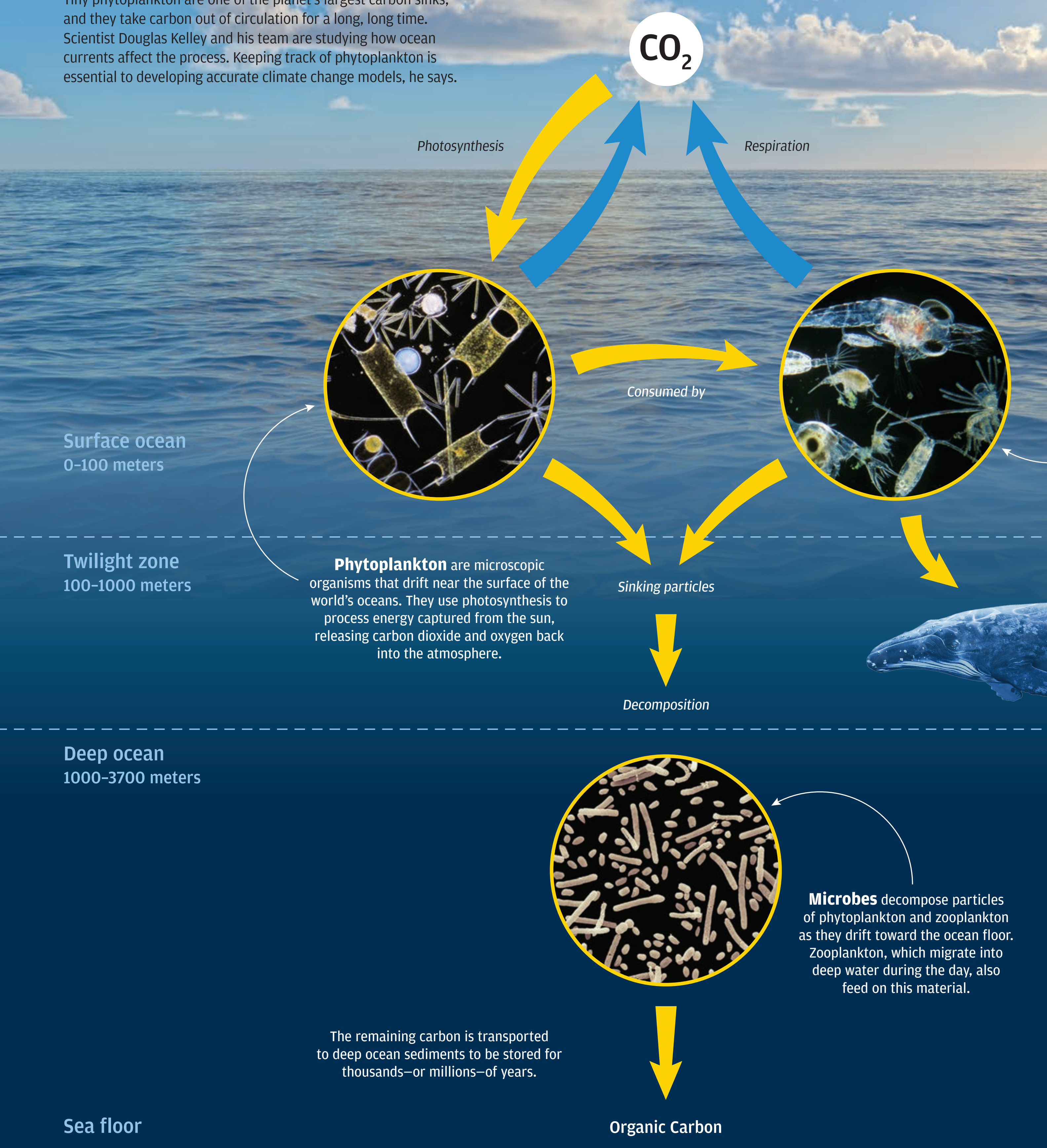
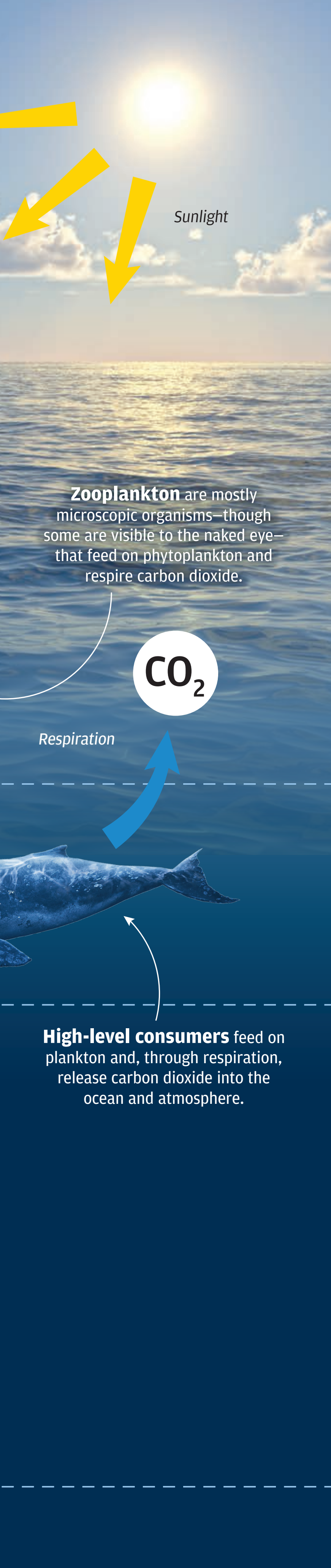
# Going Deep

Tiny phytoplankton are one of the planet's largest carbon sinks, and they take carbon out of circulation for a long, long time. Scientist Douglas Kelley and his team are studying how ocean currents affect the process. Keeping track of phytoplankton is essential to developing accurate climate change models, he says.




STEVE BOERNER (GRAPHIC); SOURCE: EARTHLABS FOR EDUCATORS/SCIENCE EDUCATION RESOURCE CENTER AT CARLETON COLLEGE




# Learn

## The Mysteries of Fluid Dynamics

### Scientist and engineer Douglas Kelley goes with the flow.

Watch the cream pour into your coffee, cloudily curling and swirling through the darkness.

It's a more enigmatic process than you might think.

"Fluid mixing, and fluid dynamics generally, is a great example of how common, everyday things can really be subtle and intricate and complicated," says Douglas Kelley, an assistant professor of mechanical engineering.

He calls fluid mixing "devilishly difficult to predict, control, and understand." But he's working to make sense of it, through his research on the space and time dynamics of fluid flows and the materials that mix within them. In some cases—notably, in his work on ocean currents and phytoplankton—his interest is purely scientific. For other work, he puts on what he calls his "engineer's hat" and pursues applications, as in his work on fluid flow in liquid batteries, an emerging technology that could transform the electric grid.

While the foundations of fluid mixing research—basic thermodynamics and the conservation of energy, momentum, and mass—have been understood for a century and a half, fundamental questions remain.

Kelley teaches his graduate students how to derive the equations that underpin the science. "But the math is beautiful in that you can't solve it, and all of these surprises come out," he says. "And that's why it's 'devilishly difficult.' Nobody can solve this stuff straight up. Instead, we do experiments. And sometimes we get really surprised."

In their mixing laboratory in Hopeman Engineering Building, he and his team are investigating phytoplankton, microscopic marine plants that perform photosynthesis as they float in the ocean. They're at the base of nearly every marine food chain.

And the tiny organisms play a pivotal role beyond the ocean's buffet. They're also one of the earth's largest carbon sinks. When trees decay, the carbon dioxide they absorbed returns to the atmosphere. But when phytoplankton die, they sink to the bottom of the ocean—and the carbon dioxide they captured is taken out of circulation for about 10,000 years, the time it takes for the ocean to turn over.

"If you want to make accurate climate models, it's really important to keep track of where that carbon dioxide is going," Kelley says.

To help do that, he and his students carry out chemical reactions in the lab that model the replication of phytoplankton in the tumult of marine currents. They've found that the fate of phytoplankton in the ocean is much like that of a flame. If you blow gently on a lit match, you can make the flame grow. But blow too hard and you extinguish it.

"We've found a very similar phenomenon in our reactive mixing experiments," he says. When the team models a gentle fluid flow, that encourages phytoplankton growth. But a fast flow dilutes things so quickly that it kills off phytoplankton growth. "So there's a 'blowout' threshold," he says. The research has just been published in *Physics Review Letters*, a top journal in the field.

Kelley's winding educational and career path has cultivated his capacity to think as both a scientist and an engineer. An electrical engineering major as an undergraduate, he earned a doctorate in physics and then completed postdoctoral work, first in a mechanical engineering department and then in a materials science department. "And now I teach mechanical engineering, but I don't have any mechanical engineering degree," he says. He calls Rochester's mechanical engineering department science focused. "So for somebody like me, who has straddled science and engineering, it's a great place to be."

He brings an engineer's mind to his work on liquid metal batteries, a technology that's being designed for grid-scale energy storage by a start-up company called Ambri, based in Cambridge, Massachusetts. The present electrical grid has almost no capacity to store electricity. Energy that's not being used during the relatively cool nights and mornings of a hot summer, for example, can't be saved for blisteringly hot afternoons, when air conditioners are running at full capacity.

But liquid batteries—just about four inches in size individually, but stacked together in groups the size of shipping containers to support the grid—are able to store a lot of energy and deliver it quickly. Using his fluid flow expertise, Kelley is investigating how battery performance and efficiency can be enhanced, and how the fluid mixing inside the batteries can be gauged to know, for instance, how a battery will perform at a certain temperature after it has been charged and discharged a certain number of times.

At a fundamental level, there are many commonalities between his oceanic and battery projects, he says—none more so, perhaps, that their unpredictability.

"You try to anticipate as many of the surprises as you can" if you're working as an engineer and "want to do practical things and control stuff," he says. "But then you can put on your scientist's hat, too—and just enjoy the surprises."

—Kathleen McGarvey