

# How and when spines changed in mammalian evolution

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Exhibit specimen of *Edaphosaurus*, a pelycosaur synapsid, from the collections at the Museum of Comparative Zoology. Pelycosaurs are the most ancient forerunners of mammals. This study shows that despite their bizarre sails, it is likely that their vertebral movements were relatively uniform along their back, more similar to living lizards or salamanders than to mammals. Credit: Harvard University Museum of Comparative Zoology.

A new study from Harvard University and the Field Museum of Natural History sheds light on how and when changes in the spine happened in mammal evolution. The research reveals how a combination of developmental changes and adaptive pressures in the spines of synapsids, the extinct forerunners of mammals, laid the groundwork for the diversity of backbones seen in mammals today.

By comparing the biomechanics of two modern animals, cat and lizard, and CT scans of synapsid fossils, the researchers overturned the traditional notion that the gradual accumulation of different regions (or independent sections) of the spine alone account for its evolving complexity. New evidence suggests that regions (like the thorax and lower back) evolved long before new spinal functions, such as bending and twisting. The study points to the idea that the right selective pressures or animal behaviors combined with existing physical regions played a significant role in the [evolution](#) of their unique functions.

The findings by Stephanie Pierce, Associate Professor of Organismic and Evolutionary Biology and Curator of Vertebrate Paleontology at Harvard, and postdoctoral researcher Katrina Jones tap into the larger question of how mammals, including humans, evolved over millions of years.

Modern mammals, for instance, have developed compartmentalized spinal regions that take on a number of diverse shapes and functions without affecting other spinal regions. This has allowed the animals to adapt to different ways of life, explained Jones.

In previous research, the authors showed that extinct pre-mammalian land animals developed these small but distinct regions during evolution.

"What we were able to show in 2018 was that even though all the vertebrae looked very similar in early mammal ancestors they had subtle

differences and those subtle differences created distinct developmental regions," Pierce said. "What we're showing with this new study is that those distinct regions were really important as they provided the raw material that facilitated functional differentiation to happen. Basically, if you don't have these distinct developmental regions in place and you have a selective pressure, all the vertebrae are going to adapt in the same way."

It's long been thought that developing different spinal regions is one important step in evolving backbones with many functions, but Pierce and Jones show that this isn't enough. An evolutionary trigger was also required, in this case the evolution of a highly active lifestyle that put new demands on the backbone.

Jones said, "We're trying to get at something that's quite a fundamental evolutionary question which is: How does a relatively simple structure evolve into a complex one that can do lots of different things? Is that determined by the limitations of development or natural selection related to the behavior of the animal?"



Illustration of Dimetrodon, pelycosaur synapsid, showing the elaborate backbone sail. This study shows that despite their bizarre sails, it is likely that their vertebral movements were relatively uniform along their back, more similar to living lizards or salamanders than to mammals. Credit: Copyright 2019 Mark Witton

The researchers compared the spines of two animals essentially on opposite ends of the evolutionary and anatomical spectrum: cat, which has highly developed spinal regions, and lizard, which has a pretty

uniform backbone. They looked at how each animal's spinal joints bent in different directions to measure how the form of the vertebrae reflects their function. They determined that while some spinal regions can function differently from one to the other, others do not; for example, the lizard's backbone comprised several distinct regions, but they all acted in the same way.

Researchers including Kenneth Angielczyk from the Field Museum of Natural History then turned their focus to finding out when different regions started taking on different functions in the evolution of mammals. They took the cat and lizard data showing that if two joints in the spine looked different, then they tended to have different functions. With that, they mapped out how spinal function in those fossils changed through time.

"The earliest ancestors of mammals have a remarkably good fossil record, considering that those animals lived between about 320 and 250 million years ago," Angielczyk said.

The researchers found that despite having developmental regions capable of performing different functions, the level of functional variation seen in mammals today did not start to take hold until late in synapsid evolution.

"We then hypothesized that maybe it was the evolution of some new mammalian behaviors that helped trigger this [in these late synapsids] and provided the natural selection that could exploit the regions that were already there," Jones said.

Their findings fit with observations that the group in which this functional diversity occurs—the cynodonts, which directly preceded mammals—have a number of mammalian features, including evidence they could breathe like a mammal. The researchers believe that these

[mammal](#)-like features shifted the job of breathing away from the backbone and ribs to the newly evolved diaphragm muscle, releasing the spine from an ancient biomechanical constraint. This enabled the backbone to adapt to interesting new behaviors, such as grooming fur, and take on new functions.

The next step for Pierce and Jones is to clarify what those functions looked like in these extinct [animals](#).

The study is published in *Nature Ecology & Evolution*.

**More information:** Regionalization of the axial skeleton predates functional adaptation in the forerunners of mammals, *Nature Ecology & Evolution*, DOI: [10.1038/s41559-020-1094-9](https://doi.org/10.1038/s41559-020-1094-9) , [nature.com/articles/s41559-020-1094-9](https://www.nature.com/articles/s41559-020-1094-9)

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