Sticking their necks out for evolution: Why sloths and manatees have unusually long (or short) necks

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As a rule all mammals have the same number of vertebrae in their necks regardless of whether they are a giraffe, a mouse, or a human. But both sloths and manatees are exceptions to this rule having abnormal numbers of cervical vertebrae. New research published in BioMed Central's open access journal *EvoDevo* shows how such different species have evolved their unusual necks.

Birds, reptiles and amphibians have varying number of vertebrae in their necks, swans have 22-25, but mammals, regardless of size of animal or the animal's neck, only have seven. Aberrant neck vertebrae are usually correlated with an increase in risk of stillbirth, childhood cancer and neuronal problems in mammals. These pleiotropic events are often associated with physical problems, such as thoracic outlet syndrome, due to misplaced or crushed nerves, muscles and blood vessels.

The only mammals which have evolved different numbers of neck vertebrae without any apparent problems are sloths and manatees. Two-toed sloths (Choloepus) have 5-7 neck vertebrae while three-toed sloths (Bradypus) have 8 or 9. There is some controversy over whether these changes are due to homeotic alteration, where mutation of a gene, such as Hox, causes incorrect skeletal patterning, or are due to an alteration in primaxial/abaxial patterning, where the thoracic structure overwrites that of the cervical vertebrae. Homeotic alteration would affect systems throughout the body and explains the associated effects seen in other mammals. Alteration in primaxial/abaxial patterning would only affect the vertebrae but may explain how sloths escape adverse effects.

After looking at evidence from sloths and related species such as anteaters and armadillos, none of which showed unusual neck structures, it became apparent that the conversion of vertebrae from cervical to thoracic for Choleopus suggested a complete foreshortening of the neck and there were ribs associated with the 7th vertebra. For C. hoffmanni these were complete ribs fused to the sternum, but for C. didactylus they were rudimentary ribs suggesting a transitional structure. In contrast, the 8th vertebra for Bradypus was still cervical and most resembled a normal 6th vertebra but the 9th vertebra had rudimentary ribs. None of these vertebrae patterns can be explained by alteration in primaxial/abaxial patterning. Furthermore other skeletal abnormalities were found in sloths including fusion of vertebrae, defective production of cartilage, ossification of sternum and pelvic girdle, abnormal fibrous bands connected to rudimentary ribs, and asymmetric ribs, which can only be explained as side effects of homeotic alteration.

Similarly the skeletons of manatees (Trichechus) were compared to dugongs and hyraxes. Manatee vertebrae and skeletons also showed similar alteration to the sloths. Surprisingly about half of the dugongs and a couple of the hyraxes studied also had reduced number of neck vertebrae and all of these had other skeletal abnormalities.

Dr Galis from the Netherlands Centre for Biodiversity Naturalis said, "Our research casts doubts on the validity of the aberrant primaxial/abaxial patterning theory and instead lends weight to Bateson's theory of homeotic transformation where the identity of the vertebrae has been changed from cervical to thoracic (or visa-versa depending on whether the neck if shorter as for Choloepus or longer as for Bradypus). The defects seen are most similar to mice with Hox mutations."

Dr Galis continued, "We think that it is the slow lifestyle and low metabolic rate which has allowed evolution to alter the neck length of sloths without any of the side effects seen for other mammals. Their low metabolic rates protect them from cancer and their low activity rates protect them from thoracic outlet syndrome." So, for a sloth, being slow allowed them to evolve unusual necks.

More information: Breaking evolutionary and pleiotropic constraints in mammals. On sloths, manatees and homeotic mutations.
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