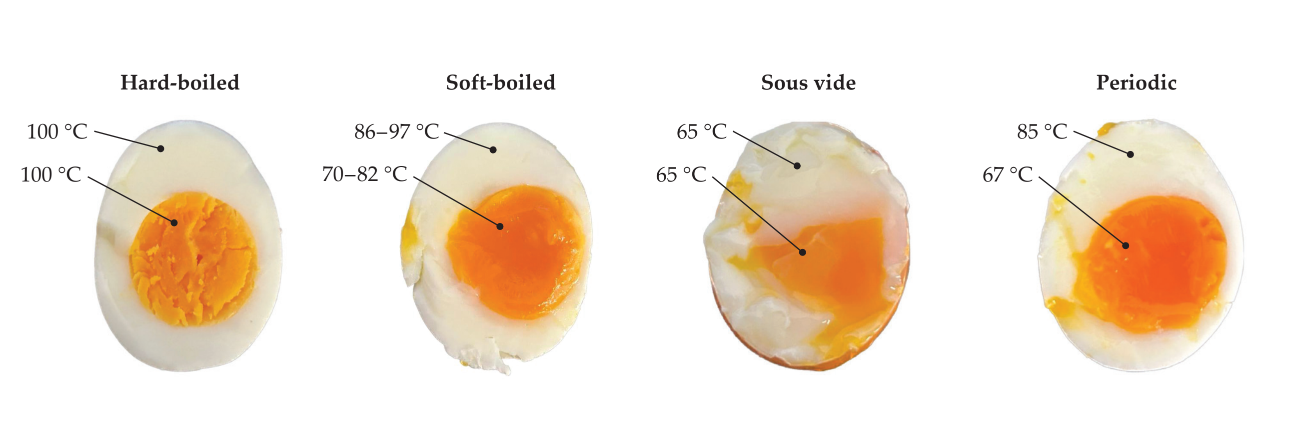


DIFFERENT EGG-COOKING METHODS yield different results. Hard-boiling often creates a flaky yolk; soft-boiling, a runny yolk; and sous vide, a white that isn't fully set. Periodically switching eggs between boiling and tepid water can achieve internal temperatures that yield a creamy yolk and a fully set white. (Figure adapted from E. Di Lorenzo et al., *Commun. Eng.* **4**, 5, 2025.)

Realizing two specific temperatures within an object is a familiar problem to Ernesto Di Maio, of the University of Naples Federico II in Italy, and his colleagues. They expose polymer foams to time-varying pressures and temperatures to induce the formation of layers with different densities or morphologies. Because eggs have both an internal boundary and foaming capacity, Di Maio asked his student Emilia Di Lorenzo to determine if similar engineering principles could be applied in the kitchen.

Guided by their previous experience, Di Maio and colleagues predicted that alternating the exterior temperature would be the best way to manipulate the interior temperature of the two egg regions in different ways. Di Lorenzo created simulations based on basic heat-transfer equations and kinetic models of gelation to refine the cooking temperatures and timing. Then, the team broke open the egg cartons.

The trick, the researchers learned, was to alternate between cooking the eggs in 100 °C and 30 °C water every two minutes, for a total of 32 minutes. The two regions of the egg respond differently to the alternating temperatures because it takes 10–100 seconds for the heat to transfer across the boundary into the yolk. The albumen oscillates in temperature, which rises and falls with each transfer between pots before it eventually settles at around 85 °C. The yolk does not respond as quickly; instead, its temperature slowly rises until it reaches 67 °C, slightly above the average of the two cooking temperatures.

Satisfied with the temperature readings, Di Maio and colleagues also found that the two regions of the periodically cooked eggs had the desired textures. Adjusting the temperature of the pots or changing the time the egg remains in each can tailor the exact outcome to accommodate personal preference in cooking. The extra time to cook might not be worth it for the average home cook, but Di Maio and Di Lorenzo—who does not even like eggs—predict that restaurants may experiment with their method. In the meantime, they have turned their attention back to multilayered polymers. (E. Di Lorenzo et al., *Commun. Eng.* **4**, 5, 2025.)

Jennifer Sieben

The protection required to deliver a powerful underwater punch

The structure of a smasher mantis shrimp's clubs protects their tissue from damaging shock waves.

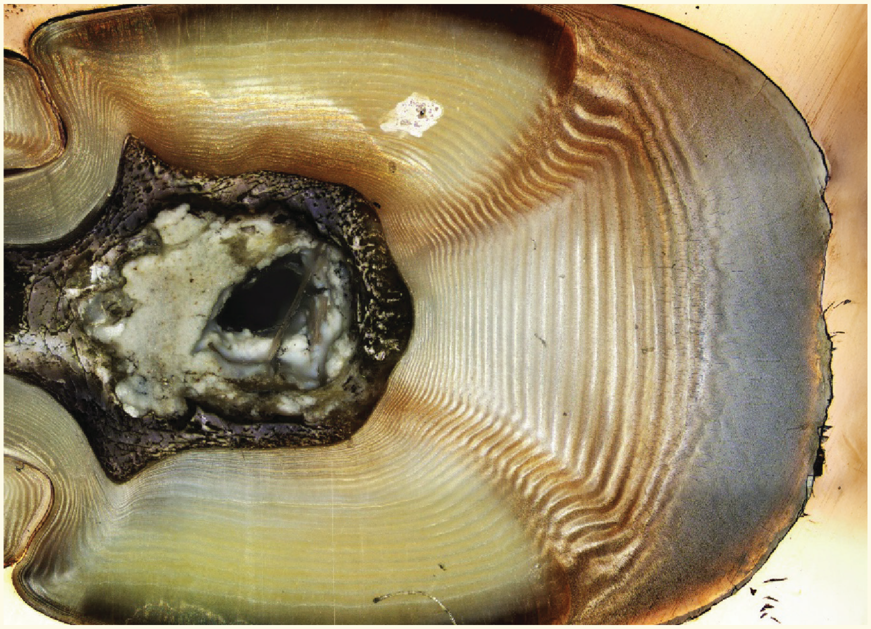
The smasher mantis shrimp is small, but it packs a large punch. It has evolved to use its specialized front appendages—the dactyl clubs, the two red bulbous structures in the photo on page 16—to shatter seashells with peak forces of around 1500 N delivered in less than 50 μs. That is the strongest self-powered strike by any known animal on Earth. Although other animals have similar attack mechanisms, they typically sustain damage, and they can attack only once per molting cycle. The mantis shrimp's attacks are not similarly limited. Now Horacio Espinosa of Northwestern University and colleagues have provided the first experimental evidence that the clubs' internal structure is what prevents substantial damage.

When a dactyl club strikes a shell, two impacts occur: one from direct contact and another from the collapse of cavitation bubbles formed in the surrounding water when the club retracts. Espinosa had learned from previous experience in studying underwater explosions that shock waves could be dangerous underwater, even if they don't generate as much force as a contact blow. The collapse of the bubbles generates both pressure waves and shear waves, with the latter being particularly harmful to biological tissue.

Previous theories suggested that phononic bandgaps—structural mechanisms for filtering stress waves within specific frequency ranges—help reduce damage to the clubs. Espinosa and his team used acoustic-wave analysis to examine how shock waves are filtered in a club. They discovered that the high-frequency waves generated by the bubble collapse match the frequencies that a dactyl club's internal structure is able to filter.

THE PEACOCK MANTIS SHRIMP—a variety of smasher mantis shrimp—uses its two dactyl clubs, the red bulbous appendages shown folded backward above the legs, to shatter various seashells, including those housing hermit crabs. The clubs' internal structure protects them from damage. (Photo by iStock.com/mantaphoto.)

Each dactyl club has a hierarchical design with multiple regions. The impact surface behaves like a ceramic: hard but resistant to fracture. Beneath that outer layer, the club contains two regions of fine chitin fibers, with the innermost region arranged in a helicoidal pattern, known as a Bouligand structure. In typical shattered glass, cracks form radially outward. In a helicoidal fiber architecture, however, cracks follow complex curved paths, which makes the material resistant to crack propagation.



A BISECTED VIEW OF A PEACOCK MANTIS SHRIMP'S DACTYL CLUB. Periodic layers of chitin fibers give it a striped appearance. The structure filters shear waves and reduces damage to the shrimp, so it can attack multiple times. (Image adapted from N. A. Alderete et al., *Science* **387**, 659, 2025.)

The periodicity of the Bouligand structure is also crucial to filtering propagating shear waves. The chitin fibers are stacked at varying angles, with the periodicity of the stacks decreasing closer to the club's core. That gradient enhances wave filtering across a broader frequency range, thereby reducing the energy transmitted to the shrimp's soft tissue.

Espinosa and colleagues used lasers to excite and measure waves propagating within a bisected dactyl club of the peacock mantis shrimp (a variety of smasher mantis shrimp) to confirm the filtering effect. Their experiments and analysis of the resulting phononic spectra showed that the club was selectively filtering harmful frequencies. Although the structure operates similarly to a phononic crystal, replicating it synthetically would require advanced nanomanufacturing techniques. (N. A. Alderete et al., *Science* **387**, 659, 2025.)

Jennifer Sieben PT