Do snails need their slime trails to move ahead? It's a sticky question

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The researchers found that snails didn't need their special mucus to travel horizontally, although it comes in handy when they're traveling up a wall. Courtesy Universidad Carlos III de Madrid

(PhysOrg.com) -- High-resolution videos of moving snails and slugs reveal the details of how snails get around on their own distinctive brand of slime.

It's tough to get around on one foot. Yet this limitation doesn't appear to hold back snails and slugs.

A snail uses its single long, muscular foot to crawl on a layer of mucus-like slime that it secretes. This mucus has unusual physical properties, and scientists assumed that these sticky properties were essential for snail movement.

But in a recent study, Stanford graduate student Janice Lai used high-resolution videos and lasers to study moving snails and slugs, and discovered that they don't really need their slime to be special.

"We were surprised to find that the special mucus properties weren't essential," said Lai. "Mucus is still very important, but we found that there are other mechanisms that the snail uses to generate the traction to move forward."

It was already known that snails and slugs propel themselves by generating a series of muscular pulses on their feet. These waves of muscle contraction and relaxation travel along the central portion of the foot from tail to head. The waves move much faster than the snail itself, and generate enough force to push the snail forward.

Lai found out that these muscular waves are sufficient to propel the snail forward on a flat surface, without needing the special mucus to provide more traction. The mucus does help the snail stick to surfaces, however, and comes in handy when traveling up a wall or across a ceiling, upside down.

Possible applications in robotics

Lai shot high-resolution videos of crawling snails and used a laser to measure how the muscle waves moved back and forth and up and down on a snail's foot. She also measured the forces that a snail generated when crawling on a gel. Her detailed measurements of how snails move could help other research groups that work on snail-like robots.

Researchers discovered nearly 30 years ago that snail mucus has some unusual properties. It allows the animal to stick to a surface while moving, with the mucus changing its characteristics according to how firmly the snail presses on it. The slime initially acts like glue, sticking the snail to the surface. But when the snail's foot presses down hard enough on the mucus, it becomes more liquid, allowing it to flow underneath the moving snail. Existing theories assumed that this special characteristic of snail mucus was always necessary for the snail to push off and move forward.

But Lai and her coworkers, professors Juan C. del Álamo and Juan Lasheras at UC-San Diego, and Javier Rodriguez, from Carlos III University of Madrid, noticed that snails could move horizontally just fine on a thin film of water, and wondered whether the mucus' special properties were really necessary.

Lasheras' lab had previously developed tools to study the movement of cells. He studied the movement of a single-cell amoeba as a model for how human cells move during development, during immune responses, and when rebuilding damaged tissues. Lai adapted Lasheras' tools to study snails and slugs. Snails are similar to our cells "in that they both have to move and adhere to a surface at the same time," she said.

Lai's experiments echoed Eadweard Muybridge's famous stop-motion photographs from the late 1800s. His photos – taken on what is now the Stanford campus – proved that all four of a horse's hooves are off the ground at the same time during a gallop. In Lai's case, she used high-resolution videos to show that parts of a snail's foot lift off the ground as the waves of motion travel through it.

If the snail's foot never lifted off the ground, then the animal would need the special mucus to achieve enough force to push itself across a horizontal surface.

But if, however, a part of the snail's foot lifted up as the waves traveled through it then the animal could produce enough thrust to push itself forward even without the special physical properties of the mucus. Lifting part of its foot reduces the amount of friction the snail has to overcome to move. This would be similar to a caterpillar, which lifts the middle part of its body up and stretches forward as it moves.

Lai tracked the movement of snails on a horizontal glass surface, using a high-resolution camera placed underneath. She measured the back-and-forth waves of muscle contractions by tracking the movement of distinctive speckles on the foot. She also used a laser to measure the distance that the foot waves moved up-and-down off the glass surface.

To measure forces, she placed the snails on a gel and measured how the gel deformed as the snails moved across it. She already knew how much force it took to deform the gel, so she was able to calculate how much force it took to produce the observed deformation.

Vertical vs. horizontal travel

Based on their new measurements, the researchers found that the snails didn't require the special mucus to travel horizontally. The lifting of the snail's foot as the waves travelled through it produced enough force to propel the animal even without the slime. The slime's adhesive ability still plays a crucial role, however, in allowing the animal to crawl upside down and up vertical surfaces.

Apart from changing how we view snail locomotion, the work has practical applications as well. A number of other research groups have been making robots that move like snails. Lai is currently working on a more detailed mathematical model of snail movement that could help refine these robots.

"Now that we understand the mechanism and have models, the next step is to apply them to robots," said Lai.

A group at MIT has already built snail robots that can move on vertical walls and upside down, and researchers from Tohoku University in Japan are building an endoscope, a tool that doctors use to look inside the body, that would move like a snail. Snail-like robots are less complicated to build as "there are no legs sticking out," said Lai, and their crawling motion allows them to traverse a wide variety of surfaces.

Lai, a mechanical engineer, was the first author of the study published last October in the *Journal of Experimental Biology*. In November, she presented an updated mathematical model of snail locomotion at the Annual Conference of the American Physical Society.

Lai started working on snail locomotion in 2007 as an undergraduate, when she spent a summer doing research with Lasheras, the paper's senior author. Lai's summer project went so well she continued the project after coming to Stanford in 2008. "I started the project with snails caught in my adviser's backyard, so it's been very fun and satisfying to get to this point," she said.

Provided by Stanford University