Why there are so many species at the equator and so few at the poles?

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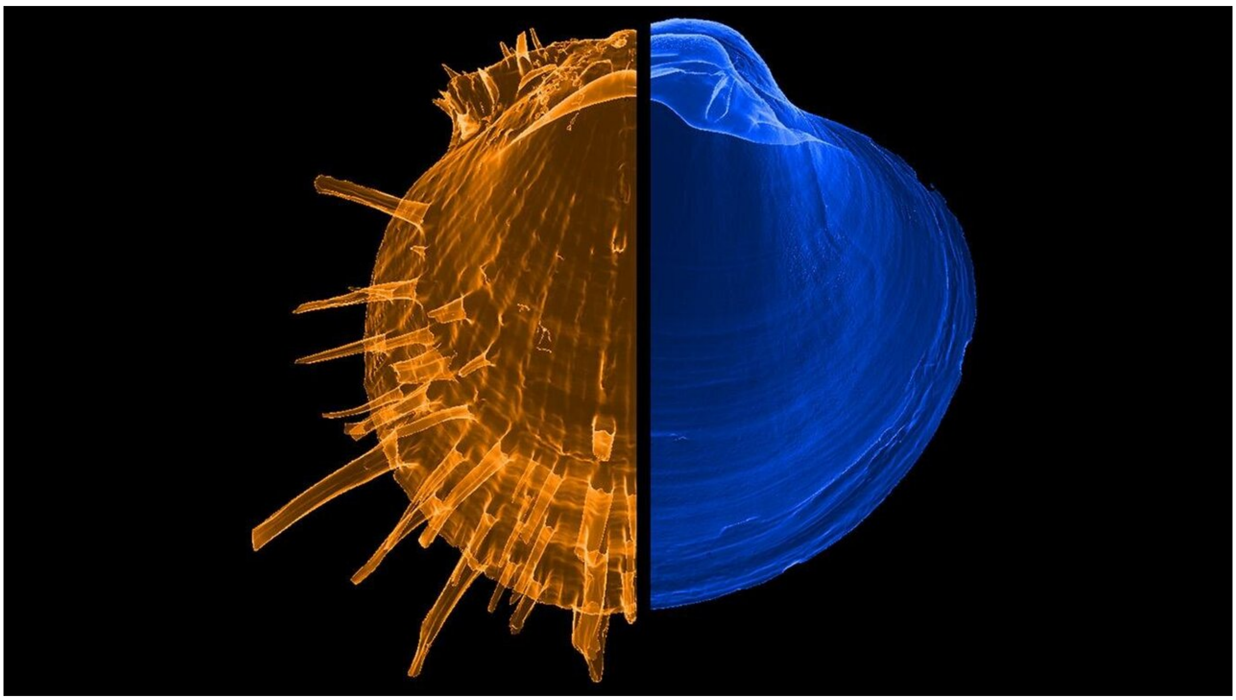


A Spondylus americanus (left) from the Florida Keys, a tropical species with long spines that act as defense against predation; and Arctica islandica, sometimes known as the Methuselah clam for its long life, which is found only in cold waters like the Gulf of Maine. Credit: Katie Collins

Earth is teeming with strange life forms—crabs with 12-foot-long legs scuttling off the Japanese coast, mushrooms that glow at night in eastern North America, butterflies that drink the tears of Amazonian turtles.

Among all of the world's natural kingdoms, however, one rule reigns supreme: There are lots of different species at the tropics, but their numbers drop off sharply as you move toward the poles. "This holds true across virtually all kinds of life and in all kinds of environments, but the reasons why are still hotly contested," said Prof. David Jablonski, a leading University of Chicago scientist of extinction and biodiversity. "This is a fundamental question that goes back before Darwin."

Jablonski's goal is to understand biodiversity, and the stakes are big—including how species will adapt to climate change.

Scientists like Jablonski—whose research on mollusks has shaped the field—have traditionally researched either a species' form (the shape of an organism's body) or its function (the way it makes a living). For example, a clam's shell can be spiny or smooth, and it can make a living eating sunken logs off a coast or by filtering plankton in tidal flats. Each way of looking at the animal tells you something different about evolution, niches and the patterns of biodiversity; but each is so complex on its own that they're rarely studied in unison. Jablonski believes integrating the two could yield important insights.

Two recent studies from his lab take this approach, combining forces with other specialists to investigate the diversity shift from topics to poles in an innovative way.

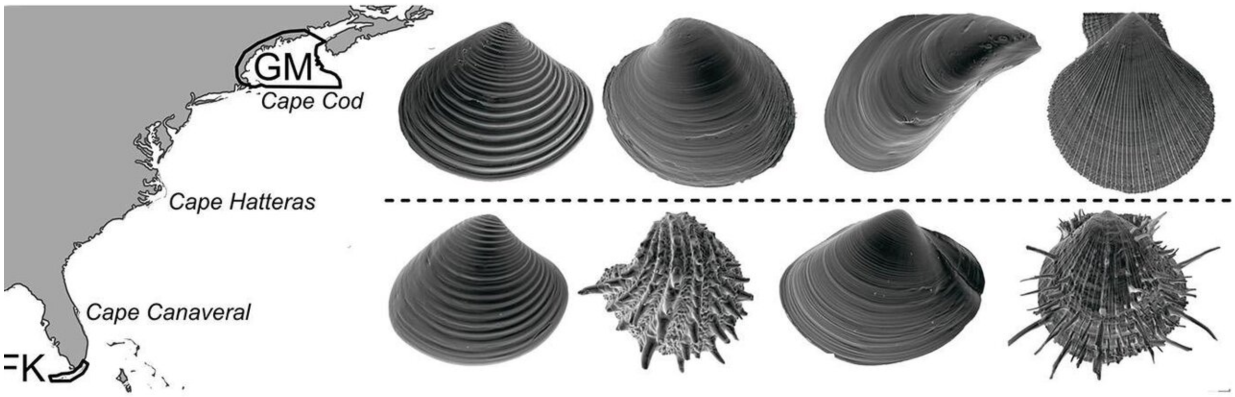
In the first study, they worked with bird biologist Prof. Trevor Price to compare Jablonski's mollusk data with Price's bird insights on how species across the world live in different environments.

In tropical birds, some ways to make a living are packed with species—lots that eat insects on tree branches, for example—and others support just a few. This pattern persists midway into the latitudes, but then there's a distinct tipping point and the number of ways to make a living, and the uneven distribution among them, drop off.

The exact same is true for mollusks. "That result knocked our collective socks off," said Jablonski, who is the William R. Kenan Jr. Distinguished Service Professor of Geophysical Sciences.

"For animals, you don't get much different than a bird and a bivalve, but you see this strikingly similar pattern," said Stewart Edie, a postdoctoral researcher and the joint first author of both papers. "That usually suggests we're looking at a higher-order control that's operating on a large scale around the planet, both on land and sea."

The theory is that in the tropics, there's more room for fine-scale specialization among species—not just birds that eat seeds, but birds that eat only one kind of seed, in one part of the environment (branches high in the forest canopy, for example). But with increasing latitude, the climate becomes more seasonal and more difficult to survive in, and it's less viable to be a specialist. "A lot of the ways of life are still present; you just have to eat every kind of seed, or live anywhere in the canopy," Jablonski said.



A map of the researchers' study area for the Florida Keys and Gulf of Maine. On the top row are the shells at higher latitudes, which tend to be smoother and plainer than their spiky, colorful counterparts closer to the equator, on bottom row. Credit: Katie Collins

That's something new about how biodiversity works, he said, and it may have implications for how things will play out as climate change progresses. "For example, what's going to happen to parasites that attack crops or plants we care about—species will arrive that can focus on specific hosts as it gets warmer," he said.

The second paper, headed by postdoctoral researcher Katie Collins, turned to technology to analyze how the forms of mollusks change from tropics to poles.

They used a micro CT scanner to scan samples of 95 percent of all the species found in the Florida Keys and the Gulf of Maine, yielding a treasure trove of 3-D images. Most studies just work with shell length and height, "but that's not the whole picture," Collins said. "A third dimension adds a new layer of understanding." "Now we can put hard numbers on shell form where we just had general impressions before," added co-author Rüdiger Bieler, curator of invertebrate zoology at Chicago's Field Museum and member of UChicago's Committee on Evolutionary Biology.

When you go to a beach in the Florida Keys, your eye is drawn to large, brightly colored shells with spines and ridges and knobs. But north of Cape Cod, you don't find those. The shells are all smooth, plain and often small, which at first blush seems to indicate a massive shift in species form.

That's not what scientists found, though. "It turns out there are plain shells everywhere," Collins said."The tropical shells are actually a mix of plain and fancy species; the fancy shells just drop out of the mix as you go north. So the individual species aren't transforming to adapt to new conditions; whole lineages of fancy things drop out."

"It looks like the high-latitude climate narrows down the range of viable shell forms, and some lineages are just frozen out, so to speak," said Jablonski.

This too has implications for humans as they continue to alter the climate and environment.

"What this suggests is that most animals are more likely to drop out than to adapt to the tougher conditions at high latitude," Collins said. "This could affect humans in a very real way. Bivalves serve a huge role in fisheries, and we don't know if the ones we like to eat most, like oysters or scallops or mussels, are going to disappear, or move out of their accessible fishing grounds, as the climate changes around them."

This study was done on modern species; the next step will be to add fossils. (Scientists love mollusks because their shells are easily fossilized.) "For example, we want to know whether the fancy lineages turn over more rapidly over time are more extinction-prone or if they're stable," Collins said.

"Taken together, these new studies show that the different dimensions of biodiversity don't all change together on a global scale, and the mismatches tell us something new about the forces shaping life on earth," said Jablonski.

More information: M. Schumm et al. Common latitudinal gradients in functional richness and functional evenness across marine and terrestrial systems, *Proceedings of the Royal Society B: Biological Sciences* (2019). DOI: 10.1098/rspb.2019.0745

K. S. Collins et al. Spatial filters of function and phylogeny determine morphological disparity with latitude, *PLOS ONE* (2019). DOI: 10.1371/journal.pone.0221490

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