TRANSECT

BIGELOW LABORATORY FOR OCEAN SCIENCES / WINTER 2020 / VOLUME 12 / ISSUE 1

ON THE COVER

Researchers cross the sea ice off the coast of Utqiagvik, Alaska. Senior Research Scientist Steve Archer and Senior Research Associate Kevin Posman spent mid-March in the remote village preparing to participate in the MOSAiC Arctic research expedition, which began in late September. During this yearlong expedition, hundreds of scientists from 19 countries are conducting research aboard the RV *Polarstern* as it drifts around the Arctic Ocean, frozen into the sea ice.

Photo: JR Ancheta, University of Alaska Fairbanks

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As Maine hunkers down for winter, the bustle of our summer outreach activities feels far away, but their excitement and importance have far from faded. About 2,000 people from around our community — and the country — visited our East Boothbay campus for our annual events. I also traveled to communities throughout New England to share our latest research with the public.

Throughout my second year in Maine, I have been continuously impressed and encouraged by the level of interest and degree of science savviness I encounter here. Most importantly, I am also finding a new openness to engage in discussions about climate change.

In the presentations I gave this year, I tried to deliver a message of hope and let people know we are not powerless to address climate change, as long as we are willing to act. This seemed an especially important message for young people, as many expressed despair over the threats we face. While there are major challenges confronting humanity, I believe in the power of science to help us overcome them.

That's one of the reasons I am so excited about our leadership role in Maine's new $20-million National Science Foundation grant to develop DNA-based tools for understanding and managing coastal ocean ecosystems.

States have always struggled to manage coastal resources, largely due to a lack of data. At the most basic level, it is difficult to even know what marine life is out there and how much there is. It's like managing a forest you can only see from miles away, at night. The new tools we are developing will utilize genetic material left behind by all living things. This environmental DNA — or eDNA — has the potential to illuminate coastal ecosystems and provide an up-close view of marine life along the coast.

Better environmental management is critical in the face of a changing climate — but we ultimately must address the root cause of greenhouse gas emissions. While politicians and regulators come to terms with the policies that are needed, science needs to work on proactive solutions. This fall, we launched the next phase of a project that not only gives me great hope in the power of science, but also in the power of individuals to make a real difference.

Methane is a greenhouse gas that is about 30 times more potent than carbon dioxide. For the past several years, Bigelow Laboratory scientists have been working to develop an algal feed supplement to reduce methane production in cattle, the largest human source of this greenhouse gas. The research has great potential to impact global methane levels, and it would not be happening without the philanthropic partnership of people who see the challenges this planet is facing and believe that science can make a difference. Through continued support from the Shelby Cullom Davis Charitable Fund, we are now working with new partners to conduct animal and economic trials of this promising approach.

This sort of visionary philanthropy from individuals, families, and foundations is making a huge difference at Bigelow Laboratory. It makes our science possible in so many ways, and it gives us renewed hope in the ability we all have to make a difference.

Deborah A. Bronk

DEBORAH BRONK, PhD

FSC FPO

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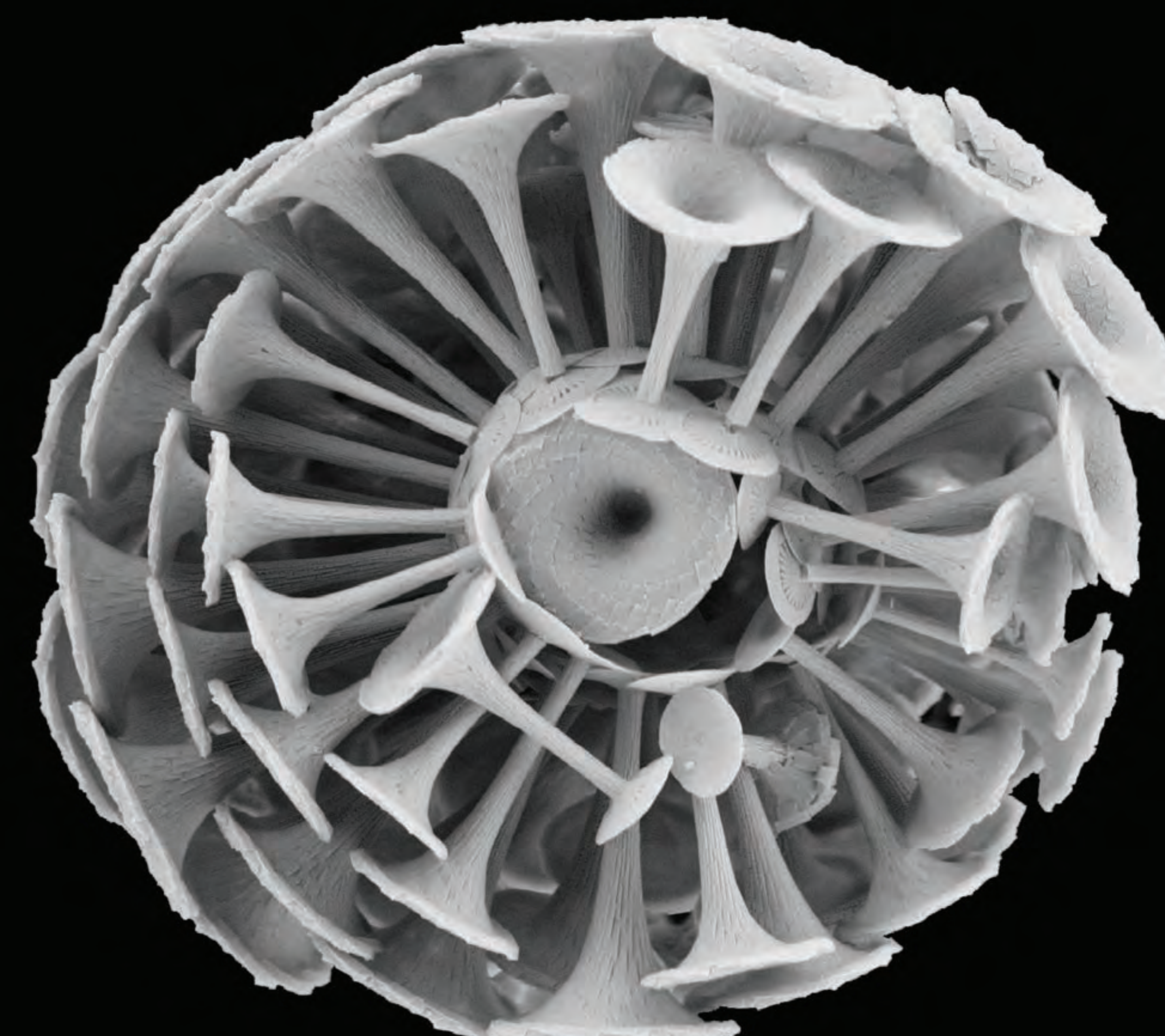


COCCOLITHOPHORES are an important algae — and mysteriously scarce in one of the most productive regions of the Atlantic Ocean, according to a new paper by Senior Research Scientist Barney Balch and his team. The researchers are continuing their investigations in January during an expedition in the Southern Ocean.

Photo: Barney Balch and Colin Fisher

The Art of Arctic Research

An interdisciplinary research team is unearthing how microbes process iron in the harsh Arctic tundra — and how they will shape the planet's response to global climate change.

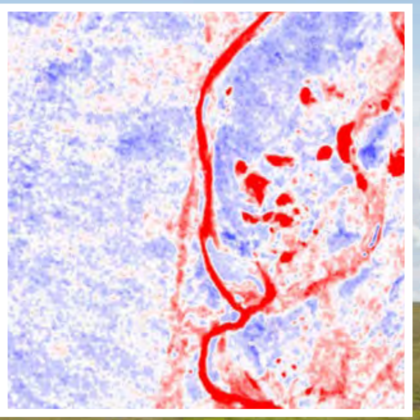
For Postdoctoral Scientist Alex Michaud, the most impressive presence in the Alaskan Arctic is not the titanic Brooks Range, the countless lakes flecking the expansive tundra, nor anything that can be seen with the naked eye — it is the microscopic iron-oxidizing bacteria.

"You don't really notice how prevalent they are until you go for a walk across the tundra," Michaud said. "But most of the ground you step on is habitat where iron-oxidizers live. As you look out over the landscape, it becomes clear that they are one of the most abundant types of organisms."

Michaud spent last summer studying iron-oxidizing bacteria at Toolik Field Station on the North Slope of Alaska. He is part of an unusually interdisciplinary team working to understand this microscopic yet major feature of the landscape — and its outsized role in the carbon cycle and other global processes.

Geomicrobiologist and Senior Research Scientist Dave Emerson leads the project, working alongside Michaud, a geochemist and microbiologist. Also on the team are mathematician and modeler Senior Research Scientist Nick Record, intern Remi Masse, artist Philippe Villard, and researchers from the University of Vermont. Their diverse range of specialties allows the team to tackle this research from multiple angles, propelling the project toward new discoveries and deepening the scientific understanding of climate change.

The chaos of global climate change is felt nowhere more powerfully than in the Arctic. Though less visible than retreating glaciers and melting sea ice, increasing global temperatures are melting another essential type of



'MOST OF THE GROUND YOU STEP ON IS HABITAT WHERE IRON-OXIDIZERS LIVE.'

IRON-OXIDIZING BACTERIA use iron to gain energy at a microscopic scale (left), forming vibrant underwater colonies visible across the tundra (middle), which create rust minerals that can be detected from the air (right).

Photos: Dave Emerson, left; Philippe Villard, center; Nick Record, right

FIELD TEAM MEMBERS trek across the tundra while collecting microbial samples at a study site near Toolik Field Station.

Photo: Alex Michaud

LEFT Toolik Field Station sits on the North Slope of Alaska. **ABOVE** Artist Philippe Villard sketches (left) and makes prints (right) in the field. **BOTTOM** A woodcut Villard made during his first collaboration with Emerson in 2008 coincidentally depicted similar species to those the team discovered.

'THIS IS AN IMPORTANT PART OF THE CLIMATE CHANGE PUZZLE WE KNOW FAR TOO LITTLE ABOUT.'

ice as well — the permafrost that underlies the region. As climate change advances, understanding how permafrost melting influences the release of potent greenhouse gases will be essential to understanding how Earth will respond.

"The changes in the Arctic are rapidly rewriting the natural cycles that distribute vital elements like iron and carbon in the environment," Emerson said. "What we are learning through this project will be essential to understanding how Arctic ecosystems are responding and how those changes will affect the rest of the planet."

Emerson's expertise in iron-oxidizing bacteria has led him from underwater volcanoes to freshwater wetlands to the Maine coast — and now it brings him to the Alaskan tundra. He is seeking to identify and characterize the iron-oxidizing bacteria that thrive in this harsh place, assess their abundance for the first time, and quantify the processes and pathways by which they interact with and shape their environment. What he discovers about these microscopic organisms will be expanded upon by mathematical models that Record will create to determine how iron cycling processes are occurring across the Arctic.

This project could yield the discovery of new microbial species, a fresh perspective on tundra ecosystems around the world, and an understanding of the intersections between essential global cycles. Its novel approach fuses the microscopic and the macroscopic, the field and the laboratory, and even the practices of science and art in an effort to engage the public.

"It's humbling to see firsthand how much effort goes into great science, and to imagine how art can convey its discoveries in a unique and powerful way," Villard said. "Art allows us to capture the natural environment and show people what is happening far beyond what the eye can see."

RESEARCH EN PLEIN AIR

The North Slope of Alaska is vast, bare — and vibrant.

"You feel as small as a microbe when you're there," Villard said. "The absence of human development and minimal vegetation create a huge contrast between what one can see on the macroscopic level compared to the microscopic. Up close, you see an entire other world, like many cities built by bacteria in the permafrost."

Permafrost is a layer of soil that remains frozen from year to year, and it is one of the underlying reasons why iron-oxidizing microbes across the Arctic tundra power such a vigorous iron cycle. On the North Slope, the permafrost layer is extensive and impermeable. Any efforts to dig a hole in the tundra are stymied after only a few shovelfuls of soil — which is typically red from the rust minerals produced by iron-oxidizing bacteria.

Constrained by the permafrost, water from rain and snowmelt create a soggy upper layer of soil about as thick as a plush mattress. The iron contained in this water gets trapped there, too. With no way of escape, iron concentrates in the surface soil, where it feeds thriving colonies of bacteria that derive energy from oxidizing iron.

"On the North Slope, you see the conspicuous red mats and red minerals they form almost everywhere," Michaud said. "It's clear that microbes are rusting the tundra."

Permafrost will play an increasingly large role in our changing climate. Globally, this icy layer holds an enormous store of organic carbon — double that of the atmosphere. As warming temperatures melt the permafrost, this trapped carbon will become food for microbes, converted into either carbon dioxide or methane, and ultimately released into the atmosphere.

Both are powerful greenhouse gases, but methane is about 30 times more potent. Which gas is produced depends upon which strategies the microbes use to gain energy from iron molecules. Emerson suspects that increased microbial activity resulting from melting permafrost may actually favor the production of carbon dioxide — the lesser of the two evils.

Iron also exerts a strong control on the availability of phosphorus, an important nutrient in the rivers and streams of the North Slope. Breck Bowden, a stream ecologist at the University of Vermont, and graduate student Will Sutor are working with the team to understand how plentiful iron oxides may determine the abundance of phosphorus in Arctic ecosystems — both now and in a warmer future.

"The scientific community doesn't know much about Arctic microbiology in general, and we know even less about the community directly involved in the iron cycle," Emerson said. "And yet, we're discovering evidence that there is far more iron cycling on the North Slope than in temperate habitats. This is an important piece of the climate change puzzle that we know far too little about."

SKETCHING AN ECOSYSTEM

For Villard, a printmaker, iron-oxidizing bacteria are not simply an abstruse genre of microbe or players in a global game of carbon chess. They are also an artistic subject matter, a source of inspiration and discovery, and a tool for creating art.

"This field season was a true exploration in the sense that I had no idea what we would find," Villard said. "There's so little vegetation on the North Slope that I wondered, 'well, what am I going to do with nothing?' But if you stick your nose to the ground, all of a sudden you start seeing incredible things."

Villard found plenty to spark his imagination. He took photographs and videos, sketched the landscape, and made prints in the field. Several of what Villard calls his "experiments" utilized the rust minerals the bacteria produced as pigment, such as when he used rocks coated with iron oxides like charcoal to sketch the mountains before him.

On his third day in the Arctic, Villard used his artistic penchant to render the invisible, visible. During his initial explorations of the area, Emerson had identified a promising study site, an unusually deep trench carved by melted permafrost that offered the perfect habitat for microbes. Villard used a GoPro camera to explore the trench, offering the researchers their first high-resolution underwater view of that microbial environment — which turned out to be dominated by similar species to those Villard portrayed in a woodcut during his first collaboration with Emerson a decade ago. The team named the location Gallionella Gulch, in honor of its prosperous microbial inhabitants.

"Seeing that video was like visiting another planet," Record said. "Having Philippe in the field let us see the environment we were studying in entirely new ways. His creativity and insight helped us look beyond our typical scientific processes to learn and observe more deeply."

Photo: Jason Stuckey

Photos, top row: Alex Michaud

LEFT Senior Research Scientists Dave Emerson and Nick Record measure dissolved oxygen in a mat formed by iron-oxidizing bacteria. **RIGHT** Intern Remi Masse collects samples of sediment colored red by the rust products made by iron-oxidizing bacteria in the Arctic tundra.

Discovering the flourishing community of iron-oxidizing bacteria in the gulch inspired the researchers to ask a host of new questions. How common were such pools of water? Were they typically of similar size? How deep were they? What were their other common characteristics?

The team decided to find out. They borrowed a drone from the field station and conducted an aerial photography survey of Gallionella Gulch and the surrounding area. They were able to identify the characteristic red color that signifies iron-oxidizing bacteria in the photographs, and will use the images to learn about this type of feature across the landscape.

“The expansiveness of iron in the landscape was stunning, and I saw things I had never seen in a career of studying iron-oxidizing bacteria,” Emerson said. “The Arctic is definitely more dynamic than you would expect for a system that’s frozen most of the year.”

TAKING SHAPE

Next summer, the team will return to Toolik Field Station. Until then, its members are focused on developing their individual project components and preparing for next season.

“It was very energizing to be in the field, surrounded by such interesting and passionate people and in such a huge landscape,” Villard said. “I’m glad that it’s a two-year project, because it’s so overwhelming how much there is to explore.”

Villard is spending the winter capturing the sensory experience of the Arctic through printmaking. Last summer, he collected and dried mud rich in iron oxides, and brought it back to the Boothbay Harbor studio he shares with his wife and artistic partner, Kim Després-Villard. They are using it to make red pigment for a series of fine-art woodcuts expressing the five senses of sight, smell, hearing, touch, and taste — as well as what they consider the sixth sense, instinct. The woodcuts will be interspersed throughout a book of the project team’s writing, photographs, and data visualizations.

Masse is now in his junior year at the University of Michigan. Before completing his internship in August, he had the opportunity to begin the next phase of the project in Maine — analyzing the bacteria samples he helped collect in the Arctic. He presented his results to the Bigelow Laboratory community at the annual Research Experiences for Undergraduates Symposium.

“This was the first time I had my own results that were truly something not known before, and it gave me an overwhelming sense of pride,” Masse said. “I’m hungry for more, and this project definitely solidified my desire to continue pursuing research as a career.”

Emerson and Michaud are now processing their samples, refining their experiments, and planning how to further this research. Emerson suspects that their samples include unidentified species of iron-oxidizing bacteria that they will be able to classify for the first time. Perhaps most importantly for the future of the planet, their findings should help resolve the microbial tug-of-war that shifts the balance of greenhouse gas production in the Arctic.

“Last summer gave us a taste for how powerful this system is, and the potential for these tiny bacteria to play a huge role in determining what our future climate looks like,” Emerson said. “It is important for our understanding of the world and our efforts to mitigate climate change that we understand these processes and the true scale of their global impact.”

Record won’t return to the field next summer — his job now is solving a landscape-sized math problem. He is using the data from the first field season to begin creating an ecosystem model of iron cycling in the tundra.

The model is fueled by Emerson and Michaud’s measurements of chemical processes. Once Record mathematically resolves how iron cycles in the discrete locations they measured, he can scale up these calculations to determine what is happening across the North Slope, and even in tundra around the world. This modeling process extrapolates the team’s findings about the microscopic world to yield a global perspective on the iron cycle.

“There are new scientific frontiers all around us, and we have already learned so much about this environment in a single field season,” Record said. “That’s what happens when you bring people with diverse expertise into the field together — you find ways you never would have expected to push the frontiers of science forward.”

Photos: Philppe Villard, left; Alex Michaud, right

SCIENCE SNAP

ALGAE-INSPIRED GLASS ART hangs in a new installation at Bigelow Laboratory for Ocean Sciences. "Ocean Breathing" was created by visiting Artist-in-Residence Krisanne Baker, who worked with Senior Research Scientist Mike Lomas and his team on the project. Bigelow Laboratory scientists regularly team up with artists to help share research findings and gain new perspectives. This summer, several of these scientist-artist teams shared their ongoing projects with more than 300 attendees at a special Café Sci event at the Laboratory.

Photo: Rachel Kaplan

Educating the Next Generation

The Keller BLOOM program celebrates 30 years of inspiring high school juniors through hands-on experiences with ocean science.

In the late 1980s, Bigelow Laboratory for Ocean Sciences was a nascent research institute nestled on the coast in West Boothbay Harbor. As the scientists continued studying the ocean's tiniest inhabitants, they also began to turn their attention toward cultivating the next generation of researchers.

One of the leaders was Maureen Keller, an expert in phytoplankton ecology and physiology and a passionate advocate for education. With the aim of making ocean science careers more accessible, especially to women, she teamed up with Trustee Jim McLoughlin and Bigelow Laboratory co-founder Clarice Yentsch. The trio designed a unique program — a week of hands-on ocean science learning that would immerse high school juniors from across Maine in a professional laboratory. The Bigelow Laboratory Orders of Magnitude (BLOOM) program was named to celebrate the diverse microbiota whose sizes span many orders of magnitude in the ocean — the focus of the new program, as well as the work of Bigelow Laboratory scientists.

"Bigelow Laboratory recognized the value of experiential education quite early on," said Tom Keller, Maureen's husband and a science education expert. "Giving high school students exposure to a professional laboratory environment and the chance to work side-by-side with scientists as peers is unique."

Maureen Keller remained at the program's helm through its first decade. When she passed away in 1999, the program was renamed to honor her leadership and contributions to ocean science and education.

Today, the Keller BLOOM program is in its 30th year. It continues to deliver upon the same ethos of providing authentic science education opportunities to Maine students, nearly 500 to date. Its graduates have gone on to pursue higher education and diverse careers — many in Maine, which is challenged by the "brain drain" of people with advanced degrees leaving the state.

"I think a weakness of science education is that many classroom laboratory experiments have predetermined results," said Nicole Poulton, a research scientist and director of the program since 2005. "When we take the students into the field, we have no idea what results they'll get. There are no right or wrong answers, and that gives the students room to ask questions and draw their own conclusions from the data. They thrive on it."

Though the BLOOM program maintains the original core mission and approach, it continues to adapt and expand to expose students to cutting-edge technologies and techniques. As part of a new component in 2019, Senior Research Scientist Nichole Price led the students in a kelp aquaculture experiment, exposing them to research at the forefront of Maine's developing blue economy.

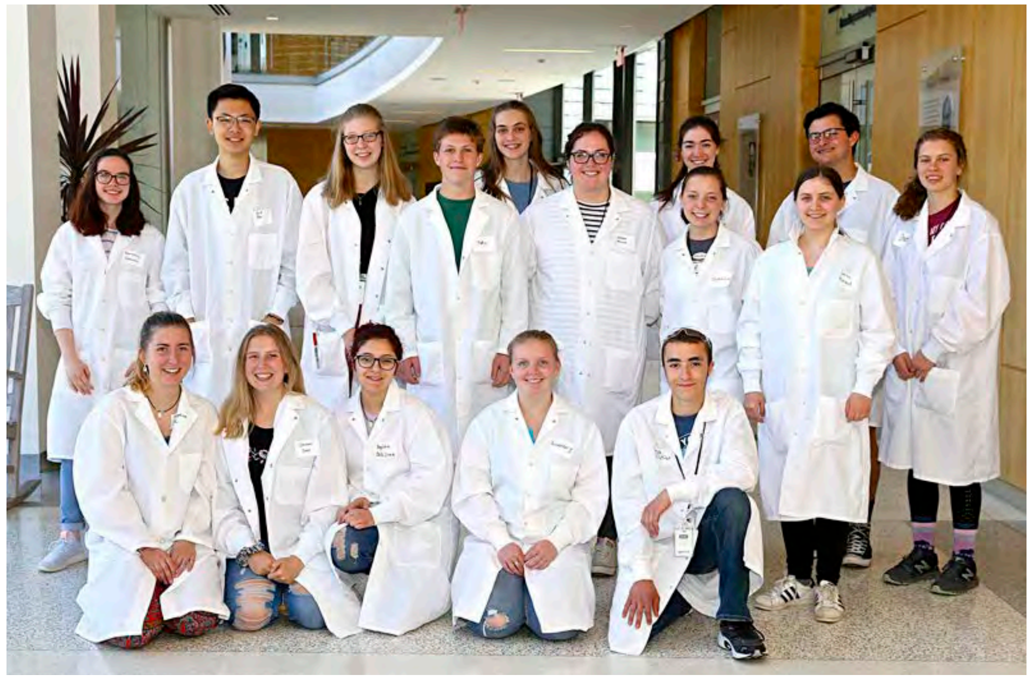
"For a high school student to be embedded in a world-class research institution for a week is both unusual and extraordinary," said David Fields, a senior research scientist who helps run the program. "And it's all due to an incredibly dedicated group of people and the support of individuals and organizations that donate to the program each year. Their efforts have allowed this program to continue uninterrupted for 30 years and offer generations of students an eye-opening experience."

THE BLOOM PROGRAM EXPOSES STUDENTS TO CUTTING-EDGE TECHNOLOGIES AND TECHNIQUES.

A CATALYST FOR CREATIVITY

Growing up in Cumberland, Jamie Currie spent his early years looking at books about fish and watching documentaries about sharks. Despite having never heard of Bigelow Laboratory, he took a teacher's suggestion and applied to the Keller BLOOM program during his junior year of high school in 2011.

"BLOOM was my first real exposure to large-scale environmental research, and it showed me the doorways I could walk through to keep the ocean in my life," Currie said. "Nicole and David and all the other scientists involved put their hearts and souls into the program, and



TOP The inaugural Keller BLOOM class poses before their research cruise in 1990. Sara Cathey sits furthest left in the middle row. **BOTTOM LEFT** The 2019 cohort poses at the beginning of the 30th Keller BLOOM program. Toby Seidel stands fourth from the left in the top row. **BOTTOM RIGHT** Student Sydnie Della Croce looks through a microscope at phytoplankton collected during a local research cruise on the Sheepscot River.

Photos, bottom: Robert Mitchell

'THE KELLER BLOOM PROGRAM WAS MONUMENTAL IN SHAPING THE PATH I'VE TAKEN.'

seeing their passion about their work lit a fire in all of us."

Currie went on to study aquatic science at Kenyon College, where he helped lead a wetland restoration effort and also learned filmmaking techniques. Today, he unites his interests in science and film as an assistant science communicator with the University of Maryland Center for Environmental Science's Integration and Application Network.

Back in 2011, Currie experienced a pivotal moment while analyzing data from the research cruise on the Sheepscot River that begins every Keller BLOOM week. He noticed a sudden spike in dissolved nutrients, and spent hours with a group of other students trying to understand why the water chemistry would change so suddenly. They finally realized that it was likely an effect from tidal processes and runoff.

"Working with other BLOOM students to figure that out showed me how we as a species affect the environment around us, and that the impacts we have are profound," Currie said. "That moment drove the point home very clearly, and it helped set me on an environmental science and communication trajectory."

Currie returned to Bigelow Laboratory in 2019, when Poulton organized a career panel as part of the 30th anniversary of the program. Along with four other alumni, he shared his experience with the current students, encouraging them to think creatively about the range of opportunities open to them.

"The night we got to meet the alumni and hear about their paths was amazing," said Toby Seidel, a Lincoln Academy student and 2019 BLOOM participant. "It was incredible to see how the Keller BLOOM program led them to other research, travels, and interesting jobs. It showed me how many possibilities there are in the scientific field, and that it's possible to find something that really fits."

LEARNING THROUGH MENTORSHIP

LeAnn Whitney didn't grow up planning to become an ocean scientist. In fact, before she participated in the Keller BLOOM program in 2000, they felt more like mythical creatures than real people.

"In my experience, scientists were only in textbooks or on TV," Whitney said. "Coming to Bigelow Laboratory and meeting card-carrying scientists who were also ordinary people had a lasting effect on me."

Whitney's experience in the Keller BLOOM program inspired her to study marine science at the University of Maine, and then to pursue a doctorate in cell and molecular biology at the University of Rhode Island.

Though she didn't know quite how she would do it, her ultimate goal was always to move back to Maine. In 2012, she returned to Bigelow Laboratory as a postdoctoral scientist to work with Senior Research Scientist Mike Lomas, bringing her background in cutting-edge molecular techniques to his study of phytoplankton in challenging environments.

Whitney credits the mentors she worked with along the way for helping her discover her research and teaching interests. Looking back, those interactions feel almost serendipitous, guiding her towards unknown areas that have become focal points of her career.

"I think the greatest effect that a mentor can have is being passionate about their work, because passion is always contagious," Whitney said. "Experiencing the impact those relationships can have has made mentoring so important to me."

In 2018, Whitney became a research scientist at Bigelow Laboratory and an assistant professor of oceanography at Maine Maritime Academy. In both roles, mentoring is one of the most important and fulfilling parts of her work.

Over the last several summers, she has mentored Research Experiences for Undergraduates interns at Bigelow Laboratory. She enjoys seeing them flourish in the lab and take ownership of their research, driving projects forward out of their own curiosity.

"Maureen would have been tremendously proud of LeAnn," Keller said. "She has shown that you don't have to leave Maine to have an impactful career in ocean science."

COMING FULL CIRCLE

A career in ocean science can be full of adventure. Sara Cathey has circumnavigated Iceland twice, gone diving on Australia's Great Barrier Reef, and managed a laboratory in Antarctica.

Cathey's interest in oceanography began during her time as a participant in the inaugural Keller BLOOM program in 1990. She went on to study biology at the University of New Hampshire, where she worked in a marine science lab studying zooplankton genetics and population dynamics. After graduating and spending three years as a ski bum in Wyoming, she returned to New Hampshire to manage the same laboratory and continue conducting research.

"Thirty years ago, the Keller BLOOM program was the first time I interacted with genuine research," Cathey said. "It left a deep impression on me as a high school student, and it was monumental in shaping the path I've taken."

Today, Cathey teaches marine biology at Oyster River High School in Durham, New Hampshire, where she seeks to give her students the same exposure to authentic research that inspired her. She runs long-term experiments with her classes, takes them on research cruises, and encourages them to intern at the University of New Hampshire. One of her current students even works in the same lab space that Cathey did in college.

Last summer, she returned to Bigelow Laboratory to participate in a version of the Keller BLOOM course that has been designed for educators. In response to requests from teachers across Maine, Poulton and Fields began the program in 2009 to expand the impact of the Keller BLOOM experience and help develop ocean literacy.

Alongside nine other BLOOM Educator participants, Cathey attended seminars by Bigelow Laboratory scientists, practiced using an ocean science sampling toolkit, and identified plankton under a microscope. She also began developing ideas for a long-term plankton sampling experiment to run with her class, and she exchanged lesson plans and ideas with other teachers.

"Educating 10 teachers each year multiplies the effect of these programs far beyond the 16 students we teach directly," Poulton said. "Just as we're teaching students about the orders of magnitude of life in the oceans, we've also increased our impact by an order of magnitude. It's exciting to think about how the program can grow over the next 30 years."

LEFT Student Jamie Currie filters water samples during the 2011 program. **MIDDLE** Bigelow Laboratory Research Scientist and Keller BLOOM alumna LeAnn Whitney works with intern Emily McDermith to tend their algae incubations. **RIGHT** Teachers Sara Cathey and Michael Masi swap curriculum ideas on a research cruise during the 2019 BLOOM Educators program.

Photo, right: Roxana Branch

PROFILE Anna Marie Thron Trustee, Bigelow Laboratory

Tall trees and cool brooks shaped Anna Marie Thron's world from an early age. Growing up on her family's New Jersey farm, a love for the land took root deep in her heart.

"I'm still happiest outside," Thron said. "I spend time outdoors every day, and it just has to be that way."

Summers find her walking, gardening, and birdwatching from her Boothbay porch with her husband, John. Winters find her carefully trekking around Portland's icy sidewalks, John somewhat reluctantly in tow.

'WE NEED MORE PEOPLE TO GET INVOLVED IN EFFORTS TO CHANGE COURSE.'

It is this passion for the natural world that has driven Thron's extensive involvement with environmental nonprofits over the last 20 years. She has given up countless hours of her retirement to serve on boards across the state. While she's helped organizations achieve major environmental wins in Maine during that time, she has also grown increasingly concerned about the trends across the planet.

"I'm terrified," Thron said. "I think we're ruining the planet, and we need more people to get involved in efforts to change course."

As the oceans cover most of Earth, she sees them as a big part of the work that needs to be done — and a promising source of potential solutions. For those reasons, she joined Bigelow Laboratory's Board of Trustees in 2013.

Anna Marie and John have lived in Boothbay for about 40 years, purchasing their summer cottage only shortly after Bigelow Laboratory first opened in its original West Boothbay Harbor location. At the time, she and John were working in Cambridge, Massachusetts, where they ran a successful software company. Each summer weekend, they'd make the three-hour trip up the coast.

"We fell in love with Maine, and Boothbay was at the furthest edge of what we could drive regularly from Cambridge," Thron said. "On weekends, we'd get in the car and just barrel off."

Following her retirement about 20 years later, she began to spend all of her summers in Boothbay and dove headfirst into board service for environmental nonprofits. Much of her focus has been on local conservation, but climate change has convinced her of the global nature of the work that is needed for conservation efforts to succeed.

Over the course of her board service, Thron has seen organizations become increasingly aware of the interconnectedness of the planet and the need to take holistic approaches to address issues. This has changed the way environmental nonprofits work and highlighted the importance of partnerships to address the multifaceted and rapidly evolving issues the planet is facing.

"Many conservation groups used to focus solely on buying land to protect it," she said. "Now there's a greater realization that if we don't also address climate change, our lands won't be protected no matter who owns them."

That is one of the reasons why Thron feels so strongly that research institutes like Bigelow Laboratory need to actively work with local, state, and national government officials. Until there are laws that set better limits and incentivize change, polluters are going to pollute and cars are going to guzzle. She has been particularly excited by the recent testimonies on ocean research delivered to Congress by Bigelow Laboratory's President Deborah Bronk, as well as Senior Research Scientist Patricia Matrai.

"We need to try to do all the little things we can as individuals," Thron said, "but it's going to take the government to get the big guys to knuckle under and change the way they do business."

Despite the challenges facing the planet, Thron says there are reasons for optimism. Increasing forest conservation, dam removal, and adoption of solar power are all sources of encouragement for her. She sees the type of changes that are needed happening all over the world, but she also knows that we need to drastically increase our rate of progress.

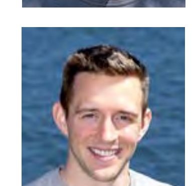
Thron believes that the science done at Bigelow Laboratory is providing vital insights into both global challenges and their potential solutions, which is why she is so passionate about making sure that the information gets into the hands of decision-makers — on both sides of the ballot box.

"I was really surprised by the incredible turnout at the laboratory's Café Sci series this summer," Thron said. "John and I showed up early, and there wasn't even a place to park. I think that's a great sign that Bigelow's science matters and that people are starting to pay more attention to what's happening and what we can do about it."

FIELDWORK 2019 Overview

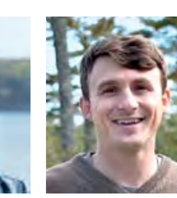
ARCTIC

1 In late September, **Dr. Steve Archer** set sail from Tromsø, Norway with the launch of the international and interdisciplinary MOSAiC research expedition. Senior Research Associate **Kevin Posman** joined the RV *Polarstern* in November. Archer and Posman are measuring gas fluxes as part of the atmospheric component of this comprehensive, yearlong study of sea ice dynamics in the Arctic. They seek to quantify the exchange of gases between the ice, ocean, and atmosphere. This information is crucial to helping researchers better understand and model how Arctic sea ice is changing and impacting the planet.



2 **Dr. Mike Lomas** went on a cruise aboard the RV *Ocean Starr* to study the Chukchi Sea as part of the North Pacific Research Board's Arctic Program. The primary goal of this study is to improve our understanding of the biogeochemical processes that structure the Arctic ecosystem, which includes documenting many ecologically and commercially important species. This baseline research is needed to understand the vulnerability of key processes in the rapidly changing Arctic.





3 In July, **Drs. Dave Emerson**, **Nick Record**, and **Alex Michaud** traveled to the North Slope of Alaska to study the iron-oxidizing bacteria that thrive in the Arctic tundra. Intern Remi Masse and Boothbay Harbor artist Philippe Villard also joined the fieldwork. The team is assessing the abundance of these bacteria for the first time, and quantifying the processes and pathways by which they interact with and shape their environment — with potential consequences for global cycles. Read more about this project on page 2.

OUR SCIENTISTS CONDUCT RESEARCH IN EVERY OCEAN AND BRING WHAT THEY LEARN BACK TO OUR LAB IN MAINE.

GULF OF MAINE

4 **Dr. Nichole Price** and **Research Associate Brittney Honisch** are continuing research into how aquaculturists can improve seawater conditions on their farms. During the summer, the team tested whether crushed oyster shells effectively lowered the acidity of seawater for juvenile oysters in enclosed upweller systems at Mook Sea Farm in the Damariscotta River. Price aims to provide Maine aquaculturists information about how to help protect their stocks against the effects of ocean acidification.

4 **Drs. Ben Twining** and **Nichole Price** worked with **Research Associate Brittney Honisch** and **graduate student Lauren Chaco** to collect sugar kelp along the coast of Maine during the summer. They aim to quantify the levels of both harmful elements and beneficial nutrients contained in seaweed. This knowledge will help inform the burgeoning aquaculture industry about the best locations for growing and harvesting seaweed in Maine.

4 In the summer, **Dr. Douglas Rasher** and his team completed a two-year ecosystem assessment of kelp forests in the Gulf of Maine. They seek to understand the degree to which kelp forests are returning to the state of Maine, identify areas of high resilience and productivity, and determine threats to the future of kelp forests in the region. This project is illuminating what changes to kelp forests mean for Maine aquaculture and how management practices may better support these ecosystems in light of an uncertain future.

4 **Dr. Barney Balch** is continuing to grow his Gulf of Maine time series, which is in its 22nd year. The data his team generates allows NASA to calibrate and validate ocean color satellites. It also creates an invaluable dataset for studying long-term change in coastal phytoplankton productivity, as well as a multitude of other physical, chemical, biological, and optical ocean properties. This research is revealing how the Gulf of Maine works and how it is responding to global climate change.

4 **Drs. Dave Emerson**, **Pete Countway**, **Nichole Price**, **Douglas Rasher**, and **Nick Record** collected Damariscotta River water and sediment in the fall during the launch of a comprehensive sampling effort of the Gulf of Maine. They are collaborating with several other Maine science institutions to develop a toolset that uses genetic information, called environmental DNA, to detect the presence of marine plants, animals, and microbes. This project aims to revolutionize the understanding and management of coastal ocean ecosystems.

NEW ENGLAND LAKES

5 Throughout the summer and fall, **Dr. Pete Countway** sampled several lakes around New England in order to screen for cyanobacterial toxins and the organisms that produce them. He analyzed these samples back in the lab using immunology-based methods that can provide a quick check for the presence of toxins. This work will improve efforts to monitor harmful algae and bacteria in many freshwater ecosystems.

PACIFIC OCEAN

6 In May, **Drs. Beth Orcutt**, **Anne Booker**, **Melody Lindsay**, and **Research Associate Tim D'Angelo** spent two weeks at the site of a seafloor ocean crust observatory off the coast of Washington. They used a system of subseafloor installations to access the fluids circulating more than 900 feet deep within the crust, with the goal of learning more about the volume, activity, and role that these microbes play in their environment and the ocean beyond. Answering these essential questions will help researchers understand how they affect global environmental cycles and could inform the search for life on other planets.

7 **Dr. Beth Orcutt** co-led a scientific ocean drilling cruise in August aboard the *JOIDES Resolution* to two study sites off the Pacific coast on the Costa Rica Rift. She led the scientists aboard in investigating two holes in the ocean crust, with the aim of learning about their structure and the marine microbes that live in the water flowing through them.

ATLANTIC OCEAN

8 Throughout the year, **Dr. David Fields** made several visits to Austevoll Research Station off the coast of Norway, where he is studying the behavior and physiology of zooplankton. By exposing a type of tiny crustacean to elevated temperatures and seawater acidity, Fields hopes to reveal how climate change will affect genetic adaptation. This is one of the first experiments that uses a marine water flea as a model organism.

9 As part of an ongoing ocean remediation experiment in the Canary Islands, **Dr. Steve Archer** returned to Gran Canaria in September. He is helping lead a project that seeks to measure the impact of nutrient-rich water from the deep sea on biological activity in the surface ocean. This experiment is determining the effectiveness of generating artificial upwelling processes, which could potentially help to remediate local ocean acidification and mitigate global climate change.

THE *JOIDES RESOLUTION* sails on a research expedition. While Dr. Beth Orcutt co-led a mission aboard the ship in late summer, she was announced as the winner of the prestigious Asahiko Taira International Scientific Ocean Drilling Prize for her pioneering research in this field.

10 In May, **Dr. Ben Twining** participated in the second of five cruises with the Bermuda Atlantic Time-series Study. He is part of an international effort to determine how the iron content of phytoplankton and water in the Sargasso Sea change over the course of a year. The team also measured the iron content of windborne dust particles that originate from Africa and help fertilize the nutrient-poor waters in this region. This research will enable scientists to improve the accuracy of models that predict future ocean productivity with changes in climate and human activities.

10 In April, **Dr. Mike Lomas** went on a cruise in the Sargasso Sea as part of the long-running Bermuda Atlantic Time-series Study, which he helps lead. In addition to their traditional measurements of key ocean processes, the research team deployed several autonomous gliders. The combination of these two approaches will yield a new understanding of the time scales on which phytoplankton sequester carbon in the region.

SOUTHERN OCEAN

11 **Dr. Catherine Mitchell** spent the summer on a cruise as part of the Southern Ocean Seasonal Experiment, an interdisciplinary project studying the variability in the seasonal cycle of the Southern Ocean. She ran an optical system that measures how light interacts with phytoplankton in the water in order to help calibrate ocean-observing satellites and improve measurements in this remote region. Read more about Dr. Mitchell's experience during this cruise on page 16.

Photo: International Ocean Discovery Program

FIELDWORK Notes from the Field

From the Southern Ocean

BY DR. CATHERINE MITCHELL

Just as the weather in Maine finally warmed up last July, I found myself travelling to wintry South Africa. My ultimate destination was a three-week research cruise in the Southern Ocean — and it was definitely cold.

I was invited to participate in the SCALE (Southern oCean seAsonaL Experiment) winter cruise by the Council for Scientific and Industrial Research in South Africa. SCALE is a new project bringing together scientists from around the world to study variability in the seasonal cycle of the Southern Ocean. The 95 scientists aboard were split into teams focused on air-sea gas exchange, sea ice, microbiology, nutrient availability, trace metals, phytoplankton, zooplankton, seabirds, physics, plastics, and weather. There was even a team studying the vibrations of the ship and how these related to seasickness.

My role was to run a system that measures how light interacts with phytoplankton in the water. The more phytoplankton in the ocean, the greener the water looks. Ocean-observing satellites measure this color, allowing scientists to make large-scale measurements of phytoplankton. However, some ship-based measurements are needed to calibrate the satellite interpretations, and these observations of Southern Ocean color are quite sparse, particularly in the winter.

As we edged our way out of the Cape Town docks in the *S. A. Agulhas II* icebreaker, we headed straight into a storm. It was a good test of our sea legs, and some fared better than others. After a few days, pale-faced scientists appeared from their cabins as they got used to the ship's movement.

We steamed south, the air and water colder with every mile. Suddenly, we spotted penguins riding the waves around us! A few icebergs appeared on the horizon, and snowflakes fell on deck. For some of the excited scientists, it was their first time seeing snow.

We started passing through patches of small, circular ice known as ice pancakes. Soon, these became larger and larger, and the open ocean between them became less and less. When the ship was surrounded by ice, we stopped for a day to allow some scientists to conduct on-ice experiments. It was -50 degrees Fahrenheit, and I lasted about two minutes on deck before retreating to the warmth of the ship and a cup of tea.

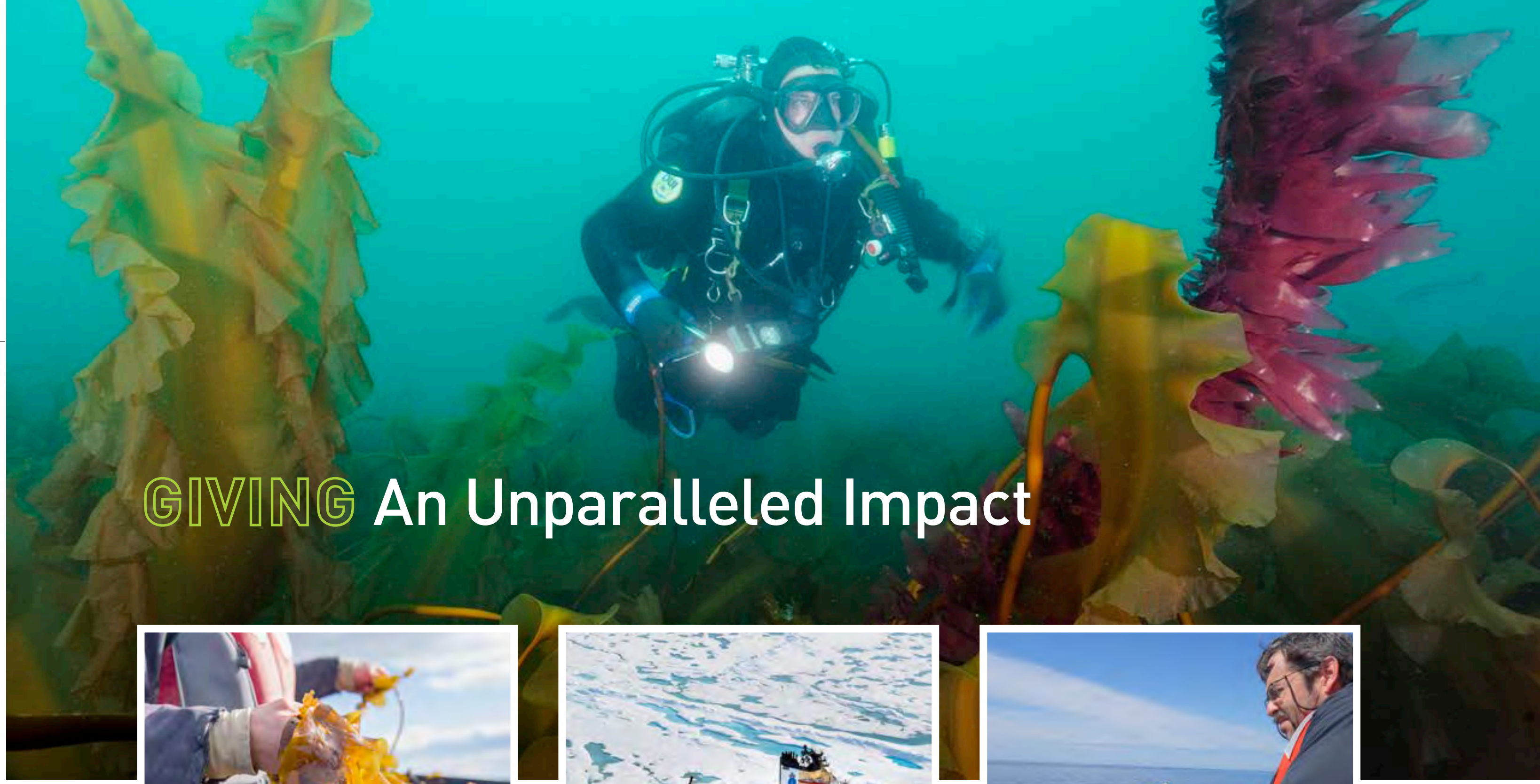
One of my main tasks was to teach PhD student Frieda Geldenhuys to run the color-observing system for future cruises. Unfortunately, due to unforeseen circumstances, a key instrument did not make it onto the ship. While something of an issue, it was a reminder that science doesn't always go according to plan. We were able to make the other measurements, and everything ran smoothly.

Our system sampled 24 hours a day, so Frieda and I traded 12-hour shifts. My days quickly settled into a routine: after breakfast at 7:30 a.m., I spent the morning on other work and attended our group meeting at 11 a.m. My shift at noon began with cleaning and calibrating the instruments, then I monitored the system and took a set of measurements every four hours. I ate dinner at 6:30 p.m., turned things over to Frieda at midnight, and went to sleep — then repeated everything the next day.

After the day stationary in the ice, we turned around and started heading back to South Africa. Instead of sailing back to Cape Town, we docked in East London, where the ship hosted two "open days" for local schoolchildren and the public. Guests toured the ship and learned about the science done onboard.

After three weeks at sea, it was great to end our trip by sharing our passion for marine research with people who might otherwise never have experienced it. While the scientists on this cruise all came from different backgrounds, our shared passion for understanding the ocean brought us together for the voyage.

Photo: Sina Wallschuss



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Photos: Brian Skerry, top; Stacey Cramp, bottom left; Lars Lehnert, bottom center

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Photo: David Fields