

Hanging with Geckos

Have you ever seen a gecko walk straight up a glass door, or sprint upside down across a ceiling, and wonder, “How can they do that?” To get the answer, you’d need an electron microscope.

At 200× magnification, you’d see the gecko’s toes are covered with tiny hairs called setae. Zoom in closer and at 1000×, you’d see that the setae are actually bunches of hairs, like in a hairbrush.

Much closer, at 55,000×, you’d see that each one of those hairs splits again into hundreds of branches of spatulae, shaped like spatulas.

The spatulae are thinner than a wavelength of visible light—so small they can get close enough to the surface the gecko is walking on that electrons in the spatula and surface material begin to pull on each other.

The force on just one spatula is weak. But multiplied by the 2 million spatulae on a gecko’s toe, it’s strong enough to hold the gecko onto glass using *just* that one toe.

When it needs to move, the gecko flexes muscles in its toes to change the orientation of the setae, turning its foot from sticky to not in an instant.

It can coordinate these on–off movements with every step, every fraction of a second, to run up a wall or across a ceiling without falling.

Scientists have been trying to emulate this incredible, controllable, atomic-level stickiness, but so far, the gecko has us beat... up, down, and sideways.



A gecko clings to a glass surface by a single toe pad as researchers test grip performance.

Credit: with permission from Dr. Travis Hagey (Mississippi University for Women)



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Background: Hanging with Geckos

Synopsis: It seems like some lizards can stick to anything. Many geckos can stick to glass surfaces, even if they are upside down. How do these reptiles adhere to surfaces, and how do they defy gravity to scuttle across them?

- Geckos have been around since the time of dinosaurs, splitting from other lizards and becoming their own group over 180 million years ago and have amazing traits.
 - In 2009, researchers found a fossilized specimen with the distinctive toe lamellae that enable geckos to cling to surfaces in Lower Cretaceous rocks in Myanmar, extending the range of these reptiles—and their sticky toes—back to at least 97–110 million years ago.
 - Geckos range from less than one-fourth of an inch (0.63 cm) (*Sphaerodactylus ariasae*) up to 14 inches (360 cm) long (*Rhacodactylus leachianus*). The largest known species is *Hoplodactylus delcourti*, an extinct species from New Zealand that grew up to around 24 inches long (600 cm).
- Geckos can be found in warm environments around the world: deserts in Africa and Australia, most tropical islands, rainforests in Asia and South America, and even the southwestern United States. In addition to these native species, humans have also accidentally introduced many species of geckos to new locations, such as the southeastern United States and Hawaii.
- Most geckos have no eyelids and therefore cannot blink, so they have to lick their corneas clean with their wide, flat tongues.
- Most geckos are nocturnal and have full-color vision even in dim light. Nocturnal species have vertical pupils (similar to snakes, frogs, alligators, and cats) that nearly overlap to keep light out of their lidless eyes when they sleep during the day. On the other hand, geckos that are active during the day have round pupils like humans.
- Geckos got their name from the Indonesia word “*gēkoq*,” which represents the sounds made by one of the first gecko species described by scientists in the 1750’s: the Tokay gecko (*Gekko gekko*). Geckos are some of the only lizards that use vocalizations to communicate. They can click, squeak, chirp, and bark—and some can even growl.
- Geckos have good hearing. The ear structure of some species makes it possible to see straight through their heads if you look into their ear holes!
- Their skin is antibacterial and anti-wetting, so it cleans itself. The scales attached to most of a gecko’s skin are like tiny cobblestones—they don’t overlap. But in some species, the specialized scales on their toe pads, called lamellae, do overlap.



A gecko trapped in Oligocene-era amber from 22 to 33 million years ago at the Australian Fossil and Mineral Museum.

Credit: PG Palmer (CC BY-SA)

References: Hanging with Geckos

5 Reasons Geckos Are the Coolest Lizards | HowStuffWorks
Geckos' Sticky Secret? They Hang by Toe Hairs | LiveScience
Sticky Situations: Big and Small Animals with Sticky Feet | Data Nuggets
Gecko Tech: Sticky Invention Lets People Scale Walls | LiveScience
Geckos May Be Sticky, but Here's What Stumps Them | National Geographic

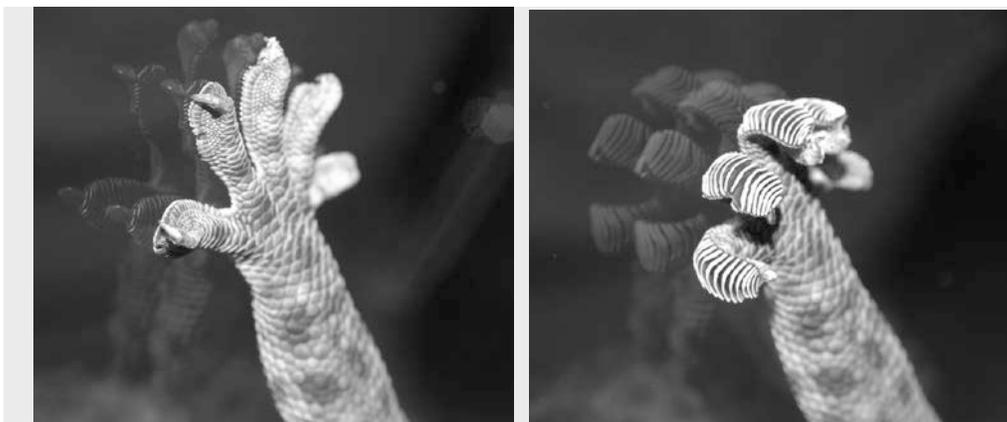
Contributors: Dr. Travis Hagey (Mississippi University for Women), Juli Hennings, Harry Lynch



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- Leopard geckos, commonly sold in pet stores, never evolved toe pads, so they can't stick like their clingy cousins. But about 60% of geckos do have adhesive toe pads and can stick to a smooth glass surface, even upside down.



Gecko toe pads flat on a glass surface (left) and hyperextended to release the surface so they can move (right).

Credit: with permission from Dr. Peter Niewiarowski (University of Akron)

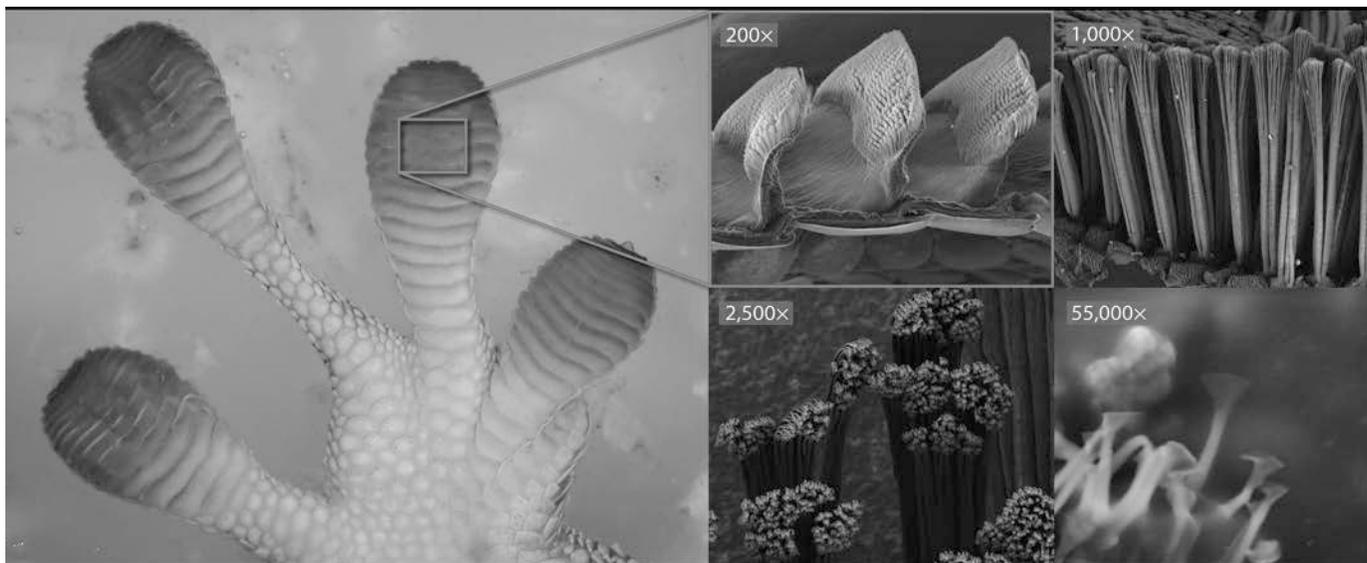
- Species with toe pads have toes that can bend forward like human fingers but also backward, hyperextending so that the tops of their toes can curl all the way back to touch the top of their foot.
- While tendons in most animals connect muscle to bone, geckos have tendons in their toe pads that connect muscle to skin, enabling them to stiffen their feet dramatically.
- The bottoms of these super-flexible toes are covered in tiny microscopic "hairs" called setae that can be from 30 to 100 microns tall. The *height* of these setae is roughly the same as the *width* of our mammalian hair.
- Each of these tiny setae splits into hundreds of smaller branches with flat tips called *spatulae* that are shaped just like tiny spatulas. Spatulae are only 200 nanometers wide—smaller than the wavelength range of visible light (700–400 nanometers)!
- These nanoscale spatulae conform to the shape of a surface that a gecko walks on. They are able to get so close that the electrons whizzing around the molecules of the surface and the electrons from the molecules of the setae start to push and pull on each other. This electron push-and-pull, known as van der Waals forces, generates a weak attractive force between the setae and whatever material the toe pads are touching.
- Even though the attractive force between a surface and any one spatula is weak, geckos have thousands of spatulae contacting on their toe pads, giving them enough attractive force to cling. Geckos stiffen their toe pads to produce the adhesion necessary to cling to surfaces and relax their feet to release their hold.
- For their most amazing trick, geckos can scuttle upside down across your ceiling at more than 20 body lengths per second while defying gravity.
 - How can they stick and run at the same time? Recent research has shown that geckos can turn the adhesive powers of their toes on and off by using their strong specialized tendons to control how much of their toe pads are touching.
 - Researchers have also found that the angle of the toe setae is important. The setae do not protrude at 90 degrees; they come out at oblique angles.
 - When running fast on the top of a surface, geckos often run with their toes lifted, which lets them run faster (imagine trying to run with suction cups on your shoes).

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Gecko toe pads are amazing when magnified using a scanning electron microscope. At 200× magnification, the setae on each lamella can be seen. At 1000×, the hairbrush look of the setae is apparent. At 2500×, the bristled ends of the setae are even clearer, and at 55,000×, the shape of the spatula is clear—its 200 nm width is just half of the shortest wavelength of visible light, violet.

Credit: gecko foot photograph used with permission from Dr. Travis Hagey (Mississippi University for Women); SEM images used with permission from Michael Bartlett (University of Massachusetts Amherst)

- When running up vertical surfaces or across the undersides of surfaces, geckos have to peel their toes every step, disconnecting their setae spatula by spatula to momentarily free their toes from the surface so they can move their feet. They also have to coordinate which toe pads remain in contact with the surface to prevent falling.
- But geckos can't stick to everything.
 - Layers of dust, oil, or even water limit adhesion to the underlying surfaces. Debris and oils can temporarily clog up a gecko's setae too.
 - If a surface is too wet, the distance from the spatulae to the surface increases, and the attractive van der Waals forces are overcome. A layer of water—even a very thin one—can block the electrons from interacting, so the setae start slipping... and so does the gecko.
- Geckos can't stick to non-stick coatings like Teflon because these surfaces are non-reactive. In Teflon, carbon atoms are joined to fluorine atoms, which hold on their electron very tightly and therefore cannot be pushed or pulled to generate van der Waals forces. The lack of accessible electrons on Teflon surfaces prevents geckos from gripping.
- Humans have tried to copy the amazing grasp of gecko toe pads for a variety of applications, from sealing wounds, to developing wall-scaling gloves and robots, to creating material adhesives that work like one-sided Velcro.

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