CBE ANNUAL REPORT

Center for Biofilm Engineering at Montana State University • 2025

PIONEERING THE FUTURE OF BIOFILM SCIENCE

CONTENTS

CBE DIRECTOR
Matthew W. Fields, PhD

INDUSTRIAL COORDINATOR
Darla Goeres, PhD

EDITOR
Kristen Griffin

DESIGN AND PRODUCTION
Jill Story

CONTRIBUTORS
Skip Anderson, Matthew Barge, Reagan Cotton, Darla Goeres, Kelly Gorham, Natasha Nater, Colter Peterson, Adrian Sanchez-Gonzalez, Diana Setterberg, Jill Story, Maren Stubenvoll, Paul Sturman, Marshall Swearingen, Matthew Taylor, Pauline Teo, Maria Yung

Center for Biofilm Engineering
366 Barnard Hall
Montana State University
Bozeman, MT 59717-3980 USA

Phone: (406) 994-4770

CBE Director Letter

The CBE celebrated its 35th anniversary in 2025—an impressive milestone that makes it one of the longest-running engineering research centers originally funded by the National Science Foundation. Over the years, we have faced both new and ongoing challenges, and 2025 was no exception. Even during a time of change for industry, government, and academia, CBE has remained grounded in science, open dialogue, and collaboration in service of society. Our mission continues to bring together university, industry, and government partners to pursue research rooted in the scientific method and focused on real-world impact.

Reaching 35 years invites reflection.

WHY WAS A BIOFILM CENTER NEEDED?

Biofilms are the most common form of microbial life on Earth. They affect major issues in water, food, energy, and health.

WHY HAS THE CBE BEEN SUCCESSFUL?

Because partnerships matter. By connecting university researchers with industry and government experts, we bring together different perspectives to solve complex problems—an approach that has driven major advances in the U.S. for decades.

WHERE AND WHEN DID THIS HAPPEN?

At a collaborative, accessible mountain-town university, over more than three decades of building trusted relationships across research labs, government agencies, and industrial operations.

HOW HAS THE CBE SUSTAINED 35 YEARS OF IMPACT?

By conducting strong fundamental research while keeping a steady focus on practical applications.

WHO MADE IT POSSIBLE?

Dedicated, collaborative people from industry, government, and academia who willingly provide their expertise and value the contributions of others.

Fundamental research that informs real-world solutions remains at the heart of the CBE. A recent example is a $2.5 million Department of Defense award (PI: B. Peyton) to address biofilm-related corrosion on military vehicles in tropical environments—demonstrating how university-industry partnerships can meet critical national needs.

I am grateful to everyone who has contributed to CBE over the past 35 years. The Center's success comes not only from outstanding scientific inquiry, but also from a culture of collaboration and shared purpose. As biofilm challenges continue to evolve, so will we—working alongside our partners to meet the opportunities ahead.

– Matthew Fields, CBE Director
cbedirector@montana.edu

CBE FACULTY SPECIALTIES

Applied dynamic systems
Scott McCalla

Aquatic microbiology
Frank Stewart

Bacterial pathogenesis
Laura Jennings*

Bacteriophages, host-pathogen interactions, infectious disease
Patrick Secor*

Biofilm control strategies
Phil Stewart

Biofilm interaction with surfaces
Chris Jones

Biomechanics
Chelsea Heveran

Correlative analytical imaging
Heidi Smith

Ecology
Markus Dieser

Environmental and industrial biotech, bioremediation, living materials
Robin Gerlach

Environmental biofilms
Matthew Fields

Environmental biotechnology
Adrienne Phillips
Abbie Richards

Environmental biotechnology and bioremediation
Brent Peyton

Environmental catalysis
James Crawford*

Environmental microbiology and biotechnology
Christine Foreman

Environmental technologies
Catherine Kirkland

Fluid-structure interactions
Jeffrey Heys

Geoenvironmental engineering & material science
Saswati Ray

Geotechnical earthquake engineering and ground improvement
Mohammad Khosravi

Infectious diseases
Seth Walk

Magnetic resonance imaging
Sarah Codd

Magnetic resonance imaging, biofilm transport phenomena, gels and colloids
Joseph Seymour

Material science and technology
Roberta Amendola

Mathematical modeling
Tianyu Zhang

Mathematics and statistics
Marty Hamilton
Albert Parker

Medical biofilms
Garth James
Kelly Kirker

MEMS sensors and actuators
Stephan Warnat

Metabolic engineering, metabolic networks; chronic wounds
Ross Carlson

Microbes in extreme environments
Dana Skorupa

Microbial activity
Roland Hatzenpichler

Microbial pathogenesis immunotherapeutics & vaccine development
Reetika Chaurasia

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

Mucosal immunology
Diane Bimczok

Polymer science
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

Virology
Emma Loveday*

Wastewater systems
Ellen Lauchnor

Water quality, drinking water treatment
Amanda Hohner

* Denotes a new faculty member
See page 14 for details

Building on Bold Achievements

Thirty-five years in business, 1,377 publications, 118,033 citations, 1,696 students, 43 affiliated faculty, 6 ASTM methods, and more than 140 industrial partners is an impressive string of numbers. Rather amazing really, for a small land grant university located in a large state once filled with more cattle than people. And while it would be easy to sit back and revel in these accomplishments, the folks at CBE are putting on their lab coats and safety glasses to tackle challenges and explore new opportunities in the rapidly expanding field of biofilm science. Whether it is Dr. Heidi Smith pushing the boundaries of imaging with CBE's state-of-the-art microscopes, or Dr. Chelsea Heveran engineering biofilms for a specific function, CBE's long-standing commitment to innovation thrives —driven in no small part by the women of impact whose leadership, creativity, and scientific rigor continue to shape the center's research culture and future direction.

In 2023, Dr. Chris Jones joined the CBE family as the PI of the Standardized Biofilm Methods Laboratory and is leaning into his industrial experience to usher in the next generation of biofilm methods. We continue to find new ways to engage our industry partners, as mentioned by Matthew on a DoD mission-critical project. This work supports two exceptional, early career biofilm researchers, Dr. Ghazal Vahidi and Dr. Kylie Bodle. And let us not forget our long-standing collaboration with NASA, where the CBE continues to explore biofilm in space. All of this makes me extremely proud of my CBE colleagues, optimistic about the future, and excited for the opportunity to serve as the CBE Industrial Coordinator. My virtual door is open, don't hesitate to reach out.

–Darla Goeres, CBE Industrial Coordinator
darla_g@montana.edu

IN MEMORIAM - PAUL STOODLEY (1960-2024)

Researcher, Colleague, Mentor, Friend

In 2024, the biofilm community lost a pioneering researcher and friend, Dr. Paul Stoodley. From his early work at the CBE to faculty roles worldwide, Paul's contributions to the study and understanding of biofilms have had broad impact in many areas, including medical and industrial applications.

INDUSTRY

MEMBERSHIP PRIVILEGES

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

One-on-One Consultation
IAs receive up to 16 hours 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 our two annual conferences.

JULY
BOZEMAN, MT
MBM MONTANA BIOFILM MEETING

ANTI-BIOFILM TECHNOLOGIES PATHWAYS TO PRODUCT DEVELOPMENT

JANUARY
WASHINGTON, DC

Current Industrial Members

Albemarle
kenvue
arxada
MASCO
ASP Advanced Sterilization Products
NASA
BAUSCH + LOMB
newell BRANDS
BD
PhaseOne
CardioQuip
P&G
CHURCH & DWIGHT CO., INC.
SANUWAVE
DeLaval
SHERWIN-WILLIAMS
Diversey A SOLENIS COMPANY
Solmetex
HAI Solutions™
solventum
HYDRITE
STERILEX Innovative Solutions for Microbial Control
icumedical
STERIS
IWC INNOVATIONS
Vantive
Johnson&Johnson
ZIMMER BIOMET

CBE researchers secure $2.5 million to

Combat microscopic threats to military vehicles

Excerpt adapted from *MSU News Service*

When the U.S. military deploys their tactical vehicles, microbes can grow on surfaces inside and out, potentially compromising crucial specialized paints and other protective coatings. These microbes can cluster into communities called biofilms, and combatting them requires identifying which microbes, exactly, comprise them.

To identify these microbes and develop better testing methods, a team of researchers from the Center for Biofilm Engineering was awarded a $2.5 million grant and a three-year contract with the U.S. Department of Defense Strategic Environmental Research and Development program.

"The Department of Defense's tactical vehicles utilize special paints to prevent rust and corrosion, as well as some coatings that are resistant to chemical agents like nerve gas," explained Brent Peyton, the lead PI on the grant. "We're trying to characterize the organisms found on these vehicles, which will help to develop better coating-testing procedures so that coatings can be tested more rapidly and more accurately."

> In the future, the academia-military-industry partnership may also lead to utility beyond the Department of Defense.
>
> – Brent Peyton

The team, including CBE director Matthew Fields, Darla Goeres, Chris Jones, Heidi Smith, and postdoctoral researchers Kylie Bodle and Ghazal Vahidi, among others, will work with the Naval Surface Warfare Center, Carderock Division to coordinate sampling procured at fleet locations.

According to Peyton, identifying the microbes that comprise biofilms found on military land, amphibious and air vehicles is necessary before the films can be fully eradicated or neutralized. But existing test methods lack reliable data because samples are submerged during the process—unlike military vehicles in many real-life situations, particularly in tropical and subtropical environments where hot and humid conditions prove fertile territories for microbial growth.

"We're trying to make the laboratory test methods more realistic," Peyton said. "We'll be growing organisms from real military vehicles in the field, some coated and some uncoated with the military paints, in specially designed bioreactors that control the humidity and the temperature in a way that is more representative of actual use."

Researchers, Kylie Bodle, left, and Ghazal Vahidi, work with a biofilm reactor used to replicate real-world conditions. Kelly Gorham

In addition to the novel 'industrial surface biofilm reactors,' the team will also use new biofilm characterization techniques for identifying dangerous organisms.

"Most of the work that's been done before has been using very traditional microbiological techniques," Peyton said. "We're upping that game with DNA sequencing, laser microscopes and other state-of-the-art techniques."

To develop better specialized coating test methods, Peyton's team is also collaborating with paint and coatings company Sherwin-Williams, industrial associate of CBE.

"Better test methods would allow Sherwin-Williams to develop and test new coatings more quickly and get them onto military vehicles that could reduce or prevent this problem," Peyton said.

In the future, the academia-military-industry partnership may also lead to utility beyond the Department of Defense.

"I believe the new test methods and coatings that result from this study would apply to a variety of environmental paints," Peyton said. "We'll publish our testing procedures so the coatings industry can use these reactors and do a better job at their testing as well." ■

Global leader in biofilm research for 35 years

By Skip Anderson, *MSU News Service*

Biofilms, which are groupings of microbes encased inside self-produced slime, have likely existed since shortly after the dawn of life on Earth. In fact, some researchers theorize that these early communal conglomerations may have put the ooze in "primordial ooze" some 3.5 billion years ago.

The world's first and largest research center dedicated to biofilms is turning 35 this year. Housed in Montana State University's Norm Asbjornson College of Engineering and originally called the Institute for Chemical and Biological Process Analysis, it is today known as the Center for Biofilm Engineering.

"A lot of the biomass on the planet is, in fact, in a biofilm form," said Matthew Fields, the CBE's director and a professor of microbiology and cell biology in MSU's College of Agriculture. "It's certainly a very common form of lifestyle for microbes."

Examples of biofilms include plaque on teeth, the muck that sometimes grows inside plumbing fixtures and the slippery coating commonly found on rocks in streams, rivers and lakes. More worrisome examples of biofilms are those that take root in a chronic wound, such as a diabetic foot ulcer, or those that form on implanted medical devices or urinary catheters. Biofilms are also what make the lung disease cystic fibrosis so problematic to treat effectively.

The research done at the CBE over the past 35 years has been dedicated to figuring out solutions to those challenges. An interdisciplinary facility from the start, CBE was founded in 1990 with a $7.5 million grant from the National Science Foundation. Over the ensuing decades, more than a dozen other such centers sprouted up around the nation and world. When the CBE was founded, around 70 research papers had been published on biofilm. Today, that number is almost 10,000.

Of all the biofilm papers published, one stands out: "Bacterial Biofilms: A Common Cause of Persistent Infections," by MSU researcher Phil Stewart. Written in 1999, it is the world's most cited publication on biofilm, being referred to in other science publications nearly 11,000 times. Stewart formerly served as the CBE's director and is a Regents Professor of chemical and biological engineering at MSU.

> Interdisciplinary from the start, CBE researchers come from fields beyond biology and engineering, adding valuable perspective while solving complex problems.

"That paper helped to get the field to rethink what it meant to be a microbial biofilm, which is why it can be considered groundbreaking," Fields said.

Microbes are the oldest, and arguably the most evolved, lifeforms on the planet, he explained.

"We came to this realization that these single-celled organisms are not only growing this film that we can see with the naked eye but they're doing complex things: They're

1980s
CBE founder/director, **Bill Characklis**, forms a 12-member **Industrial Associates program**, a precursor to the CBE's current IA program

1990
CBE FOUNDED
NSF awards $7.5M to launch the **Center for Interfacial Microbial Process Engineering**, later known as the Center for Biofilm Engineering

1991/92
Student REU program begins, funded by DOW Chemical and Conoco
CBE acquires its first Confocal Scanning Laser Microscope (CSLM)

1993/94
Bill Costerton named Center's second director
Center renamed **Center for Biofilm Engineering**
MSU partners with BioSurface Technologies to create the **Annular Reactor**

1995
5 YEARS
Industrial Associates program grows to **24 members**
CBE hosts **bioremediation workshop** for the EPA
CBE develops the **Rotating Disk Reactor**, a predecessor of the CDC Reactor

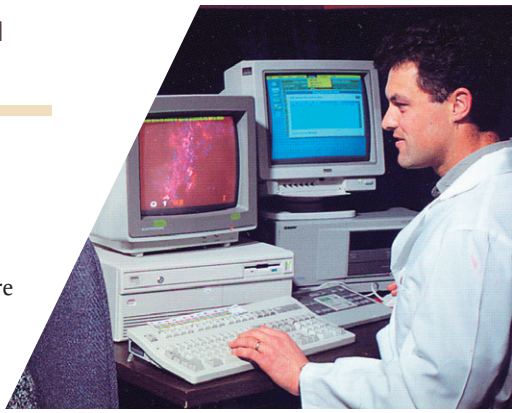
1996
The concept of biofilm is becoming more mainstream as *Science* features CBE in article titled "Biofilms Invade Microbiology"

1997
CBE develops the **Drip Flow Reactor**

1998
CBE shows quorum sensing **signals in biofilm effect chronic diseases** such as cystic fibrosis, prostatitis, and chronic wounds

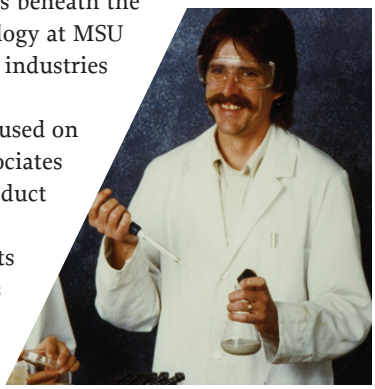
KEY AREAS OF RESEARCH

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



compartmentalizing; they're forming gradients across a film that can be observed; and they're communicating with one another," Fields said. "These are attributes we typically assign to higher, more complex, organisms."

A core facility at MSU, the CBE's Bioimaging and Analytical Core Labs are among the most powerful microscopy labs in the world specifically geared to examine what's beneath the surface of biofilms and the microbes that inhabit them. Having this technology at MSU benefits students and faculty, as well as one of the center's key constituencies, industries affected by biofilm.



According to Fields, working with industry keeps the center's efforts focused on real-world problems. The center conducts testing through its Industrial Associates program, whose members include organizations such as consumer product companies and manufacturers of medical implants.

Some members ask the CBE to test the efficiency of antibiofilm products that are being developed. Others have sought solutions to biofilm challenges through government grants. NASA, for example, is seeking a solution to biofilms that grow in the water lines aboard the International Space Station.

"I think appreciation for biofilms has grown over the past 35 years and so have the technologies and methods to study microbes as a biofilm," Fields said. "It's exciting to be a part of that change."

Since its inception, the CBE has worked with 1,013 undergraduate researchers, 192 master's students and 135 doctoral candidates. Many of them come from fields beyond biology and engineering, which adds valuable perspective, according to Fields.

"Any time you want to embrace the complexity of a system, you're going to have to come at it from different angles," Fields said. "We do that in this academic environment, where we train students from all these different fields and bring them together in this applied context, all while making sure we interact with industry and perform relevant research. The university-industry partnership is a cornerstone to the CBE's continued success." ■

1999
CBE researchers publish in *Science* detailing biofilm mechanics—matrix-enclosed cell clusters with nutrient flow channels, and chemical signals

2000
10 YEARS
CBE dives into new research emphasis: **Standardized Biofilm Methods**

2001
Lancet publishes the influential paper "Antibiotic resistance of bacteria in biofilms," authored by Phil Stewart and Bill Costerton, which has since been **cited nearly 4,000 times**

2002
ASTM approves the **Rotating Disk Reactor Method** developed at the CBE

2003
CBE opens a Microscope Resource Room, with a new confocal microscope, flow cytometer, and facilities for image analysis

2004
CBE establishes its **Medical Biofilm Laboratory**

2005/06
15 YEARS
Phil Stewart named Center's third director

CBE researchers publish applied research on the use of bioelectric signals to eliminate environmental biofilms

2007
Fundamentals of Biofilm Research textbook is published, establishing CBE as a leader in biofilm foundations

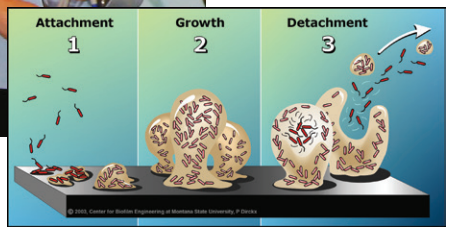
HISTORY

CBE Women of Impact

Women have played an essential role in the success of the Center for Biofilm Engineering since its founding. From the outset, CBE has prioritized the recruitment and mentorship of women engineers and scientists, recognizing that a balanced and inclusive environment strengthens research through broader perspectives. Together, their achievements highlight the lasting impact of women's leadership, innovation, and mentorship within CBE.

ANN CAMPER
Researcher
1975-2019

Anne Camper, an international authority on water and biofilms, was awarded the first doctorate degree in MSU's civil engineering program (male or female). During her career, she secured more than $10 million in research funding, authored 77 publications, co-invented an international patent, mentored dozens of graduate students, and served MSU for over 40 years as a scholar, leader, and advocate for public health and equity. Anne was the first woman named as a Montana University System Regents Professor, the system's highest faculty honor.



PEG DIRCKX
Visual Communications
1990-2015

From the beginning, the CBE held a core belief that communication is an integral part of education and research. Peg Dirckx worked alongside CBE researchers to illustrate their discoveries and communicate complex concepts to other researchers and funding agencies. Peg's biofilm illustrations, including "Biofilm Formation in 3 Steps," have been some of the most downloaded and adapted figures by biofilm researchers.

2008/09
ASTM approves the **Drip Flow Reactor Method**

2010
20 YEARS
CBE receives $1M grant to upgrade microscopes

Researchers implicate biofilm in chronic wounds and diabetic ulcers

2011
CBE Industrial Associates program grows to **33 members**

2012
ASTM approves a standard test method, **the single tube method**, for evaluating the efficacy of disinfectants against biofilms

2013
CBE publishes in *Water Research* showing the effects of biofouling on a water filtration system

2014
CBE cosponsors the FDA's first public biofilm workshop

2015
25 YEARS
1,000 peer-reviewed papers published

730+ undergraduates

235+ graduate students

Funded interaction with more than 100 companies

2016
Matthew Fields named the CBE's fourth director

CBE Bioprocessing Lab advances a **fracture-sealing method for oil and gas wells** using biofilm-forming bacteria and MICP

2017
International panel, including CBE expert Garth James, revises chronic **wound guidelines** to recommend earlier and more aggressive treatments

BETSEY PITTS
Microscopy Facilities Manager
1993-2018

Betsey Pitts managed the CBE microscopy lab for nearly 25 years, establishing its reputation as a world-class facility. While at the CBE she trained hundreds of students and researchers on the instruments, with biofilm-specific techniques. She assisted in proposal writing, methods development, and trouble-shooting. Her influence extended throughout the CBE, where she was well known and respected by all.

CHRISTINE FOREMAN
Distinguished Professor
2003-present

Christine Foreman is a leading polar microbiologist whose research has transformed understanding of life in Earth's most extreme environments. With 11 Antarctic field seasons and landmark publications in *Science*, her work revealed how airborne microbes seed snow, survive extreme cold, and influence global carbon cycles and climate science. An MSU professor, associate dean, and director of Women in Engineering, Foreman is also a nationally recognized mentor, advancing student success and scientific leadership.

DARLA GOERES
Industrial Coordinator
1997-present

Darla Goeres has more than 25 years of experience researching biofilm bacteria in industrial systems and the built environment. Under her direction, CBE's Standardized Biofilm Methods Laboratory advanced the development and validation of six quantitative biofilm methods. A recognized leader in biofilm standardization, she helped develop the first ASTM-approved standard method for biofilm bacteria. As Industrial Coordinator, she now connects industry, academia, and regulators to advance biofilm science and technology.

HEIDI SMITH
Bioimaging Core Facility Manager
2018-present

Heidi Smith is part of the next generation of female leaders at the CBE. When she assumed management of the bioimaging facility, she had an ambitious vision to expand its capabilities to reshape biofilm research. She has since secured millions of dollars in grants and upgraded the majority of the equipment with advanced, customized microscopes. Heidi continues to train students and researchers on equipment, and has a wide range of influence in the field.

2018
EPA adopts standard test method developed at CBE for biocide efficacy

2019
Biofilm "Bash" brings together researchers from around the world for collaboration

NASA seeks CBE's expertise to tackle **biofilms in space**

2020
30 YEARS

CBE researchers develop **testing for COVID-19**, including a saliva-based detection test

CBE and allies launch the Int'l Biofilm Standards Task Group

2021
ASTM approves **Intraluminal Catheter Test Method**

CBE shares $3M for REU program to study **extremophiles** in Yellowstone NP

2022
$1M upgrade makes **CBE's bioimaging facility** the most specialized in the PNW for studying biofilms

Researchers awarded $6.4M in grants to advance **algal biofuel research**

2023/24
CBE hosts workshop uniting the emerging field of **Engineered Living Materials (ELMs)**

The *Economist* features CBE in a story about the deadly impacts of biofilm

2025
35 YEARS

1,500 peer-reviewed publications

1,700 students and visitors trained

Funded interactions with over 150 companies

Collaboration among the DoD, industry, and CBE exemplifies government–industry–research partnerships

A new era at CBE:

Engineered Living Materials

Excerpt adapted from *MSU News Service*

In addition to marking 35 years of biofilm research, CBE is celebrating two years of its NSF partnership to explore Engineered Living Materials (ELM)—an emerging field that could transform everyday infrastructure. To remain at the forefront of understanding ELM's benefits and challenges, the center's team is advancing a range of state-of-the-art research initiatives.

The CBE–NSF partnership, officially titled "Future Manufacturing," began in 2023 as a four-year, $3 million Future Manufacturing Research grant focused on sustainability, durability, and performance of ELM. By integrating microbial organisms into construction materials such as bricks, these "living building materials" can self-repair, filter air, and purify rainwater runoff—capabilities that could reduce carbon emissions while offering cost-effective alternatives for construction and related industries.

"We think there's immense potential to functionalize our infrastructure materials so they can clean air and water and contribute other positive benefits," project co-PI Robin Gerlach said at the 2023 Montana Biofilm Meeting. The collaborative effort includes PI Chelsea Heveran, co-PIs Matthew Fields, Recep Avci, Adrienne Phillips, and Erika Espinosa-Ortiz, along with partners across academia, industry, and government.

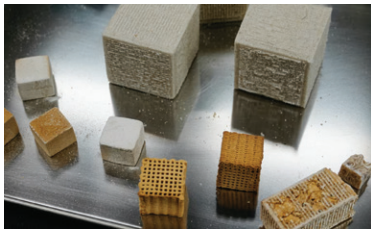
Heveran's research explores how ELM can conserve energy, reduce environmental costs, and expand access to building materials in disaster relief and resource-limited settings. Her team first demonstrated microbes as the primary catalyst in a durable building material in the 2020 *Matter* paper "Biomineralization and successive regeneration of engineered living building materials." The researchers showed that *Synechococcus* cyanobacteria can survive within sandy brick materials for more than a month under controlled temperature and humidity, creating replicable bricks that reduce the need to mine, process, and transport traditional binders. Although weaker than concrete—closer in strength to cement mortar—the living bricks demonstrated promise as recyclable, cost-effective alternatives for certain infrastructure applications. "It's likely that many materials around us that are now inert will eventually include living components that perform useful functions," Heveran noted.

> We think there's immense potential to functionalize our infrastructure materials so they can clean air and water and contribute other positive benefits.
>
> -- Robin Gerlach

The grant also supports Eco-Start, an eco-manufacturing research and training program that provides hands-on laboratory and industry experience for students. "The Eco-Start workforce development program is up and running, and our second cohort of undergraduate researchers completed their first summer of research," Gerlach reported in August 2025. Several first-cohort participants secured internships with industrial partners, helping build a workforce prepared to engage with emerging bio-based manufacturing technologies.

Alongside foundational research, the team is exploring new frontiers, including ELM feasibility in extreme environments and biomaterial sensitivity to mechanical stimuli inspired by living bone. Researchers are also combining advanced approaches such as 3D printing of microbes to improve structural integrity and to engineer self-healing and responsive properties into materials. Both Heveran and Gerlach have received NSF Emerging Frontiers in Research and Innovation awards to support continued progress in these areas.

While advancing technical innovation, the project also addresses the social dimensions of ELM adoption. Collaborators from MSU's History & Philosophy, Psychology, and Arts departments are examining public



Biomineralized mycelium scaffold (lower right) compared with other materials built from hydrogels and cellulose. Maren Stubenvoll

FEATURED ON CNN

CBE researchers are highlighted for their work using fungi and bacteria to create engineered living materials that could one day be used to build sustainable, self-repairing homes.

READ THE ARTICLE HERE

perception, communication strategies, and ethical considerations. A multidisciplinary workshop held during the 2023 Montana Biofilm Meeting identified social, legal, regulatory, and collaboration challenges that could influence ELM adoption. These findings informed the 2024 *Matter* article "Unlocking the societal potential of engineered living materials," which emphasized the importance of proactive engagement to maximize benefits while minimizing risks and public concern.

This cross-disciplinary effort is supported by an MSU Research Collaborative Grant. Project lead Kristen Intemann, professor of ethics, philosophy of science, and science communication, emphasizes that unfamiliarity with ELM remains a central barrier. "Most people are unfamiliar with ELMs, or even biofilms, making it difficult for them to form opinions about the technology," she explained.

To address this challenge, the team partnered with artist Sara Mast and graduate student Kevin Tracy to develop visual materials for study participants, while psychologist Brandon Scott evaluates public reactions through interviews and behavioral research. Understanding concerns—including the so-called "yuck factor," or instinctive discomfort with living materials—helps guide design, application development, and public outreach strategies. Findings on this topic were published in Global Challenges in 2025, and the team continues to study how perception shapes adoption of emerging technologies.

As research initiatives expand, the team continues to convene events that foster dialogue around ELM. They co-hosted a second interdisciplinary workshop at Rice University in October 2025 and organized an art-and-science exhibit in Bozeman in February 2026. Together, these efforts advance scientific discovery while building the collaborative, societal, and educational foundations needed to support the future of engineered living materials. ■

Novel research published on

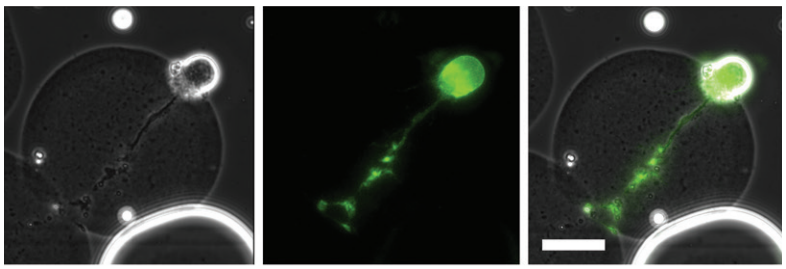
Cell response to viral infection

Excerpt adapted from *MSU News Service*

Montana State University scientists published unique research on individual cell response to viral infection. The project was the first of its kind to culture, infect, and track infection in real time on a single-cell level, and the results were published in the leading scientific journal *Science Advances*. CBE researchers were central to this novel approach, including faculty member Emma Loveday (pictured), former faculty member Connie Chang, and former PhD students Shawna Pratt and Jake Frederickson.

"It was truly a collaborative effort," said Matthew Taylor, associate professor in the Department of Microbiology and Cell Biology and co-lead on the project. "Jake figured out how to grow neurons inside gels on a micron scale. Each little bead grew a single cell." These gel beads were created using drop-based microfluidics, a faster, cheaper way to conduct experiments on a microscopic scale.

After Fredrikson streamlined the process of growing individual nerve cells inside the beads, the team introduced herpes simplex virus-1, a common virus that causes cold sores. The virus had a uniquely engineered quality, fluorescing in different colors under a microscope, which gave the team a visual trigger as infection progressed in the cells. The virus would appear yellow in infected cells and red once it started replicating.



A neuron grown in a micro gel infected with HSV-1 that expresses a yellow fluorescent protein.
Matthew Taylor

But not every cell responded the same way, which Taylor said was unexpected. Although most cells turned yellow, not all of them proceeded to then turn red—some cells were stopping the virus from replicating itself.

"We know that the cells are infected because they're yellow," said Taylor. "Now we're decoupling the process of infection from productive replication. We're kicking the roots of virology, challenging these assumptions of what people think infection means." Understanding why cells interrupted replication will guide future research, and microfluidics may enable studying brain and lung cells for treatments. ■

CBE researchers publish evidence for new groups of

Methane-producing organisms

Excerpt adapted from *MSU News Service*

Researchers at Montana State University have provided the first experimental evidence that two new groups of microbes thriving in thermal features in Yellowstone National Park produce methane. This discovery could one day contribute to developing methods to mitigate climate change and provide insight into potential life elsewhere in our solar system.

Roland Hatzenpichler, CBE affiliate faculty and associate professor of chemistry and biochemistry, published the findings in two scientific papers in *Nature* journal, one of the world's leading scientific journals, describing the first known examples of single-celled organisms other than the *Euryarchaeota* lineage to produce methane. The organisms, called methanogens, are anaerobes that ingest carbon dioxide or methanol and exhale methane to survive. For decades, scientists believed all methanogens belonged solely to the *Euryarchaeota* phylum, but about 10 years ago microbes with methanogenesis genes began to be discovered in other phyla, including *Thermoproteota*.

"All we knew about these organisms was their DNA," said Hatzenpichler. "No one knew if they actually used their methanogenesis genes or if they were growing by some other means."

Hatzenpichler and his team harvested samples from sediments in Yellowstone National Park's hot springs and then grew the microbes in their lab, where they observed methane production. Together with Lei Cheng at China's Biogas Institute of the Ministry of Agriculture and Rural Affairs and Diana Sousa at Wageningen University, Netherlands, the scientists jointly published their work in what has become the first experimental work on two newly identified groups of methanogens under *Thermoproteota: Methanodesulfokora* and *Methanomethylicia*. According to Hatzenpichler, the former seem to be confined to hot springs and deep-sea hydrothermal vents, while the latter are widespread.

These organisms are found in wastewater treatment plants, the digestive tracts of ruminant animals and in marine sediments, soils and wetlands. They produce 70% of the world's methane, a gas 28 times more potent than carbon dioxide in trapping heat in the atmosphere, according to the U.S. Environmental Protection Agency.

"Methane levels are increasing at a much higher rate than carbon dioxide, and humans are pumping methane at a higher rate into the atmosphere than ever before," said Hatzenpichler. He said that while these experiments answered an important question, more questions were generated that will fuel future work, such as whether *Methanomethylicia* that live in non-extreme environments rely on methanogenesis to grow. Knowing this property could help scientists learn how to alter conditions in different environments so that less methane is emitted into the atmosphere. ■

THE ECONOMIST NEWS MAGAZINE FEATURES THE CENTER FOR BIOFILM ENGINEERING IN A FEATURE STORY ABOUT BIOFILMS

The Sept. 27, 2023, edition of *The Economist* news magazine featured the Center for Biofilm Engineering in a feature story on biofilm research's urgency. CBE Director Dr. Matthew Fields was a key source for the story, which details how biofilms help contribute to antibiotic-resistant bacterial infections in open wounds and on medical implants by aggregating into colonies.

"Matthew Fields, a microbiologist at Montana State University, reckons that most of the bacteria living on the planet exist in colonies," states the article. It also highlights three methods being tested by companies to hinder biofilms: bacteriophages, cold plasma, and therapies that weaken biofilms' antibiotic resistance. The article goes on to emphasize the importance of more companies working together to solve the growing number of problems posed by biofilms. The CBE continues to work with researchers around the world to unlock the mysteries of biofilms and advance the frontiers of health, environment, energy and industry through biofilm research, education and outreach.

FIND THE FULL STORY HERE

Darla Goeres leads a network of people committed to promoting biofilm in EU and UK regulations

While scientists continue to push the state-of-the-art in biofilm methodology, there are a variety of underlying issues preventing these scientific advancements from being adopted for regulatory decision-making creating a large gap between fundamental science and current regulatory guidelines in relation to biofilms. COST Action CA23152 titled "Building Consensus on Biofilm Regulatory Decision Making (Regulatory ToolBox)" established a network of 175+ stakeholders from across the European Union from diverse biofilm research fields to develop guidance on what is needed in terms of agreement on the scope and ontology for academic, industrial, and regulatory decision makers to close the gap between academic research and regulatory science. Action outputs include publications, white papers, training schools and modules. COST (European Cooperation in Science and Technology) is an EU funding agency that supports the development of networks to enable researchers and innovators to grow their ideas. ■

Biofilm Regulatory Toolbox

cost

Funded by the European Union

THE PROJECT BUILDS A EUROPEAN NETWORK TO MODERNIZE BIOFILM RESEARCH FOR REGULATORY DECISION-MAKING

IT BRIDGES GAPS BETWEEN ACADEMIA, INDUSTRY, AND REGULATORS

Priority Questions: Microbial Biofilms

Identifying priority questions for biofilm research

CBE researchers and staff were part of a comprehensive study outlining a roadmap for advancing the field of biofilm research by identifying key research priorities. The product of this interdisciplinary working group was the research article, "Global Challenges and Microbial Biofilms: Identification of Priority Questions in Biofilm Research, Innovation, and Policy," published in *Biofilm Journal* in December 2024. This comprehensive study identifies key priorities for research, innovation, and policy development in the field moving forward.

> This endeavor will likely set the agenda for biofilm research for the next decade or more.
>
> -- Matthew Fields

Microbial biofilms play critical roles in health and disease and are found in a wide range of environments, from industrial settings to medical devices. Utilizing a priority question exercise for framing and setting agendas, the study bridges the gap between research and impactful advancements in policymaking and funding. It was guided by members from the National Biofilms Innovation Center (NBIC), the Center for Biofilm Engineering (CBE), the Singapore Centre for Environmental Life Sciences Engineering (SCELSE), the COST AMiCI Consortium, the ESCMID Study Group for Biofilms (ESGB) and various partners.

Using an unbiased selection process, researchers gathered responses from the international biofilm research community and practitioners across industry, environment and medicine, to 78 questions that highlight opportunities for researchers, funders, and policymakers and inform future research, innovation, and development strategies to address biofilm-driven challenges.

"The efforts of this working group will play an important role in bridging the gap between the data generated by researchers and the information needed for policymakers to make funding or regulatory decisions," said CBE director Dr. Matthew Fields. "This endeavor will likely set much of the agenda for biofilm research for the next decade or more." ■

CBE engineering professor recognized with

Prestigious NSF CAREER award

Excerpt adapted from *MSU News Service*

Chelsea Heveran, associate professor of mechanical and industrial engineering was awarded a prestigious CAREER award from the National Science Foundation (NSF) in 2024. Heveran, who works with bone tissues, received a five-year, $685,033 grant that supports her research, "Osteocyte Regulation of Bone Tissue Fracture Resistance." Osteocytes are long-lived cells within bone that coordinate the size, shape and composition of bone tissue in response to loads on the skeleton.

"Osteocytes have been known for years to coordinate the activities of other bone cells to regulate how bone is resorbed and replaced, which together influence how much bone you have," said Heveran. "However, bone mass is not the only determinant of fracture risk. The quality of the bone tissue matters too. Recently, we've learned that osteocytes can directly remove and replace bone tissue. This work is focused on determining the impacts of these direct osteocyte interactions with bone on the fracture resistance of the tissue."

Her NSF funding also supports a graduate student for the grant's duration. As part of Heveran's award, she is also implementing a new program to engage non-traditional undergraduates—students ages 25 and over—in focused engineering research projects.

"The NSF CAREER award is among the most prestigious recognitions for junior faculty members who exemplify teacher and scholar roles through outstanding research and education and integrating scholarship activities for broader impact," said Dilpreet Bajwa, head of MSU's Department of Mechanical and Industrial Engineering.

The knowledge gained from these CAREER studies could lay the foundation for new therapeutic strategies that target the improvement of bone-tissue quality through modulating the activities of the osteocyte, according to Heveran. This could possibly lead to drugs to improve the fracture resistance of bone tissue by acting on the osteocyte. Current drugs for bone fragility target bone mass, not the fracture resistance of the tissue itself.

NSF CAREER AWARD

THIS AWARD IS AMONG THE MOST PRESTIGIOUS RECOGNITIONS FOR JUNIOR FACULTY MEMBERS WHO EXEMPLIFY RESEARCH AND EDUCATIONAL ROLES

"Improving knowledge about the metabolic needs and processes used by osteocytes can deliver new drug targets," Heveran said. She hopes that these studies will improve diagnostics and therapies for people at risk of bone fracture, as "more than half of women and more than one-third of men over 50 will experience a major fracture." ■

NEW AFFILIATED FACULTY

JAMES CRAWFORD
Assistant Professor
Chemical & Biological Engineering

Crawford's research focuses on catalytic conversion of gaseous molecules into fuels, chemicals, and building materials. His team develops synthetic materials mimicking urease to function under high temperatures and pressures, advancing sustainable energy generation and economically viable energy solutions.

EMMA LOVEDAY
Assistant Professor
Microbiology & Cell Biology

Loveday's lab investigates influenza A virus (IAV) evolution, transmission, and virulence. By developing novel tissue culture systems, her team aims to better understand IAV and other zoonotic pathogens while mentoring the next generation of infectious disease researchers.

LAURA JENNINGS
Assistant Professor
Microbiology & Cell Biology

Jennings studies bacterial pathogenesis, exploring how biofilm polysaccharides and epigenetics drive infection, antibiotic resistance, and vaccine escape. Her lab develops strategies to counter microbial heterogeneity and resilience by uncovering mechanisms underlying bacterial adaptation and persistence.

PAT SECOR
Associate Professor
Microbiology & Cell Biology

Secor's lab works with clinicians and industry partners to help connect bacteriophage science to translatable outcomes such as vaccines, diagnostics, and phage-based therapies. He aims to leverage these insights to better understand how viruses shape microbial communities in chronic disease.

CBE graduate student earns top NASA fellowship

Excerpt adapted from *MSU News Service*

As Haley Ketteler was in the throes of preparation to defend her master's thesis in electrical and computer engineering, she received the great news that she had been awarded NASA's Space Technology Graduate Research Fellowship. After a successful master's thesis defense, Ketteler, is now using the distinguished NASA award to pursue her doctorate in mechanical and industrial engineering at MSU.

The four-year fellowship, to support Ketteler's project "Electrochemical impedance sensors for microbial monitoring in spacecraft wastewater systems," has a maximum value of $84,000 per year that includes a stipend, health insurance, tuition and fees, and other support.

> It has been my dream to work for NASA since I was a little girl, and this is a wonderful step toward that dream.
>
> -- Haley Ketteler

"It has been my dream to work for NASA since I was a little girl, and this is a wonderful step toward that dream," said Ketteler. "It is also extremely encouraging to have my research interests and questions supported by established space tech developers who have a clear vision of what is needed in future space technology."

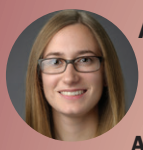
Ketteler's research interests include designing and building sensors to detect biofilms in spacecraft water-reclamation systems, such as on the International Space Station. These systems recycle and sanitize wastewater produced by astronauts and other sources but are fertile ecosystems for biofilm formation.

"In many future spacecraft, part of the operating procedure will be to place life-support systems into dormancy when astronauts are not on board, so we need a way to autonomously monitor the amount of biofilm in these systems to avoid system failure when emerging from dormancy," said Ketteler. "That's where the sensors I work on will come in."

As part of her fellowship, Ketteler will travel to NASA's Marshall Space Flight Center in Huntsville, Alabama, to test biofilm sensors in the model systems available at the facility. ■

CBE Awards

CBE AWARDS



ADRIENNE ARNOLD
John Neuman Student Citizen Award
presented in honor of John Neuman, CBE Technical Operations Manager, for exhibiting a commitment to lab safety.

CHIACHI HWANG
Outstanding Researcher Award
recognizes a CBE researcher for their research quality, teamwork, and willingness to mentor others. It also recognizes their contributions to CBE outreach through CBE semi-annual biofilm meetings and workshops.

BRENT PEYTON
CBE Outstanding Faculty Award
recognizes a faculty member for their outstanding contribution to Center goals—interdisciplinary research, education, and industrial interaction.

KATHRYN ZIMLICH
W.G. Characklis Award
presented to a CBE doctoral student for their contributions to research and education. The award honors CBE founder Bill Characklis, who envisioned students working in interdisciplinary teams, participating in innovative educational programs, interacting with industry, and assuming leadership roles.

ASTM AWARD

DARLA GOERES
ASTM Merit Award
is the highest society award granted to an individual member for distinguished service and outstanding participation in ASTM International committee activities. Recipients also receive the honorary title of Fellow.

NACOE AWARDS

ROSS CARLSON
Distinguished Professor Award
honors the accomplishments of outstanding faculty members in the College of Engineering.

KRISTEN CONNOLLY
Award for Excellence, Professional Staff
recognizes staff in the College of Engineering who significantly exceed job expectations through outstanding performance, initiative, innovation, and service.

CHELSEA HEVERAN
Excellence in Research, TT Faculty
celebrates significant contributions, innovation, and alignment with the university's goals—grant success, publication records, and real-world impact in engineering.

DANA SKORUPA
Excellence in Advising, Professional Staff
recognizes outstanding dedication to student success, focusing on strong interpersonal skills, caring attitudes, helping with academic/career planning, providing support, and demonstrating leadership in advising.

STEPHAN WARNAT
Lloyd Berg Distinguished Mentor Award
recognizes faculty for deep commitment to student development, focusing on integrating teaching, research, and outreach.

35 years

fy25 CBE BY THE NUMBERS

1,340 total students trained since 1990
1,013 undergraduates
327 graduate students

EDUCATION fy25

48 affiliated faculty ↑26% increase

149 students trained
73 undergrads
76 grad students

16 disciplines

IMAGES

4,000 images downloaded since 2011 inception

CENTER FOR BIOFILM
CBE
ENGINEERING

INDUSTRY fy25

46 testing projects

28 sponsors

1,500 total testing projects for **300** companies

RESEARCH fy25

↑67% increase from previous year

$10M new research grants

46 papers **40** journals

118,000+ CBE citations have far exceeded any other biofilm research center since 1990

1,331 publications since 1990