

Robotic Fish Gather Data, Prize By Kari Lynn Dean

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Imagine rushing to the car from a late lunch at 7-Eleven, yogurt spoon still in mouth, and your cell phone rings. An unknown caller declares you've won a half-million bucks, unsolicited and no strings attached, because you are quite "original."

Whatever your reaction, don't hang up. In fact, you might want to sit down.

Last week, 23 unsuspecting and relatively unknown "original" people -- from writers and inventors to biologists and civic do-gooders -- received that phone call.

Each had won a contest that none had entered. Since 1981, anonymous sponsors appointed by the MacArthur Foundation have made [confidential nominations](#) and foundation directors have selected winners for what are known as the annual "genius awards."

Each winner was chosen not as much for past achievements as for contributions he or she might make to the future. In fact, [past MacArthur fellows](#) have been known to go on to bigger and [more prestigious awards](#).

For the next few weeks, Wired News will profile a handful of these genius creators of the future, specifically those selected for dedication to creativity in the fields of science and technology.

Marine roboticist Naomi Ehrich Leonard, 40, is the first of these scientists, and the one who was sitting with her yogurt in a parking lot when the MacArthur Foundation called. A Princeton University professor of mechanical and aerospace engineering, Leonard combines fluid mechanics, robotics, computer science, oceanography and biology to understand, predict and mimic forces within the ocean. To do that, she trains robotic fish.

Leonard designed the brains of her fleet of battery-operated fish -- also known as underwater autonomous vehicles, or UAVs -- to survive, manage uncertainty and collect data, based on her investigation of how schools of real fish coordinate efforts to find food.

"Social foraging is a great metaphor," she said. "A single fish isn't very bright or cooperative. But they know if they work together, they will find food more successfully. But instead of looking for food, we are looking for useful data. The submersibles know to go someplace where something really interesting is happening."

[upwellings](#), cold blooms and phytoplankton masses -- anything that might help scientists understand ocean dynamics and apply the findings to above-ocean climate activity. Coordination of efforts between her dozen or so underwater gliders is key to locating that activity, as well as to their survival as they face currents, undertows and predators.

"There's no leader in a fish school -- it may look like there's someone in front, but it's always changing and everybody has basic rules," Leonard said. "You sense your neighbors and environment and know you should stay close, but not too close. And not too far, because you want to keep track of what everyone is doing - - if others are moving away fast, you follow your neighbor."

Leonard's "adaptive ocean sampling" algorithms enable each [off-the-shelf submersible](#) to analyze its environment and other UAV positions to make decisions about data collection and the safest courses of action.

"Cruise control is the same idea. Enter the speed you want to go and the algorithm adjusts acceleration to maintain it," Leonard said. "But it also makes adjustments to what's happening -- responds to a bumpy road, raining and other environmental changes.

"Control laws ensure not just the speed, but also that the ride is not jerky, so passengers are comfortable and so you don't overshoot your speed and get a ticket," she said.

Leonard's smart baby subs are 5-foot-long 50-pounders that can cost up to \$50,000 each. To stay quick, light and agile, they use wings, a rudder and a buoyancy engine that takes in and lets out water to control direction. Because they lack propellers, they can swim for weeks, taking measurements of temperature, salinity and chlorophyll concentrations, linking to GPS and Iridium satellites without a battery recharge.

"We can see the atmosphere from space, but the ocean is opaque to satellites, so you basically have to go into the ocean to take measurements which is very expensive," said James Bellingham. As director of engineering for [Monterey Bay Aquarium Research Institute](#), Bellingham has worked extensively with Leonard with programming AUVs for ocean sampling. "Naomi's work has big implications for oceanography and long-term climate prediction."

Leonard credits her graduate school adviser for helping her make the kind of scientific progress that merits a half-million-dollar fellowship.

"I'd go into his office sometimes feeling like I'm working on something so small and unimportant and then emerge feeling like I'm going to save the world," she said.

In spending her windfall, Leonard has no restrictions, but is contemplating two directions. One would provide a better understanding of the ocean and of how to predict red tides, improve search-and-rescue design, and trace pollution plumes to their sources.

She is equally interested, however, in pursuing how nature regulates its behavior and how natural systems often remain robust despite environmental perturbations.

"I want to understand why certain ecosystems work so well even though things always happen and change," she said. "If we can learn how to emulate those ecosystems, we might know how to help when they don't work well."



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