Learning from animal evolution to reproduce materials for vibration damping and acoustic wave control

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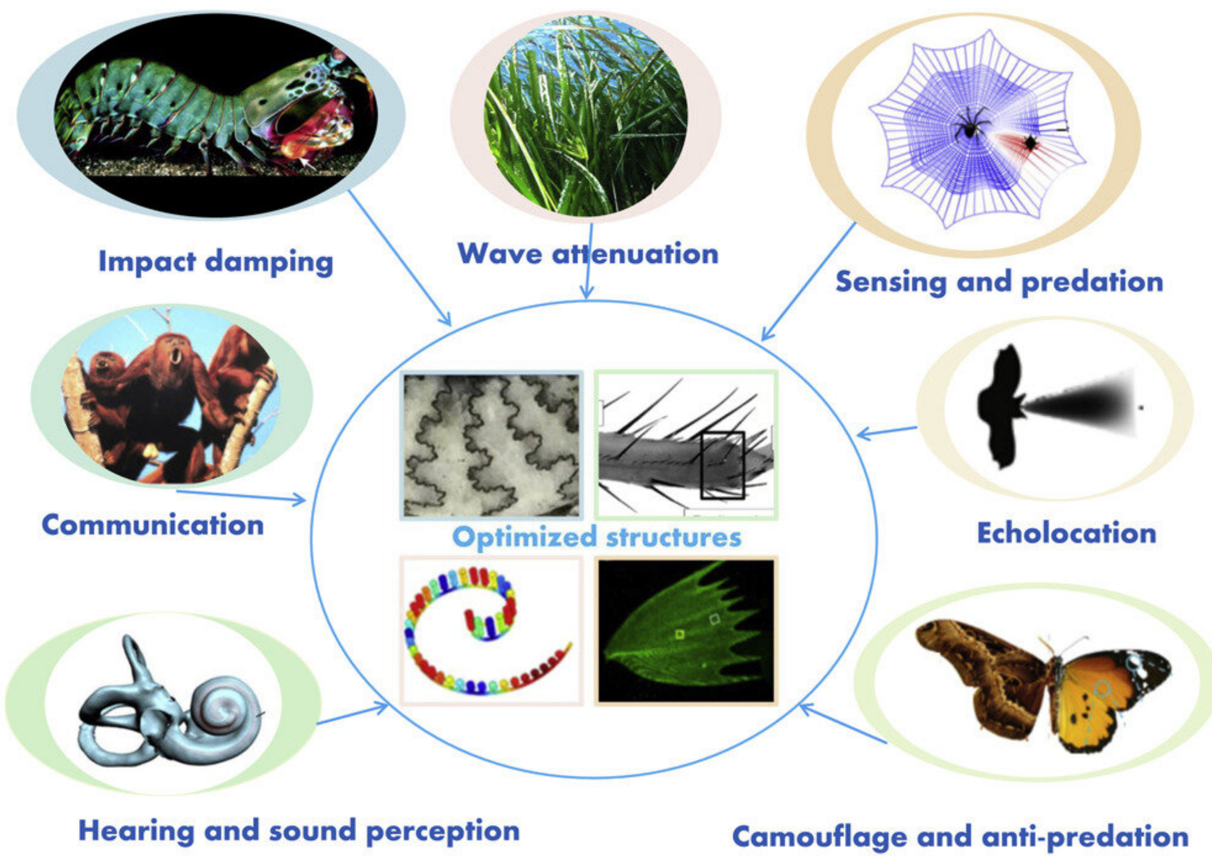

Learning from animal evolution to reproduce materials for vibration damping and acoustic wave control. Credit: Politecnico di Torino

Through millions of years of evolution, nature has produced biological systems with exceptional properties and functionalities. Many organisms have adapted to their particular environment by creating extraordinarily efficient materials and structures. These materials are optimized in terms of their mechanical, thermal, and optical properties in a way that sometimes even technology is still unable to reproduce.

These properties are often achieved by means of "hierarchical" structures, with characteristic lengths ranging simultaneously from the macro- to the nanoscale, hierarchical structures that are easily observed in materials such as wood, bones, spider webs or sea sponges.

So far, the focus has mainly been on structures that nature has optimized from the point of view of the "quasi-static" mechanical properties, such as fracture strength, toughness or adhesion, while there are far fewer studies on the dynamic properties such as vibration damping, noise absorption or sound transmission.

In particular, limited knowledge currently exists on how hierarchical structures play a role in the optimization of natural structures.

In a recent article published in the journal *Matter*, researchers from the Politecnico di Torino Federico Bosia, Antonio Gliozzi and Mauro Tortello, together with colleagues from the Universities of Turin, Trento and the CNRS in Lille, collected and systematized some striking examples, existing in nature, of structural optimization for wave and vibration control, highlighting some common traits and strategies in different biological systems.

The study will make it possible to "mimic" some of these structures and adopt a bio-inspired approach, applying it to the design of acoustic metamaterials (i.e., innovative materials that have recently emerged to control sound waves).

Biological structures of interest from this point of view can be classified into three main categories:

- Structures that are extremely resistant to impacts—such as the skull of the woodpecker, the "hammer-like club" of the mantis shrimp, or the structure of some sea shells
- Structures for perception and predation—spiders, scorpions, moths (one type of moth has evolved to form wings consisting of a natural metamaterial that makes them invisible to the sonar of bats), even elephants, each of which has developed an innovative strategy to generate and exploit vibrations of various frequencies
- Structures for controlling, focusing and amplifying sound—for example the echo-localization system of dolphins and the complex and exceptional structure found in mammals: the cochlea

Ultimately, it is often possible to find common traits in the various cases considered, such as heterogeneity of components, variable porosity, hierarchical organization and efficient resonance mechanisms.

"This review work," comment Federico Bosia, Antonio Gliozzi and Mauro Tortello, "helps to better understand the many systems that nature has optimized through millions of years of evolution. A better understanding of their functioning and common traits can help to develop materials that employ what nature has already optimized. This can be useful for a variety of applications involving the manipulation of acoustic or elastic waves, ranging, for example, from systems for protection against seismic waves to others that allow elastic wave energy to be 'harvested' at the microscale (energy harvesting)."

More information: Federico Bosia et al, Optimized structures for vibration attenuation and sound control in nature: A review, *Matter* (2022). DOI: 10.1016/j.matt.2022.07.023

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