The weird and wonderful world of breeding sea stars

February 9 2022, by Adrienne Berard

A male and female (right) brittlestar are examined and prepared for spawning inside the Allen Lab at William & Mary. Credit: Adrienne Berard

It takes a bit of work to get brittlestars in the mood to procreate in captivity. They need to be well-fed, in total darkness and convinced the world is ending.

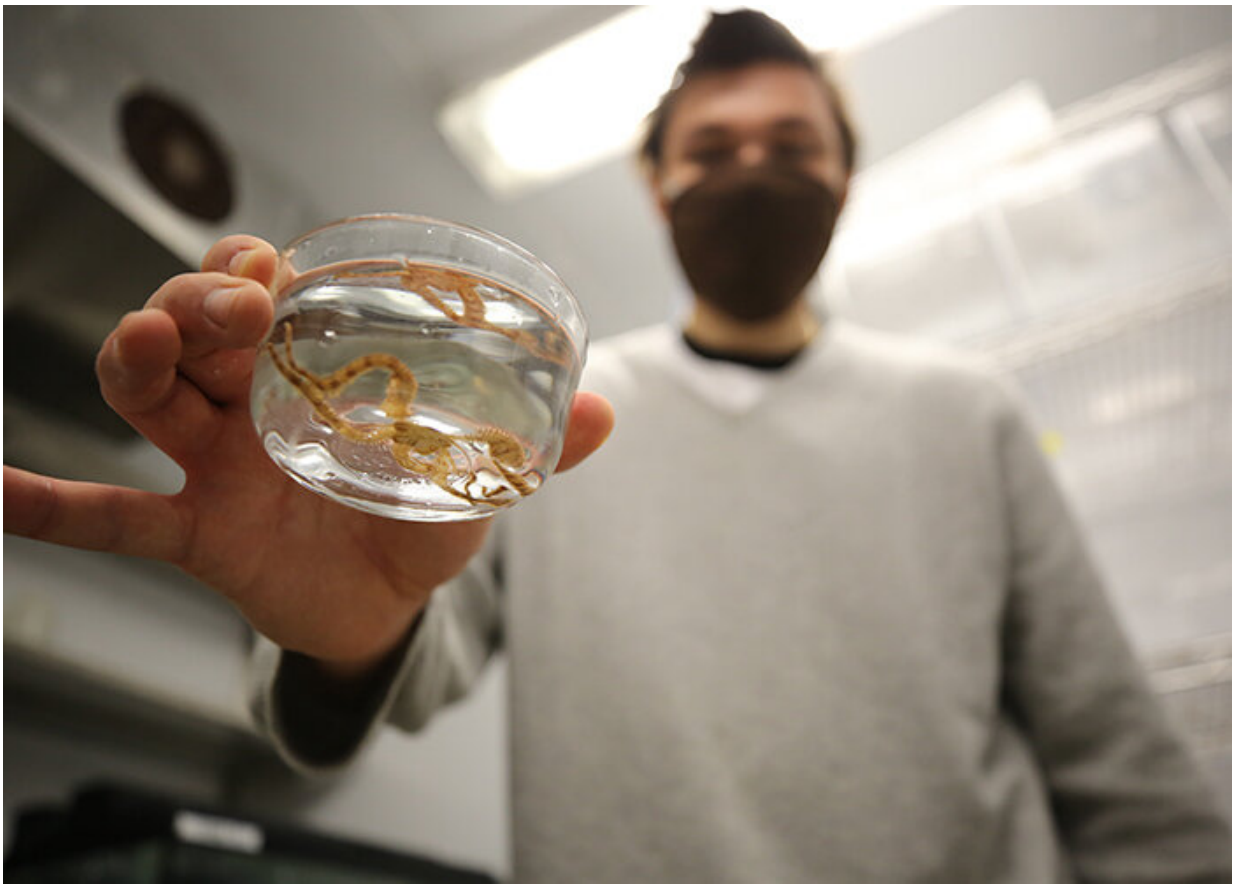
"It's like a war of attrition," says Augie Davis, a senior honors student at William & Mary. Davis had just finished pedaling a pushcart loaded with little bowls of brittlestars around the second floor of William & Mary's Integrated Science Center. "After we take them for a few laps,

we flip them upside down in their bowls, but they flip themselves back over, so we have to flip them upside down again and shut the lights off on them. It's scientific, but there's also some voodoo involved."

Every year around Valentine's Day, the lab run by W&M biologist Jon Allen plays starfish matchmaker by mimicking nature in clever ways to study the animals' incredible lifecycle.

Research in the Allen Lab focuses on the life histories of marine invertebrates. Students, both undergraduate and graduate, study the ecology and evolution of the larval stages of diverse organisms including sea urchins, snails, flatworms, sea stars and, on the rare occasion, brittlestars.

Allen explained that brittlestars are hard to come by for researchers. The animals are hyper abundant in the deep sea, but are rare and cryptic near the coasts, avoiding light and living under rocks with only the tips of their fragile arms exposed. With any luck, Davis's mood-setting efforts would result in baby brittlestars for the lab to study.



Augie Davis ’22 prepares mature brittlestars for spawning inside the Allen Lab at William & Mary. Credit: Stephen Salpukas

"It depends how you want to anthropomorphize it," said Allen. "You're either tiring them out and convincing them that the world is gonna end, so therefore they should spawn—or you're somehow turning them on, because maybe they're into that sort of thing."

One thing that manifestly does not turn brittlestars on is other brittlestars. In the wild, male and female brittlestars rarely interact, Allen explained. But while there are no brittlestar meet cutes, there is still an intricate breeding process taking place just below the water's surface.

"In nature, starfish and brittlestars just throw off their eggs and sperm into the water, so Mom and Dad actually never even see each other," Allen said. "It's their gametes, the sperm and the eggs, that have all the fun."

Allen explained that there is a very intimate communication system between starfish eggs and sperm. The eggs are highly attuned to certain qualities in the sperm, especially a species-specific protein called bindin, and are selective in their choice of which sperm are permitted entry to the cytoplasm of the egg. The sperm are just as selective, only actively swimming if the precise egg match is present and following a trail of chemicals laid down by mature eggs.

Augie Davis ’22 pedals a pushcart loaded with little bowls of brittlestars around the second floor of William & Mary’s Integrated Science Center. Credit: Stephen Salpukas

"That's what's so fascinating to me about these animals," Allen said. "There is this whole chemical ecology, a whole world of fertilization and selection, and the parents aren't even involved."

He added that climate-change-driven variations in water temperature and current could have the potential to change population outcomes for a species whose survival quite literally depends on going with the flow.

For example, the brittlestar is an arctic species, meaning the animals come into spawning condition when the water is relatively warm for them, around mid-February. The female brittlestar takes cues from certain changes in her environment, like the water temperature, that let her know it's time to start releasing eggs. And while male and female never meet, the brittlestars still have a form of mating dance.

"When they do their thing, they get up on all fives and twist their middle back and forth," Allen said, describing the motion that male and female brittlestars make when releasing gametes. "They stand up on their legs to get above what's called the boundary layer, where the water's not moving up to where the water's moving. Then they wriggle around and shed eggs and sperm from their armpits."

Alexis Reece ’22 stands beside a sea star tank inside the Allen Lab’s aquarium at William & Mary’s Integrated Science Center. Credit: Adrienne Berard

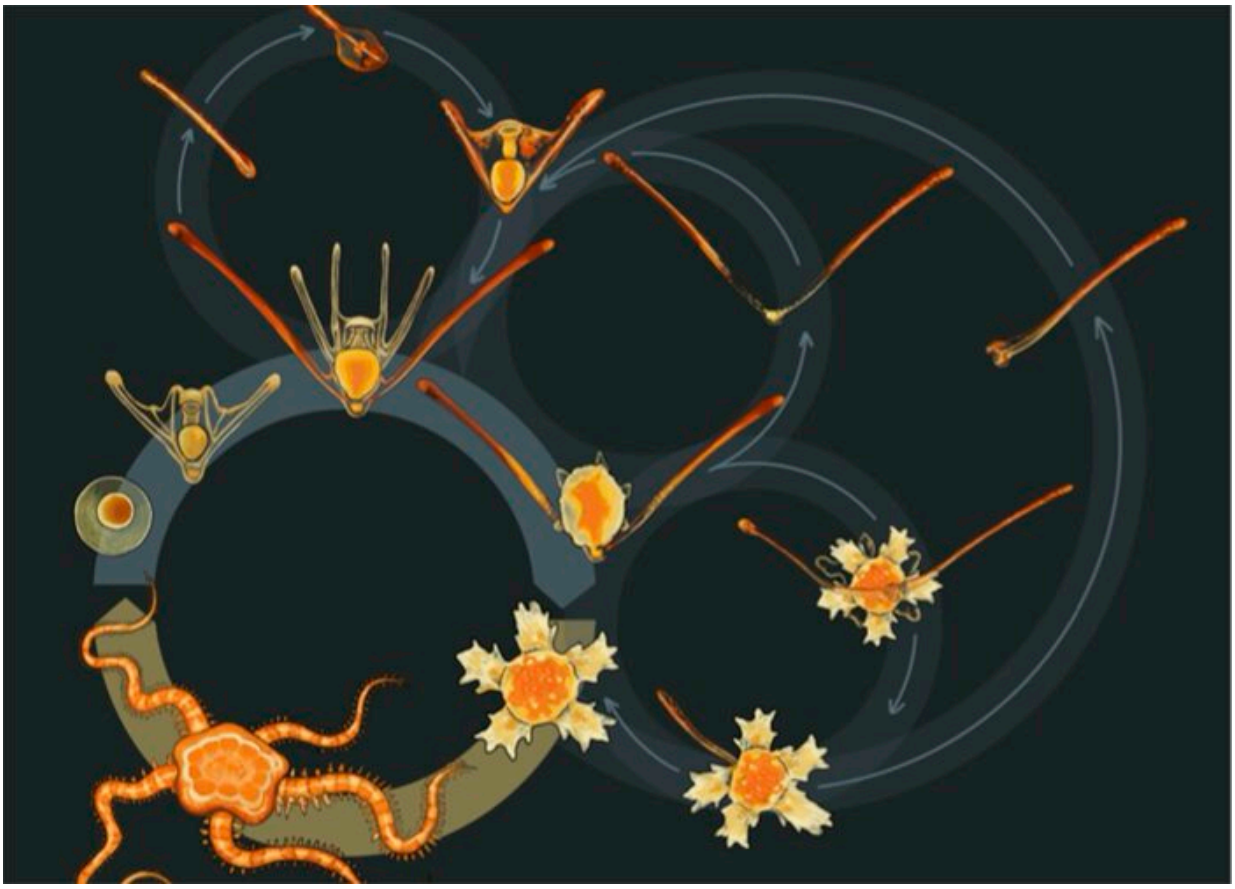
In brittlestars and sea stars, the math works against survival for almost all of the animals produced during a spawning event, Allen explained. Imagine a stable population of sea stars, where Mom and Dad produce just enough offspring to replace themselves over their lifetime. In a large-bodied species, like some of the west coast sea stars Allen works on, a reproductive female might make 50 million eggs per year. That same female can live for decades, and if she is reproductive at that level for 20 years, she would produce one billion eggs in her lifetime—only two of which survive on average.

"That means that each adult sea star we find is almost literally a one-in-a-billion event," Allen said.

While the pressure is on for a successful spawning season, Allen is quick to add caveats to any analogy to romance in the phylum Echinodermata (brittlestars, sea stars, sea urchins etc.). The creatures don't have a brain or central nervous system. They have thousands of eyes that have been found to be sensitive to light, but brittlestars don't have a sophisticated system for processing visual stimuli.

"Well, we can probably rule out love at first sight," Allen quipped. "Because the jury is still out on whether these animals can even see."

Caroline Vanduzer ’23 injects a spawn-inducing hormone into a sea star. Credit: Stephen Salpukas



A brittlestar lifecycle: Adult on the bottom left releases eggs into the water column that develop into larvae and eventually juveniles. In each cycle that spins off, larval cloning produces a new larva asexually. Credit: Anna Mehlhorn '22

In the end, the brittlestar romance was successful in the Allen Lab, with multiple animals spawning over the course of two days and nights. Each reproductive female produced tens of thousands of eggs, so Allen and his students will have more than enough brittle babies to work with for

their research. They will use the newly produced animals to study how environmental cues, like changes in temperature and salinity, affect cloning during the larval stage. Each larval brittlestar has the capacity to asexually produce genetically identical clones of itself. Understanding that process is the focus of the lab's most recent work.

While the brittle babies mark a successful spawning season for one species, another of the lab's spawning attempts was less of a triumph. As Davis was jumbling and flipping brittlestars, a team of undergrads (Caroline Vanduzer '23, Alexis Reece '22 and Nhu-Lan Pho '25) used a more scientific, chemical induction method to spawn Asterias forbesi, a species of starfish native to the East Coast and found along Virginia's beaches. The students injected six male and six female sea stars with a hormone proven to stimulate spawning.

The goal was to mix the gametes and study the resultant larval-stage sea stars, who, as a prior lab student discovered accidentally, cannibalize each other in an elaborate, micro-sized Darwinian display. Unfortunately for this year's researchers, the female starfish did not respond to the hormone and held fast to their eggs.

"Those were the star-crossed lovers," Allen laughed. "We went through all the right motions of romance, if we want to call it that, but fate got in the way. Of course, ultimately our goal was to figure out why they eat each other, so let's be truthful about the science here. Sometimes in nature, it gets a little crazy."

Provided by The College of William & Mary