How sticky toepads evolved in geckos and what that means for adhesive technologies

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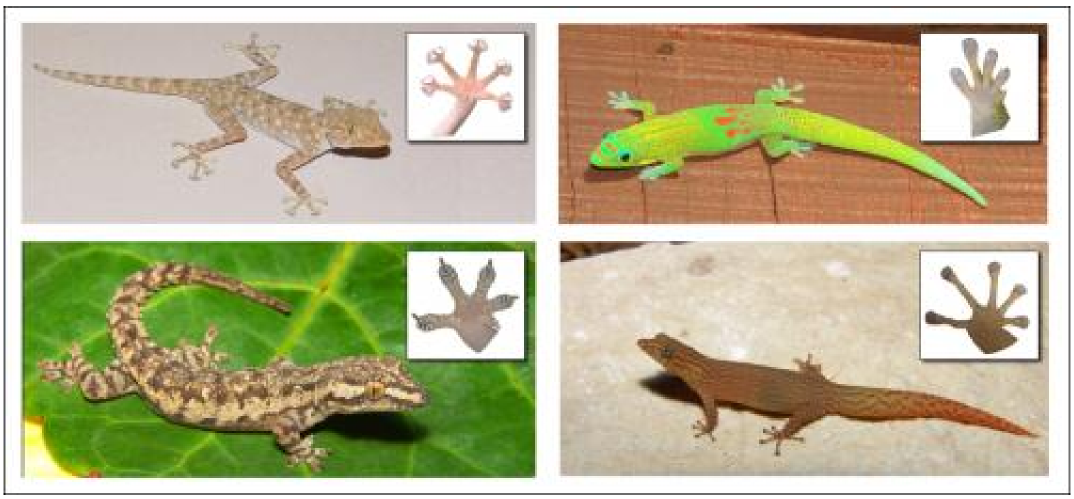

Photos of four gecko species along with a photo of their feet showing the diversity of adhesive toepad types. Clockwise (from upper left) Ptyodactylus guttatus, Phelsuma laticauda, Sphaerodactylus elegans, and Hemidactylus frenatus

Geckos have independently evolved their trademark sticky feet as many as 11 times, and lost them nine times, according to research published June 27 in the open access journal *PLoS ONE.*

Geckos are known for sticky toes that allow them to climb up walls and even hang upside down on ceilings. A new study shows that geckos have gained and lost these unique adhesive structures multiple times over the course of their long evolutionary history in response to habitat changes.

"Scientists have long thought that adhesive toepads originated just once in geckos, twice at the most," says University of Minnesota postdoctoral researcher Tony Gamble, a coauthor of the study. "To discover that geckos evolved sticky toepads again and again is amazing."

The findings are published in the most recent edition of *PLoS ONE*. Gamble is a researcher in the College of Biological Sciences' Department of Genetics, Cell Biology and Development. Aaron Bauer, a professor at Villanova University, is the study's senior author. The research is part of a long-standing collaboration on gecko evolution among biologists at the University of Minnesota, Villanova University and the University of Calgary.

Geckos, a type of lizard, are found in tropical and semitropical regions around the world. About 60 percent of the approximately 1,400 gecko species have adhesive toepads. Remaining species lack the pads and are unable to climb smooth surfaces. Geckos with these toepads are able to exploit vertical habitats on rocks and boulders that many other kinds of lizards can't easily get to. This advantage gives them access to food in these environments, such as moths and spiders. Climbing also helps geckos avoid predators.

Photo of the underside of a foot of the house gecko (Hemidactylus frenatus) showing the expanded adhesive pads on the toes.

The researchers found that sticky toes evolved independently in about 11 different gecko groups. In addition, they were lost in at least nine different gecko groups. The gain and subsequent loss of adhesive toepads seems associated with habitat changes; e.g., living on boulders and in trees versus living on the ground, often in sand dunes, where the feature could be a hindrance rather than an advantage. "The loss of adhesive pads in dune-dwelling species is an excellent example of natural selection in action," Bauer says.

Repeated evolution is a key phenomenon in the study of evolutionary biology. A classic example is the independent evolution of wings in birds, bats and pterosaurs. It represents a shared solution that organisms arrived at separately to overcome common problems.

In order to understand how the toepads evolved, the research team produced the most complete gecko family tree ever constructed, including representatives of more than 100 genera (closely related groups of species) from around the world. This family tree can serve as the basis for answering many other questions, such as how and when did live birth, temperature-dependent sex determination, and night color vision evolve in geckos? The family tree will also allow the authors to revise gecko taxonomy to best reflect the group's evolutionary history.

Gecko toepads adhere through a combination of weak intermolecular forces, called van der Waals forces, and frictional adhesion. Hundreds to hundreds of thousands of hair-like bristles, called setae, line the underside of a gecko's toes. The large surface area created by this multitude of bristles generates enough weak intermolecular forces to support the whole animal.

The amazing clinging ability of Gecko toes has inspired engineers to develop biomimetic technologies ranging from dry adhesive bandages to climbing robots. "Gaining a better understanding of the complex evolutionary history of gecko toepads allows bio-inspired engineers to learn from these natural designs and develop new applications," says co-author Anthony Russell, of the University of Calgary.

While scientists have a good understanding of how geckos stick at the microscopic level, they are just beginning to understand how geckos use their adhesive toepads to move around complex environments in the wild. Learning how gecko toepads have evolved to move in nature is an important step in developing robotic technologies that can do similar things. "It's one thing to stick and unstick a piece of 'gecko tape' to a smooth surface in a lab, but something else altogether to get a robotic gecko to move across a complicated landscape in the real world and stick to all the different shapes and textures it will encounter," says Gamble. Examining the repeated evolution of gecko toepads will let scientists find common ways natural selection solved these problems and focus on the characteristics shared across different gecko species.

More information: Gamble T, Greenbaum E, Jackman TR, Russell AP, Bauer AM (2012) Repeated Origin and Loss of Adhesive Toepads in Geckos. *PLoS ONE* 7(6): e39429.doi:10.1371/journal.pone.0039429

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