tuations in membrane potentials that went hand in hand with the growth oscillations. When they added glutamine directly to the nutrient broth so the bacteria didn't have to make it out of glutamate, the fluctuations stopped. Those results demonstrated a connection between the growth oscillations and membrane potentials.

The next step was to figure out what ions were involved in the membrane-potential changes. Süel and his colleagues used fluorescent dyes that bind to either Na^+ or K^+. They found that changes in the extracellular concentration of K^+ were directly correlated with the changes in the membrane potential, as shown in figure 2.

They deduced that when peripheral cells overconsume glutamate, the starved interior cells open a potassium-specific ion channel called YugO. As shown in figure 3, the K^+ signal propagates across the length of the film. Crucially, the signal doesn't decay—a sign that neighboring cells actively amplify the K^+ signal by releasing their own K^+. In effect, the starving interior cells send out a metabolic SOS, and neighboring cells relay that distress call to the biofilm's periphery like a bacterial bucket brigade.

The added extracellular K^+ changes the peripheral cells' membrane potentials and hinders them from absorbing glutamate. Glutamate then becomes available to the interior cells, the ion channel closes, and the cycle starts over.

Süel notes that the signaling mechanism in *B. subtilis* is similar to a slowly moving wave of depressed membrane potentials in the brain, which has been associated with migraines. Both involve extracellular K^+, and both are triggered by metabolic stress. "In a sense, the bacteria in biofilms communicate like neurons in the brain."

The inner workings of the YugO channel—how it opens and closes in response to glutamate shortage or extracellular K^+—are still largely a mystery. In addition, the researchers want to see if other bacterial species use similar electrochemical communication.

Another avenue that Süel wants to follow is to see if K^+ signals travel beyond a single colony. In their work, they observed that extracellular K^+ concentrations extend past the biofilm edge. Potentially, the K^+ signal could reach cells or other colonies not in direct contact with the biofilm.

Sung Chang

References

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at sending gravity waves into the upper mesosphere. That finding overturns the previous assumption of a linear relationship that was built into climate models. (B. Kaifler et al., *Geophys. Res. Lett.* **42**, 9488, 2015.) —CD

DISCHARGE-BUBBLE LUMINESCENCE

When a bubble in a liquid collapses, the gas inside it can get compressed and heated to the point that it spontaneously ionizes. The resulting plasma is short-lived, and when its atoms recombine it gives off a flash of light. (See PHYSICS TODAY, April 2012, page 18, and the article by Detlef Lohse, PHYSICS TODAY, February 2003, page 36.) The process was first studied using ultrasound-generated bubbles some 10–100 µm in size that lasted tens of microseconds; the picosecond light bursts from the collapsing bubbles earned the moniker sonoluminescence. Dielectric breakdown at the focus of a pulsed laser can also induce bubbles—an order of magnitude larger and lasting an order of magnitude longer than the acoustic bubbles, with flashes lasting nanoseconds. A new paper by Keping Yan and colleagues at China's Zhejiang University examines a more recent source of luminescing bubbles: electric discharge. Connecting an underwater electrode to a pulsed power source, the team produced an oscillating bubble for a sufficiently strong voltage pulse. A high-speed camera, capturing a frame every 25 µs, recorded the bubble expansion and collapse. The discharge-induced bubbles grew up to a centimeter across and lasted for milliseconds, and the luminescence lasted some tens of microseconds. A key question of bubble collapse is the internal temperature, and the longer duration of discharge-induced luminescence should provide opportunities to accurately measure the emission spectrum. The researchers' modeling suggests their bubbles reach peak temperatures of about 7000 K. That's close to what's been reported for ultrasound and laser bubbles; the temperature determination in all the systems, however, depends on mass transfer, chemical reactions, and other modeling details of the collapse dynamics. (Y. Huang et al., *Appl. Phys. Lett.* **107**, 184104, 2015.) —RJF

WATCHING WAVES

Wind blowing across the sea induces waves of various heights, wavelengths, and speeds. Although the waves' rich spectrum can be derived from linear theory, nonlinearities are significant, even when the wind is just a breeze. Measuring the wave spectrum is challenging because it entails tracking the height of the sea surface over a range of length and time scales. Fabrice Ardhuin of the French Research Institute for Exploration of the Sea in Plouzané, Brest, France, and his collaborators have met that challenge using high-speed stereoscopic video. Their experiment is set up on a fixed platform situated 500 meters off the southern tip of the Crimean Peninsula. From a vantage 11 meters above the surface, two 5-megapixel cameras monitor the same, roughly 100-square-meter patch of the Black Sea and gather data at 12 frames per second (see figure for two typical frames and the study patch outlined in blue). Correlating the two images—frame by frame, pixel by pixel—yields the surface elevation. Fourier transforming the elevation yields the spectrum. The team now reports the results of an experimental run that took place in October 2011 on a day when the wind was a strong steady breeze of 13 m/s. Thanks to the cameras' ability to resolve propagation directions, the researchers could measure the amount of wave energy that travels in opposite directions. Because the waves' interactions contribute to the background noise detected by underwater seismometers, the state of the sea might one day be characterized from seismic data alone. Among their other findings: Waves 1/15 the length of the dominant spectral component tend to travel 70° away from the wind direction. (F. Leckler et al., *J. Phys. Oceanogr.* **45**, 2484, 2015.) —CD PT