Inspired by snails, researchers invent a reversible adhesive strong enough to hold a person

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Superglue is incredibly useful—right until you end up attached to your craft project. But a new adhesive invented by University of Pennsylvania scientists is just as strong as standard superglue, and far more forgiving. The adhesive, based on snail slime, can be unattached and reattached over and over without losing its strength, and may save manufacturers from costly mistakes.

Humanity has been searching for the best way to stick two things together for a very long time. As early as 200,000 years ago, humans were making sticky tar by carefully burning birch bark in a time-intensive process. Nearly 4,000 years ago, ancient Egyptians were boiling animal parts to make the first liquid glues. Rubber-based glues were invented in 1830, with modern superglue hitting convenience store shelves in 1958. But all of these adhesives come with a frustrating trade-off: They can be strong and permanent, like superglue, or reusable but not very sticky, like Post-its.

Now, a team led by Shu Yang, professor of material science and engineering at Penn, has managed to combine the best properties of both.

Yang shared her findings in a new study published last week in the *Proceedings of the National Academy of Sciences*. Just two stamp-size pieces of Yang's adhesive were enough to easily hold the weight of a 160-pound person, the study said.

Named PHEMA, after its chemical composition (polyhydroxyethylmethacrylate), it is so effective that at first, Yang had trouble measuring its strength. "I thought it was very strong, but I didn't know how strong," she said. The strength of an adhesive is measured by pulling until the attachment breaks.

"It took my student over a year to measure it," said Yang. Even a

graduate student, Jason Jolly, stepped up to prove the adhesive's strength—by suspending himself in the air. In the end, the team had to design straps made out of Kevlar—the material used in bulletproof vests—to pull the PHEMA apart.

But what makes PHEMA stand out is that its stickiness can be turned off and on again. The adhesive holds tight when dry, but add some water and within a few minutes, PHEMA detaches, ready to be reused.

"To be able to let go—that's a big deal," said Andrew Smith, professor of biology at Ithaca College in New York, who has developed a medical glue based on slug slime, and was not involved in the study. "We have very good glue for certain things. The challenges (include) when you need something that's reversible."

PHEMA's abilities comes from the fact that it isn't a liquid, like glue, but a hydrogel, such as those found in Jell-O or soft contact lenses. "Hydrogels are soft, squishy materials ... . If immersed in water, they suck up water," said Yang. And when a hydrogel dries out, it becomes rigid.

When squishy and wet, PHEMA is able to fit into the microscopic grooves and imperfections that are on all surfaces, even seemingly smooth materials like glass. Drying locks PHEMA against these grooves, attaching it to the surface.

However, before you try to hang from the ceiling using Jell-O, Yang explained that PHEMA is unique: "When you dry (a hydrogel), they normally shrink. Our material doesn't."

While the idea of a reversible superglue is new to humans, snails have been making something similar for millions of years. "Some snails anchor themselves to a tree with (a structure called) their epiphragm ... .

It can be attached so hard that you can't pull it off with your hand—you need to get a chisel." said Gary Rosenberg, curator of mollusks at the Academy of Natural Sciences of Drexel University. Once it rains, the snails detach and continue crawling around.

Only some snails make epiphragms. One famous example is Helix aspersa, the snail eaten in French cuisine as "escargot." Philadelphians might even be able to see this ability for themselves. Several species of Polygyridae snails have been reported in the region, according to the citizen science app iNaturalist, and all can make a hydrogel glue that works just like Yang's PHEMA.

PHEMA, or other adhesives like it, might one day be part of our daily lives. Elliot Hawkes, assistant professor of mechanical engineering at the University of California, Santa Barbara, suggests that PHEMA might be useful around the house, especially for hanging up decorations. "Painted drywall is challenging for dry adhesives, due to its slight roughness. This technology could be a nice solution, depending on whether it would discolor your wall," he said in an emailed statement. Hawkes was not involved in the PHEMA study.

As for Yang, she thinks that PHEMA will be incredibly helpful for heavy manufacturing, such as car assembly. By using the reversible adhesive to test how parts fit together, PHEMA will allow assembly workers to check and swap out defective components before it is too late.

Smith agreed that these applications sound "pretty plausible," but cautions that because PHEMA needs water, it won't be a good fit for many industries. And since PHEMA detaches when wet, the glue can't hold up in humid environments.

To get around this limitation, Yang's team wants to develop a new

version that switches on and off based on specific chemicals, electricity, or heat, instead of water.

This next innovation may already be out there in nature. Snails, slugs, mussels, geckos, octopuses, and even cockroaches are being studied for the way they can stick to things. "There's a lot of animals that produce glues with lots of unusual properties," said Smith. "You're getting adhesives designed for all sorts of situations, with lots of variation that can inspire us."

More information: Hyesung Cho et al. Intrinsically reversible superglues via shape adaptation inspired by snail epiphragm, *Proceedings of the National Academy of Sciences* (2019). DOI: 10.1073/pnas.1818534116