LUMBAR VERTEBRAE EVOLUTION

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Evolution of the functional morphology of the lumbar region in tetrapods: A review

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OBJECTIVES

- Define lumbar vertebrae from a structural, functional, and genetic perspective.
- Analyze the evolutionary changes found in the lumbar region of terrestrial vertebrates.

INTRODUCTION

In tetrapods the cervical and sacral regions of the spine appear. In certain clades of the amniote group two new regions are differentiated in the trunk: the thoracic region, with rib-articulated vertebrae; and the lumbar region, in which the vertebrae do not bear ribs (*fig.*1) [1].

Fast terrestrial locomotion involves the synchronized movement of the forelimbs in a forward direction causing the sagittal flexion of the vertebral column. Absence of ribs in the more flexed area optimizes fast synchronized locomotion [1].

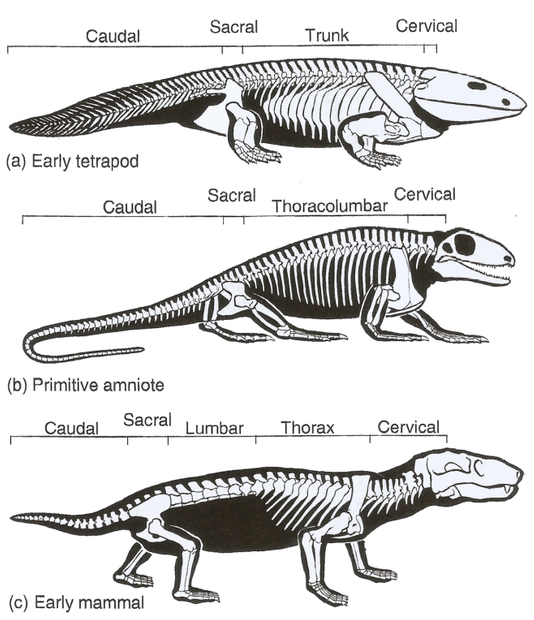

Fig.1. Regionalization of the vertebral column increases along with the optimization of terrestrial adaptation. (a) Labyrinthiodont. (b) Primitive amniote. (c) Early mammal. [1]

LUMBAR VERTEBRAE FORMATION

The amniote vertebrae origins lie in the Seymouriamorph lineage, in which the pleurocentre is the main element in centrum formation. It supports the neural arch which has the zygopophyses for vertebral articulation [1].

Hox10 genes expression results in the suppression of rib formation on the lumbar column. Mutant mice with modified *Hox10* expression (fig.2) show no presence of lumbar vertebrae [2].

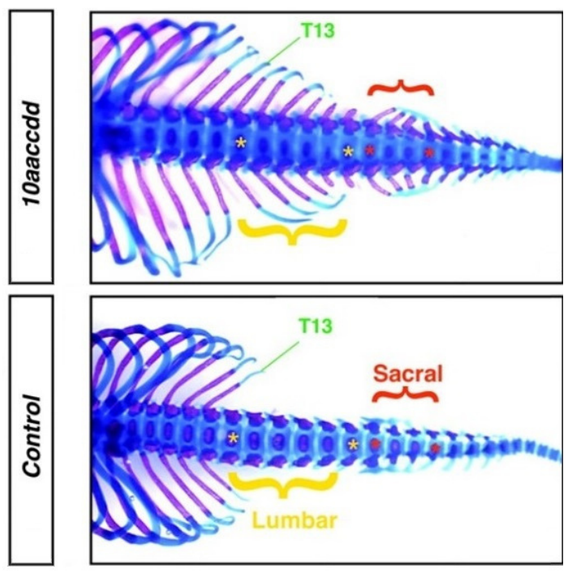

Fig. 2. Ventral views of the posterior axial skeleton of a Hox10 triple mutant and a control mouse. [2]

TRUNK VERTEBRAE IN AMNIOTES

Squamates do not have a differentiated lumbar region. The frontal zygapophysial articulation is strengthened by the zygosphene-zygantrum complex that restricts the sagittal movement of the trunk (fig.3) [1].

In Crocodylia species, frontal zygapophysial articulation is seen in thoracic and lumbar vertebrae. Sagittal flexion is more homogeneously spread in the column [3].

In Cynodontia, longer distance between consecutive joints, in lumbar frontal zygapophysial articulation, allows bigger sagittal flexion [4].

In quadrupedal terrestrial mammals, zygapophysial articulation in the sagittal plane enables marked sagittal flexion of the lumbar region while increasing resistance to torsion (fig.4). Encompassing joints (at the dorsal and sagittal planes) increase dorsal shear resistance in addition to torsion (fig.5) [5].

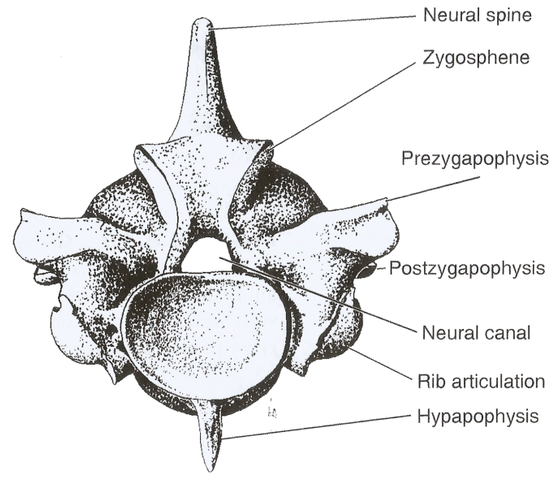

Fig.3. Squamate vertebra and parts ilustration model, anterior view. [1]

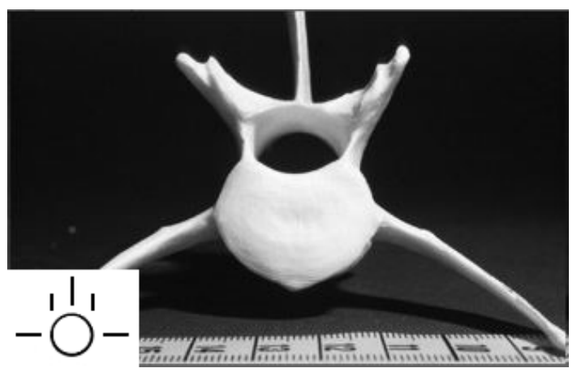

Fig.4. Acinonyx jubatus 3rd lumbar vertebra showing sagittal plane joints, anterior view. [5]

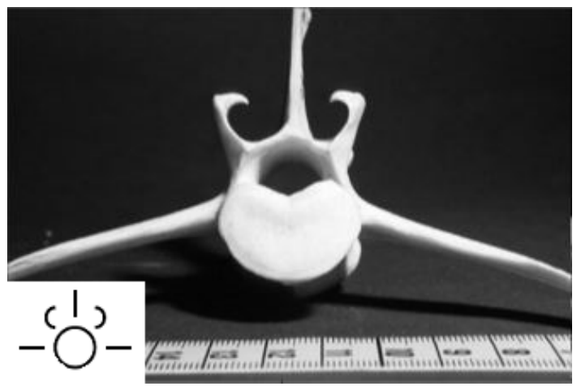

Fig.5. *Lama vicugna* 3rd lumbar vertebra showing encompassing joints, anterior view. [5]

CONCLUSIONS

- Vertebral phylogenetic origin and embryonic formation is different in Lissamphibia and Amniota.
- Hox10 genes differential expression is essential in lumbar regionalization, however its role in morpholical heteregoneity has not been described.
- Sagittal flexion in crocodiles is more homogeneously spread in the column resulting in a less morphologically differentiated lumbar vertebrae.
- In Mammalia's lumbar region, zygapophyseal articulation in the sagittal plane optimizes dorsoventral flexion of the column during fast quadrupedal terrestrial locomotion.

REFERENCES

1. Kardong, Kenneth V. (2015). Vertebrates: Comparative Anatomy, Function, Evolution (7th ed. International ed.) McGraw-Hill Education.
2. Wellik, D. M., & Capecchi, M. R. (2003). Hox10 and Hox11 genes are required to globally pattern the mammalian skeleton. Science (New York, N.Y.), 301(5631), 363–367.
3. Molnar, J. L., Pierce, S. E., & Hutchinson, J. R. (2014). An experimental and morphometric test of the relationship between vertebral morphology and joint stiffness in Nile crocodiles (Crocodylus niloticus). Journal of Experimental Biology, 217(5), 758-768.
4. Jones, K. E., Angielczyk, K. D., & Pierce, S. E. (2019). Stepwise shifts underlie evolutionary trends in morphological complexity of the mammalian vertebral column. Nature Communications, 10(1), 5071.
5. Boszczyk, B. M., Boszczyk, A. A., & Putz, R. (2001). Comparative and functional anatomy of the mammalian lumbar spine. The Anatomical Record, 264(2), 157–168.