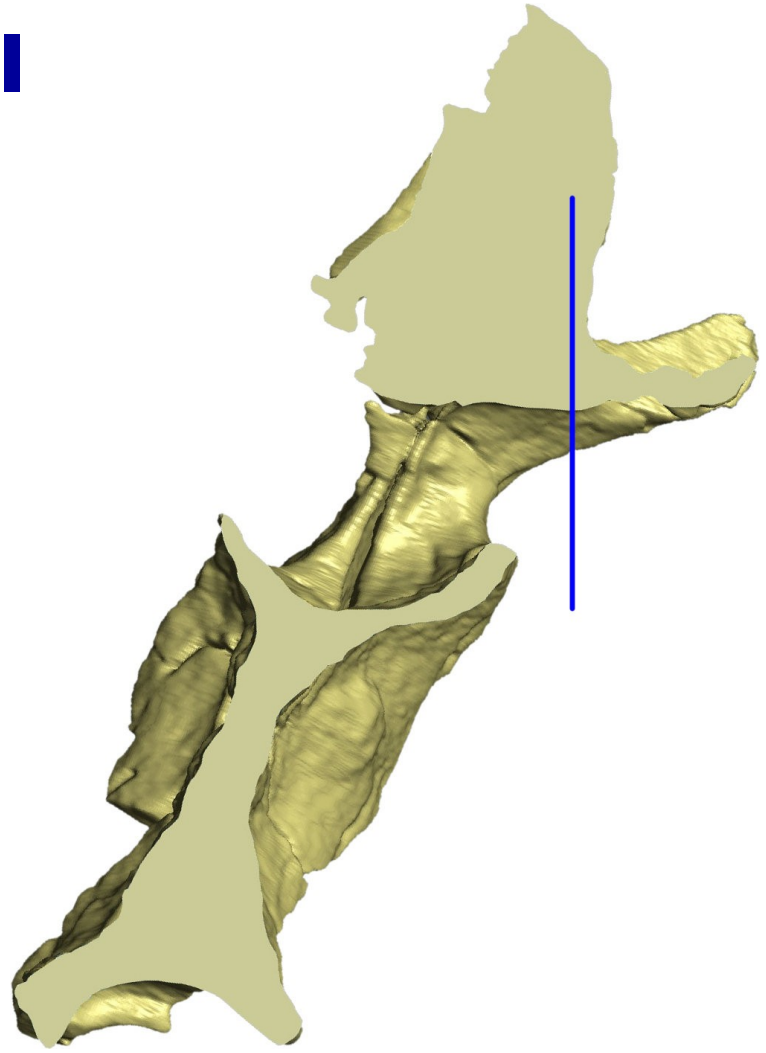

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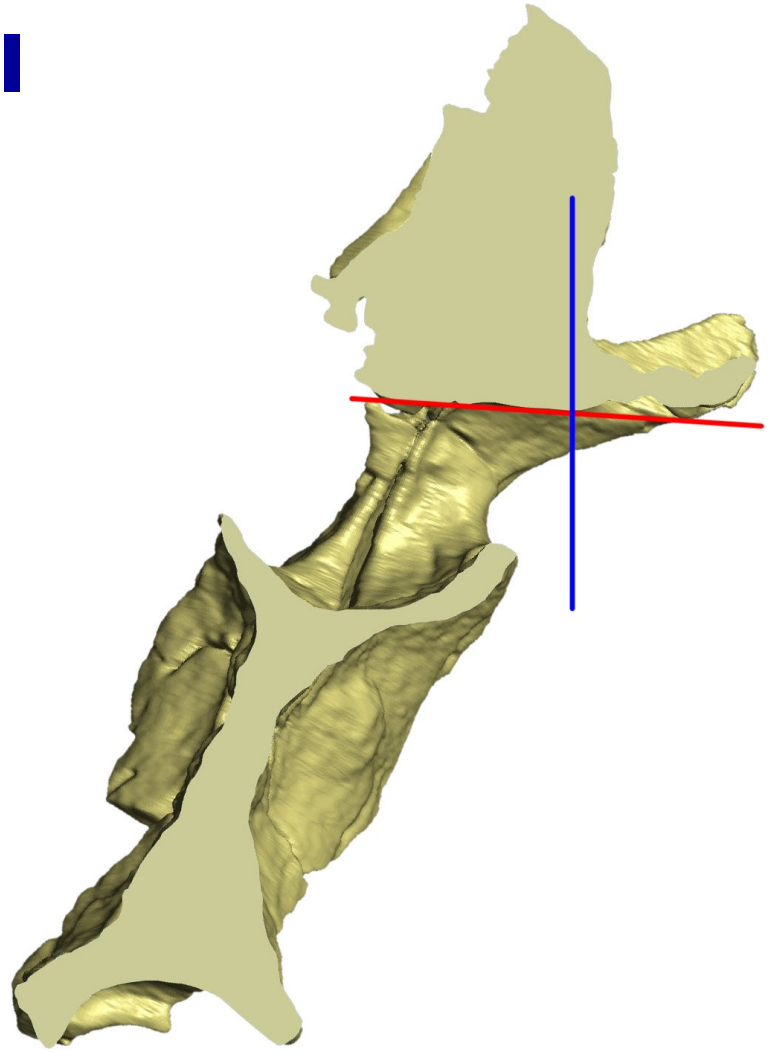
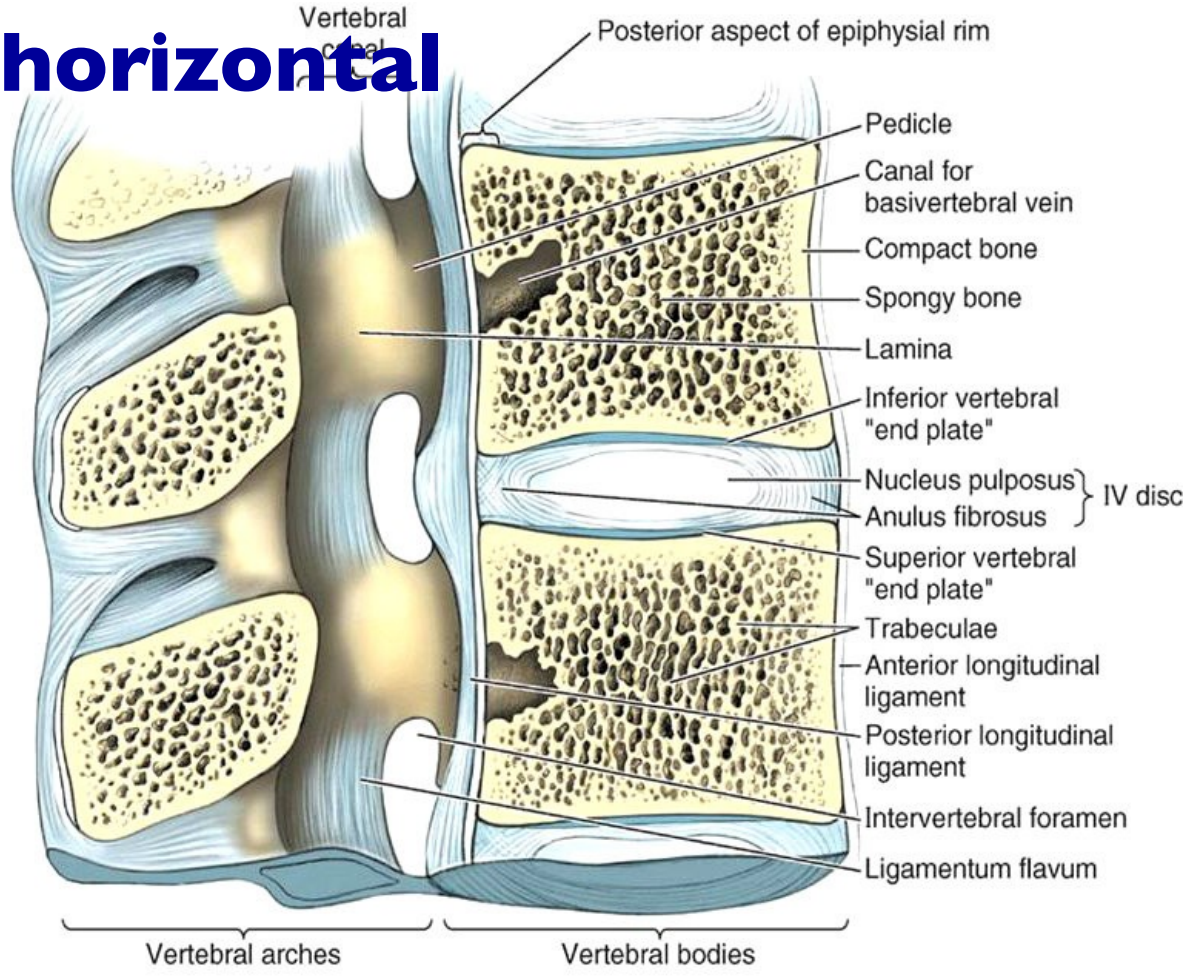


3. Neural canal is horizontal

When one or both of the margins is convex, there is no straight line to measure.



Medial view of left halves of two adjacent hemisected vertebrae

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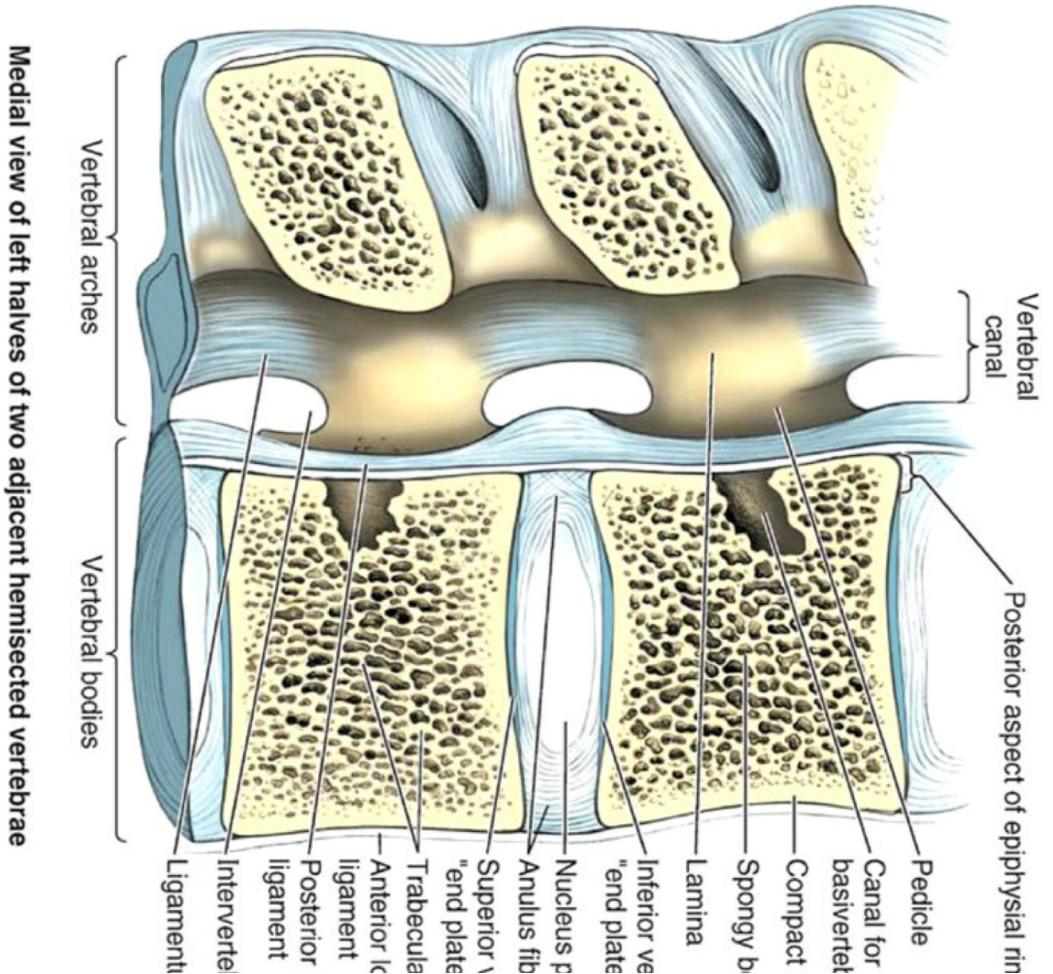

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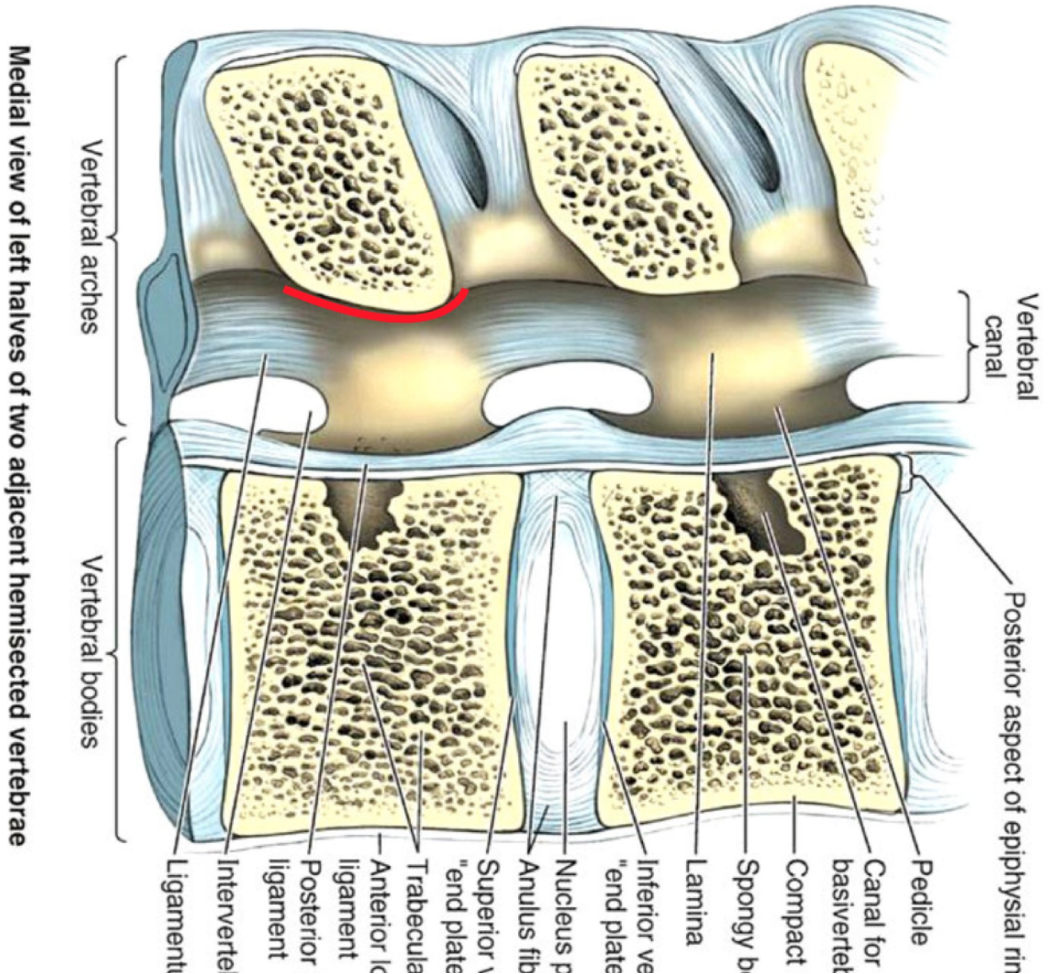

4. Similarity in articulation

Can we find a “horizontal”
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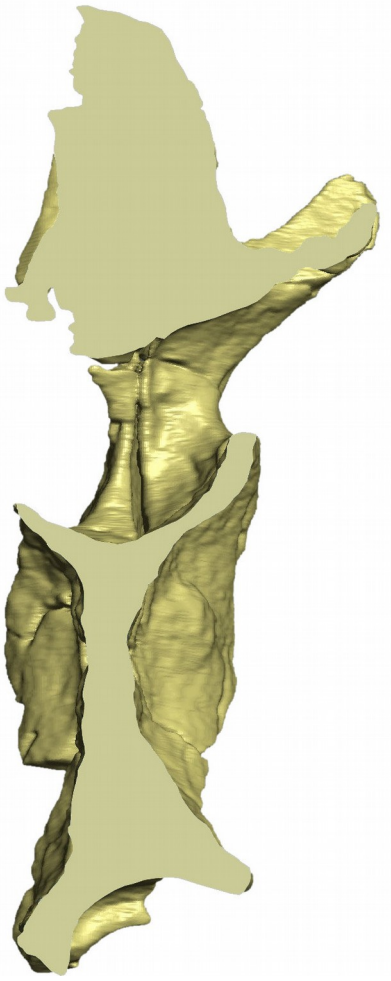
1. Depict the vertebra in *any* orientation.



4. Similarity in articulation

Can we find a "horizontal"
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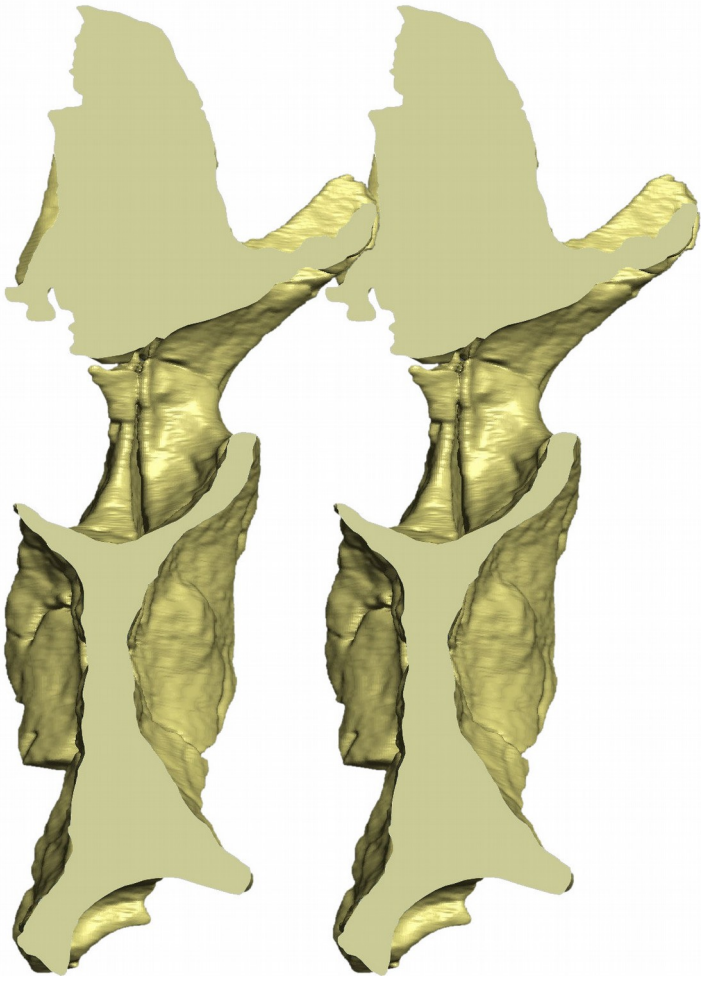
1. Depict the vertebra in *any* orientation.
2. Add another copy in the same orientation



4. Similarity in articulation

Can we find a "horizontal"
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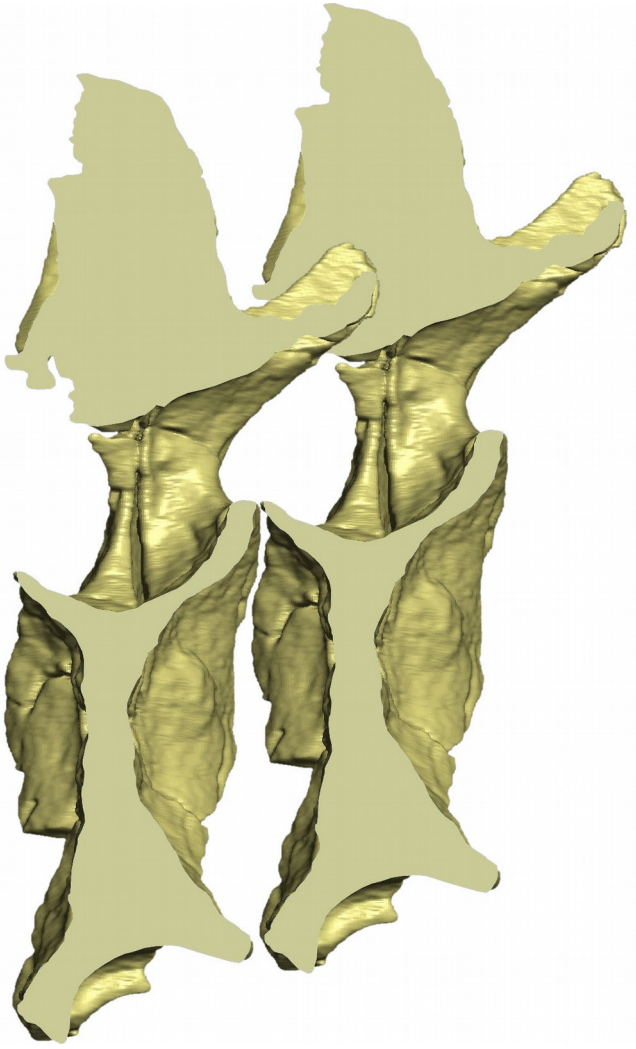
1. Depict the vertebra in *any* orientation.
2. Add another copy in the same orientation
3. Articulate the copies without rotating.



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1. Depict the vertebra in *any* orientation.
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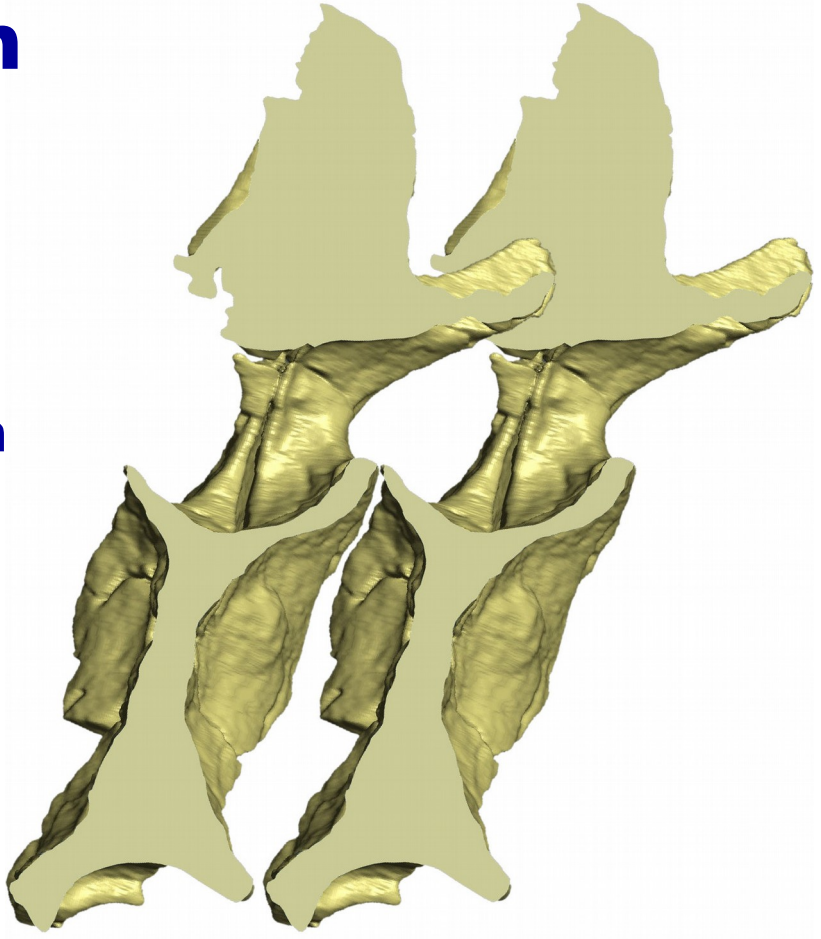
3. Articulate the copies without rotating.
4. Rotate both copies until at same height.



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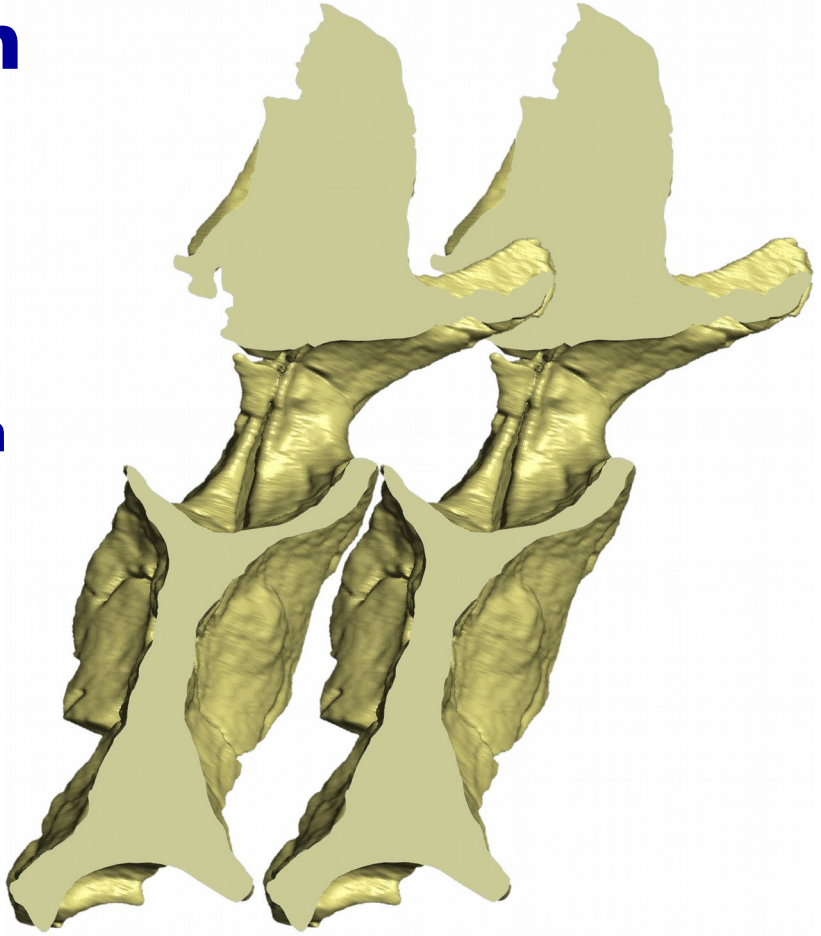
Note: two *copies* of the *same* vertebra.
Method does not require two vertebrae.



4. Similarity in articulation

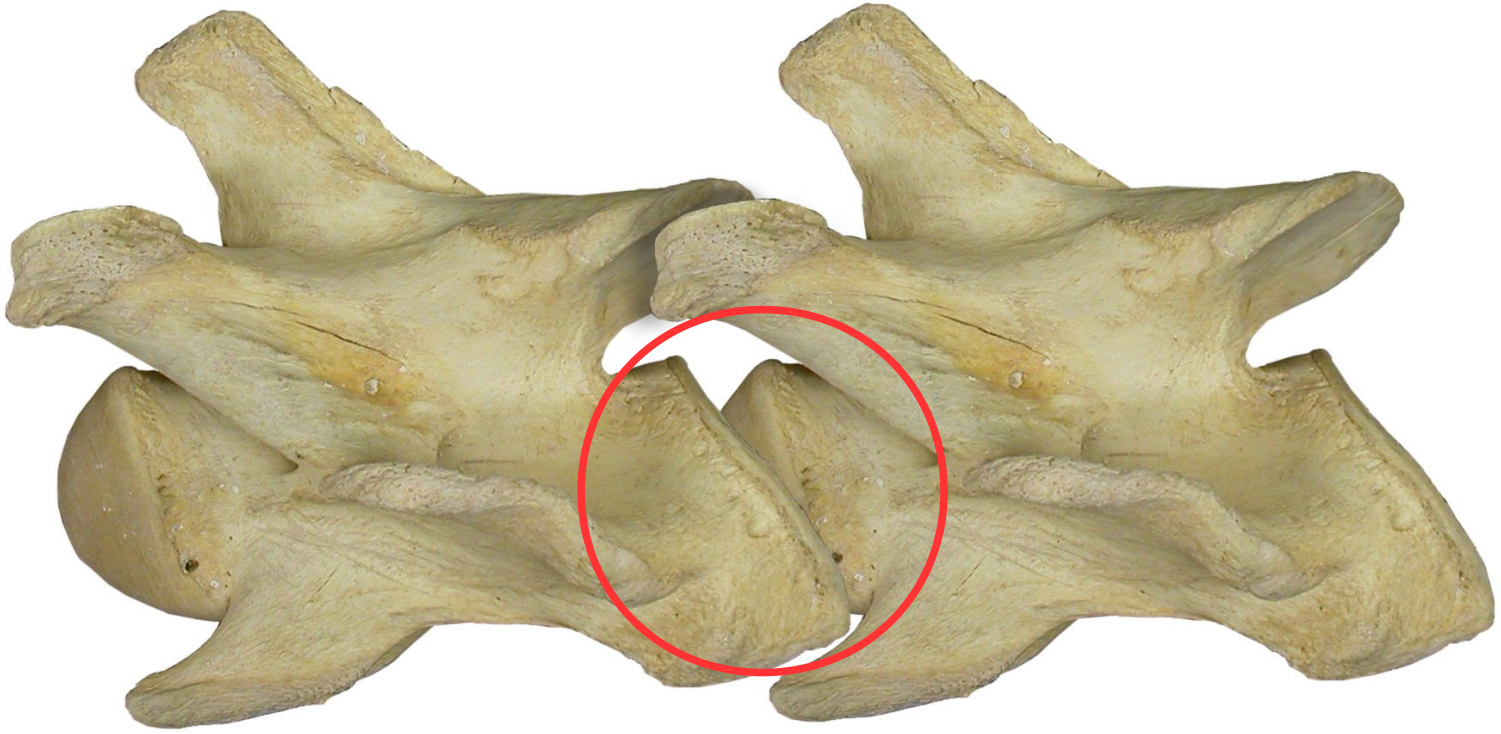
The method applied to *Giraffatitan* C5.

4. Similarity in articulation

The method applied to the giraffe C7.

4. Similarity in articulation

The articulation is optimal given that we do not rotate either copy.



4. Similarity in articulation

This is less intuitive than definitions 1–3, but:

- More precise
- Constrains subjectivity
- Can be determined for any complete vertebra, irrespective of whether the articular faces are parallel or the neural canal is tubular.

4. Similarity in articulation

We may hope that this method is less vulnerable to yielding a distorted result when the vertebra is damaged.

Haplocanthosaurus MWC 8028
probable caudal 1
(Foster and Wedel 2014: fig. 5)

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But it can't be done at all for *Xenoposeidon*, which is where we came in.

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Comparison

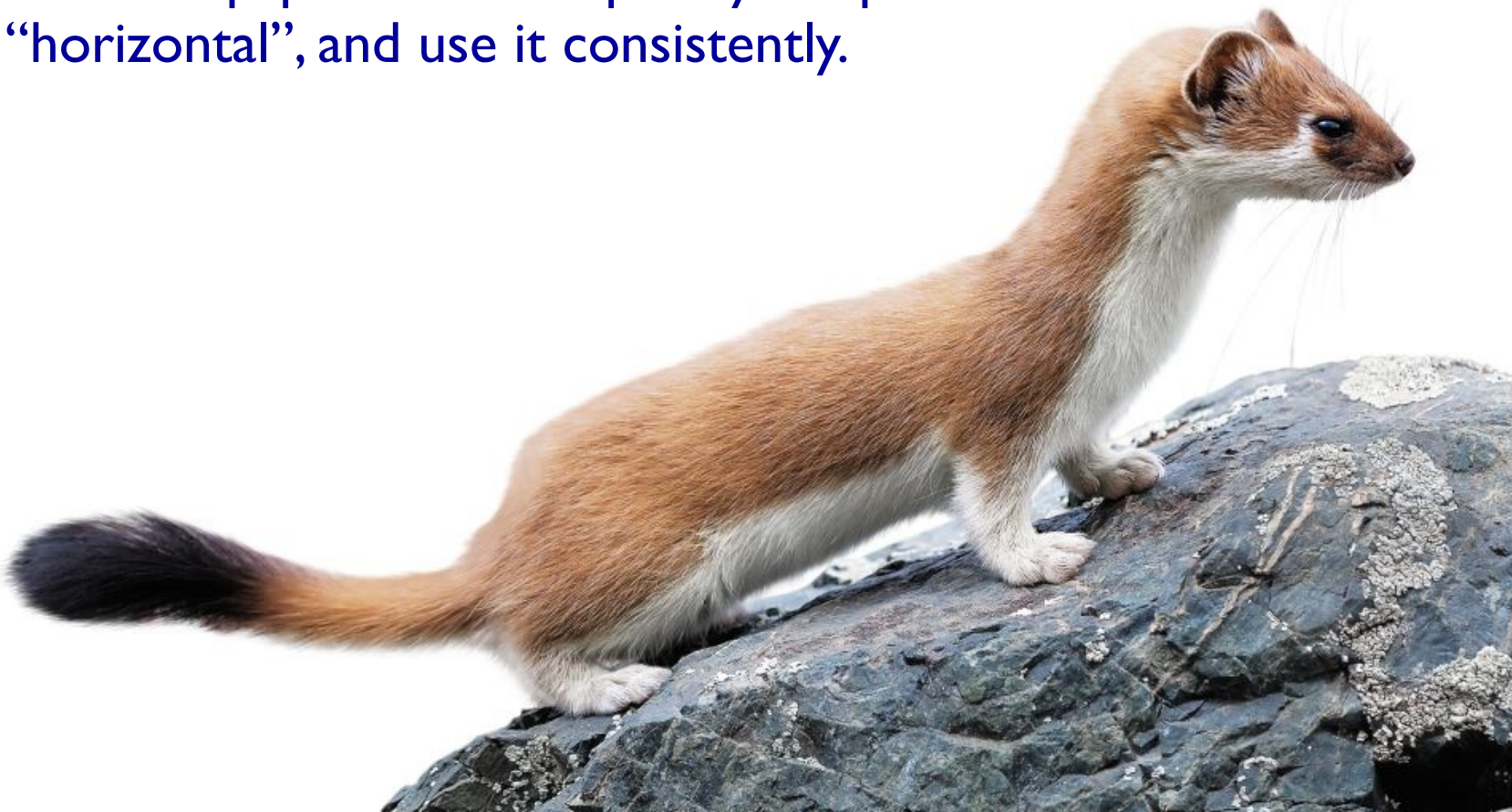
When we floated these notions on SV-POW!, all the methods had adherents.

No one method can satisfy all desiderata.

https://svpow.com/

Conclusion

We advocate that each paper should explicitly adopt a definition of "horizontal", and use it consistently.

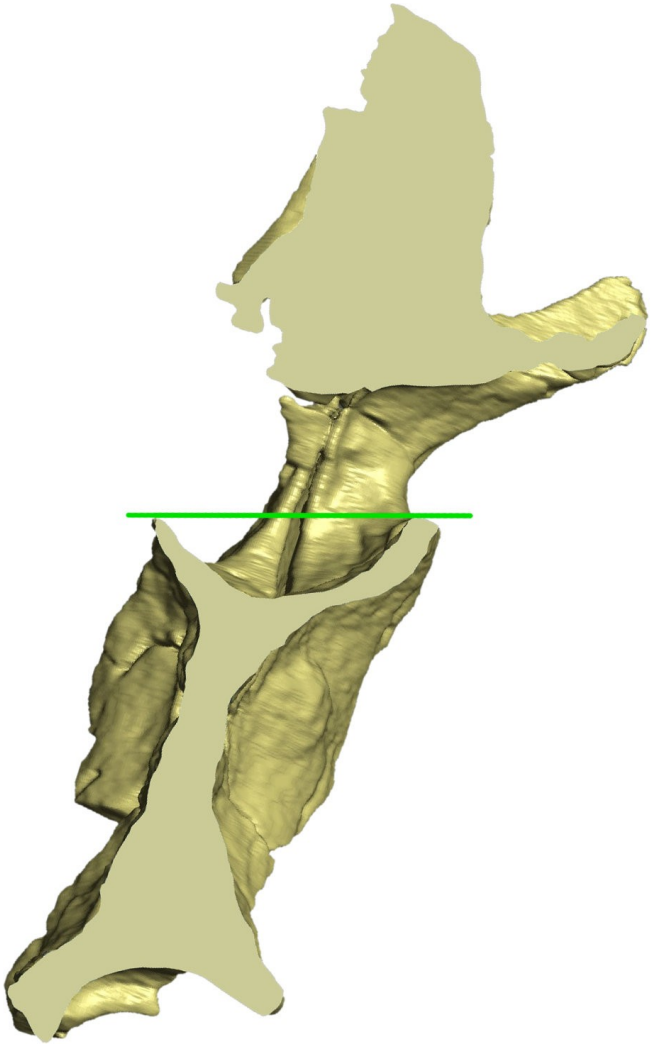


Conclusion

Yes, this is a feeble conclusion.

We *tentatively* recommend the base-of-the-neural-canal-is-horizontal method.

We actively solicit feedback.



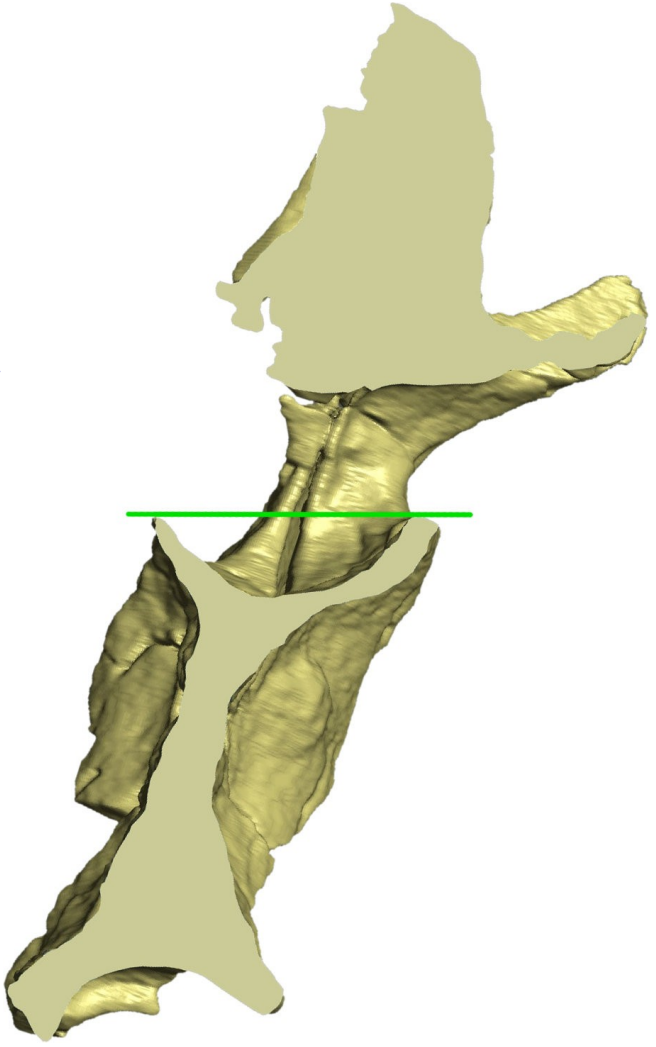
Acknowledgements

For access to specimens:

- Daniela Schwarz, MfN Berlin (*Giraffatitan*)
- Julia McHugh, Dinosaur Journey (*Haplocanthosau*
- Bill Simpson, FMNH (giraffe)
- Neftali Camacho, LACM (Komodo dragon)
- Sandra Chapman, NHMUK (*Xenoposeidon*)
- Ken Noriega, WesternU Vet Med (horse)

For CT scanning and 3D modelling:

- John Yasmer and Thierra Nalley, WesternU



What do we mean by the directions “cranial” and “caudal” on a vertebra?

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What do we mean by the directions “cranial” and “caudal” on a vertebra?

(Answer: we don’t really know.)

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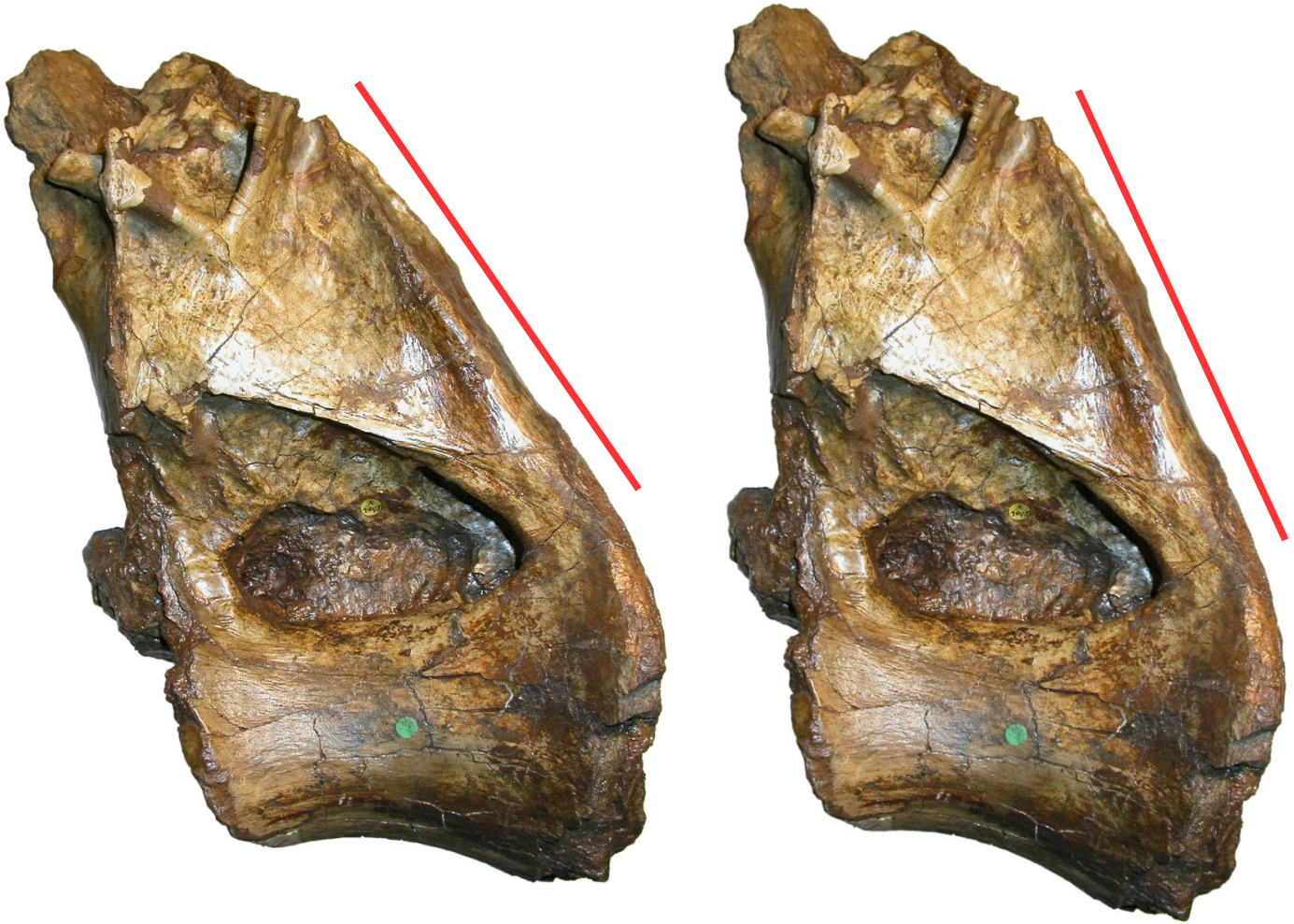
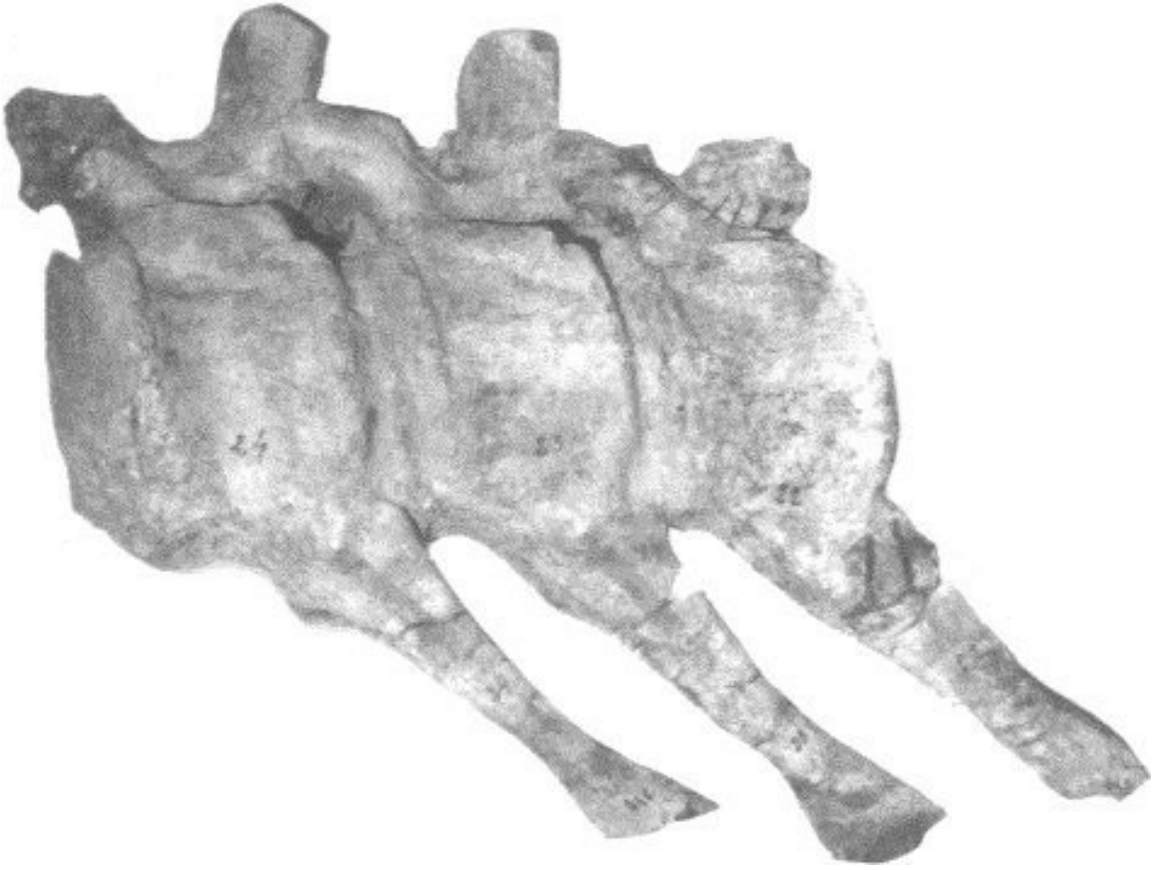
Consistency

Consistency is important, so we can objectively assess and compare the slope of the neural arch, neural canal, or articular surfaces.



3. Neural canal is horizontal



Opisthocoelicaudia skarzynskyii, caudals 6–8.
(Borsuk-Bialynicka 1977: plate 5: figure 2a.)