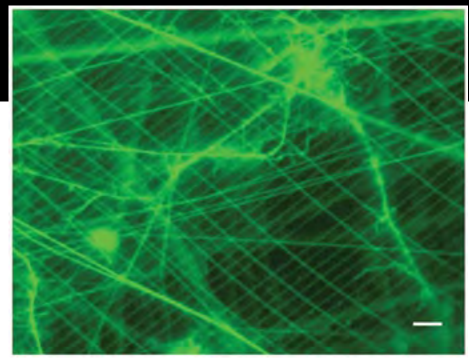
To Catch the Ocean's Tiniest Organisms

Salps' internal feeding nets are remarkably engineered



Courtesy of Kelly Sutherland, WHOI

Inside their transparent gelatinous bodies, salps use mucus to create feeding nets (stained green), which trap food particles. The strands are sticky, and they snare bits of food as tiny as bacteria that would otherwise slip through the holes.

Salps are sometimes called "the ocean's vacuum cleaners." The soft, barrel-shaped, transparent animals take in water at one end, filter out tiny edible plants and animals with internal nets made of mucus, and squirt water out their back ends to propel themselves forward.

In a surprising new finding, scientists at Woods Hole Oceanographic Institution (WHOI) and the Massachusetts Institute of Technology showed that the salps' nets are remarkably engineered to catch extremely small particles that scientists assumed would easily slip through the 1.5-micron holes in the nets. (A micron is a millionth of a meter, or 10^{-6}m.) Their discovery revealed a previously unsuspected biological mechanism that helps operate the marine food web and also removes the greenhouse gas carbon dioxide from the upper ocean.

In experiments at the Liquid Jungle Lab in Panama, Kelly Sutherland, then a graduate student in the MIT/WHOI Joint Program, and colleagues put salps in water containing different-size food particles—in concentrations representing those in the ocean. The particles were smaller, around the same size as, and larger than the mucus net openings.

Sutherland found that "80 percent of the particles that were captured were the smallest particles in the experiment," she said. "It's counterintuitive. Your intuition tells you that the salps should capture particles larger than the holes in their nets. They catch those things—*and* things that are smaller than the holes."

The key is that the mucus strands are sticky. "It's like dust blowing through a window screen; any dust that hits the window screen strands sticks to them," said Sutherland, now a postdoctoral scholar in bioengineering at the California Institute of Technology.

Alexandra Techet, Massachusetts Institute of Technology

Do salps prefer their meals in bigger or littler bits? To find out, former MIT/WHOI graduate student Kelly Sutherland fed them food particles of different sizes.

That allows salps to "consume particles spanning four orders of magnitude in size," said Larry Madin, director of research at WHOI and Sutherland's Ph.D. advisor. "This is like eating everything from a mouse to a horse." Sutherland, Madin, and Roman Stocker of MIT's Department of Civil and Environmental Engineering reported their findings in the Aug. 9, 2010, issue of *Proceedings of the National Academy of Sciences*.

The finding is important for a number of reasons. First, it helps explain how salps—which can exist either singly or in "chains" that may contain a hundred or more individuals—can survive in the open ocean, their usual habitat, where the supply of larger food particles is low. "Their ability to filter the smallest particles may allow them to survive where other grazers can't," Madin said.

Second, and perhaps most significantly, it enhances the importance of the salps' role in cycling carbon from the atmosphere into the deep ocean. As they eat, they consume a very broad range of carbon-containing

Larry Madin, WHOI

Andrew Gray, UC Santa Cruz

Kelly Sutherland scuba dives to collect salps at Liquid Jungle Lab off the Pacific coast of Panama.

"Salps consume particles spanning four orders of magnitude in size. This is like eating everything from a mouse to a horse."

particles and efficiently pack the carbon into large, dense fecal pellets that sink rapidly to the ocean depths, Madin said.

"This removes carbon from the surface waters," Sutherland said, "and brings it to a depth where you won't see it again for years to centuries." And more carbon sinking to the bottom reduces the amount and concentration of carbon in the upper ocean, letting more carbon dioxide enter the ocean from the atmosphere, explained Stocker.

The research, funded by the National Science Foundation and the WHOI Ocean Life Institute, "does imply that salps are more efficient vacuum cleaners than we thought," Stocker said. "Their amazing performance relies on a feat of bioengineering—the production of a nanometer-scale mucus net—the biomechanics of which still remain a mystery." (The net strands are mere nanometers, or billionths of a meter, thick.)

A big step in the research was getting accurate images of the salps' nets to get precise measurements of the size and pattern of holes within them. Previously, scientists had to dry and freeze the nets to take images. "That distorts something as fragile as a mucus net," Sutherland said. "We wanted accurate measures while the nets were wet."

To make the first images of "live" mucus nets in salps, Sutherland inserted thin pieces of glass (slide cover slips) into living, swimming salps' body cavities, letting the mucus net adhere to it. "You can never tell if a salp has a net in it or not," she said, "because the net is transparent in a transparent animal."

She retrieved nets and, working with Anthony Moss, a marine biologist at Auburn University, she stained them with a fluorescent dye that revealed the meshes in all their glorious precision and regularity.

—Kate Madin

Tom Kleindinst, WHOI

Kelly Sutherland (right), now a postdoctoral scientist at the California Institute of Technology, and biologist Larry Madin, her doctoral advisor at WHOI, studied the feeding of salps, such as this one preserved in a jar. With MIT professor Roman Stocker (not shown), they showed that salps can catch and eat some of the smallest particles in the ocean.

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