Making use of jellyfish on dry land

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John Dabiri, assistant professor of aeronautics and bioengineering at Caltech who won a MacArthur Award this year, is fascinated by jellyfish. He believes jellyfish propulsion can inform engineering, which in turn can inform efficiency in wave and wind technology. He recently spoke with the Los Angeles Times.

Q: Is your background in engineering or biology or both?

A: I was trained as a mechanical engineer, and I always thought I'd end up working in the auto industry because I'm from the Midwest, and that's what a lot of people do there. But when I went to college, one of my professors suggested I come out to do a summer internship with a professor (at Caltech). I started to understand that we can learn a lot from animal systems and apply that to different engineering technologies.

Q: What's the connection between engineering and jellyfish?

A: At the end of the day, when you look at fluid flows, whether it's air or water or blood, they can all be described by the same equations. The math and the physics don't really care whether you're talking about an airplane, a jellyfish or the human heart. So you can start to understand, for example, what makes a jellyfish efficient, and then use that information to design submarines that are more efficient, or diagnose when the heart is no longer performing efficiently. It all goes back to the fluid dynamics.

Q: Tell us some of what you've learned about how jellyfish move.

A: For a long time, people thought of jellyfish swimming as like jet propulsion - like a rocket that shoots out exhaust and goes the other way. But it's a bit more subtle than that. They create vortex rings, like the smoke rings you might create with a cigar. And those doughnut-shaped swirls of water are an efficient way of propulsion because (the animals) can basically push off of those doughnuts of water.

What we wanted to understand was how do they form these swirling currents, and whether then we could build underwater vehicles that could also create these same type of water currents while they propelled themselves.

Q: What is it about jellyfish that you were drawn to?

A: At the beginning, it was just their simplicity. They're about the simplest things you can think of - it looks like they are just kind of floating around.

It turns out they do have these interesting fluid dynamics, but we only learned this after we started measuring their fluid flow, using different visualization techniques. The problem when you try to study water flow is that it's pretty much transparent. You can, as a simple thing, just put dye - food coloring - in the water around the animals. The animals will swim through, and then you'll be able to see the water currents they create while they're swimming.

Q: Do you get in the water with the jellyfish or just add dye to a tank and observe?

A: A little bit of both. With the smaller animals, you can do this in the lab. But grad students in my lab and my collaborators will go out to the field to Croatia or to the Atlantic in Woods Hole (Oceanographic Institution) in Massachusetts, and go scuba diving with them.

Q: Which species?

A: The moon jelly - that's the most common one. You see them in the aquarium; they are sort of white-colored. They don't sting humans very much, and they're very plentiful, so it's pretty easy to find them. Then there's one called the lion's mane - which has a reddish color with really long tentacles. Those are the two main species we looked at because they are easy to access and the sting isn't horrible.

Q: To inform engineering, would your research only work with jellyfish?

A: These vortex rings show up in other animals. So you could have picked a trout, let's say, or a shark.

They have more complicated wake flow patterns: The shape of their fins and the way they move is just more complicated. With a trout or a shark, as it's flapping its tail, it's creating these vortex rings, but they are sort of linked up into more complicated chains. So if you were to do that dye experiment - if you could do it with a shark - it would be messier, and harder to interpret what you were seeing.

Q: What's the next phase of your research?

A: The bigger picture for our lab is a field of what we call bio-inspired engineering - we study different biological systems and try to understand what they do well and what they aren't able to do well, then apply that knowledge to engineering systems.

Recently, we've been doing work in wind energy to find an alternative to the very large propeller-style windmills. These require lots of land, because you have to space them far apart so the wakes of the turbines don't interact with one another. And these days there's more and more opposition just because people don't want to see them in their backyards. There are issues potentially with birds. And so on.

There is another technology out there for wind energy generation - instead of using these large wind turbine structures, they rotate around a vertical axis. They are smaller structures, so they are maybe 30 feet tall instead of 300 feet.

We've been interested in how many of these smaller structures could be situated very close together in order to generate as much power as you get from the very large ones. We were able to learn something about this from how fish school.

Fish like trout or tuna or mackerel will often swim in groups in pretty regular patterns. One of the leading hypotheses for why they do this is that the individual fish can interact with the vortices that are being shed by the tails of their neighbors and go from point A to point B using less energy as a group than if they were going individually through the water.

We tested a mathematical model to describe what arrangement of the fish in a school works for this energy savings - except instead of fish, we had these wind turbines. We did a field demonstration this summer out in Lancaster, and were able to show that using this bio-inspired design for this wind farm, we could actually perform much better than existing technologies that are out there.

The systems don't need to be identical for you to learn from them.

More information: (This interview was edited for clarity and space from a longer discussion.)

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