Whales use nested Russian-doll structure to protect nerve tissue during lunge dives

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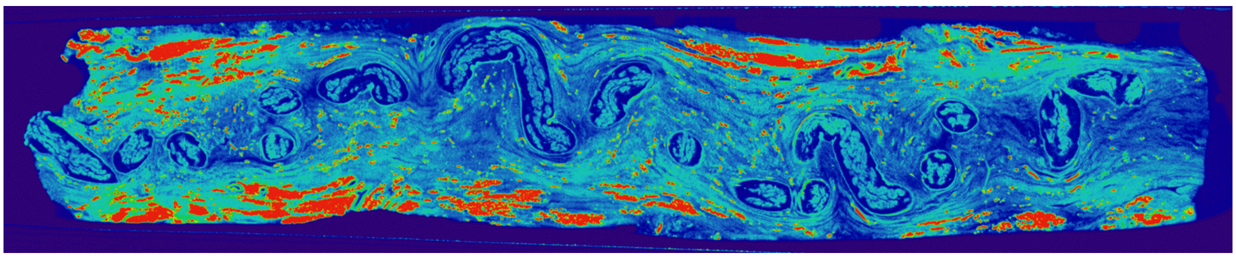

Rorqual whales use a Russian-doll-like structure to protect nerve tissue during lunge dives, according to new research by University of British Columbia researchers. Credit: University of British Columbia

When rorqual whales eat, they open their mouths and lunge. Their tongues invert as their mouths take in a huge volume of water and prey. In the process, nerves running through the ventral groove blubber along the floor of the whales' mouths stretch to more than double their length and then recoil again without suffering any damage in the process. Now, researchers reporting in *Current Biology* on February 16 have discovered that the secret to that stretch is not one but two layers of waviness.

"Waviness in nerves has been known for a long time, and it's widely believed that when a nerve is lengthened in use, the inner parts simply straighten out without getting longer, even though from the outside it can look like the whole thing is stretching," says Margo Lillie of the

University of British Columbia. "What we found is that it is not always so simple—at least not in some whale nerves when physiological use requires very large changes in length."

The trouble is that folding a nerve can cause problems too. That's because bending or folding a nerve also involves a big and potentially damaging stretch. To get around this, Lillie and her colleagues show, the whales' nerves are wavy at two length scales. The large-scale waviness allows the nerves to elongate with body movement. Smaller-scale waviness gives the nerves the extra slack they need to go around tight folds without suffering damage.

Lillie says the waviness of the nerves was obvious from the time she first looked at one through a microscope. "Waviness in nerves per se isn't surprising, but we saw what appeared to be tight hairpin turns in the tissue that we thought couldn't be right—nerves shouldn't be able to bend so tightly," she says. "We realized that we did not understand the geometry of how they folded into a relatively short nerve between feeding lunges, so we set out to identify the full 3D morphology of the nerves and link that with the way they responded to elongation when we pulled on them in the lab."

The researchers turned to micro-CT scanning and tests of nerve mechanics. They scanned six intact, formalin-fixed nerves, plus one nerve in which the outer sheath was removed after fixation, in all, to reveal the two layers of waviness.

Each nerve has an outer sheath surrounding many nerve fascicles bundled together into an inner core, Lillie explains. Their studies showed that the prevailing shape adopted by the nerve core when recoiled is that of a sine-generated curve, a family of waveforms they liken to a meandering river. That regular sine-generated shape helps to reduce strain when the nerves bend and recoil.

Next, they examined the inner nerve structure to find that small-scale fascicle waviness was generally lower on the outside of a core bend and higher on the inside. "This made sense from the engineering theory of bending strain, which tells us that when a rod is bent, the material on the outside is stretched and on the inside compressed," Lillie says.

According to their calculations, some of the fascicles would need to stretch by more than 60% around a bend, enough to cause nerve damage. Damage doesn't occur because the waviness gives each fascicle the slack it needs to make even the tightest bend without stretching too far.

Lillie says next steps include looking at nerves from other tissues in other organisms that have to elongate substantially, to find out whether they stretch without damage in the same way or whether, perhaps, through the course of evolution, they've found another solution to the same problem.

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