

Do big tadpoles turn into big frogs? It's complicated, study finds

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An adult female reed frog from Cameroon. In this African family, adult and tadpole body sizes are closely related among species, so that species with larger adults have larger tadpoles and species with smaller adults have smaller tadpoles. Credit: John J. Wiens/University of Arizona

If you have any children in your life, imagine for a moment that they don't look anything like their parents, they don't eat anything humans normally eat, and they're active only while adults sleep.

While that might sound like an idea from a work of surreal fiction, it's actually the norm rather than the exception in the [animal kingdom](#). Most animals go through what biologists call a complex life cycle, starting as larvae that often have little, if anything, in common with their parents.

To become adults, they have to go through a process known as metamorphosis, which is one of nature's most remarkable feats. During this process, the larval bodies of many animal species undergo dramatic changes that turn them into adults that have little, if any resemblance with their juvenile stage. Butterflies may be the most familiar example of this. Yet, despite complex lifecycles being widespread, surprisingly little is known about how they evolve, specifically the extent to which evolution in one life stage impacts the others.

To better understand the evolutionary consequences of a complex life cycle across a large group of related species, University of Arizona biologists studied another familiar example: frogs and their tadpoles.

Tung Phung, Joao C. S. Nascimento and John J. Wiens of the UArizona Department of Ecology and Evolutionary Biology took a closer look at the evolution of body size across 542 [frog species](#) belonging to 42 families, most of which have a tadpole stage. The study, which was co-authored by Alexander Novarro of The Nature Conservancy, is published in the scientific journal *Proceedings of the Royal Society B*.

"We wanted to know, do large frogs have large tadpoles and small frogs small tadpoles, or are the sizes between the two decoupled?" Wiens said, alluding to a prevailing hypothesis in [evolutionary biology](#) that states that larvae and adults should evolve rather independently, especially in

species in which the two life stages have very different lifestyles.

If larval and adult stages evolve completely independently of each other, there should be little correlation between larval size and adult size among species. In other words, big frogs could have little tadpoles, and big tadpoles could become small frogs, with no relationship between the size of frogs and tadpoles.



An adult sabinal frog from Mexico, with its tadpoles. Credit: John J. Wiens/University of Arizona

The team scoured the scientific literature for data on the sizes of tadpoles and adult frogs for each species, assembled an evolutionary tree among the species, and applied statistical analytical tools.

The team discovered that while there is a striking amount of variability among frog families, the association is not completely random. Across frogs as a group, larval and adult body sizes are significantly and positively related.

"It's not just 'anything goes,'" Wiens said. "We included almost every family of frogs that has a tadpole stage, and we did find there is constraint. In some cases, it's really strong; adult size strongly predicts larval size in many of the families we looked at."

In other families included in the study, the researchers found the relationship to be much more variable. For example, in the spadefoot toad (*Scaphiopodidae*) family, species with large adults have small tadpoles and species with small adults have large tadpoles.

There was also variation in the relative size of adults and tadpoles among families. For example, the paradox frog, *Pseudis paradoxa*, is a species with normal-sized adults that develop from giant tadpoles that are three to four times bigger than the adult. On the other end of the spectrum are some giant South American toads, whose tadpoles are about a tenth the size of the adult.

"Overall, the size of tadpoles relative to adults changes widely across frogs, but why, we don't know," Wiens said.

The authors also compared the rates of evolution in body sizes between tadpoles and adults. These were found to be clearly decoupled. For example, in glass frogs, the tadpole stage runs a broad gamut of sizes, indicating it has been evolving very quickly, while the adults vary much

less in size. Other groups, such as the true toads, have fast evolutionary rates in both stages, while yet others, such as the African bullfrogs, show the opposite pattern, with adults evolving fast and tadpoles changing slowly.



The tiny, thumbnail-sized tadpoles of the cane toad grow into adults that are among the largest amphibians, requiring both hands to pick one up, according to John Wiens, who took this photo in Costa Rica. Credit: John J. Wiens/University of Arizona

Once tadpoles, which are confined to water, morph into frogs that spend

most of their time hopping around on land, their bodies undergo an extreme makeover: The tissues that make up their powerful tail, used to propel them underwater, are recycled into other tissues; appendages begin sprouting beginning with the legs, then the arms, and they lose their feeding apparatus. This feeding system usually consists of a big beak, bordered by five or more rows of tiny teeth, which themselves are surrounded by a ring of short, fleshy tentacles. Inside, a filter system uses streams of slime to extract food from the water. Some tadpoles seem to use the teeth and beak to scrape algae off of rocks. Others suck up decaying organic matter from the bottoms of their freshwater habitats. But some tadpoles are carnivorous and may even be cannibalistic.

"Their feeding mechanism is so weird that people still don't know exactly how it works or even what most [tadpoles](#) eat," Wiens said. "In adult frogs, the mouthparts are completely different, so they have to take this whole system down and rebuild during metamorphosis."

While the huge variability in tadpole size relative to adults makes frogs especially interesting to Wiens and his research team, he said another reason for choosing frogs for this study was their status as endangered animals that are highly beneficial to the natural environment.

Of the more than 7,200 [frog species](#) that have been described, most live in the tropics, and many have been disappearing at an alarming rate, Wiens said. This is worrisome as they play critical roles in ecosystems across the globe—for example, acting as a natural pest control.

"Many of them eat insects that destroy crops, so they are really useful that way," he said.

While the current study is limited to amphibians, it does open up questions for other groups of animals, said the paper's first author, Tung

Phung, a first-year doctoral student in Wiens' lab who did most of the work while still an undergraduate.

"Our study is the first to address evolutionary rates of larval and adult life stages at a large scale," he said.

More information: Tung X. Phung et al, Correlated and decoupled evolution of adult and larval body size in frogs, *Proceedings of the Royal Society B: Biological Sciences* (2020). [DOI: 10.1098/rspb.2020.1474](https://doi.org/10.1098/rspb.2020.1474)

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