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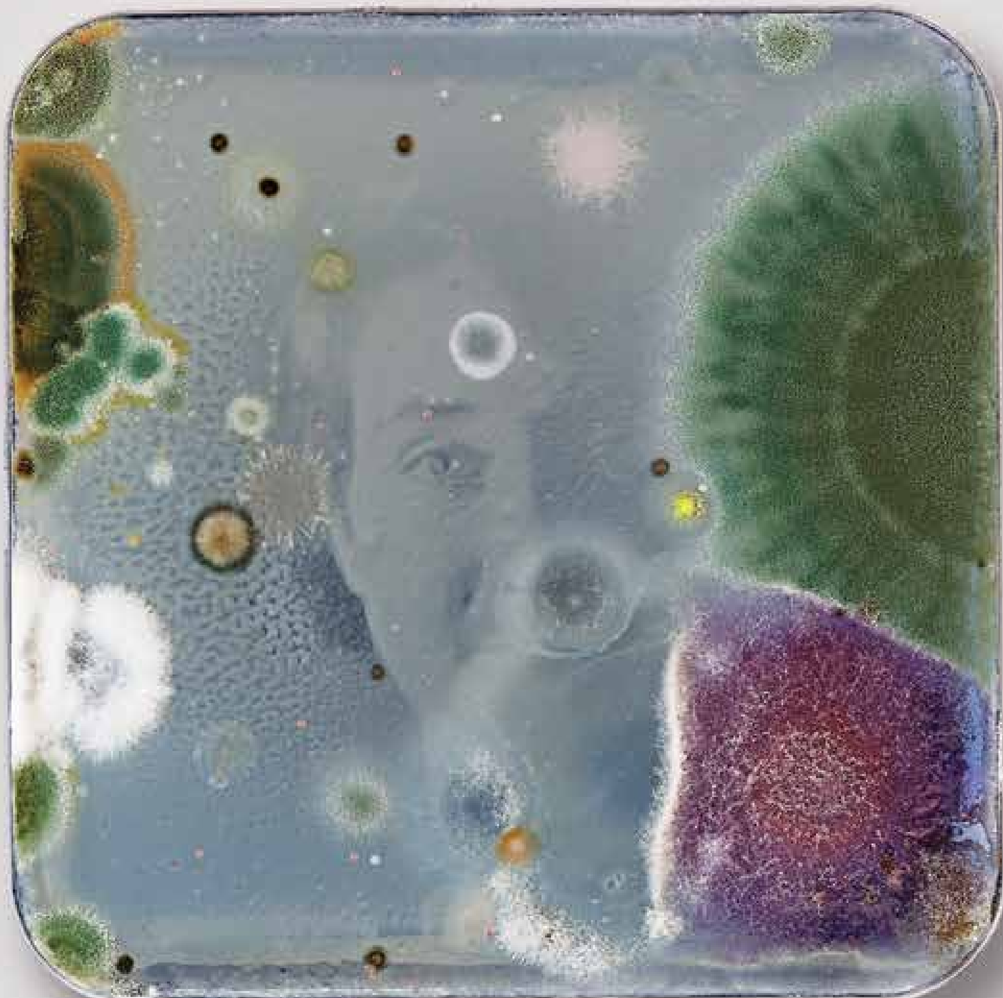

THE HIDDEN BEAUTY OF THE MICROBIOME

How artists and scientists share the search for life's smallest creatures

Oregon State UNIVERSITY

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Oregon's leading public research university

FEATURES

ALSO IN THIS ISSUE

Receding ice is reshaping the biology of the Arctic Ocean. Last fall, OSU oceanographer Laurie Juranek led a research expedition to gather evidence for late-season productivity. See "Altered Arctic," Page 4. (Photo: Kimberly Kenny)

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Oregon State is Oregon's leading public research university with more than $336 million in research funding in FY2016. Classified by the Carnegie Foundation for the Advancement of Teaching in its top category (very high research activity), OSU is one of only two American universities to hold the Land-, Sea-, Sun- and Space-Grant designations. OSU comprises 11 academic colleges with strengths in Earth systems, health, entrepreneurship and the arts and sciences.

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On the cover
Living Images Yeastograms, by Johanna Rotko of Kotka, Finland, combines photography and live yeast cultures. It will be featured in *Microbiomes: To see the unseen* at The Arts Center of Corvallis, April 13 to May 27. (Image courtesy of Johanna Rotko)

Oregon State UNIVERSITY

It Starts with a Spark

An art and science celebration

I live with a clay artist. In addition to vases, bowls and jars, pots sculpted into seed pods and tide-pool creatures emerge from her studio like scenes from an alternate Fantasia. These creations spring from her close observation of nature and speak to me of the joy that comes from a feeling of kinship with the world.

Her ability to breathe life into clay — sticky, malleable and common as mud — still strikes me as a miracle. It takes a persistent curiosity, well-developed skills and a willingness to try something new, perhaps fail, and try again.

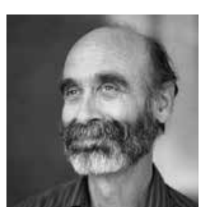
These qualities also describe people who do science: the oceanographer who collects water and mud from an ice-cold sea to run experiments; the soil scientist who explores how human history is written in the materials under our feet; the chemist who designs molecular compounds with new colors and useful properties; the sociologist who explores the human dimensions of wildfire and climate change in a rural community.

So it makes sense for us to celebrate the infectious spirit that drives these endeavors with SPARK, Arts + Science @OSU. For a community bent on changing the world, art and science are not just complementary. The qualities that underlie them are necessary for tapping our imagination, for understanding how the world works and for connecting new knowledge with our values. They fuel the mission of this place as surely as the air we breathe.

I am reminded of that when I walk into spaces designed to foster research and see art that delves into the pursuit of knowledge or invites people to participate in the journey. If you walk up the main staircase in the Memorial Union, look at the murals of oceanographers at sea. Or in the Hallie Ford Center for Healthy Children and Families, check out the paintings by Linfield College professor Ron Mills de Pinyas. They leave no doubt about this center's deep commitment to family and community life. At the Linus Pauling Science Center, a light sculpture offers a brilliant interpretation of chemical analysis.

This winter, a SPARK presentation highlights OSU's favorite animal. From February 1 to 28, the Beaver Tales Art Show at the LaSells Stewart Center features original works highlighting the aesthetic, ecological and cultural aspects of these industrious creatures and their habitats. Scientists like Caroline Nash, whose work in Eastern Oregon appears in this issue, continue to explore the impacts that beavers have on watersheds.

This spring, April 13 to May 27, The Arts Center of Corvallis will present another example of collaboration between artists and scientists. *Microbiomes: To see the unseen* will feature works in a variety of media.



Nick Houtman
Editor

Deep Impact

OSU research builds the economy, saves lives

BY CYNTHIA SAGERS, VICE PRESIDENT FOR RESEARCH

Every day at Oregon State University, our scientists work at the leading edge of research, striving to address some of our world's most pressing problems. From innovative approaches to cancer treatment to the complexities of global climate change, OSU faculty confront tough issues. The positive impact of their accomplishments reaches far and wide.

Indeed, the ramifications of research produced by Oregon State's faculty are awe inspiring. The effects can be felt from the depths of our oceans to the tops of forests throughout the world. Consider these major efforts:

» In October, the College of Forestry kicked off construction of the new Oregon Forest Science Complex, which will showcase innovative uses for wood in building construction and design. The college is also encouraging economic development in our state. "The complex is crucial to the future of our working forest landscapes," said Thomas Maness, OSU's Dean of Forestry, at the groundbreaking. "The way we thought about forestry, natural resources and wood science in the past is very different from how we think about them now. This complex will help prepare our students to tackle our most complex landscape challenges, improve rural economies and establish a healthy forest landscape."

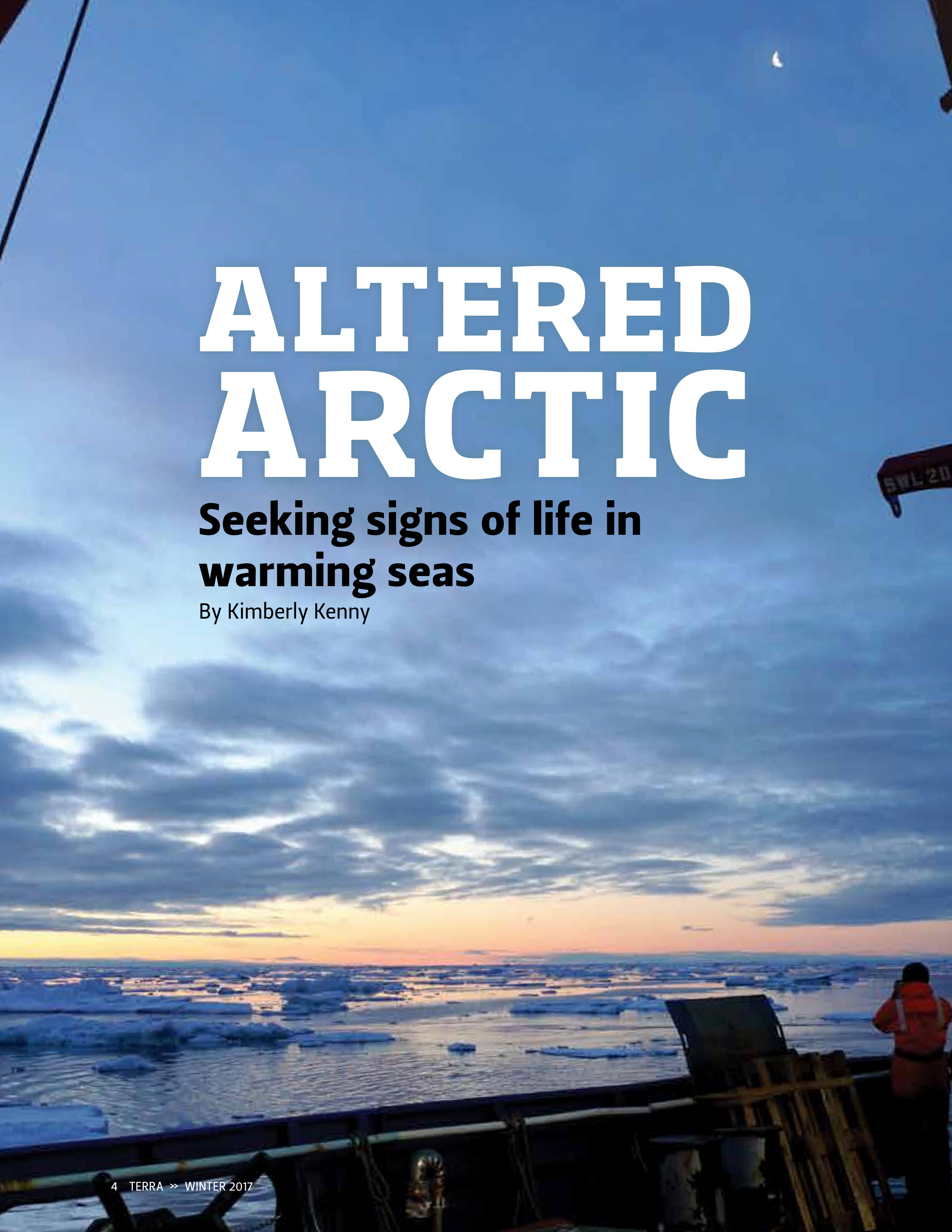
» Microbes in the human gut have profound impacts on health. OSU researchers are learning how bacteria influence digestion, pathogen resistance and even brain function. For example, Natalia Shulzhenko in Veterinary Medicine and her colleagues have found that communication between the immune system and one species of bacteria helps regulate glucose metabolism. Her research may provide clues on how to treat the scourge of diabetes.

» The Cascadia Lifelines Program, operated by Oregon State and its public- and private-sector partners, has created a new online tool that anyone in Oregon can use to identify risks from an earthquake. Called the Oregon Hazard Explorer for Lifeline Program, or OHELP, the program is free to anyone — individual, homeowner, agency, business or industry. It will be especially useful in preparing for the consequences of a quake on the Cascadia subduction zone.

These striking examples show how OSU research is integral to our communities and to the economy of the state. Academic inquiry and discovery inform decisions and drive solutions. Taken altogether, they help create a more sustainable future for everyone.

We all hope that the new administration in Washington, D.C. will continue to support our community's unprecedented levels of research funding to advance these significant efforts on behalf of the people of Oregon and the world.

Below: Artist rendering of the rebuilt Peavy Hall, part of the new Oregon Forest Science Complex at Oregon State.



ALTERED ARCTIC

Seeking signs of life in warming seas

By Kimberly Kenny

The ship glides through the frigid stillness of the Arctic Ocean. On this September night, the Chukchi Sea off the northwest Alaska coast is a quiet, snow-globe world. A maze of ice sculptures screeches along the hull. Radio chatter mixes with banter between scientists and the gurgle of brewing coffee.

Laurie Juranek worriedly taps her long fingers on her thermos. Sea ice threatens her carefully laid plan to sample water from predetermined spots. The map in front of her shows large swaths of ice directly over the ocean patches where she'd like to deploy equipment.

Sometimes, when the ship encounters ice, she stands on the bridge in fascination, visibly calmed, occasionally taking photos.

But tonight is not the time to be meditative; tough decisions must be made. Where should Juranek direct the ship? Which science should be prioritized? The cost to operate this vessel is about $50,000 per day. Teams from Oregon State, the Virginia Institute of Marine Science and the University of Alaska Fairbanks all need time to collect data.

Should the ship steam southwest and retrace a path that might yield promising results? Or should Juranek take a longer path and transit east around the ice field?

Juranek is a chemical oceanographer at Oregon State University and the chief scientist on a 28-day expedition aboard the research vessel Sikuliaq ("young sea ice" in the native Iñupiaq language). She is soft-spoken, humble, deliberate. She is also tough. Her early sea-going days were spent as the only female researcher on Ukrainian cargo carriers. Her faith in persistent work propelled her through a Ph.D. at the University of Washington and research trips in the South Pacific, the Pacific Northwest and the Arctic.

As Arctic ice retreats, ocean scientists aboard the R/V Sikuliaq want to understand how sea life responds. (Photo: Kimberly Kenny)

Getting access to the Arctic at this time of year proved to be a tricky and lengthy process for Juranek's team. The Alaska Eskimo Whaling Commission had misgivings about allowing a research vessel in the area at a time when bowhead whales are known to be migrating. After much negotiation, the cruise was allowed to proceed, as long as it remained at least 30 miles offshore and a community observer was present onboard.

Hot Zone for Climate Change

If you want to see the effects of climate change right now, look no further than the Arctic. It is being transformed by the unprecedented retreat of the ice. What was normal for this region decades ago is no longer guaranteed or even predictable. According to the National Snow and Ice Data Center, Arctic sea ice is declining at an increasing rate in all months of the year. In September alone, when sea-ice coverage normally reaches its annual minimum, NASA satellites indicate a decline of about 13 percent per decade.

Owned by the National Science Foundation and operated by the University of Alaska Fairbanks, the Sikuliaq can break through ice up to 2 1/2-feet thick. (Photos: Kimberly Kenny)

Left: Last September, scientists sampled ocean water and sea floor sediments along this track. (Map: Heather Miller)
Below: Lead scientist and Oregon State professor Laurie Juranek (Photo: Kimberly Kenny)

This trend matters for many reasons. Sea ice acts as a reflective blanket on top of the ocean. Without it, water absorbs more sunlight and warms more quickly. Average air temperatures in the Arctic have increased twice as fast as the global average. Warmer seasons stretch longer; animal species adjust their behavior; indigenous communities that have thrived for thousands of years struggle to adapt; and scientists scramble to keep up.

These might seem like distant dramas, but what happens in the Arctic affects the rest of the world. This ocean is in constant motion. When ice forms here, cold, salty water sinks and circulates through the deep ocean around the planet with consequences for marine chemistry and biology that spread like the tentacles of some giant sea creature.

And then there's the annual feeding frenzy that occurs during the Arctic summer. Whales, seals and birds flock here to reap the bounty of plankton "blooms," tiny sea plants that are so important to the food chain that scientists call it primary productivity. News that primary productivity in the Arctic has increased almost 50 percent since 1997 made headlines last fall. Individual blooms are getting larger and occurring earlier in the year.

But what hasn't been well studied is whether or not this trend is continuing later in the season, after summer passes and sunlight starts to wane. That's the issue that concerns Juranek and her team on the Sikuliaq. With funding from the National Science Foundation, they are investigating primary productivity during the barely studied late season from August to November.

"What we're trying to figure out is how biology is impacted by the lack of sea ice," Juranek says, "In general, there's less ice coverage later in the season than there has been historically. And that is likely to impact how things grow and live and die."

Course Change

"Back to the Wainwright line," Juranek says in characteristic brevity to Captain Adam Seamans, who receives the decision with an empathetic shrug, their normal mode of communication. The Wainwright line stretches toward the north away from the coast. It is part of a larger network of study sites created by the Arctic research community.

For the next several weeks, the Sikuliaq crisscrosses the Chukchi sea, stopping to collect water samples at stations along the line. At each

This device, known as a multi-corer, gathers mud samples from the seafloor for analysis in the lab. (Photo: Kim Kenny)

one, scientists deploy an instrument known as a CTD. Consisting of sensors and two dozen cylinders that can open and close to grab water, the CTD provides clues about marine organisms and ocean conditions — conductivity, temperature, depth — at selected locations from the surface of the sea to the bottom.

When the CTD is hoisted out of the water, OSU professor Miguel Goñi rousts troops of undergraduates and research technicians who run lab equipment and record data. Eager scientists peek through the circular window of a water-tight door in the lab. When the all-clear is given, the door opens and they clamber en masse toward the CTD. They squat next to nozzles and fill bottles, cold water running over their hands. A few minutes later, in the Sikuliaq's two labs, water whirls through tubes, down funnels and over filters.

Farther aft, after the CTD is out of the water, a winch lifts another piece of equipment called a multi-corer from the deck. The crew watches closely as the multi-corer sways off the ship and into the water. As it sinks to the ocean floor, scientists in the computer room watch a live video feed of its progress. When the multi-corer lands on the seafloor, brittle stars, worms and other creatures come into view. The multi-corer projects a tube into the mud and collects a sample to bring back to the surface. On deck, this column of sediment will later be sliced into sections, each representing a layer of ocean history.

With the CTD and multi-corer safely stowed on deck, OSU oceanographer Burke Hales goes to work with another sampling device that he developed. It goes by the scientific name of "SuperSucker." As the crew tows the sensor-laden instrument behind the ship, it pumps water into the lab for rapid analysis. Data arrive as colored lines on Hales' computer screen, indicating levels of oxygen, carbon and other elements dissolved in the sea.

From day to day, the science team and crew alternate between collecting water with the CTD and bringing up mud with the multi-corer. These activities become routine. Day and night, the work proceeds in shifts in a schedule governed by the need to accomplish the task at hand. The ship becomes its own ecosystem of personalities working toward the goal of discovery.

Ah Ha! Moment

Near the end of the cruise, the decision to change course pays off. Goñi bounds into the computer room, balancing a laptop on his forearm and pointing at the screen. "It looks like a phytoplankton bloom! We've got a phytoplankton bloom," he tells Juranek.

Results from the CTD and the SuperSucker show there might be higher primary productivity on the Wainwright line than expected. Juranek is cautious to jump to conclusions, but she admits that her own measurements of oxygen levels are also higher than expected, a telling indicator of increasing primary productivity.

"There's a lot of focus on the early season," says Juranek. "There's a huge bloom when the ice retreats. It turns a big, green, goopy color, just loaded with phytoplankton. We're finding higher levels of primary productivity than we thought would

Marine technician Ethan Roth, left, and OSU professor Miguel Goñi monitor "surface underway" measurements of water conditions near the ship. (Photo: Kimberly Kenny) be here at this time of year, than people think there is. But somehow — and the how is really what we're after — phytoplankton are able to grow and be happy at this time of year too."

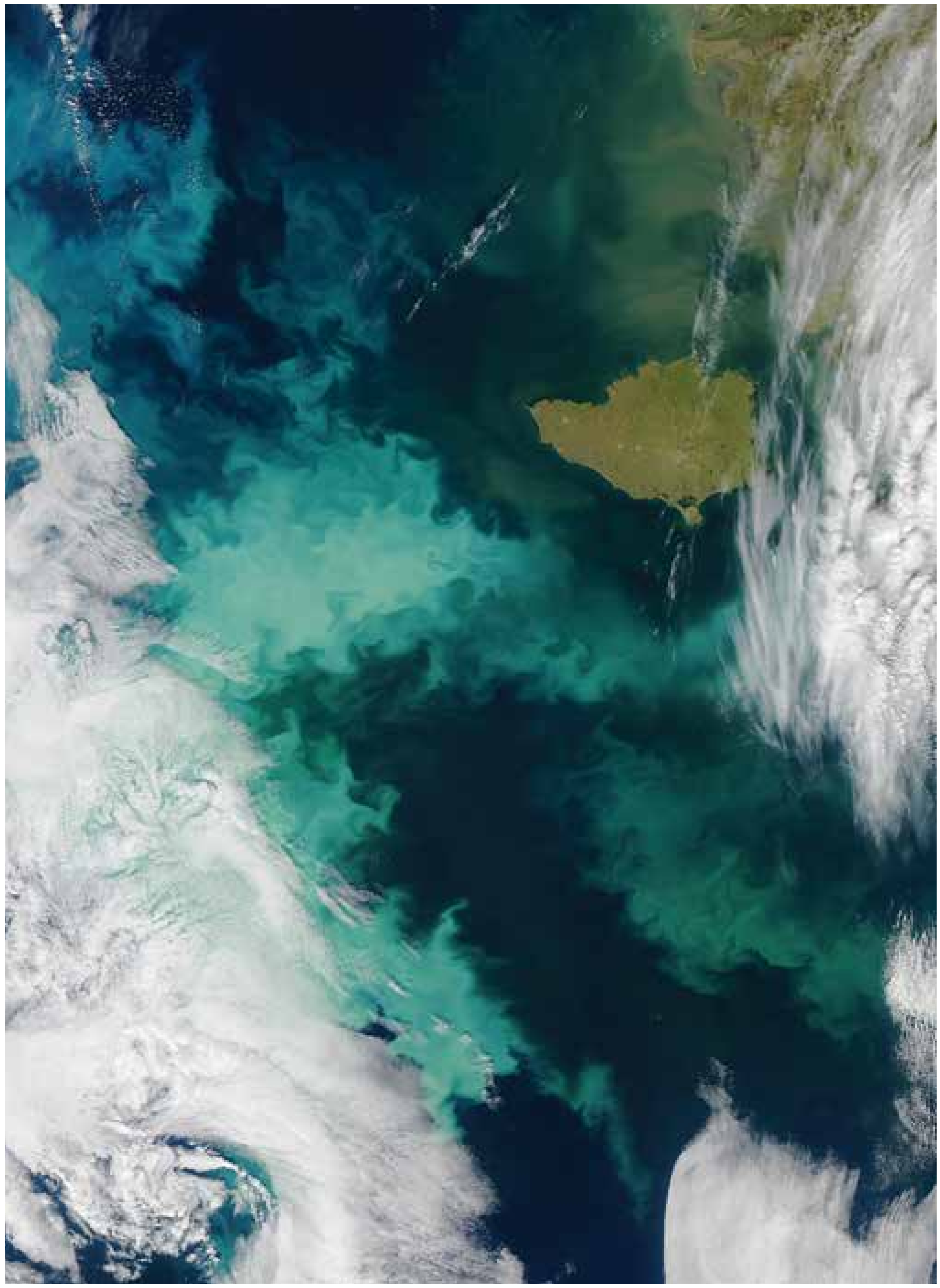
Back to School

The expedition has gone well and is ahead of schedule. The Sikuliaq makes a brief stop at Point Hope, Alaska. The local school welcomes Juranek and other researchers who share a bit of their science and what they hope to accomplish on their journey. They would clearly like to inspire the next generation to follow in their footsteps.

After the ship docks at Nome, the OSU scientists return to their labs in Corvallis. They are still analyzing their data, but a preliminary look suggests that the trend of increasing primary production is indeed continuing late in the season. By tracking dissolved oxygen, carbon dioxide and other gases in the water throughout the cruise, Juranek was able to see hot spots of biological activity. To her, the evidence is compelling but by no means the end of the story.

"I'm interested in what I'm doing on a day-to-day basis," says Juranek, an assistant professor in OSU's College of Earth, Ocean, and Atmospheric Sciences. "But I see it as a small piece of a bigger whole. As a community, scientists are trying to figure out the way our Earth works. And we're making this incremental progress. Nobody gets the answers in one go.

"Even throughout a whole career, you might just get a few little pieces of information that then get passed down to the next generation for people to build on. I feel like I'm contributing to the understanding of the way our planet works, and hopefully that will bring knowledge and some insight into courses of action."



As sea ice retreats in summer, more sunlight reaches the upper layers of the water, triggering increased blooms of phytoplankton, seen as blue-green masses, in the Bering Sea. (Photo: NASA)

As the altered Arctic continues to unfold, scientists are focusing on more than the extent of seasonal ice or a change in productivity. What's at stake is a fundamental shift in a massive ecosystem. Primary productivity adds fuel to the fire of life, from whales to polar bears, in a place that is still draped in darkness half the year. By studying a region so clearly positioned at the forefront of climate change, scientists are gaining valuable clues about the likely future of the planet. terra

Editor's note: Kimberly Kenny received honors baccalaureate degrees in biology and international studies from Oregon State in 2015 and a master's in journalism from Stanford University in 2016. Her participation in the Sikuliaq cruise in September 2016 was supported by the National Science Foundation.

Small Beauties

The art and science of the microbiome

BY NICK HOUTMAN

In a bathtub-sized kiln at the back of her art studio, Jerri Bartholomew stacks layers of glass, one on top of each other like an oversized deck of cards. She closes the lid, flips a switch and waits for the temperature to climb. When the glass begins to glow red-hot, it melts and fuses into a single object, becoming a translucent collage of form and pattern.

As an artist, Bartholomew applies favorite images to her pieces — the graceful arch of a tree, a memorable camping spot on Mount Adams, a dragon fly's wing, a Chinook salmon. "Most of what I do comes from nature," Bartholomew says. "A lot of my pieces tell a story about a place. But I enjoy the process of collage, taking random images and putting them together and trying to get the feeling of place. It's as much about the composition as it is about the subject matter."

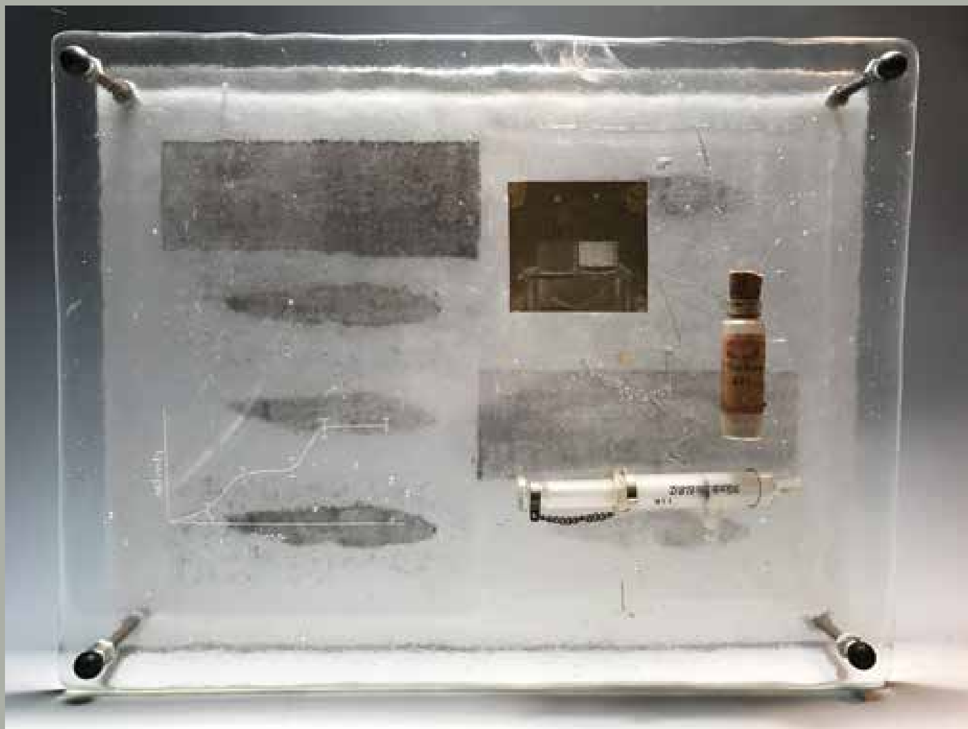
Layers of meaning also concern Bartholomew in her day job, head of the microbiology department and the John L. Fryer Aquatic Animal Health Laboratory at Oregon State University. She and her research team pursue clues about cause and effect — how a parasite kills fish, how a pulse of river water changes the risk of infection, how a worm no bigger than an eyelash forms a vital link in a deadly cycle.

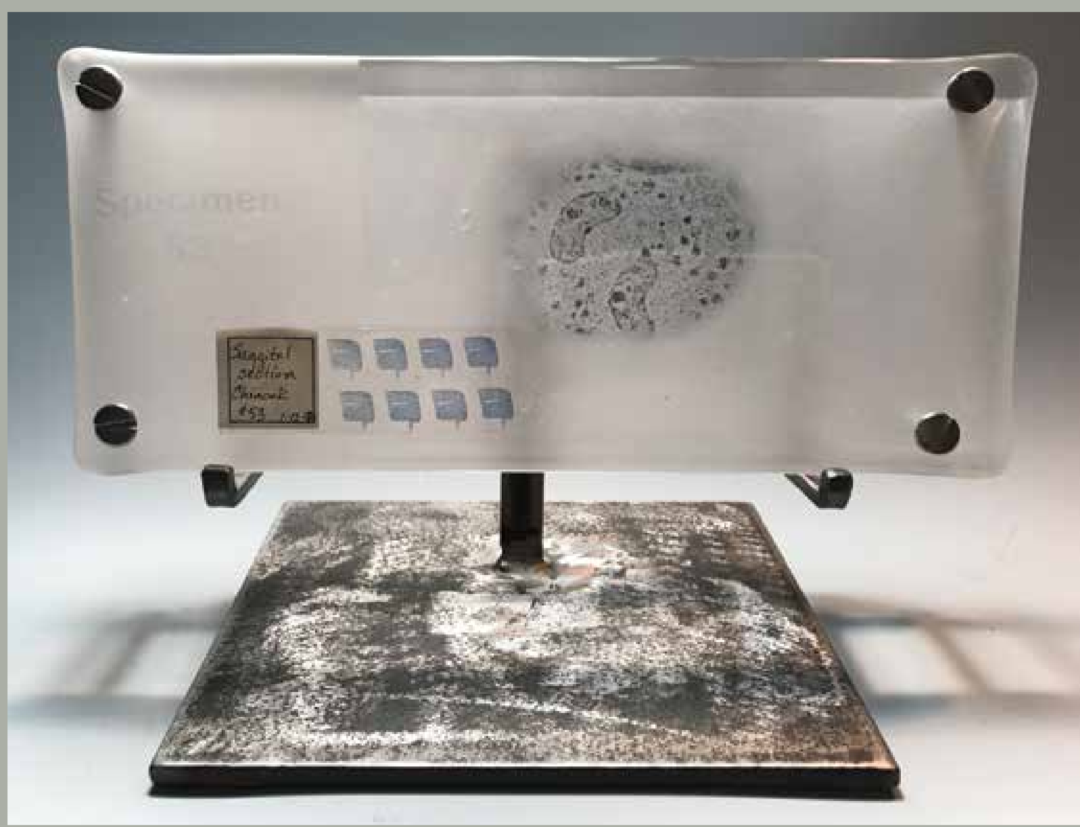
"In some ways, science is stripping away the layers to see what's beneath," says Bartholomew, "and art is the opposite, building up the layers to create something new." Both draw from the same creative impulse, a desire to ask questions, to experiment and to learn from trial and error.

In a collaboration with The Arts Center in Corvallis, Bartholomew is bringing her two worlds together, culminating in April in a show — *Microbiomes: To see the unseen*. The scientist and her colleagues have hosted artists in their lab to explore life forms as diverse as they are micro. Researchers shared their knowledge and curiosity about bacteria and their kin, which morph from one shape to another, communicate through chemical signals, invade other organisms and disperse like dust through air, water and soil.

In turn, the artists conducted their own observations by collecting microbes from surfaces — a door knob, a slice of bread, a pet's hair, their own skin — and seeing what would grow on standard laboratory agar. They reflected on how microorganisms cheat or steal from each other and how some seem to communicate like gossips at a picnic.

The goal is simple: to bring scientists and artists together and to spur a conversation. "I think that's going to really change the creative process," Bartholomew says. "The artists are going to start asking questions that are compelling, that we haven't thought of, because they're looking at the microbiome in a different way."





Science and favorite places show up in Jerri Bartholomew's glass art.
Far left: The journey of a parasitic fish killer — *Ceratonova shasta*
Top: Steps in developing a vaccine to protect fish from infection
Immediate left: Hell's Canyon
Right: Specimen 53, *Ceratonova shasta*

Ripen in the Mud

Bartholomew and her colleagues have spent their careers asking their own questions of the microbiome. In particular, they have focused on a parasite that is extraordinarily lethal to fish and goes by the name *Ceratonova shasta* — *C. shasta* for short. If that's not memorable enough, the illness it causes might be: gut-rot disease.

The scientists have asked how this creature does its dirty work. Where did it come from? Who are its relations? How is it influenced by climate, hydrology and the animals that serve as repository or host?

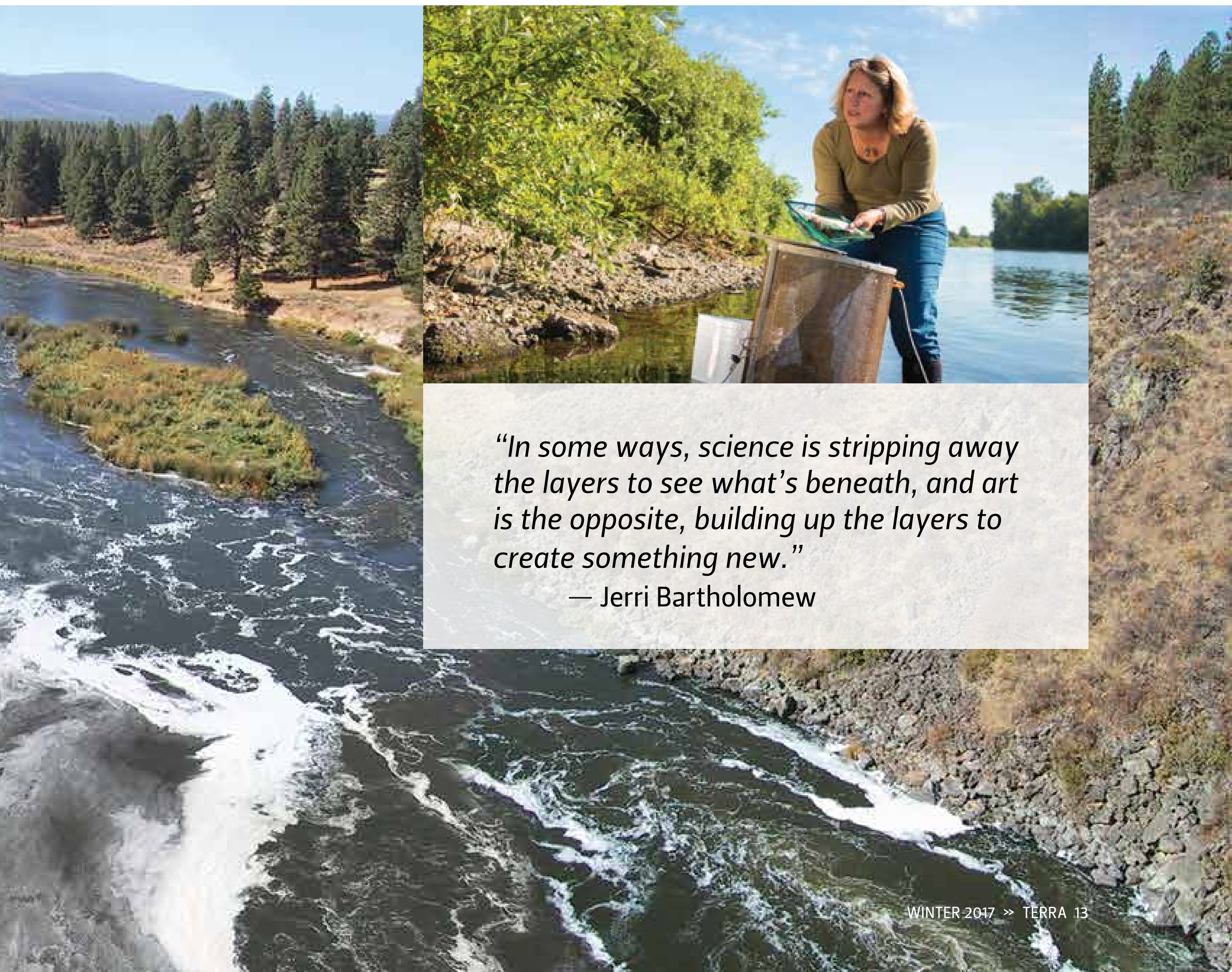
First discovered in a fish hatchery near Mount Shasta in 1948, gut rot (aka enteronecrosis) has been found in fish in many Oregon rivers: the Columbia, Willamette, Cowlitz, Clackamas, Deschutes and Rogue. However, the Klamath is ground zero. Here, the parasite thrives in sluggish channels on warm summer days, causing severe and ongoing losses in juvenile Chinook salmon. When Bartholomew came to Oregon State as a graduate student in 1981, scientists had been stumped about just how *C. shasta.* lived. They knew the organism is a member of a clever group of parasites known as

Top: Researchers, Indian tribes and government agencies monitor the Klamath River for parasites and fish health.
Bottom: The Klamath River roils at Keno Eddy in the upper portion of the basin.

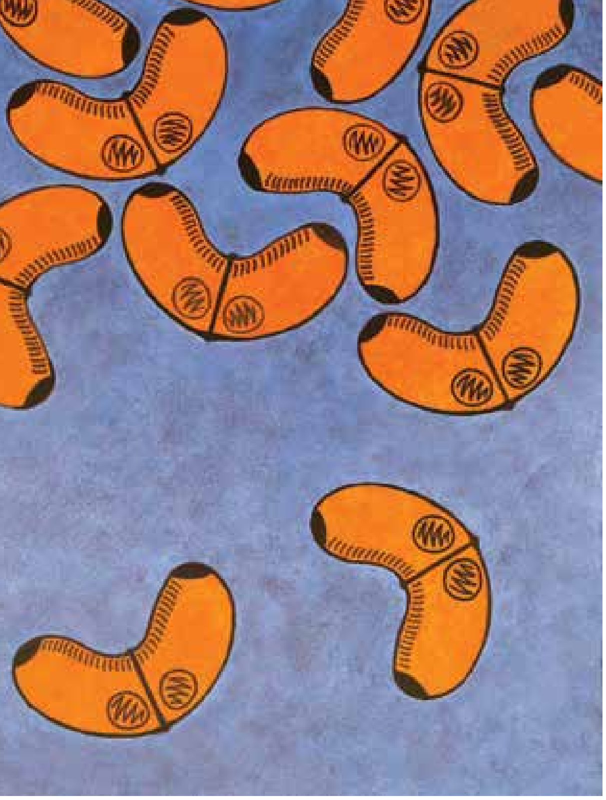
Myxozoans, which kill fish with a variety of illnesses: whirling disease, PKD (proliferative kidney disease) and even one called hamburger gill disease.

These microbes are about the size of a blood cell and invisible to the naked eye. In rivers around the world, evidence of their presence accumulates as dead fish pile up in eddies and along shorelines. Last summer, in an effort to control the spread of a PKD infection in mountain white fish, more than 200 miles of the Yellowstone River in Montana were closed to recreation for about six weeks. Another Myxozoan parasite deforms fish and causes them to swim in a corkscrew fashion — a condition known as whirling disease. This microbe, a European immigrant, has spread to much of the Northeast and the West, decimating trout in some streams. Partly in a need to get to the bottom of such problems, Fryer had established one of the country's premier fish-disease research programs at Oregon State. Scientists in his lab were pursuing vaccines to protect fish from bacterial diseases, but Bartholomew launched into a study of *C. shasta*. A graduate student had already shown that, unlike infectious diseases such as the flu or the common cold in humans, gut-rot disease could not be passed directly from one fish to another. The conventional wisdom, Bartholomew says, was that to complete the infection cycle, the microorganism had to "ripen in the mud."

Even more puzzling was another mystery. Fish would be infected in some parts of the river but not others. Through a series of trial-and-error experiments, it took Bartholomew, Fryer and their colleagues 16 years to identify a tiny worm that comprises a critical part of the disease process.



"In some ways, science is stripping away the layers to see what's beneath, and art is the opposite, building up the layers to create something new."
— Jerri Bartholomew



It Goes Like This

When an infected fish dies, *C. shasta* spores (a kind of microbial seed) pour out of the carcass and into the water like rats off a sinking ship. As the microorganisms float downstream, they pass mats of worms living on the streambed. About the size of an eyelash, these worms feed indiscriminately by gathering particles from the water.

Once ingested by the worm, *C. shasta* does something remarkable: It fires two filaments into the wall of the worm's feeding tube. Once the filaments penetrate the wall, C. shasta opens up, and out crawls an amoeba that shimmies its way into the body of the worm.

"The amoeba wriggles through the worm's gut cells and begins to proliferate and make spores," says Sascha Hallett, a scientist in Bartholomew's lab. In this process, the spores also transform themselves into a different shape. Although they are the same microbe, these shape-shifters no longer look the same as the spores that came out of the fish.

C. shasta isn't lethal to the worm, which discharges the transformed spores back out into the water. "Unless the worm is really heavily infected," says Bartholomew, "they

Myxospore stage of *Ceratonova shasta* (Illustration: Stephen Atkinson)

(Photo: Blaine Bellerud)

Standing Watch on the Klamath

Monitoring for parasites shapes river management

Over the last decade, Bartholomew's lab has collaborated with tribes and with state and federal agencies to monitor parasite infections at a dozen locations along the Klamath River. They use a three-pronged approach, looking at parasite concentrations in water, infections in fish and densities of the worm host, to develop a model for disease severity.

Throughout the year, water is collected and filtered at a few selected sites and sent to Bartholomew's lab for analysis. It takes only a few days for data on the concentration of *C. shasta* cells in the river to be sent to those responsible for managing the river.

In spring, summer and fall, so-called "sentinel fish" (rainbow trout, coho and Chinook salmon) are held in cages in the river at strategic spots and then transported to the lab in Corvallis for observation over the following nine weeks. How many of these fish die of gut-rot disease provides another measure of infection risk.

In 2015, from April through September, the death rate for sentinel fish varied from zero to 90 percent in Chinook. In the upper Klamath, rainbow trout are particularly susceptible. In some months at some locations, all sentinel trout die of gut-rot disease.

The monitoring results that Bartholomew's lab shares with collaborators help the agencies and dam operators to determine how much water to pass by the Klamath's system of dams. Past monitoring has shown that infection risk increases as water temperatures rise and flows diminish. By agreement, when water temperatures reach 15 degrees Centigrade (59 degrees Fahrenheit), water releases must be considered to minimize disease risks to the fish.

can just continue to release these spores continually for a long period of time."

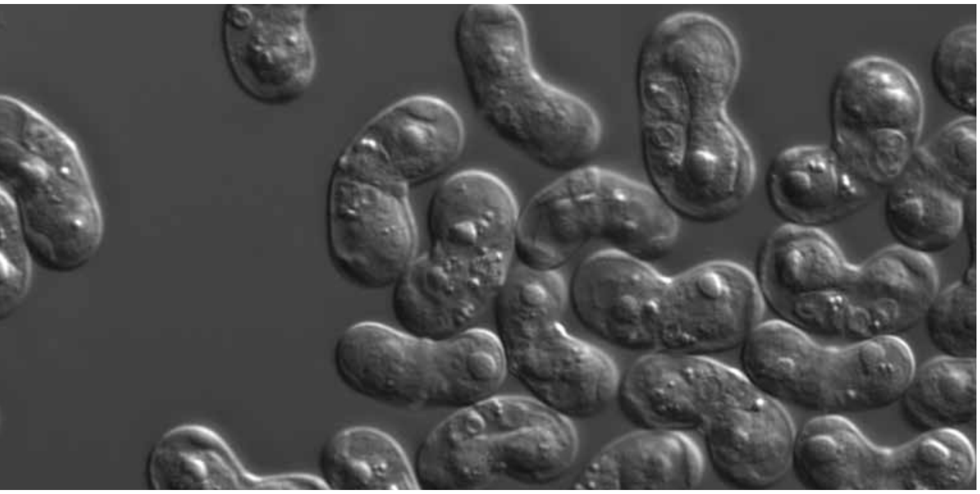
As these *C. shasta* spores drift aimlessly in the current, they wait for a fish to pass. When a salmon or trout comes close enough, through a signal that is still not understood, the parasite again fires its filaments and, like a pirate boarding party, climbs aboard through the gills. Thus begins the final leg of this complicated journey.

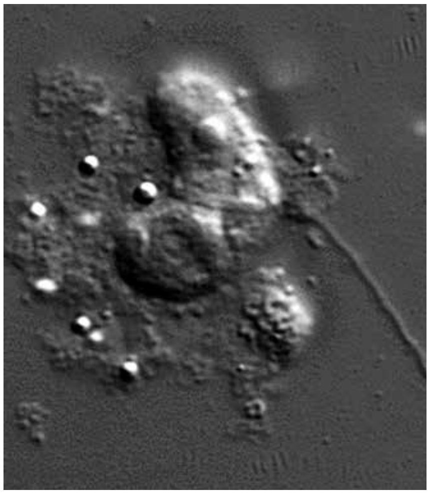
C. shasta navigates through the host's blood, following a path forged long ago by a primordial ancestor. When it arrives in the gut, it fulfills its destiny and launches into a reproductive frenzy, eventually causing inflammation that is fatal to its host. The dying fish empties its load of parasites into the water to begin the cycle all over again.

Most of the *C. shasta* story has been discovered in the last 20 years. While the life cycle provides clues about how and where the parasite infects commercially important fish, scientists are still writing other chapters. For example, Stephen Atkinson, a research associate in Bartholomew's lab, has found that there are several types of *C. shasta.* Each one infects a single species of fish.

Other researchers have demonstrated that Myxozoans have an unlikely family history. Most of their distant kin live in the ocean, including jellyfish, corals and sea anemones. Bartholomew is collaborating with scientists in Israel on a project to understand the filament firing mechanism of this diverse group. One of the goals is to find a treatment for Myxozoan parasites that infect fish raised in Israeli aquaculture farms.

To date, these microbes have not been detected in humans. However, researchers have found Myxozoan infections in ducks and shrews. "So now we have them in mammals and birds as well as fish. I think there's a lot to be discovered about their diversity," says Bartholomew.





Ceratonova shasta and the worm in which the parasite completes its life cycle show up in these microscope images.
Above left: *Ceratonova shasta* cells known as myxospores infect fish.
Above right: A *Ceratonova shasta* myxospore has fired a filament to attach itself to a fish.
Left: This polychaete worm has ingested parasitic cells. (Images courtesy of the Bartholomew lab)

Creativity in Science

Back in her studio, Bartholomew reflects on the relationship between her science and her art. “Science is incredibly creative,” she says. “You start by thinking about what questions you should be asking, then by thinking about the experiments that could answer those questions. You often do a lot of experimenting on a small scale to test these ideas and to refine your questions before embarking on a large study.

“That’s kind of what I do when I come into the studio. Because glass can be an unforgiving medium, I often conduct a series of experiments in a small format, changing one variable at a time. Once these experiments work, I can take the piece to a bigger scale.”

Answers in both science and art lead inevitably to new questions. For example, discovering the importance of the worm in the *C. shasta* life cycle caused Bartholomew’s team to rethink what they had already learned. “And then we understood why it was found in one river system and not in another one,” she says, “because one river is conducive to the worm being present, and another is not.”

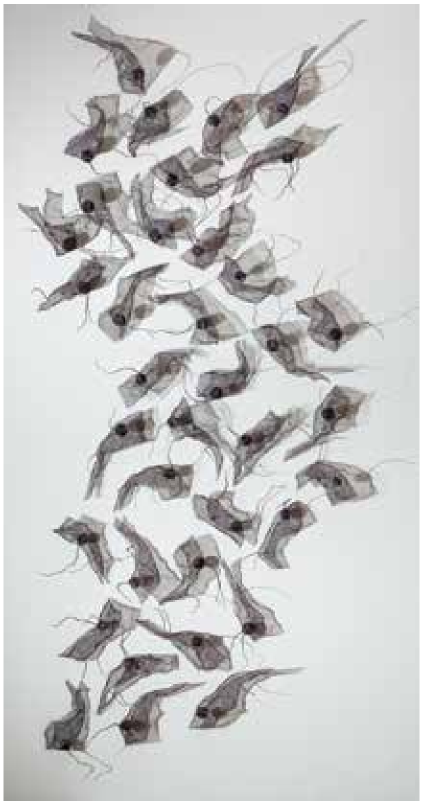
It takes persistence and technical skill to uncover the life cycle of something you can’t see with the naked eye. Nevertheless, she adds, the practice of exploring relationships through art provides fuel for the journey. “Giving myself the space to be creative in art is helpful when I approach my science. I look at science as a big puzzle. I get excited about new ideas and new techniques that we can use to think about how we can fit things together,” she adds.

“Each piece may require a different approach, so you have to be really creative about how you put them together. Once we solved the life cycle, we could start asking a whole other set of questions. You have to be creative about what these approaches are and be willing to go beyond your own discipline. You have to ask how an engineer or a hydrologist or a mathematician would approach the problem.

“It’s like in art. The more techniques you know, the more possibilities you have. I’m learning video now. Who knows what that’s going to do? You’re always adding to your tool box.”

The Microbiomes show at The Arts Center provides Bartholomew an opportunity to do something that she has avoided until now: to present the *C. shasta* parasite in her art. “The parasite itself is really beautiful,” she says. “To this day I rarely sit down at a microscope without uttering a silent ‘wow.’”

Below: This entry into *Microbiomes: To see the unseen* by Lanny Bergner of Anacortes, Washington, is titled *Zika*.
Bottom of page: These laboratory agar plates have been cultured with microorganisms. (Photos by microbiology students, courtesy of Stephen Atkinson)



SPARK

Arts + Science @ OSU

Microbiomes: To see the unseen, is part of SPARK at Oregon State University. Through June 2016, SPARK brings together OSU students, staff and faculty to celebrate the convergence of art and science. Activities include art displays, lectures, fairs and performances. For a calendar of activities, see **spark.oregonstate.edu**.

These three pieces are among those to be featured in *Microbiomes: To see the unseen* at The Arts Center.
Top left: *Growth-One*, by Debby Sundbaum Sommer, Philomath
Top right: *Dog Kisses*, by Kate McGee, Philomath
Middle: *Undulata Bas*, by Kristin Levier, Moscow, Idaho

Microbiomes: To see the unseen

April 13 to May 27

Microorganisms affect our health, the food supply and the environment. How can we visualize and understand these creatures that vastly outnumber us and adapt and reproduce with such clever promiscuity? That is the challenge facing artists and scientists alike.

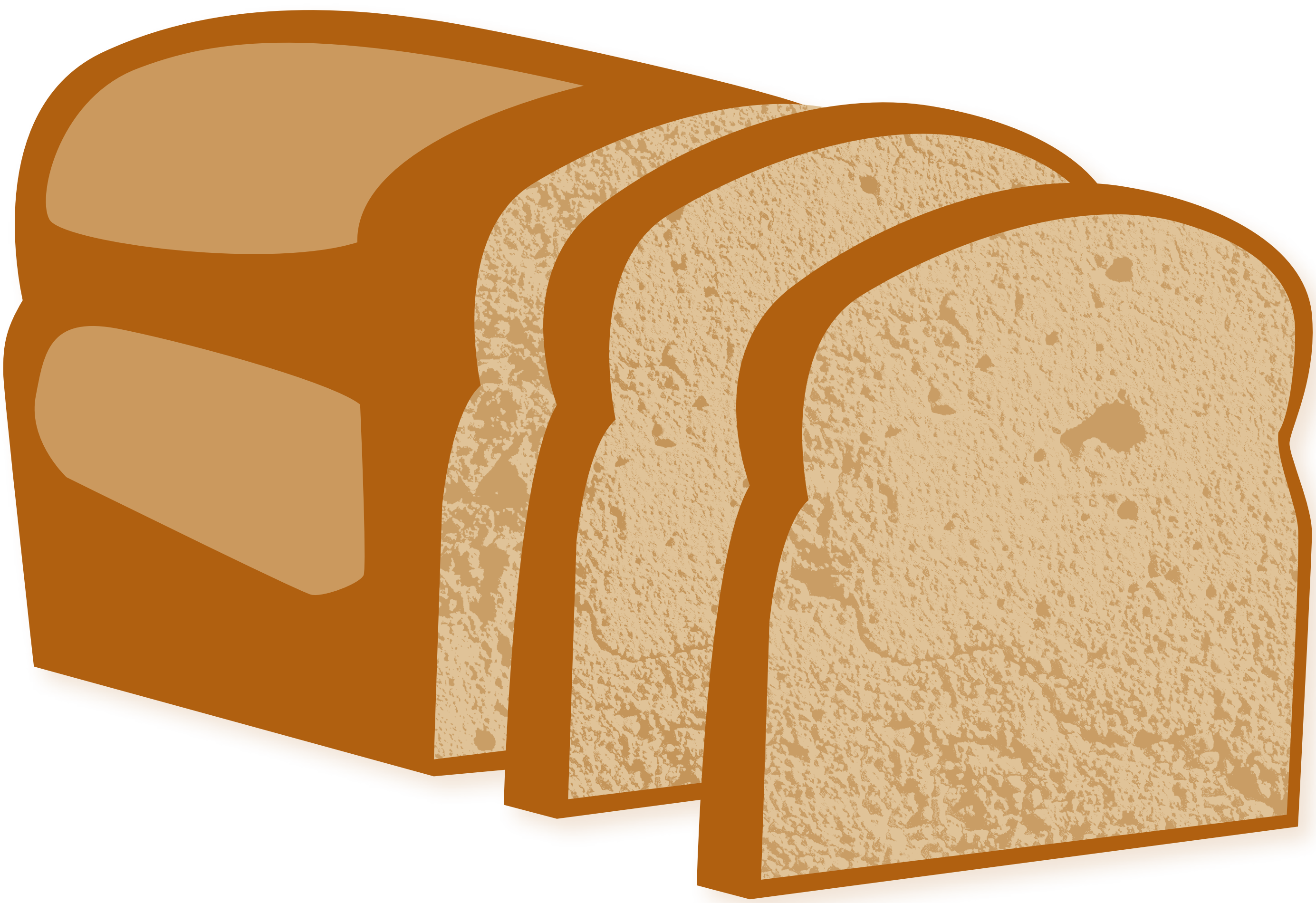
At The Arts Center, 700 SW Madison Ave. in Corvallis, artists working in glass, wood, porcelain, metal, fabric, photography and other media offer their interpretations of the microbiome. An opening celebration is scheduled for April 20, 4-8 p.m. On May 21, an event is planned featuring a musical composition by Dana Reason of the OSU music department and poetry and prose from OSU's Spring Creek Project for Ideas, Nature and the Written Word.

"The arts and science belong together," says Cynthia Spencer, director of The Arts Center. "*To see the unseen* is a chance for everyone to become awe-inspired again through the arts."

A Sense for Starch

Food scientists discover possible sixth taste

BY NICK HOUTMAN



In a provocative study of food and human evolution, Harvard primatologist Richard Wrangham did things that some people might find a bit extreme. He ate raw goat meat mixed with tree leaves. He sampled the uncooked fruit of the African pepper-bark tree — food favored by monkeys and chimpanzees. Its hot taste, he wrote, makes it "impossibly unpleasant for humans to digest."

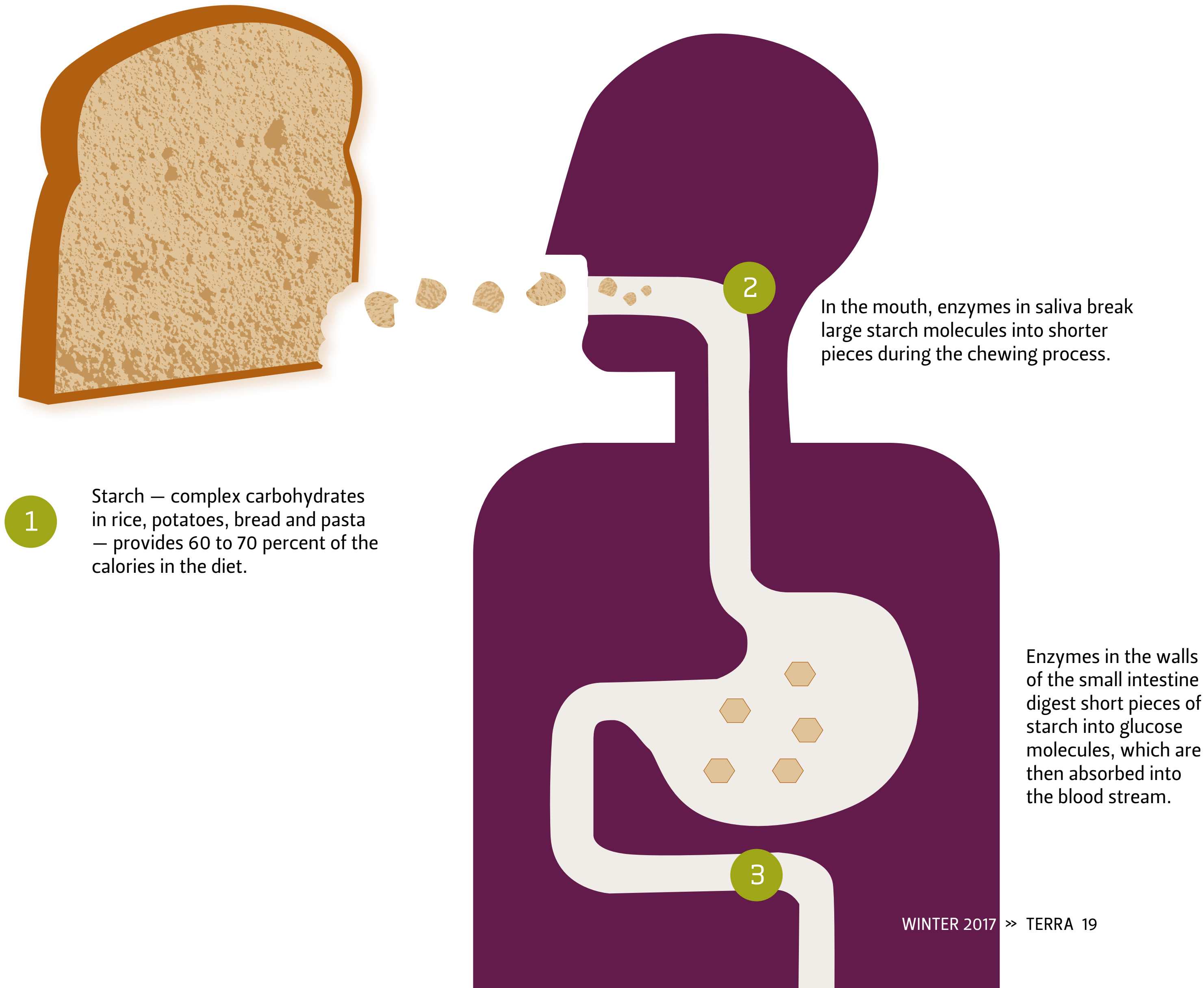
Partly as a result of his work, Wrangham and others have proposed that cooked foods suit our taste buds better than raw. Cooking, they argue, may have helped to fuel human development by giving our ancestors access to more calories.

Heating goat meat may indeed make it more flavorful, but scientists have long debated the role of taste in human health. Our love of sweets reflects the critical importance of glucose, the sugar that flows in our blood and fuels our bodies. An adult requires a minimum of about 150 grams, or 5 ounces, of glucose a day. We tend to reject foods with a bitter taste, which is often associated with toxins. Salty, sour and savory (aka umami) round out the five well-known taste categories (See "Kinds of Tastes," Page 21). Now, Juyun Lim at Oregon State University has discovered a possible sixth.

At first, she thought it was a mistake, but the associate professor and her collaborators in Food Science and Technology are learning that taste is about more than preferring bananas to strawberries or being a picky eater.

The Taste of Starch

At the Center for Sensory and Consumer Behavior Research, Lim explores the mechanisms of what food scientists call the human sensory system: taste and smell.



As often happens, she stumbled onto her discovery in the course of studying something else. In this case, she was looking at a question near to the heart of parents everywhere: How do we learn to like the flavor of foods, such as kale? Can parents really help kids to finish their broccoli?

"Some people dislike a vegetable like broccoli at first. But after eating it many times, they may start to like it," says Lim. "What's that process like? Are they just getting used to it? Or does it have to do with getting calories, feeling satisfied and associating the experience with the flavor? What is it?"

Lim and her research team set up experiments and gave volunteers vegetable juice with and without a starch-based food supplement that is considered tasteless: maltodextrin. "My graduate research assistant came back to me and said her subjects could taste maltodextrin, and I said, 'No, I don't think so,'" says Lim. "I thought it must have some impurities that cause a taste."

The starches we usually eat — whether in corn tortillas, whole-wheat bread or rice pilaf — are comprised of extraordinarily long and complex glucose molecules. If an individual glucose were the size of a twig, a starch molecule would be as big as a tree. "It's so big and insoluble, no one thought it would activate any taste receptors," says Lim.

However, maltodextrin is made of much shorter starch molecules, the equivalent of small trees with only a few branches. Is it possible, she wondered, that our taste buds can detect these shorter molecules through the well-known sweetness receptor on the tongue? Or was another unrecognized taste receptor at work? After all, the receptors on our taste buds get triggered by a variety of chemicals, such as salt or sugar.

So, in a second round of experiments, Lim and her team decided to purify their samples and go one step further. They added a commonly used food additive called lactisole. Food processors use lactisole to reduce the sweetness of jams and jellies, so more of the fruit flavor can come through. Lim gave lactisole to her subjects because it blocks the sweetness receptor on the tongue.

In blind taste tests, the volunteers were again able to taste the purified samples. Clearly, one or more previously unknown taste receptors were being activated.

Under guidance from Oregon State food scientist Juyun Lim (at right), researchers apply sample compounds with a cotton swab. Pinching off the nose ensures that taste sensations stem from the tongue and are not linked to aromatic compounds in the nasal passages. (Photos: Chris Becerra)

Lim and her team refined their samples further and determined that their subjects were detecting a specific component of maltodextrin. It's likely, she says, that when we chew a piece of bread and mix it with saliva, we break up the starch into smaller compounds that we can taste.

"Our volunteers told us that the samples we gave them taste like root vegetables or that it was pasta-like, or bread-like," says Lim. "From the standpoint of human evolution, this makes sense. We get 60 to 70 percent of our calories from carbohydrates, which include starches."

The Spit Test

Last summer, in the journal Chemical Senses, Lim and her team published their potential discovery of a sixth sense of taste, setting off a flurry of publicity around the world. But the researchers haven't stopped there. Lim wants to understand exactly what happens when we put foods composed of starch in our mouths. Does it make a difference if they are cooked or raw, barely chewed or thoroughly masticated?

The question gets back to Richard Wrangham's suggestion that cooking produces more of the compounds that we can taste. By enabling us to get more calories out of what we eat, cooking may also play a fundamental role in human evolution. Lim's experiments with maltodextrin offer one way to study these questions.

Last fall, Lim and her team gave corn starch — both raw and cooked — the spit test. Saliva contains an enzyme that breaks down starches into the short molecules that we can taste. So volunteers were asked to spit into a cup for one minute (in case you are wondering, we vary a lot in how much saliva we produce, but we typically generate two to four pints of saliva every day).

Lim's team then mixed samples of raw and cooked starch with saliva. To consider how long we chew, they analyzed some mixtures after a few seconds and others after 30 seconds. The samples that had been cooked or mixed with saliva for a longer time generated a lot more of the short molecules than those that were uncooked or mixed for shorter times.

"By cooking, we are able to generate more of the compounds we can taste. And the longer you chew, the more of them are produced in your mouth," says Lim.

But the real payoff, she adds, doesn't come just from enjoying the flavor of a baked potato or cornbread. It's possible, she says, that the taste system may play an important role in health by prompting the body to release insulin even before these foods arrive in the stomach.

To test this hypothesis, Lim is working with a Corvallis physician to determine how tasting carbohydrates affects insulin levels in blood. She and her team are gathering data this spring.

KINDS OF TASTES

Taste buds contain receptors to detect molecules in food and are concentrated on the tip, sides and back of the tongue.

SWEET
The sensation of sweetness is usually caused by sugars and other sweet tasting substances such as aspartame and saccharin.

SOUR
Sour flavors are generated mostly by acidic solutions such as lemon juice or organic acids.

SALTY
Food containing table salt is mainly what we taste as salty. Mineral salts (potassium or magnesium) can also cause a sensation of saltiness but can also be bitter.

BITTER
A bitterness sensation is brought about by many different substances, such as quinine or caffeine. About 35 different proteins in sensory cells respond to bitter substances.

SAVORY
The "umami" taste is somewhat similar to the taste of meat broth. Glutamic is largely responsible for these flavors. Ripe tomatoes, meat and cheese all contain glutamic acid.

STARCHY (UNCONFIRMED)
Complex carbohydrate molecules are thought to be too large to interact with our taste receptors. Juyun Lim and her research team at Oregon State have found that, as carbs in rice, potatoes, bread and other starchy foods are broken down, they generate a taste response in volunteers.

Adapted from the U.S. National Library of Medicine

MEADOWLANDS

Can beavers restore these eroded stream channels?

BY NICK HOUTMAN

Across parts of the West, green meadows have given way to eroding banks like this creek near Izzy in Eastern Oregon. The white layer is ash from the eruption of Mount Mazama, which led to the creation of Crater Lake more than 7,000 years ago. (Photo: Gordon Grant)

When beavers build dams, streams slow down, sediment accumulates and ponds grow. Meadows are born. Water nurtures new vegetation, a boon for wildlife and livestock.

But without beavers, streams speed up, scour channels and turn into gullies. Meadows dry out. Willows, sedges and other wetland vegetation give way to drought-tolerant shrubs.

At least that's the theory. In the arid valleys of Eastern Oregon, Caroline Nash is learning that the truth may be a lot more complicated.

The Oregon State University Ph.D. student in Water Resources Engineering is testing the idea that beavers are key to restoring streams that have cut their way down into the soil and left their floodplain meadows high and dry. Hydrologists have a word for these channels: "incised."

"Theories about incised streams have been around in the scientific literature for over 100 years," says Nash. "We have a pretty good idea about what causes this to happen in specific locations, but we don't have a universal theory. There are so many reasons a creek can do this, and there are so many things that can happen when it does, depending on the climate and what the vegetation was when you started. There are a lot of factors."

The story may actually start with the forces that created meadows in the first place. Fast-moving streams often splash and tumble over boulders and create spectacular landscapes along the way. "You typically see more erosion happening in headwater streams," says Nash. "In meadows, erosion is stopping, and deposition is occurring. Why is that?"

The question isn't just a hydrologic curiosity. Across the West, landowners and organizations interested in meadow restoration are taking cues from nature and installing artificial beaver dams on small streams. A team of federal and Portland State University scientists has even published The Beaver Restoration Guidebook to promote the practice.

These structures are typically made of local materials: wood, rocks and clay. They stretch from bank to bank and raise water levels from a few inches to a foot or two. But there are regulatory hurdles. State law requires fish passage, although waivers can be granted. New rules for artificial beaver dams are under development by the Oregon Department of State Lands.

Working with Gordon Grant, hydrologist in the U.S. Forest Service and Oregon State's College of Earth, Ocean, and Atmospheric Sciences, Nash is digging into the origins of a meadow in the floodplain of Cottonwood Creek on the Silvies Valley Ranch north of Burns. She wants to learn how long the meadow has been there, how it grew and whether beavers are necessary for long-term stability. And she is seeking permits to install artificial beaver dams to track the impact of such structures on meadow development in the animals' absence.

Ice and Cattle

To collect data on when and where water is flowing, she is monitoring streamflow, groundwater and the weather. This tributary to the Silvies River is typical of an incised stream in ranch country but presents scientists with a difficult challenge. It practically dries up in the summer. In the winter, snow and ice can damage sensitive equipment. Nearby Seneca holds the record for the lowest temperature ever recorded in Oregon: minus 54 degrees Fahrenheit.

“In meadows, erosion is stopping, and deposition is occurring. Why is that?”

– Caroline Nash

And then there are curious cattle. To measure streamflow, hydrologists often install weirs, small dams with a V-shaped opening through which water flows. The pond that backs up behind the weir becomes an irresistible attraction to thirsty livestock. That means monitoring equipment must be put behind a fence.

Solving these problems led Nash into an unexpected partnership with skilled laborers — the people who weld, drill wells, irrigate and maintain fences at the ranch. “There’s a lot of knowledge and brilliance among the people who do this for a living,” she says. “We had to come up with a way that is collaborative, practical, economic and still effective.”

Nash grew up in Connecticut and has learned about more than the science of stream monitoring. With support and encouragement from owner Scott Campbell, she and the Silvies Valley Ranch team have adapted the tools of the hydrology trade to the rigors of an arid, working landscape. “I’ve become a passionate proponent of working with professional field workers and tradesmen to design and install equipment,” she adds.

Fortunately, Nash is getting help from the stream itself. That’s because as the water cuts down through the

soil, it reveals ancient layers of sediment and leaves an exposed timeline that ticks off deposition over decades and centuries. One layer in particular — ash from the eruption of Mount Mazama that created Crater Lake more than 7,000 years ago — gives the researchers a starting point that is common in other meadows around the Northwest.

"Our goal is to look at the water and the geology and make our best professional judgment about why we think these meadows were here to begin with," says Nash. "That leads us to what we think a responsible set of restoration strategies could be. Ultimately, if we can support landowners who want the ability to restore some of these creeks without costing the state a lot of money, that would be a really good thing."

Nash hopes to complete her study in the spring of 2018. terra

Left: A weather station installed by Nash provides data for her research.
Right: On Cottonwood Creek, Caroline Nash has installed weirs to monitor water flow. Collecting such baseline data will help her determine how water and weather combine with geology to shape meadows. (Photos: Susan Doverspike)

(Photo: Kirsten Mathieson)

What Do We Love Too Much to Lose?

"A Call to Life" gathers international momentum

By Theresa Hogue

Concert pianist and OSU music professor Rachelle McCabe had been collaborating with philosopher Kathleen Dean Moore for more than a decade when she found herself in the audience of one of Moore's climate-change talks in 2014. Moore was challenging everyone to step up and take action against environmental degradation and the destruction of species. McCabe, who had previously set some of Moore's writings to classical-music pieces, was so moved by Moore's challenge that she leapt to her feet at the conclusion and stopped Moore in the aisle.

"I said 'I need to work with you on this,'" McCabe says. A month later, the two met to talk about how their previous collaborations could expand into something much bigger. After considering various approaches, McCabe hit upon a favorite piece of music that she felt was perfectly suited to a discussion about extinction and safeguarding the Earth's abundance.

The piece, Sergei Rachmaninoff's Variations on a Theme of Corelli, Op. 42, is in large part a deeply dark and lonely work, at times almost a lament, but with a compelling sense of purpose and eventually, a glimmer of hope. "The music," says McCabe, "lends itself to anger and frustration and resolution."

The project that evolved from their discussion — A Call to Life: Variations on a Theme of Extinction — combines musical performance with spoken word. Moore and McCabe have performed it up and down the West Coast and as far away as Hawaii and Calgary. Everywhere they go, audiences are moved to tears, and often, to taking direct action against the extinction of species and the onward progress of habitat destruction. And in the face of a changing political climate, the artist and philosopher are determined that their message is more important than ever.

Musical Narrative

When McCabe played the Rachmaninoff piece to Moore, they poured over every aspect, as McCabe talked about how each portion of the piece made her feel, and how that might translate into a call to action. Moore, in response, began writing a narrative to accompany the composition, and the two flowed together organically.

"Rachelle played it many times, and I would sit here and listen, and we'd just look at each other and try not to cry," Moore says. "It was clear to me that this was music about loss. I said this is going to be a piece about extinction, about irretrievable loss. And we knew it also had to be a call to action, because you cannot dwell on tragedy when there's still a chance to avert it."

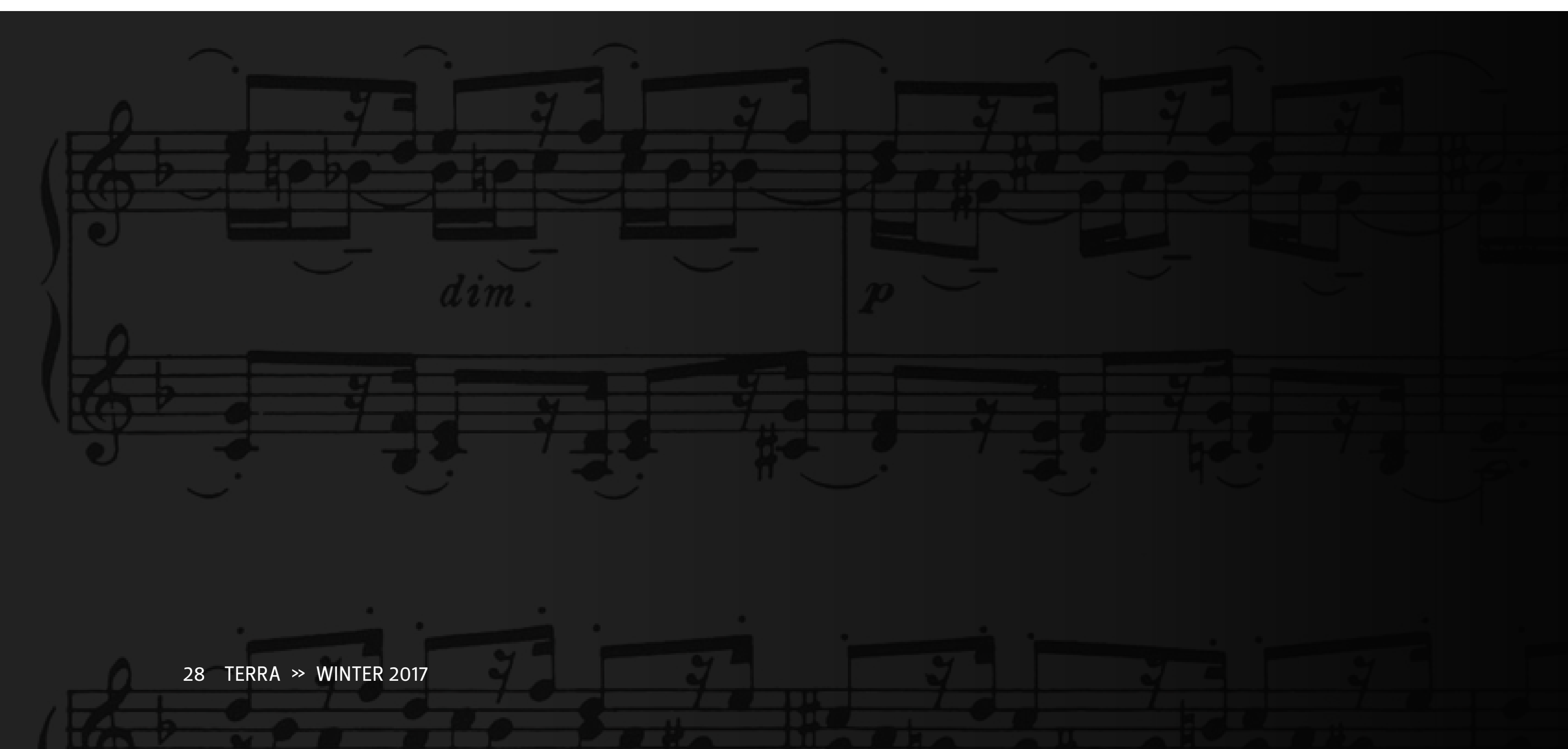
And although the languages of music and philosophy at first seem far removed, they found translation easy. "Rachelle does see the world through music," Moore adds, "so when something comes into her mind it's transformed into music."

Quickly the project took shape, and their first presentation was at the Corvallis-Benton County Library, to a packed house. They were both nervous about the reception but immediately sensed that their message was getting across.

"They absolutely were moved," McCabe recalls. "I looked out a couple times to see their eyes. You can tell when a group is engaged."

"They were frozen, and they were weeping, and then when it was over, they stood up and they roared," says Moore. "And then so many of them came up afterward and they all said two things to us: 'You've got to get this out farther than Corvallis' and 'Tell me what to do.'"

Call to Life directly tells participants what to do, once they determine what it is that they love too much to lose. Audience members receive dozens of suggestions



on how to halt the extinction of species. "There are three things I talk about," Moore says. "We can stop making it worse. We can protect, create and restore habitat. We can imagine new human life-ways."

Call to Action

Braced by the success of their first performance, Moore and McCabe found ways to take their show on the road. "We were astonished and maybe a little bit frightened at the power of this," Moore says. "You stand up in front of a large group, and you really don't know what will happen. We were taken aback by people's response to this."

They visited a village in Alaska, a huge conference in Hawaii, as well as Calgary, Washington, California, Illinois and Arizona. And at each location, they found the same emotional reaction.

"We say that we want to open people's hearts without breaking them," says Moore. "People are so emotionally taken by it, suddenly they allow themselves to understand, to actually see. They knew this all along, but it opens their hearts into this direct perception. The ideas ride the music the way spindrift rides the waves."

And audience members started taking action. In Arizona, a woman told them, "When we go to a lecture my brain is filled. But today I feel my heart is filled as well." A man from Illinois spontaneously decided to turn his property into a wildlife sanctuary. And a young pianist, feeling adrift, pledged to hold concerts as fundraisers for environmental causes. He keeps McCabe updated on his progress.

Following the recent presidential election and what McCabe and Moore see as a deepening backlash against the science of climate change, they've become more dedicated to getting their message across. While they're conscious of the carbon cost of air travel and are limited by the financial costs as well, they've made their collaboration available online with help from Eric Gleske in Information Services at Oregon State. The presentation includes a video and a study guide. Their hope is that people will organize viewing parties with friends, neighbors and colleagues and then collaborate to make their own changes in the world.

"We really want to bring people to this work," Moore adds. "We're just now beginning to think that through. You can't have people practically pounding on you to get this out to the world and not feel a real compulsion to do that."

Above all, Moore and McCabe want to elevate the discussion on habitat destruction and environmental degradation from a place of doom and gloom to a place where individuals feel that they can still make a difference. "Out of death there is a ray of hope," McCabe says. "Life continues. That's the hopeful outcome Kathy always has in her writing. This is not the end, there's more." terra

Performance Set for April 7 at the LaSells Stewart Center

McCabe and Moore will give an encore presentation of "A Call to Life" at the LaSells Stewart Center's Austin Auditorium at 7 p.m., April 7. The event will include a panel of researchers and science teachers who will discuss extinction and the astonishing wonder of plants and animals.

For more information: **riverwalking.com**

Rachelle McCabe, left, and Kathleen Dean Moore (Photo: Zachary C. Person)

The Sustainability Grind

Karl Haapala applies academic theory to industrial practice

By Steve Frandzel

Turn. Drill. Bore. Cut gear. Grind. Vapor degrease. Induction harden. Heat treat. Cadmium plate. Process complete.

That's one possible sequence for turning a steel-alloy bar into a gear. It's not glamorous or poetic; process flowcharts are not the stuff of dreams. Yet it's here, in the elegantly rational trenches of industry, that Karl Haapala, an associate professor of manufacturing engineering, thrives and hones a better way to build things. Sustainable manufacturing balances social responsibility, economic competitiveness and environmental impact.

"Manufacturing includes everything from minute processes to a complete supply chain, and I look at it all through a lens of sustainability, which accounts for a critical set of environmental, economic and social values," says Haapala, who directs Oregon State's Industrial Sustainability Lab. "It also considers the well-being of people — your workforce, your customers."

The word "sustainable" can conjure notions of some remote and costly ideal, but Haapala says it is consistent with good practice. Most manufacturers already embrace basic sustainability, which comprises reduced energy, water and raw materials consumption; fewer worker injuries; less waste; and lower distribution and transportation costs. All of these factors translate into lower production costs and greater profitability. But he wonders why more companies don't rush to take advantage of sustainable manufacturing.

"Business is motivated by profit, but companies that operate in a sustainable manner have greater longevity and perform better than average financially," says Haapala. "Sustainable practices force companies to innovate, and innovation adds resiliency, as does reduced supply chain uncertainty that results from choosing more abundant materials over rarer ones. Why would you not manufacture in a sustainable manner?"

The ethos of sustainable production is gaining steam with the public. Awareness of connections between threats like water scarcity, depletion of scarce resources and environmentally related disease too often trace back to unsustainable production patterns. According to Haapala, a growing swath of consumers who value economic, environmental and social responsibility are generating demand for sustainable products and practices. Manufacturers that don't adapt risk losing market share.

Tempering Haapala's sanguine view is what he considers ill-placed resistance or limited understanding of sustainable practices. "Over the past two years, I have interacted with about 30 small, medium and large companies to learn about their sustainable manufacturing

Karl Haapala works with industry to identify sustainable manufacturing options. (Photo: Chris Becerra)

activities," he says. "One surprising finding has been how universally challenged companies are — small to large — in deciding how to do the right things right. They want to be business savvy and be good corporate citizens, but there are a lot of complexities they must navigate, which often results in ad hoc, uncertain qualitative decisions."

To equip industry for a more definitive response, Haapala is creating comprehensive tools that enable manufacturers to quantify the impact of sustainable manufacturing alternatives. In one seminal study conducted for a large aerospace company, he and graduate student Michael Eastwood applied mathematical models to compare three different ways to produce a hypothetical bevel gear. They evaluated energy consumption, material choices, water use, effluent discharge and occupational health and safety, among other factors. "We set out to develop an assessment tool that holistically considers inputs to the design and production process, something not previously available for industry," Haapala says.

Refinements are needed before the tool becomes a practical, automated application. That's the goal of ongoing research by Haapala in a project supported by the National Institute of Standards and Technology. "One ray of sunshine was that engineers at the company changed the way they thought about problems," he adds. "I believe this helped them to see the value of looking at things from a sustainability-performance perspective rather than just a cost-performance perspective. It made them think about the secondary implications of decisions. That, to me, is progress."

Work like this exemplifies not only Haapala's vision for responsible manufacturing, but also his place astride the intersection of academia and industry. Almost half of the 39 projects that Haapala has participated in since 2009, his first year at OSU, have been industry collaborations. Partners have ranged from startups and small concerns to large corporations. Last fall, Haapala received Oregon State's Industry Partnering Award (accompanied by a $10,000 grant), which "recognizes a faculty member who achieves extraordinarily high impact innovations through research collaborations with industry."

Public- and industry-sponsored research frequently differ in important ways, Haapala notes. "In academic research, you don't always have a destination in mind, and the path to get wherever you're going may not be very clear. There's more flexibility and uncertainty in developing new knowledge."

Working with industry can entail frequent consultation in shaping the trajectory of the project, he adds. "Often a business needs a quick solution, and there's usually some definite end goal. At the end of the day, you have to put theory into practice. That's the nature of industry research." terra

Research Investment

Oregon State researchers made advances in fields such as agricultural crops, robotics, public health and ocean sciences last year with a record $336 million in grants and contracts. Below is a selection of recently funded projects in energy, manufacturing, the environment and biotechnology.

> **"The capacity to innovate is fast becoming the most important determinant of economic growth and a nation's ability to compete and prosper in the 21st century global economy."**
>
> — *Rising to the Challenge*, National Academy of Sciences (2012)

Wave Energy Test Facility

Newport center planned for 2020

Oregon State University's Northwest National Marine Renewable Energy Center will use a grant of up to $40 million from the U.S. Department of Energy to create the world's premier wave energy test facility in Newport.

The NNMREC facility, known as the Pacific Marine Energy Center South Energy Test Site, or PMEC-SETS, is planned to be operational by 2020. It will be able to test wave energy "converters" that harness the energy of ocean waves and turn it into electricity. Companies around the world are already planning to test and perfect their technologies at the new center.

"We anticipate this will be the world's most advanced wave energy test facility," says Belinda Batten, the director of NNMREC and a professor in the OSU College of Engineering.

"This is a tribute to the support we received from the state of Oregon and the efforts of many other people who have worked for the past four years — in some cases since the mid-2000s — to see this facility become a reality." Those technologies, Batten adds, are complex and expensive.

"These devices have to perform in hostile ocean conditions; stand up to a 100-year storm; be energy efficient, durable, environmentally benign — and perhaps most important, cost-competitive with other energy sources," Batten says. "This facility will help answer all of those questions, and is literally the last step before commercialization."

The DOE award is subject to appropriations and will be used to design, permit and construct an open-water, grid-connected national wave energy testing facility. It will include four grid-connected test berths.

Investments in marine and hydrokinetic energy technology will encourage domestic manufacturing, create jobs and advance this technology to help achieve the nation's energy goals, DOE officials say. Studies have estimated that millions of homes could be powered if even a small portion of the energy available from waves were recovered.

Manhattan Project for Chemical Manufacturing

Research targets energy efficiency, innovation

Oregon State University and the Pacific Northwest National Laboratories will co-direct a key component of a new five-year, $70 million advanced manufacturing institute with the goal of greater energy efficiency, increased manufacturing innovation and more jobs in the nation's chemical industries.

The new institute, Rapid Advancement of Process Intensification Deployment, or RAPID, will be coordinated by the American Institute of Chemical Engineers.

The new program will seek to improve domestic energy productivity and efficiency, cut operating costs and reduce waste in chemical industries as diverse as oil and gas, pulp and paper and biofuel processing. Improved technologies have the potential to save more than $9 billion annually just in process costs. Gains of 20 percent in efficiency and productivity within five years are being sought.

"Through matching grants and other support by state governments, private businesses and industry, this will encourage more than $140 million in technology development, education and training," says Scott Ashford, the Kearney Professor and dean of the OSU College of Engineering.

"The emphasis will be on the development of chemical manufacturing equipment that is smaller, lighter-weight and more energy efficient. The result will be lower costs and modular production of chemical plants that will help to boost the nation's economic growth."

OSU and PNNL have worked collaboratively for more than a decade to develop and commercialize such technologies. RAPID consists of 75 companies, 34 academic institutions, seven national laboratories and other organizations.

"The selection of OSU and our colleagues at PNNL to lead this focus area is a tribute to 15 years of commitment by state leaders, Oregon businesses and our research universities," says Brian Paul, the Tom and Carmen West Faculty Scholar of Manufacturing Engineering in the OSU College of Engineering, and leader of the new initiative.

Collaboration between OSU and PNNL was spurred through the Microproducts Breakthrough Institute, which began in 2001. The success of that partnership has evolved into the Advanced Technology and Manufacturing Institute, located on the HP campus in Corvallis.

Managing Dams for Salmon

Study will focus on the upper Willamette

Christina Murphy, a doctoral student at Oregon State University, has received a $132,000 Science to Achieve Results, or STAR fellowship, from the U.S. Environmental Protection Agency.

Murphy, who is pursuing a Ph.D. in the Department of Fisheries and Wildlife at OSU, is conducting research on how best to manage dams to protect salmon.

Murphy earned three honors bachelor's degrees at OSU in biology, fisheries and wildlife, and international studies, and then conducted a Fulbright research project in Chile. She earned a master's degree at the Universitat de Girona in Spain and then returned to Oregon State to pursue her doctorate.

"Northwest reservoirs have different hydrologic regimes and changes in timing and magnitude of drawdown," Murphy says. She is evaluating physical and chemical conditions in the water as well as phytoplankton, zooplankton, benthic insects, diversity and populations of fish and habitat availability within reservoirs — both before and after hydrologic changes — in order to inform decisions on dam and reservoir management.

Murphy is focusing her studies on four reservoirs in the upper Willamette basin in Oregon: Blue River, Fall Creek, Lookout Point and Hills Creek.

"The Pacific Northwest relies on hydropower for more than half of its electricity, with high-head dams forming large reservoirs on rivers historically supporting anadromous salmon," Murphy adds. "Improved understanding of the ecological mechanisms and responses of Pacific Northwest reservoirs with respect to water-level fluctuations is critical to ensuring ecologically sound practices for the long-term operation and greening of our hydropower infrastructure."

(Photo: Tim Marshall)

(Photo: Caleb Jones)

Fed by the Sea

How will climate change affect the redwoods?

The atmosphere within Northern California's coast redwood forests is humid, the air pungent and loamy, smelling at once like the sea and earth. This olfactory fusion stems from the sea-sourced fog that enables these forests to thrive.

With a $1.75 million National Science Foundation grant, researchers from seven institutions, including Oregon State University, have formed an interdisciplinary team to study the relationships among upwelling, fog, redwood forests and climate change. The Summen Project, named after the indigenous Ohlone word for "redwood," aims to unravel the complex ocean-atmosphere-land interactions supporting one of the Earth's most productive and alluring terrestrial ecosystems and make predictions about how climate change may alter them.

Coastal fog is generated by warm, high-pressure air mixing with cold ocean water brought to the sea surface through upwelling. Drawn into redwood forests, fog bears vital moisture as well as nutrients (nitrogen, phosphorus and minerals) picked up from ocean waters.

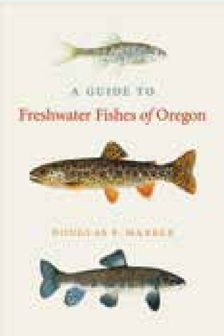
"Predicting the extent of fog formation is a complex and delicate task, and one of the most difficult parameters to get right in computer simulations of the atmosphere," says Eric Skyllingstad, professor of atmospheric sciences at OSU and part of the Summen Project.

Complicating matters is that fog appears to be sensitive to a changing climate. Redwood trees rely on moisture from fog during the dry summer, and coastal fog has declined over the last half-century. Scientists suspect this trend may be connected in some way to changes in the upwelling season.

OSU professor Roger Samelson says that the tangled relationship between the ocean and atmosphere is precisely why he and colleagues Skyllingstad and Simon de Szoeke were brought on board. "We are one of the few groups looking at the coupled ocean-atmosphere system in an upwelling context."

Book Notes

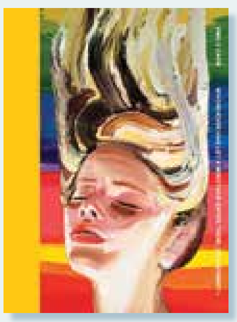
Recent publications by Oregon State faculty



A Guide to Freshwater Fishes of Oregon

Doug F. Markle

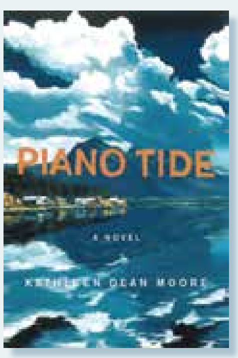
Oregon is home to 137 known species and subspecies of freshwater fish. In this first-ever authoritative guide, Doug Markle describes nearly all of them, from larval stages to adults. He provides insight into naming conventions and biological diversity and bridges the gap between scientific communication and the fishes' place in nature. The guide includes photos by the author and full-color drawings by renowned fish illustrator Joseph R. Tomelleri. Markle is an emeritus professor of fisheries.



Whosoever Has Let a Minotaur Enter Them, Or a Sonnet

Emily Carr

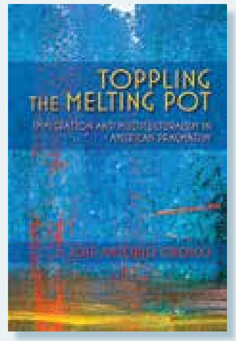
Emily Carr's collection of poems manifest emotions through love and divorce and places them in a contemporary, dynamic life. The crisis at the heart of these poems, she says, is that she is falling out of love but doesn't know it yet. She evokes an interplay of grief, acceptance and celebration. Through the written word, she explores the person she is becoming. Carr is the director of the OSU-Cascades Master's of Fine Arts program.



Piano Tide: A Novel

Kathleen Dean Moore

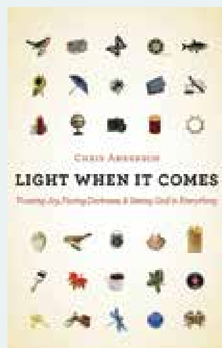
Kathleen Dean Moore's first novel delves into this question: Is our world anthropocentric or biocentric? In a small coastal Alaska town, Axel Hagerman sells timber and fish and is planning a bear pit. He clashes with a recent arrival, Nora Montgomery, who moves to The Last Frontier with her piano and distaste for the lower 48. She objects to Hagerman's values and lifestyle, thus setting up an iconic conflict over how we care for the places where we live. Moore is an award-winning naturalist, emeritus distinguished professor of philosophy and co-founder of the Spring Creek Project for Ideas, Nature and the Written Word at Oregon State.



Toppling the Melting Pot: Immigration and Multiculturalism in American Pragmatism

José-Antonio Orosco

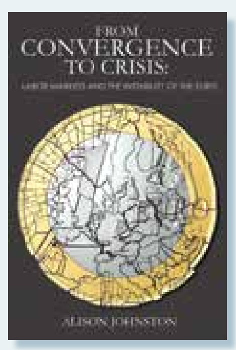
In the early 1900s, in response to a tide of European immigration, American political thought centered on the classic pragmatic ideas of John Dewey, W.E.B. Du Bois, Josiah Royce and Jane Adams. They were wrestling with the challenges that immigration posed to American democracy. An associate professor of philosophy, Orosco argues that we can use their views to better understand how immigration bolsters our democratic foundations. He shows how American pragmatism can work as a lens on immigration, citizenship and education.



Light When It Comes: Trusting Joy, Facing Darkness, and Seeing God in Everything

Chris Anderson

The simple, daily events in our lives can move us deeply, but significant moments can pass without thought. We can shift from light to darkness in a flash. They can also invoke doubts and delights, fears and hopes. Chris Anderson shows how such encounters can also lead us to God. A Roman Catholic deacon and professor of rhetoric and composition, Anderson explores how we can recognize these events through mindful reflection and prayer.



From Convergence to Crisis: Labor Markets and the Instability of the Euro

Alison Johnston

Europe's debt crisis played out differently for northern members states than for those in the South. What explains the gap? Alison Johnston, assistant professor in the School of Public Policy, finds an answer in labor markets. She argues that the wage-setting institutions of northern European countries undercut the competitiveness of southern trading partners. Through a cross-national analysis of economic performance and case studies from both regions, Johnston shows how northern Europe's corporatist wage-setting institutions became toxic for the South.

The Tao of Forest Management

Doing nothing in our forests could lead to catastrophic fires

BY THOMAS MANESS, THE CHERYL RAMBERG-FORD AND ALLYN C. FORD DEAN, COLLEGE OF FORESTRY

When it comes to proper management of our public forests, some would like to take a page from the ancient Chinese philosopher Lao-Tzu. He posed the concept of non-action as an approach to life. In our forests, if we do nothing and let nature take its course, this line of reasoning goes, these landscapes will return to a more "natural state" on their own.

The trouble is, the natural state of forests includes fire — a lot of fire. They will never return to a state that existed in the past, because the conditions that created them no longer exist. What actions should we take to manage our forests for the multiple benefits we expect? We need to recognize that fire has a role to play and that, at the same time, we can reduce the risk of catastrophic loss.

As a worldwide leader in forestry, Oregon State University conducts balanced and unbiased research to help drive land management decisions. We have shown that our public forests would benefit from two proactive management techniques with a positive environmental impact: thinning and prescribed burning.

Thinning reduces the density of trees and allows the remaining ones to grow faster. Fire doesn't move as quickly across the landscape. Removing branches on the ground — so-called ladder fuel — greatly reduces the risk of fire climbing into the upper canopy and getting out of hand.

Unfortunately, thinning is expensive. It costs taxpayer dollars, and there will never be enough to properly thin all of our forests unless we can simultaneously produce income to offset some of the costs.

Prescribed burning, on the other hand, is a relatively inexpensive option that accomplishes the same goal. By burning on a cool day when humidity is high, fire can be controlled as it reduces the fuel load and improves the health of the forest. It is an idea that is struggling to gain traction with the public.

We are conducting research that will indicate the best locations for prescribed burning. We are also identifying those where thinning would be preferred, such as near communities.

Today's forest ecosystem was shaped by fire – both human-caused and natural – over hundreds of years. The pattern of trees remaining after one fire directly affects the next fire. The resulting forest is like a Jackson Pollock painting with random splashes of color and line. The uniqueness of a given ecosystem is marked as much by what is not there as much as by what is.

Along with foresters around the country, I grow increasingly concerned with the health of our federally managed forest lands. We also worry about the health of rural communities. Due to many factors — a changing climate, political inaction, the financial burden of managing a huge land base that produces very little — our approach to these forests has created a landscape ripe for large fires.

Also like a Pollock painting, our federal forests are extremely valuable. Using proactive management techniques will help retain their value for years to come. We are working with leaders on all sides to help drive a more proactive approach for managing our forests and ensuring a healthy landscape for generations to come. Although we have made small strides, the time has come to take action.

THE OREGON STATE UNIVERSITY ADVANTAGE

Connects business with faculty expertise, student talent and world-class facilities, and helps bring ideas to market and launch companies.

Disruptive Software

Medical applications are just first on the list

Even the world's largest tech companies need help leveraging their innovations.

Software to manage and analyze data has been around as long as the computer, but when HP Inc. needed an innovative approach to managing company-wide inventory and sales data, developers at HP in Corvallis created their own product: ORCA. Now that same homegrown platform is being called "disruptive technology" by those outside of HP who have seen ORCA in operation.

ORCA's disruptive nature comes from its simplicity. The software is fully deployable within mere days, compared to the months, or even years, required to build competitive systems — and at a fraction of the cost of comparable enterprise-size data management and analytics platforms.

A year ago, when HP began its search for a company to commercialize ORCA, it turned to the Oregon State University Advantage Accelerator and its directors Karl Mundorff and Mark Lieberman for help. Leveraging their personal and professional networks of Oregon-based entrepreneurs, Lieberman and Mundorff sought out companies that had an application-ready need and a vision for expanding ORCA into a new business. They presented HP with a long list of candidates and arranged meetings with the most promising prospects. Presentations were followed by proposals and business plans. In the end, HP licensed ORCA to Due North Innovation of Portland.

"There are a lot of other data management tools out there. This one is super powerful but very easy to use from an implementation point of view," says Michael Baker, partner in Due North. "I've been in this business for 25 years, and it's the first time that we have seen a software solution that allows for the management of very large data through common language searches."

ORCA is well-suited to meet the current and future needs for data searching using large medical informatics databases to allow providers to enhance clinical outcomes and reduce medical care delivery costs.

Baker founded Home Dialysis Plus based in part on microchannel research at OSU. That company, now known as Outset Medical, markets Tablo, a portable system for conducting dialysis treatments at home and in dialysis clinics.

As a firm geared toward bringing innovation out of the lab and into the market place, Due North will use ORCA in two new products: Qview Health and CORI^2. Qview Health tracks health-care performance in hospitals and pinpoints sources of errors. CORI^2 manages data from endoscopy exams. It helps clinicians to predict patient outcomes on the basis of data from 11 years of such procedures at 126 hospitals around the world. In both cases, ORCA will provide the information engine that accesses data for analytical purposes.

Other ORCA applications are on the horizon. Due North may use it to drive a system that could lead the way for personalized medicine. It could combine information about a patient's genetic profile with real-time reporting on activity, diet and other factors that affect health.

Outside health care, ORCA could boost analytical power for other data management purposes. "ORCA works with any type of data," adds Baker. "It's the most robust algorithm set I've seen. It's unique within the family of these products."

(Photo: Ilya Pavlov)

To discover what the **Oregon State University Advantage** and the **Advantage Accelerator program** can do for your business, contact Brian Wall, assistant vice president for research, commercialization and industry partnering, 541-737-9058, brian.wall@oregonstate.edu. **oregonstate.edu/advantage**

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Zika, a work of art by Lanny Bergner of Anacortes, Washington, will be featured at The Arts Center of Corvallis in an upcoming show, *Microbiomes: To see the unseen*, co-organized by the OSU Department of Microbiology. See "Small Beauties," Page 10. (Photo courtesy of Lanny Bergner)