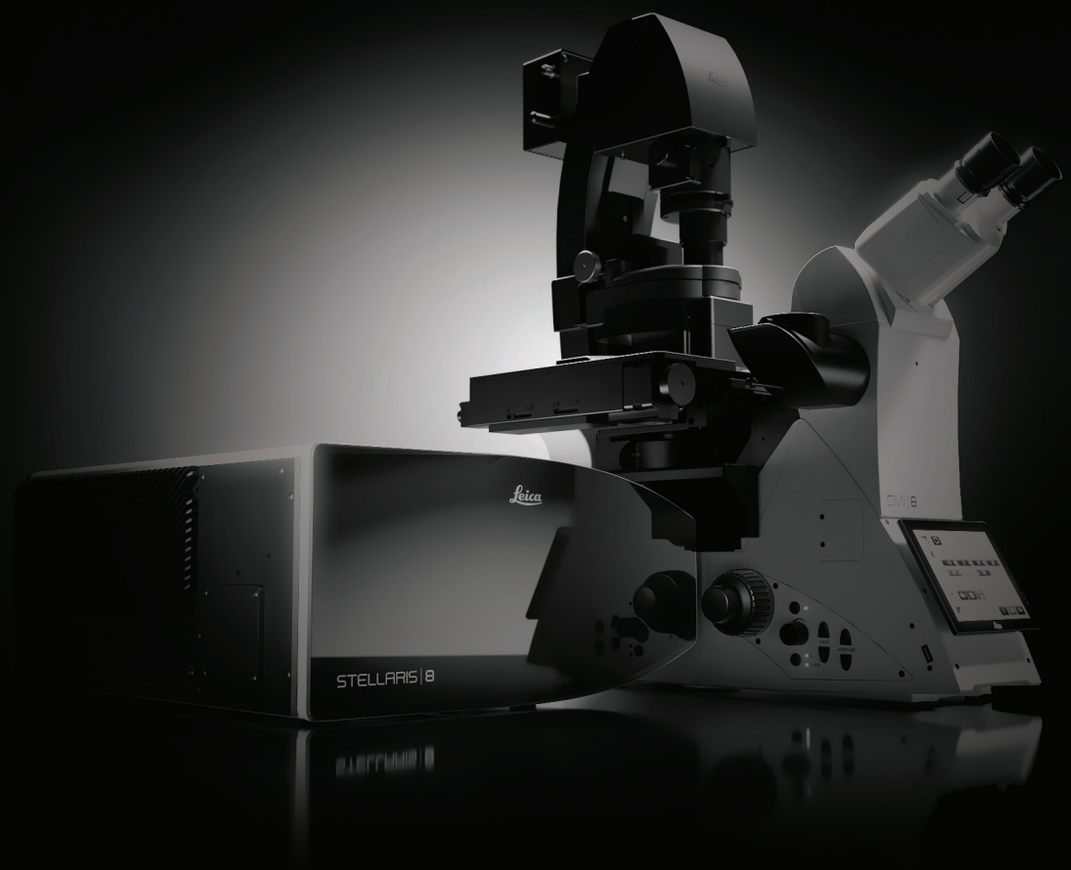
CBE ANNUAL REPORT

Center for Biofilm Engineering at Montana State University • 2022



UNMASKING THE MATRIX

CENTER FOR BIOFILM
CBE
ENGINEERING

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ON THE COVER:
Photo courtesy of Leica Microsystems

More than 350 years later, the CBE stands on the shoulders of a Dutch businessman

The CBE will soon enter a new era of research fueled by powerful new microscopy tools. You can read about that in our cover story on Page 8. But I'd like to put the possibilities of these new tools into perspective. And to do that, we need to time travel to the Netherlands around the 1660s.

In the town of Delft, a businessman named Antonie Philips van Leeuwenhoek worked in the textile industry. He needed to see the threads of his wares – primarily draperies – more closely. Despite his lack of formal scientific or engineering training, he developed a tool that would help solve his problem – and eventually establish the field of microbiology. He designed and built a single-lens microscope (making his own spherical glass lenses nonetheless) that helped him be more precise in his job. Over the next decade, van Leeuwenhoek improved upon his design and eventually began to experiment with microbes (e.g., scrapings from between his teeth – biofilm!), which he called "small animals." He eventually became the first person to microscopically document muscle fibers, bacteria, spermatozoa, and red blood cells. He never wrote books. Rather, he documented his discoveries in letters to the esteemed Royal Society who published many of them.

Today, the CBE stands on the horizon to chart the course for the future of biofilm research. We already have one of the most advanced microcopy facilities of its kind in the Pacific Northwest. And thanks to several grants secured by the manager of the CBE Bioimaging Facility, Dr. Heidi Smith, the forthcoming hardware upgrade could well revolutionize biofilm research, allowing us to extract a great deal more data from biofilm samples than was previously possible.

Like van Leeuwenhoek, we are peering into the unseen to unlock many of the mysteries of our (microbial) world. How do microbial communities assemble and localize over time and space to establish and maintain biofilms that survive and thrive under so many different conditions? And then once the biofilm establishes, what happens inside the biofilm matrix, physiologically speaking, that enables communication between microbes, enables the transfer of nutrients from within its slimy protective coating, and processes waste effectively so it doesn't choke out the life to which it provides safe harbor?

Our researchers will be asking these and similar questions using these new tools to visualize biofilms at improved spatial and temporal resolutions. These potential advancements promise to translate knowledge and understanding to potential application in virtually every industry sector that is affected by biofilms.

Dr. Matthew W. Fields
CBE Director, Professor of Microbiology & Cell Biology

IN MEMORIAM

Dr. Allan Hamilton, a longtime advocate and friend of the CBE, passed away Dec. 5, 2021. Hamilton wholeheartedly supported CBE founder Bill Characklis' establishment of the center, and provide guidance after Characklis passed away in 1992.

CBE FACULTY SPECIALTIES

Applied dynamic systems
Scott McCalla

Biocorrosion and metal-microbe interactions
Iwona Beech

Biofilm control strategies
Phil Stewart

Biofilms in extreme environments, metagenomics
Luke McKay

Biofilms in waste remediation, industrial systems
Paul Sturman

Biology, imaging
Heidi Smith

Biomechanics, biomimetic materials
Chelsea Heveran

Cell Biology
Diane Bimczok

Ecology
Markus Dieser

Engineered waste remediation
Otto Stein

Environmental biofilms
Matthew Fields

Environmental biotechnology
Elliott Barnhart
Adrienne Phillips
Abbie Richards

Environmental biotechnology and bioremediation
Robin Gerlach
Brent Peyton

Environmental technologies
Erika Espinosa-Ortiz
Catherine Kirkland

Fluid-structure interactions
Jeffrey Heys

Infectious diseases, microbial ecology and evolution
Seth Walk

Magnetic resonance imaging
Sarah Codd
Joseph Seymour

Material science and technology
Roberta Amendola

Mathematical modeling
Tianyu Zhang

Mathematics and statistics
Martin Hamilton
Albert Parker

Medical biofilms
Garth James
Kelly Kirker
Elinor Pulcini

MEMS, sensors, and actuators
Stephan Warnat

Metabolic eng., metabolic networks; chronic wounds
Ross Carlson

Microbes in extreme environments
Dana Skorupa

Environmental microbiology
Roland Hatzenpichler

Microbial ecology
Rebecca Mueller

Microbial ecology in cold temperature environments
Christine Foreman

Microfluidics
Connie Chang

Molecular genetics, gene expression, alginate biosynthesis; Pseudomonas
Michael Franklin

Physical and material biofilm properties
James Wilking

Polymer science; scanning probe microscopy
Lewis Cox

Polymers & composites
Cecily Ryan

Rheology and biofilm mechanics
Jennifer Brown

Standardized biofilm methods
Darla Goeres

Subsurface biotechnology and bioremediation
Al Cunningham

Tool and machine design
Kevin Cook

Wastewater Systems
Ellen Lauchnor

FY2022 CBE INDUSTRIAL ASSOCIATES

With its Engineering Research Center award in 1990, the CBE began as one of the first-generation of Engineering Research Centers funded by the National Science Foundation. The CBE was fortunate to have an existing industry program with approximately 10 subscribing members. From these beginnings, the CBE has grown to more than 30 subscribing members from a broad cross section of industry. The common thread among these businesses is a need to understand and control biofilms in industrial, medical, and environmental settings. As the list of industries that our work impacts continues to grow, commitment to helping our industrial partners only strengthens.

Paul Sturman, CBE Industrial Coordinator

Industrial Associate Tony Rook discusses Sherwin-Williams' interests in biofilm research

By Skip Anderson

The Sherwin-Williams Co. has participated in the CBE's Industrial Associates program for 13 years. Biofilm plays a costly role in the manufacturing and long-term storage of surface coverings such as paint and stains. So much so that Tony Rook, Sherwin-Williams' designated representative to the CBE, asked to convene a panel discussion at the CBE's 2022 regulatory meeting in Washington, DC, Anti-Biofilm Technologies: Pathways to Product Development. The discussion, titled "The need for a variety of biocide chemistries to prevent biofilms in paint and coatings," included Rook, Riaz Zaman (American Coatings Association) Rodney Rees (Thor Specialties, Inc.), Adrian Krygsman (Troy Corporation), and Greg Sarnecki (Behr Corporation, a division of Masco).

Why is it important that you hosted a panel discussion on coatings and paints at the CBE's most recent Pathways to Product Development meeting?

The CBE's PPD meeting was conceived nearly a decade ago to provide a venue for regulatory decisionmakers to participate within sessions which discuss advancement of science, product development, and regulatory hurdles related to bringing new technologies which control, kill, or remove biofilms across wide industrial applications.

The paint and coatings industry relies upon the US Environmental Protection Agency-regulated antimicrobial pesticide technologies to ensure our products are preserved against the potential for wet-state spoilage and enables our products with properties to protect against defacement and damage of the finished dry-film by fungal and algal colonization.

The modern paint and coatings market has embraced formulations to meet the growing emphasis on environmentally sustainable ingredients and processes. The benefits of bringing increasingly more sustainable formulations to market is clear. However, these formulations are also more susceptible to the potential of product degradation caused by microbial spoilage. The antimicrobials used for product preservation are the key enabling ingredients to allow the sustainable formulations to be brought to market without the unwanted effects of microbial contamination.

The core antimicrobial technologies used broadly within the water-borne paint and coatings industry as preservative ingredients are currently undergoing a significant review by the US EPA's Antimicrobial Division's Reevaluation Branch. The reduction and/or restriction of use of these critical and enabling ingredients within paint and coatings products is a potential outcome of this regulatory review process.

The CBE's Annual Pathways to Product Development meeting provided an excellent forum for the members of the American Coatings Association to communicate the critical importance of antimicrobial preservative technologies to the paint and coatings industry. The participation of regulatory stakeholders, particularly within the EPA, was a key driver to hosting this panel discussion at this year's PPD meeting. The panel allows for members of the ACA to describe the critical need to maintain the use of key antimicrobial preservative ingredients for protection against wet-state spoilage, dry-film defacement, and ingredients utilized for sanitization of manufacturing equipment.

What are some of the challenges of combating these biofilms?

Biofilms have the potential to impact product preservation of paint and coatings in three ways:

1) Water-borne paint and coating manufacturing processes have the potential for microbial contamination within raw material storage and production equipment which may lead to the development of biofilms within the process. The best practice within the industry includes continuous microbiological monitoring of raw materials, equipment, and finished products; and utilizing antimicrobial ingredients for routine cleaning and sanitization of production equipment to control the potential formation of biofilms. Maintaining the continued use of sanitizing antimicrobial ingredients at effective use rates is a key goal the industry to ensure responsible control of these biofilms.

2) Water-borne paints and coatings manufactured within processes where effective industrial hygiene practices are not optimal to control biofilms may lead to the potential of wet-state spoilage due to microbial contamination. Responsible formulation with effective wet-state preservative ingredients known to control the potential for wet-state spoilage are critical to water-borne finished products and the raw materials utilized for their formulation. Under-preserved paint and coating formulations may lead to wet-state spoilage which may be difficult to remediate and subsequent waste. A contributing factor to the difficulty

in recovering wet-state microbial spoilage within paint and coatings is due to microbial attachment to solids within the paint matrix. This often-overlooked biofilm mechanism is critical to understanding why responsible preservation strategies to prevent microbial spoilage is critical for water-borne consumer products with a high solids content, such as paint and coatings.

3) A core function of paints and coatings is to protect and beautify surfaces across a range of applications. Dry-film preservatives are critical ingredients utilized to protect the coating itself from microbial attack by mildew and algae. If formulations are not responsibly formulated with antimicrobial preservative ingredients, microbial degradation of the coatings can damage the coatings. Protection of dry-film coatings from fungal and algal biofilms enables the coating to protect the surfaces applied throughout its intended service life.

Sherwin-Williams has been a member of CBE's innovative Industrial Associates program since 2009. What has kept this longstanding and fruitful relationship thriving?

The Sherwin-Williams Company recognizes that to enable our portfolio of sustainable paint and coating formulations, we must embrace the best practices for responsible microbial control both within our products and our processes. In this regard, we have found great value in partnering with the Center for Biofilm Engineering's world-leading research focus on biofilms. Specifically, by participating as a member of the CBE Industrial Associates program we gain access to industrially relevant biofilm research across a wide array of applications. Each year, members of the Industrial Associates program gain access to current biofilm research by participating in the two scientific meetings which are prepared and hosted by the CBE leadership team. The PPD regulatory meeting held each February provides an opportunity to engage with government regulators across a number of agencies, which helps us better understand the regulatory hurdles but also to develop relationships with key members of the regulatory community. Likewise, the Montana Biofilm Science & Technology Meeting held in Bozeman each summer presents current progress within academic biofilm research areas as well as relevant industrial biofilm related applications. In addition to excellent content, the appropriate size of these meetings offers a terrific opportunity to interact directly with the academic researchers and develop partnerships with other members of industry.

> [A]s a member of the CBE Industrial Associates program we gain access to industrially relevant biofilm research across a wide array of applications.
>
> -- Tony Rook

Furthermore, a benefit to membership within the Industrial Associates program is access to the CBE biofilm researchers and opportunity to engage with projects which are able to leverage the word-class laboratory resources to study applications relevant to our business. The CBE's commitment to educational outreach provides an excellent training resource for our staff scientists. Some key areas include access to the knowledge portal on the CBE website, awareness of the latest publications by the CBE staff and the new Hybrid Seminar Series which offers a virtual opportunity to stay engaged with current biofilm research. ■

MEMBERSHIP PRIVILEGES

Access
Industrial Associates (IAs) have preferred access to CBE researchers and pre-publishing updates on research.

One-on-One Consultation
IAs receive up to 2 days per year of consultation with CBE researchers.

Long-Term Research Visits
The CBE Bioimaging Facility and 12 laboratories are available to IAs to conduct research in collaboration with our researchers. IAs also have access to our Medical Biofilms Lab and Standardized Biofilm Methods Lab.

Sponsored Research
IAs can direct our expertise toward specific challenges by sponsoring research beyond the pooled research program.

Specialized Workshops
The CBE can provide workshops in our labs or yours. Fees may apply.

Tailored Communications
IAs get premium access to CBE publications, podcasts, videos, seminars, and CBE reprints and posters.

Access to CBE-Trained Students
IAs have premium access to CBE-trained students for internships and employment.

CBE-HOSTED BIOFILM MEETINGS

Direct access to emerging advances in biofilm science and technology via several avenues, including two conferences each year.

JULY
BOZEMAN, MT

MBM
MONTANA BIOFILM MEETING

ANTI-BIOFILM TECHNOLOGIES
PATHWAYS
TO PRODUCT DEVELOPMENT

FEBRUARY
WASHINGTON, DC

Department of Energy taps CBE director to serve on advisory committee

By Marshall Swearingen

CBE director Matthew Fields has been asked to advise the U.S. Department of Energy on a wide range of pressing energy and environmental topics.

Fields has been named to the DOE's Biological and Environmental Research Advisory Committee, a 23-member panel that provides advice on the agency's biological and environmental research programs. Topics under the committee's purview include advancing alternative fuels like algal biofuel, hydrogen, and methane, as well as improving traditional energy development and addressing environmental impacts, he said.

"I'm honored to have this opportunity," Fields said. "The Department of Energy is addressing some really important societal challenges, things that that impact everyone and touch not only on energy but on environmental and human health."

Fields said he is excited to apply his MSU research perspective to scientific issues of national importance. His research interests include studying how biofilms form on a wide variety of surfaces, with direct applications in harnessing microbes to make fuel, sealing hard-to-reach leaks in oil and gas wells and preventing costly corrosion in fuel pipelines.

"We have a lot of expertise in this area, both in studying the fundamentals in the lab and in connecting that with real-world applications in the field," Fields said. "That's what the CBE is all about. And I think MSU is strong in that way too — we do research with the big picture in mind."

Fields is serving a three-year term on the committee. ■

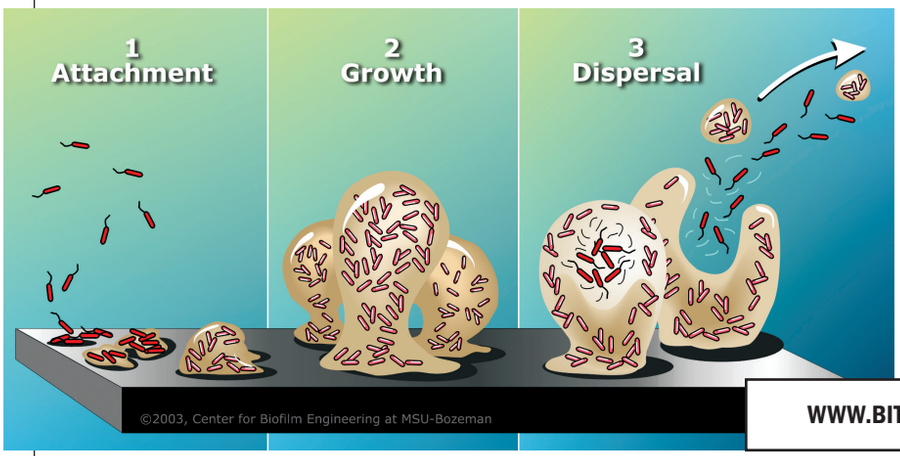
ASTM approves SBML's latest method

Darla Goeres, CBE research professor of regulatory science, and collaborators at Burroughs Wellcome are pleased to announce the approval of ASTM Method E3321, which describes how to evaluate antimicrobial urinary catheters for prevention of *Escherichia coli* biofilm growth.

Goeres, who played a leading role in developing the first standards referenced in regulatory guidelines for biofilm-related products, also won the ASTM Professor of the Year Award from ASTM International, the primary organization that develops technical standards for a wide range of materials and other goods. The award comes with a $4,000 honorarium, with $2,000 going to Goeres' lab.

"I feel very honored to receive this award," Goeres said. "It's a wonderful recognition of all the work MSU has done to make biofilm research more relevant and accessible to industry and, in turn, to people's lives." ■

CBE IMAGE LIBRARY APPROACHES 4K DOWNLOADS



Since 2011, the CBE has made available for education and presentation purposes graphics that convey succinctly biofilms themselves, the processes that sustain them, and dozens of the fundamental findings made at the CBE. The 53 images in the library have been downloaded nearly 3,800 times by users in every state and 40 countries.

WWW.BIT.LY/CBE_IMAGE_LIBRARY

Goeres accepts chairperson position of the Int'l Biofilm Standards Task Group

Darla Goeres, CBE research professor of regulatory science and principal investigator of the world's leading Standardized Biofilm Methods Lab, was recently tapped to chair the International Biofilm Standards Task Group.

The Task Group focuses on testing methods in healthcare settings, industrial systems, and the built environment. By doing so, the group seeks to enable informed and consistent decision-making regarding international regulation of antibiofilm products.

Months prior to her appointment to the leadership post, Goeres and Paul Sturman, a research professor of civil engineering and CBE industrial coordinator, participated in a virtual panel discussion on the role of regulatory standards in biofilm research and industrial innovation for the 18th International Biodeterioration and Biodegradation Symposium. Goeres was also a co-organizer of the discussion, which was one of the task group's first outreach efforts.

GOERES RECENTLY CHAIRED THE INFLUENTIAL ASTM COMMITTEE E35 ON PESTICIDES, ANTIMICROBIALS, AND ALTERNATIVE CONTROL AGENTS. HER TERM EXPIRED IN LATE '21.

THE ORGANIZATION NAMED HER PROFESSOR OF THE YEAR SHORTLY THEREAFTER.

The panel focused primarily on the need for biofilm methods in the oil and gas industry, the advantages and disadvantages of a standard test method versus best practices guidelines, and how regulatory hurdles are placing constraints on biofilm technology development and innovation.

The Task Group includes leading researchers from the CBE, National Biofilms Innovation Centre, and the Singapore Centre for Environmental Life Sciences Engineering.

Goeres, Sturman, and CBE Director Matthew Fields, also represented the CBE at a workshop held in the United Kingdom titled, "NBIC-CBE Biofilm Regulations and Standards Workshop." Goeres delivered an overview of the regulatory process in the US, which she was instrumental in creating in regard to biofilm claims. ■

Priority Questions: Microbial Biofilms

International group works toward position paper

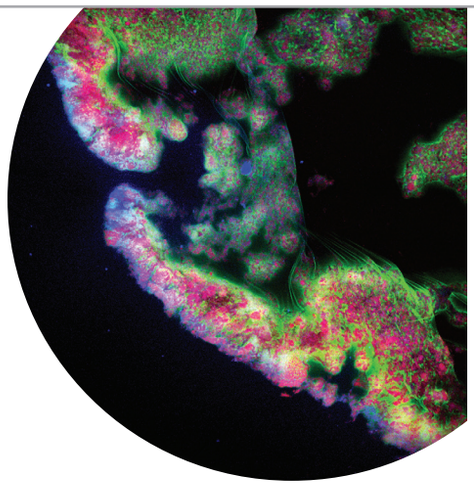
A team from the CBE is collaborating with biofilm researchers from around the world on a years-long project to identify emerging issues in science, innovation, and policy for the biofilm field. Prior to the formation of the "Priority Questions" working group, there had not been an international and community-wide synthesis of key questions and priority research or innovation areas for the biofilm field.

"This effort will play an important role in bridging the gap between the data generated by researchers, and the information needed by policymakers to make funding or regulatory decisions," said CBE director Matthew W. Fields, who, along with staffers Kristen Griffin and Skip Anderson, represents the CBE in the group.

Other biofilm research organizations serving on the working group are the Singapore Centre for Environmental Life Sciences Engineering, two representatives from the COST AMiCI Consortium, the ESCMID Study Group for Biofilms, and the National Biofilms Innovation Centre. The group engaged hundreds of researchers from the international biofilms community to identify important questions that, once answered, would make a considerable impact on the fundamentals of the field.

The working group gathered input from the global biofilm research community, and is currently holding focus groups comprised by scientists from academia, industry, and other stakeholders to organize subsets of related questions and finalize a set of priority questions. The end result will be to publish an insightful position paper to serve as a resource for the field to help shape the future of biofilm research.

"This will likely set much of the agenda for biofilm research for the next decade or more," Fields said. "Of course, this will also impact policy and outreach as well. ■



The future of biofilm research is

Microscopic

By Skip Anderson

In 2018, when Dr. Heidi Smith undertook the challenge of leading the CBE's Bioimaging Facility, she had hardly settled into her new office before laying out an ambitious vision: Expand the capabilities of the center's notable Bioimaging Facility in a way that could reshape the field of biofilm research.

Smith, along with CBE principal investigators Connie Chang, Matthew Fields, Christine Foreman, Robin Gerlach, and Jim Wilking, secured $1.75 million in grants to replace much of the existing hardware with two state-of-the-art Leica-brand confocal scanning laser microscopes capable of advancing science much faster than previously possible, as well as other microscopes. The development of imaging technology is typically aimed toward cell biology research, and biofilm researchers have exhausted the capabilities of traditional microscopy tools and need tools that are versatile and tailored for real-time, high-sensitivity imaging of intact, complex biological samples.

"Biofilm imaging is so unique, and there really aren't instruments that are developed just for biofilm imaging," said Smith, who is also an assistant research professor in the Department of Microbiology & Cell Biology. "We asked Leica how we might modify their latest microscopes so that we can investigate biofilms much more rigorously."

The CBE has a strong collaborative relationship with Leica spanning 20 years of interactions in microscopy research, which has aided in the customized configuration of the two new confocal scanning laser microscopes.

"Heidi came into this position at a critical juncture for our microscopy facility," said Matthew Fields, CBE director. "She understood that for us to expand our understanding of how biofilms work, we needed to think big as we sought to expand the capabilities of our facilities."

Smith led a working group at the CBE to identify specific imaging capabilities needed by CBE labs, and worked with Leica's technical team to meet those needs. This summer Leica will install two state-of-the-art microscopes which will catapult the CBE, its stakeholders, MSU, and the region into the next transformative era of imaging. The first is a customized DMI8 Inverted Digital Light Sheet confocal laser scanning microscope. And the second is an upright DM6 FS Upright DIVE CSLM multiphoton microscope.

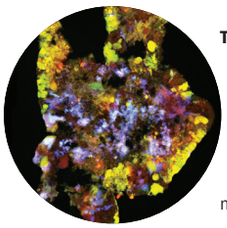
"The systems that Leica will install will vastly advance the CBE's ability to perform biofilm imaging," Smith said. "Combined, these capabilities offer a giant leap forward for biofilm research."

In addition to the high-powered Leica microscopes, the upgrade will include a new image analysis computer, high-speed network connections, and active data storage capabilities -- all of which are requirements for analyzing the large volumes of live cell imaging data produced by the new instrumentation. On the whole, this equipment offers cutting-edge, real-time, high-sensitivity imaging of intact, complex biological samples.

So, what will CBE researchers be able to do with these highly specialized tools that they couldn't do before? For starters, the multiphoton and digital light sheet will enable them to peer far deeper than ever before into thick biofilms. Previously, details about the processes, structures, and microbes deeper than ~40 microns below the surface of a live sample were largely left to the imagination. Biofilm researchers will now be able to explore samples eight times deeper than that. The difference is akin to the time the Hubble Telescope famously peered much deeper than previously possible into a curiously dark patch in the night sky only to discover scores of galaxies.

> [T]hese capabilities offer a giant leap forward for biofilm research.
>
> -- Heidi Smith

Speed is another gamechanger. Functioning at around eight times faster than the previous equipment will reveal processes with far greater temporal and spatial resolution than ever before. It's the difference between watching a baseball spring off a bat and high-speed photography showing how the bat temporarily deforms



These two microscopy images show key macromolecules alongside target bacteria within an aerobic granular sludge section (30 um). The colors represent different components of the biofilm, including proteins, beta-polysaccharides, bacteria, and lipids. The researchers captured these images at the CBE using a demo model of a Leica confocal microscope. ©2021, Kylie Bodle, CBE-MSU

the ball at the moment of impact.

"What we often see are dark spots from within the deeper parts of our images and we're left to hypothesize what those objects are and what they might be doing," Smith said. "That has been a frustrating limitation for biofilm researchers for decades. And that will soon change."

It's not just CBE researchers and members of its Industrial Associates program that will benefit from the pending upgrades. The CBE Bioimaging Facility is available to researchers from across campus, students, and visiting biofilm researchers from academia and industry alike.

"This facility directly benefits the state of Montana, the Northwestern US, and biofilm researchers from around the world," Smith said.

A National Science Foundation grant totaling $1 million provided two-thirds of the funding, while the M.J. Murdock Charitable Trust provided more than a half-million dollars, enabling the CBE to procure the Leica systems.

Smith is not idly waiting for the day the hardware becomes operational – she's already executing Phase 2: trying to add a sophisticated laser called a Stimulated Raman Scattering laser, or "SRS" – to the Leica Stellaris Inverted Digital Light Sheet CSLM.

"We're currently pursuing funding sources to secure ~$450,000 in order to add SRS to the new instrument," Smith said.

The SRS allows direct 3D visualization of chemical bonds to target events and structures, which are inaccessible with traditional optical microscopy methods.

"The 10^8-fold increased sensitivity of SRS compared to other Raman techniques is required for analysis of biological samples," she said. "The SRS will enable us to get pure chemical analyses from within the matrix without adding stains or chemicals."

Of the four instruments known to be in use nationally, only two are at public institutions and none are being applied to biofilm systems.

"This will revolutionize how biofilm imaging is conducted," Smith said. "This is such an exciting time to be involved in biofilm research." ■

CUSTOMIZED DMI8 INVERTED DIGITAL LIGHT SHEET CONFOCAL LASER SCANNING MICROSCOPE

- Eight-fold increase of image-acquisition speeds
- Significant decrease of phototoxicity, enabling faster processes and long-term imaging
- The Digital Light Sheet module is ideally suited for sensitive 3D imaging of intact, living, and complex samples
- The environmental control chamber extends the time samples remain viable under the microscope

HELP US FUND THE SRS!

UPRIGHT DM6 FS UPRIGHT DIVE CSLM MICROSCOPE

- Able to explore far greater depths of intact biofilm matrix in real time
- Label-free imaging of mixed microbial samples
- Image the entirety of an intact biofilm
- The white light laser enables light gating to be applied to any excitation line
- Extended IR laser enables excitation and imaging of red-shifted fluorophores
- Environmental-control chamber

On May 10, Jeremy Benton (pictured) and Chris Gomes, Leica Field Service Engineers, began installing the new INVERTED microscopy equipment at the CBE Bioimaging Facility. CBE photo by Skip Anderson

Dana Skorupa, left, with a graduate student during a research trip into Yellowstone National Park last summer. MSU photo by Kelly Gorham

NSF awards $3 million to support innovative graduate research NRT on extreme microbes

By Marshall Swearingen

LISTEN TO DANA ON THE 'BIOFILM FIRST' PODCAST

With a $3 million grant from the National Science Foundation, MSU and the CBE are advancing cutting-edge research while helping to pioneer a new model of graduate education designed to prepare scientists and engineers for a wide range of careers.

The five-year funding through the NSF Research Traineeship program, known as NRT, supports 21 PhD students as they study microbes that inhabit extreme environments.

"It's going to prepare our PhD students to tackle complex, multifaceted research problems and help them develop key skills needed in their future careers," said project co-leader Dana Skorupa, assistant research professor in the CBE, who is partnering with MSU's Thermal Biology Institute to offer the program.

According to project leader Brent Peyton, director of the TBI and CBE-affiliated faculty, the study of extremophiles is a good fit with NRT because it's inherently interdisciplinary. He also noted that MSU is exceptionally well positioned to study extremophiles due to its proximity to Yellowstone National Park where a variety of microbes thrive in thermal features like acidic hot pools.

"A lot of industrial systems have similar conditions," in which the specialized microbes often form biofilms and cause problems like clogged valves amid high heat, pressure, salinity or extremes in pH, Peyton said. The microbes can also be harnessed for beneficial uses, such as sealing hard-to-reach leaks in oil and gas wells or recycling plastic. "There's still a lot more to know about extremophiles and their potential applications," Peyton said.

CBE director Matthew Fields is co-leading the project. CBE faculty members include on the grant are Ross Carlson, Christine Foreman, Robin Gerlach, Roland Hatzenpichler, and Heidi Smith.

The NRT program is one of several ways that MSU is using its longstanding expertise in extremophiles to provide unique educational opportunities. MSU recently received a $397,000 NSF grant to offer a 10-week Research Experience for Undergraduates in which students from around the country come to MSU to study microbes in extreme environments. Peyton and Skorupa also take students into the Yellowstone backcountry each fall for an Honors College course called Extreme Microbiology in Yellowstone. ■

KEY AREAS OF RESEARCH

- Biofilm Control Strategies
- Energy Solutions
- Environmental Technologies
- Health & Medical Biofilms
- Industrial Systems & Processes
- Standardized Methods
- Water Systems

OPTIMIZING ALGAE BIOMATERIALS PRODUCTION

With a series of grants totaling **$6.4 million**, CBE-affiliated faculty, Robin Gerlach, Ross Carlson, and Matthew Fields, are exploring ways to optimize the use of algae for making biofuel and other products while removing carbon dioxide from the air.

WATCH THE KBZK NEWS VIDEO CLIP

First-generation college student earns prestigious NSF fellowship to pursue PhD at MIT

By Marshall Swearingen

Michael Espinal, a CBE undergraduate researcher who graduated in December 2021 with a degree in mechanical engineering, was awarded an NSF fellowship to pursue a doctorate degree at Massachusetts Institute of Technology beginning this fall.

When the first-generation college student reflects on his past four years at MSU, one spring day during his sophomore year stands out. He was studying when he got an email about an event happening that afternoon. He took a break and wandered down the hall. When he entered a room full of fellow students presenting their research, a new path opened up. "I didn't even know that engineers did research," said Espinal, who graduated with his bachelor's in mechanical engineering. Excited by the student research presentations, Espinal approached Chelsea Heveran, a CBE-affiliated faculty, about working in her lab. It was surprising to Espinal that Heveran offered him a position in her lab.

"I thought, 'What if I fail? What if this is a big mistake?'" Espinal said.

He worked on a project with Heveran and fellow CBE-affiliated faculty members, Adrienne Phillips and Cecily Ryan, that focused on treating shards of recycled plastic with specialized microbes so that the plastic would adhere to the cement. Espinal helped write the paper that announced the findings in the journal *Materials*.

For Espinal, working in Heveran's lab became the cornerstone of his MSU experience.

"Being around such a positive group in the lab has kept me motivated," he said. "I've had a lot of mentors who have helped me out." ■

Photo courtesy of NASA

CBE PHD STUDENT 'TRAVELS' TO MARS IN NASA SIMULATION

The 45 days Madelyne Willis spent in the capsule were part of an experiment called the Human Exploration Research Analog, and gave her a glimpse of what an astronaut's life may be like on a future mission to Mars or beyond. HERA is one of NASA's Earth-based analog programs that allow scientists to study crew cohesion and autonomy.

LEARN MORE ABOUT THE HERA CREW IN THIS VIDEO

PhD candidates win awards

PhD candidate **Matthew McGlennen** was named the W.G. Characklis Award winner. This award is presented annually to a CBE doctoral student based on their contributions to research and education.

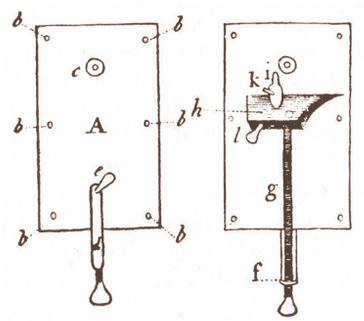
PhD candidate **Isaac Miller** was named winner of the John Neuman Student Citizen Award for his professionalism, thoughtfulness, and collaborative spirit.

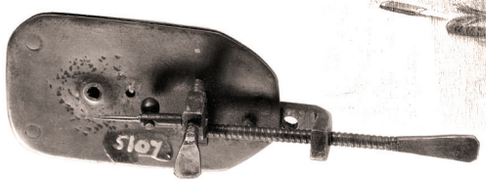
CBE Undergrad wins NSF fellowship

CBE undergraduate student **Abbey Murray** won a prestigious NSF fellowship to fuel her work in University of Washington's Construction, Energy & Sustainable Infrastructure doctoral program.

CBE student prevails in '3-Minute Thesis'

CBE students have dominated the "3-Minute Thesis," winning seven of eight competitions since its debut. Most recently, **Cailin Casey**, a CBE PhD student, won the Judges' Award for her buzz-worthy presentation titled was "What's All the Buzz With Insect Flight?"





The origins of biofilm research

With no formal training as a scientist, Dutch textile businessman who would become known as the Father of Microbiology, Antonie van Leeuwenhoek, built single-lens microscopes that achieved up to 275x magnification. These were notably small devices, the longest being about 5 centimeters. The user would place the lens very close in front of the eye while a specimen rested on a pin on the other side of the microscope. The user could manipulate three screws adjust the to focus and navigate through the sample.

CBE BY THE NUMBERS fy22

INDUSTRY

86 testing projects
44 sponsors

$1.2 million generated from testing projects

EDUCATION

1,254 students trained
since 1990
303 graduate students (graduated)
951 undergraduates

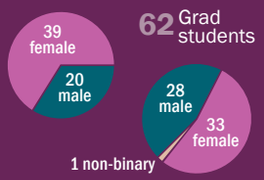
IMAGES

113 images downloaded from the CBE image library
12 states / 18 countries

3,761 images downloaded
since 2011 inception
50 states
40 countries

120 students trained

59 Undergrads



62 Grad students

12 student departments

- Architecture
- Cell Biology & Neuroscience
- Chemical & Biological Engineering
- Chemistry & Biochemistry
- Civil & Environmental Engineering
- Computer Science
- Directed Interdisciplinary Studies (Honors College)
- Ecology
- Land Resources & Environmental Sciences
- Mathematical Sciences
- Mechanical & Industrial Engineering
- Microbiology & Cell Biology

45 affiliated faculty

7 faculty disciplines

- Chemical & Biological Engineering
- Chemistry & Biochemistry
- Civil Engineering
- Land Resources & Environmental Sciences
- Mathematical Sciences
- Mechanical & Industrial Engineering
- Microbiology & Cell Biology

1,331 publications
since 1990

RESEARCH

40 papers, 36 journals

$9.4 million new research grants

85,000 CBE citations have far exceeded any other biofilm research center since 1990