2020 APPENDIX

Center for Biofilm Engineering

Montana State University
Bozeman

Reporting Period:
June 1, 2019–May 31, 2020

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RESEARCH

EDUCATION

TECHNOLOGY TRANSFER

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RESEARCH:

CBE RESEARCH AREAS

Research at the Center for Biofilm Engineering is driven by industrial, environmental, and health issues of national importance. CBE research has contributed new insights into microbial processes in a wide variety of contexts.

CBE RESEARCH:

- is motivated by industrial concerns and involvement of industry partners;
- is conducted at multiple scales of observation, from molecular to field-scale;
- involves interdisciplinary investigations;
- provides relevant research opportunities for undergraduate and graduate students;
- is enhanced by productive collaborations with researchers at other institutions;
- is funded by competitive grants and industrial memberships; and
- produces both fundamental and applied results.

The CBE's long history of research success results from **adaptability** to new information and analytical technologies, and **flexibility** in addressing biofilm issues in comprehensive ways, using its deep bench of **MSU researchers with diverse specialties** in biofilm studies.

APPLIED RESEARCH AREAS & PROJECTS

Biofilm control strategies antimicrobial efficacy | biocides | bioelectric effect | disinfectants | inhibitory coatings | bioactive compounds

Energy solutions biofuels | product souring | coal bed methane production | microbial fuel cells

Environmental technologies bioremediation | wetlands | CO_2 sequestration | biobarriers | biomineralization | microbes & mining issues

Health/medical biofilms chronic wound healing | catheter infections | oral health | food safety

Industrial systems & processes biofouling | biocorrosion | product contamination | microbe-metal interactions

Standardized methods product claims | regulatory issues | ASTM methods acceptance

Water systems drinking water quality | premise plumbing | water treatment | distribution systems

FUNDAMENTAL TOPICS

Biofilms in nature microbes in hot & cold environments | role of biofilms in natural processes | biomimetics | biogeochemistry

Cellular/intracellular phenotype | genetics | metabolic pathways | proteomics

Multicellular/extracellular flow and transport in biofilm systems | material properties | quorum sensing | structure-function | heterogeneities | matrix

Ecology/physiology population characterization | spatial and temporal population dynamics | anaerobic systems

ANALYTICAL TOOLS & TECHNIQUES

Instrumentation microscopy | nuclear magnetic resonance imaging | gas chromatography | microfluidics

Methods development experimental design | variability | ruggedness | repeatability | statistical evaluation

Modeling cellular automata modeling | mathematics | hydrodynamics | cohesive strength

Basic microbiology techniques total and direct counts | MIC determination | viable cell counts

Molecular biology techniques DNA extraction | PCR | DGGE | microarrays | sequencing

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RESEARCH:

2019–2020 CBE GRANT-FUNDED RESEARCH ACTIVITY

Current CBE Research Grants for Fiscal Year 2020 (July 1, 2019 to June 30, 2020)			
Research Area	**Title**	**Principal Investigator**	**Funding Agency**
Biofilm Mechanics	Exploring Biofilm Material Properties with Micromechanical Tools	Wilking	NSF
Biofilm Mechanics	Collaborative Research: Modeling Gastric Mucus Layer Physiology with Application to Helicobacter Pylori and Gastric Organoids	Wilking	UTAUNI
Biofilm Mechanics	3D-Printing of Microbial Communities for Optimal Resource Processing	Wilking	ARREOF
Biofilm Mechanics	VIPER: Viral Interdiction through Population Engineering and Restructuring	Chang	NCSU
Biofilm Mechanics	CAREER: Understanding Spatial Heterogeneity in Biofilms Using Colloidal Engineering	Chang	NSF
Biofilms in Nature	SLICE: Spectral Signs of Life in Ice	Foreman	NASA
Biofilms in Nature	Eradication of Microbial Contamination in Metal Working Fluids	Foreman	NSF
Biofilms in Nature	Continued Monitoring of the Bridger Bowl Wetland System	Stein	Bridger Bowl
Energy Solutions	Lipid derived biofuels: Bicarbonate induced triacylglycerol accumulation in microalgae	Peyton	Church & Dwight
Energy Solutions	Screening for biofilm production in ISS microorganisms using CDC bioreactor	Peyton	Jet Propulsion Lab
Environmental Substance Technologies	Building Genome-to-Phenome Infrastructure for Regulating Methane in Deep & Extreme Environments	Gerlach	South Dakota School of Mines
Environmental Substance Technologies	Application of Biofilm Covered Carbon Particles as a Microbial Inoculum Delivery System in Weathered PCB Contaminated Sediment*	Stewart	University of Maryland
Environmental Substance Technologies	Developing Biomineralization Technology for Ensuring Wellbore Integrity	Gerlach	Montana Emergent Technologies Inc
Environmental Substance Technologies	Bio-cement Coating of Waste Ores and Tailings	Lauchnor	Pegasus Technical Services
Environmental Substance Technologies	Exploring the use of biomineralized mixed plastic waste materials as admixtures into concrete: technical and market feasibility analysis	Phillips	Hawthorn Foundation

Environmental Substance Technologies	A comprehensive strategy for stable, high productivity cultivation of microalgae with controllable biomass composition	Gerlach	University of Toledo
Medical Biofilms	Synergy between omics, symptoms, and healing trajectories of venous ulcers	Stewart	University of Florida
Medical Biofilms	Development of a predictive moderate throughput assay to screen novel Designer Proline-rich antimicrobial peptide Chaperone protein inhibitors (DPCs) against multi-drug resistant pathogens	James	Arrevus Inc
Methods Development	Methods to assess biofilm prevention on medical devices	Goeres	Burroughs Wellcome Fund
Methods Development	Antimicrobial Test Method - Statistical Support & Consultation	Goeres	EPA
Methods Development	Biofilm and Biomineralization Methods Development in Support of CRC 1313 Projects C04 and C05	Cunningham	Deutsche Forschungsgemeinschaft
Modeling	Development of Robust Microbial Communities through Engineered Biofilms	Carlson	ARREOF
Modeling	A Robust Biofilm-Biomat Reactor for Conversion of Mission-Relevant Feedstocks to Products	Carlson	Sustainable Bioproducts
Modeling	A Robust Biofilm-Biomat Reactor for Conversion of Mission-Relevant Feedstocks to Products	Carlson	Sustainable Bioproducts
Physiology & Ecology	Environmental Networks Integrated with Genomes and Molecular Assemblies	Fields	Lawrence Berkley National Laboratory
Physiology & Ecology	RII Track-2 FEC: Data Driven Material Discovery Center for Bioengineering Innovation	Fields	South Dakota School of Mines
Water Systems	Strengthening Little Big Horn College Research Capacity through Improving Rural Families' Access to Safe Drinking Water, Crow Reservation, Montana	Eggers	Little Bighorn College
Water Systems	Characterizing health risks from arsenic soil and groundwater contamination on the Crow Reservation, Southcentral Montana	Lauchnor	NIH
Water Systems	104B State Water Resources Research Institute Program	Kirkland	US Geological Survey

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FY20 New CBE Research Grants (July 1, 2019 to June 30, 2020)

New CBE Research Grants Awarded in Fiscal Year 2020 (July 1, 2019 to June 30, 2020)				
Sponsor	**Title**	**PI**	**Period**	**Award Amount**
EPA	Antimicrobial Test Method - Statistical Support & Consultation*	Darla Goeres	6 months	$14,912
Jet Propulsion Lab	Screening for biofilm production in ISS microorganisms using CDC bioreactor	Brent Peyton	1 Yr	$60,000
NIH	Characterizing health risks from arsenic soil and groundwater contamination on the Crow Reservation, Southcentral Montana	Ellen Lauchnor	1 Yr	$94,361
South Dakota School of Mines	RII Track-2 FEC: Data Driven Material Discovery Center for Bioengineering Innovation	Matthew Fields	1 Yr	$1,400,000
Hawthorn Foundation	Exploring the use of biomineralized mixed plastic waste materials as admixtures into concrete: technical and market feasibility analysis	Adie Phillips	6 months	$57,405
Sustainable Bioproducts	A Robust Biofilm-Biomat Reactor for Conversion of Mission-Relevant Feedstocks to Products	Ross Carlson	2 Yr	$225,000
USGS	104B State Water Resources Research Institute Program	Catherine Kirkland	1 Yr	$15,000
	Total New Grant Awards to CBE in Fiscal Year 2020			**$1,866,678**

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RESEARCH:
PUBLICATIONS
June 2019–May 2020

2019 Publications

NOTE:
2019-001 through 2019-026 are listed in 2019 Appendix

Boyce JM, Laughman JA, Ader MH, Wagner PT, **Parker AE**, **Arbogast JW±**, "Impact of an automated hand hygiene monitoring system and additional promotional activities on hand hygiene performance rates and healthcare-associated infections," *Infect Control Hosp Epidemiol.*, 2019 July, 40(7): 741-747. 2019-026

Patel A, **Carlson Ross P**, Henson MA, "In silico metabolic design of two-strain biofilm systems predicts enhanced biomass production and biochemical synthesis," *Biotechnol J.*, July 2019, 14(7):1-2. 2019-027

Christensen GA, Gionfriddo CA, King AJ, Moberly JG, Miller CL, Somenahally AC, Callister SJ, Brewer H, Podar M, Brown SD, Palumbo AV, Brandt CC, Wymore AM, Brooks SC, **Hwang C**, **Fields MW**, Wall JD, Gilmour CC, Elias DA, "Determining the reliability of measuring mercury cycling gene abundance with correlations with mercury and methylmercury concentrations," *Environ Sci Technol.*, July 2019, 53(15):8649-8663. 2019-028

Simkins JW, **Stewart PS**, **Codd SL**, **Seymour JD**, "Non-invasive imaging of oxygen concentration in a complex in vitro biofilm infection model using ^{19}F MRI: Persistence of an oxygen sink despite prolonged antibiotic therapy," *Magn Reason Med.,* August 2019; 82: 2248–2256. 2019-029

Krantz GP, Lucas K, L.-Wunderlich E, Hoang LT, Avci R, Siuzdak G, **Fields MW**, "Bulk phase resource ratio alters carbon steel corrosion rates and endogenously produced extracellular electron transfer mediators in a sulfate-reducing biofilm," *Biofouling*, 2019, 35(6):669-683. 2019-030

Zelaya AJ, **Parker AE**, Bailey KL, Zhang P, Nostrand JV, Ning D, Elias DA, Zhou J, Hazen TC, Arkin AP, **Fields MW**, "High spatiotemporal variability of bacterial diversity over short time scales with unique hydrochemical associations within a shallow aquifer," *Water Res.*, November 2019, 164:114917. 2019-031

Davis KJ, **Platt GA**, **Barnhart EP**, **Hiebert R**, Hyatt R, **Fields MW**, **Gerlach R**, "Biogenic coal-to-methane conversion can be enhanced with small additions of algal amendment in field-relevant upflow column reactors," *Fuel*, November 2019, 256:115905. 2019-032

Skorupa DJ, **Akyel A**, **Fields MW**, **Gerlach R**, "Facultative and anaerobic consortia of haloalkaliphilic ureolytic micro-organisms capable of precipitating calcium carbonate," *J Appl Microbiol.*, October 2019, 127:1479-1489. 2019-033

Goeres DM, **Walker DK**, **Buckingham-Meyer K**, **Lorenz L**, **Summers J**, Fritz B, Goveia D, **Dickerman G^**, Schultz K, **Parker AE**, "Development, standardization, and validation of a biofilm efficacy test: The single tube method," 2019, *J Micro Meth*., 165: 10564. 2019-034

Sidar B, Jenkins BR, Huang S, Spence JR, Walk ST, **Wilking JN**, "Long-term flow through human intestinal organoids with the gut organoid flow chip (GOFlowChip)," 2019, *Lab Chip*, 19: 3552-3562. 2019-035

Dieser M, **Smith HJ**, Ramaraj T, **Foreman CM**, "*Janthinobacterium* CG23_2: Comparative genome analysis reveals enhanced environmental sensing and transcriptional regulation for adaptation to life in an Antarctic Supraglacial stream," *Microorganisms*, 2019, 7(454):1-18. 2019-036

Lawson CE, Harcombe WR, **Hatzenpichler R**, Lindemann SR, Loffler FE, O'Malley MA, Martin HG, Pfleger BF, Raskin L, Venturelli OS, Weissbrodt DG, Noguera DR, McMahon KD, "Common principles and best practices for engineering microbiomes," *Nat. Rev. Microbiol.*, 2019, 17:725-741. 2019-037

Pratt SL, **Zath GK, Tatsuya A, Williamson KS, Franklin MJ, Chang CB**, "DropSOAC: Stabilizing microfluidic drops for time-lapse quantification of single-cell bacterial physiology," *Front Microbiol.*, 2019, 10:2112.2019-038

Martinello RA, Arbogast JW, Guercia K, **Parker AE**, Boyce JM, "Nursing preference for alcohol-based hand rub volume," *Infect Control Hosp Epidemiol.*, November 2019, 40(11):1248-1252. 2019-039

Godoy-Santos F*, Pitts B, **Stewart PS**, Mantovani HC, "Nisin penetration and efficacy against *Staphylococcus aureus* biofilms under continuous-flow conditions," *Microbiology*, 2019, 165(7):761-771. 2019-040

Walsh, Danica J., Tom Livinghouse, **Darla M. Goeres**, **Madelyn Mettler^**, **Philip S. Stewart**, "Antimicrobial activity of naturally occurring phenols and derivatives against biofilm and planktonic bacteria," *Front Chem.*, October 2019; 7:653. 2019-041

Ghimire N, **Pettygrove BA**, Pallister KB, **Stangeland J^**, Stanhope S, Klapper I, Voyich JM, and **Stewart PS**, "Direct microscopic observation of human neutrophil-*Staphylococcus aureus* interaction in vitro suggests a

potential mechanism for initiation of biofilm infection on an implanted medical device," *Infect Immun.*, November 2019, 87(12): e00745-19. 2019-042.

Smith, Erin, Selena Ahmmed, MaryAnn Running Crane, **Margaret Eggers**, Mike Pierre, Kenneth Flagg, Carmen Byker Shanks, "Contribution of wild foods to diet, food security, and cultural values amidst climate change," *J Agric, Food Sys, Comm Dev*., 9(B), 191-214. 2019-043.

Stewart, Philip S., **Ben White**, **Laura Boegli**, Timothy Hamerly, Kerry S. Williamson, **Michael J. Franklin**, Brian Bothner, **Garth A. James, Steve Fisher**, Francisco G. Vital-Lopez, Anders Wallqvist, "Conceptual model of biofilm antibiotic tolerance that integrates phenomena of diffusion, metabolism, gene expression, and physiology," *J Bacteriol*., Oct 2019, 201(22): e00307-19. 2019-044.

Summers, Jennifer, **Darla M. Goeres**. 2019. Catheter-associated urinary tract infections: Development of a test method for assessing the efficacy of antimicrobial technologies/products. In Dustin L. Williams (Ed.), Targeting Biofilms in Translational Research, Device Development, and Industrial Sectors (pp. 29-53). Springer. 2019-045.

McGlennen, Matthew, **Markus Dieser**, **Christine Foreman**, **Stephan Warnat**, "Effects of *Escherichia coli* K12 biofilm on sensor thin film materials," *J Microelectromech Sys*, 2019, 1-4. 2019-046.

Neubauer, Michael, **Matthew McGlennen**, Sawyer Thomas, **Stephan Warnat**, "3D printing on glass for direct sensor integration," *Eng Res Exp*., 2019, 1(2): 3-10. 2019-047.

Kirkland, Catherine M., **Drew Norton**, **Abby Thane**, **Randy Hiebert**, Johannes Hommel, Jim Kirksey, Richard Esposito, **Alfred Cunningham**, **Robin Gerlach**, Lee Spangler, **Adrienne Phillips**, "Biomineralization and wellbore integrity: A microscopic solution to subsurface fluid migration," 14th Greenhouse Gas Control Technologies Conference, Melbourne, 2019. 2019-048.

Jay, Zackary J., **Kristopher A. Hunt**, Katherine J. Chou, Gerrit J. Schut, Pin-Ching Maness, Michael W. W. Adams, **Ross P. Carlson**, "Integrated thermodynamic analysis of electron bifurcating [FeFe]-hydrogenase to inform anaerobic metabolism and H_2 production," *Biochimica et Biophysica Acta (BBA) Bioenergetics*, 2020, 1861(1): 148087. 2019-049.

2020 Publications

Dutra de Oliveira, Rosa Virginia*, Fernanda Salloume Sampaio Bonafé, Denise Madalena Palomari Spolidorio, Cristiane Yumi Koga-Ito, Aline Leite de Farias, **Kelly R. Kirker, Garth A. James**, Fernanda Lourenção Brighenti "*Streptococcus mutans* and *Actinomyces naeslundii* interaction in dual-species biofilm," *Microorganisms* January 2020, 8(2): e194. 2020-001.

Hatzenpichler, Roland, **Viola Krukenberg**, **Rachel L. Spietz**, **Zackary J. Jay**, "Next-generation physiology approaches to study microbiome function at single cell level." *Nat Rev Microbiol.*, 2020, 18:241–256. 2020-002.

Steward, Katherine F., Brian Eilers, Brian Tripet, Amanda Fuchs, Michael Dorle, Rachel Rawle, Berliza Soriano, Narayanaganes Balasubramanian, Valérie Copié, Brian Bothner, **Roland Hatzenpichler,** "Metabolic implications of using BioOrthogonal Non-Canonical Amino Acid Tagging (BONCAT) for tracking protein synthesis," *Front Microbiol.*, 2020, 11:97. 2020-003.

Fields, Matthew W., **Paul Sturman**, **Skip Anderson**, "The establishment of the CBE launched biofilms as a field of specialized research," *Biofilm*, 2020, 2:100020. 2020-004.

LaBelle, Mark W., Derrick M. Knapik, **James W. Arbogast‡**, **Lisa Bowersock**, **Albert Parker**, James Voos, "Infection risk reduction program on pathogens in high school and collegiate athletic training rooms," *Sports Health*, 2020, 12(1):51-57. 2020-005.

Walsh, Danica J., Tom Livinghouse, **Greg M. Durling**, Yenny Chase-Bayless, **Adrienne D. Arnold**, and **Philip S. Stewart**, "Sulfenate esters of simple phenols exhibit enhanced activity against biofilms," *ACS Omega*, 2020, 5 (11):6010-6020. 2020-006.

Alhede, Maria, Morten Alhede, Klaus Ovortrup, Kasper N. Kragh, Peter O. Jensen, **Philip S. Stewart**, Thomas Bjarnsholt, "The origin of extracellular DNA in bacterial biofilm infections in vivo," *Pathogens and Disease*, 2020, 78(2):fyaa018. 2020-007.

Schwarzer, Saskia, **Garth A. James**, **Darla M. Goeres**, Thomas Bjarnsholt, Karen Vickery, Steven L. Percival, Paul Stoodley, Gregory S. Schultz, Slade O. Jensen, Matthew Malone, "The efficacy of topical agents used in wounds for managing chronic biofilm infections: A systematic review," *J Infect*., 2020, 80(3):261-270. 2020-008.

Simkins, Jeffrey W., **Philip S. Stewart, Sarah Codd**, **Joseph D. Seymour**," Microbial growth rates and local external mass transfer coefficients in a porous bed biofilm system measured by 19F magnetic resonance imaging of structure, oxygen concentration, and flow velocity" *Biotechnol Bioeng.*, Jan 2020, 117(5):1458-1469. 2020-009.

Thrane, Linn W., **Ryanne L. Daily**, **Abby Thane**, **Catherine Kirkland**, Evan R. McCarney, Robin Dykstra, **Sarah L. Codd**, **Adrienne Phillips**, "Detecting microbially induced calcium carbonate precipitation in porous systems using low-field nuclear magnetic resonance relaxometry," *J Geotech Geoenvironl Eng.*, Apr 2020, 146(4): 04020012. 2020-010.

Langergraber, Gunter, Gabriela Dotro, Jaime Nivala, **Otto R. Stein**, Anacleto Rizzo. (Eds.). 2020. *Wetland Technology: Practical Information on Design and Application of Treatment Wetlands*. IWA Publishing. 2020-011.

De Grazia, Antonio, Gareth LuTheryn, Alireza Meghdadi, Ali Mosayyebi, **Erika J. Espinosa-Ortiz, Robin Gerlach**, Dario Carugo, "A microfluidic-based investigation of bacterial attachment in ureteral stents," *Micromachines*, 2020, 11(4):408. 2020-012.

Simkins, Jeffrey W., Sebastian Schuhmann, Gisela Guthausen, Martin Heijnen, **Sarah L. Codd, Joseph Seymour**, "Characterization of biofilm distribution in hollow fiber membranes using compressed sensing magnetic resonance imaging," *J Membrane Sci.*, 2020, 594: 117437. 2020-013.

Kirkland, Catherine M., **Abby Thane**, **Randy Hiebert**, Robert Hyatt, Jim Kirksey, **Alfred B. Cunningham**, **Robin Gerlach**, Lee Spangler, **Adrienne J. Phillips**, "Addressing wellbore integrity and thief zone permeability using microbially-induced calcium carbonate precipitation (MICP): A field demonstration," *J Petro Sci Eng.*, 2020, 190: 107060.

Parker, Albert E., J.A. Christen, **Lindsey Lorenz**, **Heidi Smith**, "Optimal surface estimation and thresholding of confocal microscope images of biofilms using Beer's Law," *J Microbiol Methods*, 2020, 174:105943. 2020-015.

Goeres, Darla M., **Albert E. Parker**, **Diane K. Walker**, **Kelsey Meier^**, **Lindsey A. Lorenz**, **Kelli Buckingham-Meyer**, "Drip flow reactor method exhibits excellent reproducibility based on a 10-laboratory collaborative study," *J Microbiol Methods*, 2020, 174:105963. 2020-016.

Martin, Christine, **John Doyle**, JoRee LaFrance, Myra J. Lefthand, Sara L. Young, Emery Three Irons, **Margaret J. Eggers**, "Change rippling through our waters and culture," *J Contemp Water Res & Ed.*, June 2020, 169:61-78. 2020-017.

Park, Heejoon, **S. Lee McGill**, **Adrienne D. Arnold**, **Ross P. Carlson**, "Pseudomonad reverse carbon catabolite repression, interspecies metabolite exchange, and consortial division of labor," *Cell Molec Life Sci.*, 2020, 77:395-413. 2020-018.

Stewart, Philip S., Thomas Bjarnsholt, "Risk factors for chronic biofilm-related infection associated with implanted medical devices," *Clin Microbiol Infect.*, 2020, 26(8):1034-1038. 2020-019.

Moon, Ji-Won, Charles J. Paradis, Dominique C. Joyner, Frederick von Netzer, Erica L. Majumder, Emma R. Dixon, Mircea Podar, Xiaoxuan Ge, Peter J. Walian, **Heidi J. Smith**, Xiaoqin Wu, Grant M. Zane, Kathleen F. Walker, Michael P. Thorgersen, Farris L. Poole II, Lauren M. Lui, Benjamin G. Adams, Kara B. De León, Sheridan S. Brewer, Daniel E. Williams, Kenneth A. Lowe, Miguel Rodriguez Jr., Tonia L. Mehlhorn, Susan M. Pfiffner, Romy Chakraborty, Adam P. Arkin, Judy D. Wall, **Matthew W. Fields**, Michael W.W. Adams, David A. Stahl, Dwayne A. Elias, Terry C. Hazen, "Characterization of subsurface media from locations up- and down-gradient of a uranium-contaminated aquifer," *Chemosphere*, 2020, 255:126951. 2020-20.

Zhang, Tianyu, **Albert Parker**, **Ross P. Carlson**, **Philip S. Stewart**, **Isaac Klapper#** , "Multiscale flux-based modeling of biofilm communities," *Multiscale Model Sim.*, 2020, 18(2):1025-1052. 2020-021.

Goeres, Darla, **Stephen Pedersen‡, Bryan Warwood‡**, **Diane K. Walker**, **Albert E. Parker**, **Madelyn Mettler^**, **Paul Sturman**. 2020. Design and fabrication of biofilm reactors. In Manuel Simoes, Anabel Borges, and Lucia Chaves Simoes (Eds.), Recent Trends in Biofilm Science and Technology (1st ed., pp. 71-88). Academic Press. 2020-022.

^Undergraduate student
‡ Industrial or Federal Agency co-author
* Previous Visiting Researcher
# Previous staff/faculty

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RESEARCH:
PRESENTATIONS
June 2019–May 2020

The following CBE researchers presented their work at 9th International Conference on Algal Biomass, Biofuels & Bioproducts, Boulder, CO, June 17-19, 2019:

Robin Gerlach, professor, chemical & biological engineering, as a platform speaker, presented "Mass transfer of atmospheric CO2 into alkaline media - modeling and experimental verification."

Poster Presentations:
Robin Gerlach, "A model to quantify the enhanced mass transfer of CO_2 into high alkalinity algae culture medium, accounting for temperature and ionic strength."

Hannah Goemann, PhD student, microbiology & immunology, "Cyanobacterial biofertilizer at the frontier of agricultural sustainability."

Matthew Jackson, PhD student, chemical & biological engineering, "Controlling growth and biomass composition of *Chlorella* strains through the use of different organic and inorganic carbon regimes."

Diane Walker, CBE Research Engineer, was an invited speaker and presented "What are Dry Biofilms and How Do They Survive in Low Moisture or Dry Environments?" at the International Association for Food Protection (IAFP) Annual Meeting, Louisville, KY, July 21-24,2019.

Matthew Fields, CBE director, professor, microbiology & immunology, "Microbial Activity in Ground Water" at the Lawrence Berkeley National Lab, Berkeley, CA, June 23-26, 2019.

Christine Foreman, associate dean, professor, chemical & biological engineering, presented "SLICE: Spectral Signatures of Life in Ice" at the 2019 Astrobiology Science Conference, Seattle, WA, June 24-28, 2019.

Diane Walker, CBE research engineer, presented "What are dry biofilms, and how do they survive in low moisture or dry environments?" at the International Association for Food Protection, Louisville, KY, July 21–24, 2019.

Philip Stewart, professor, chemical & biological engineering, presented "Live imaging of the action of neutrophils against early *Staphylococcus aureus* biofilms in vitro and in vivo" and a poster entitled "P. risk factors for chronic biofilm related infection" at the Eurobiofilms 2019, Glasgow, Scotland, September 3-6, 2019.

Philip Stewart, professor, chemical & biological engineering, presented "Chronic Biofilm Infections: Insights from Mathematical Modeling" and "Innate Immunity at the Biomaterial Interface" at the Ohio State University, Columbus, OH, September 24-26,2019.

Al Parker, CBE statistician, presented "Bayesian Analysis and Design of Experiments of Biofilms Over Space and Time," at the International Symposium on Inverse Problems, Design and Optimization in Tianjin, China, September 24-26, 2019.

Luke Mckay, assistant research professor, land resources and environmental science, presented "Early evolved microbial metabolisms and virus-host dynamics mediate sulfur and methane cycling in diverse geothermal environments," at the Carnegie Geophysical Lab Seminar Series, Washington DC, September 30, 2019.

Garth James, professor, chemical & biological engineering, presented "Kinetics of Bacterial Attachment to Breast Implant Surfaces" for the V World Symposium on Ergonomic Implants in Lago di Garda, Gardone, Italy, Oct 2-6, 2019.

Luke Mckay, assistant research professor, land resources and environmental science, presented "Adventures in Extremophile Research," at MSU Honors' College Undergraduate Research Symposium, Bozeman, MT, October 5, 2019.

Matthew McGlennen, MS student, mechanical & industrial engineering, presented his research poster "In-situ groundwater monitoring using micro-fabricated sensors: Advantages and challenges," at the 36th annual Montana Section of the American Water Resources Association, Red Lodge, MT, October 9–11, 2019.

Robin Gerlach, professor, chemical & biological engineering, presented "Two biotechnology tools in the CCU/CCS toolbox: High pH & high alkalinity cultivation of algae and biologically induced precipitation of calcium carbonate minerals," at EcoTech4CCU, Tromso, Norway, October 16-19, 2019.

Matthew Fields, CBE director, professor, microbiology & immunology, presented "Identifying Causative Relationships and Active Populations in Polymicrobial Communities" at the Triservice Microbiome Conference, Dayton, OH, October 21 - 25, 2019.

The following CBE researchers presented research at the Crossroads of Discovery in Bozeman, Montana, October 26, 2019:

Ellie Jackson, undergraduate student, cell biology & neuroscience, and **Petria Russell**, undergraduate student, chemical & biological engineering, presented "Looking at drop-based microfluidics to produce microscopic drops and particles."

Caitlin Carmody, undergraduate, mechanical & industrial engineering, presented "Explosive seed dispersal of Leafy Spurge, a noxious weed on the M Trail here in Bozeman."

Madelyn Mettler, undergraduate, chemical & biological engineering, presented "The design of a new biofilm reactor that can mimic the conditions present in a cooling tower to study biofilm growth."

Jacob Rotert, undergraduate, chemical & biological engineering, presented "A study of the dangers that dead legs can pose specifically with regards to antimicrobial tolerance."

Kelsey Meier, undergraduate, microbiology & immunology, presented "Evaluate biofilm growth in hydration bladders over a six-week period."

Darla Goeres, professor, chemical & biological engineering, presented "Proposed Standard Method for Antimicrobial Urinary Catheters," at the ASTM F04 symposium, Houston, TX, November 4-6, 2019.

The following CBE researchers presented research at the American Institute of Chemical Engineers Meeting, Orlando, FL, November 8-15, 2019:

Reha Abbasi, PhD Student, chemical & biological engineering, presented "Structuring Microbial Biofilms with 3D Printing."

Sobia Anjum, PhD student, chemical & biological engineering, presented "Relating mechanical properties of biofilm-mineral composites to bulk consolidated media properties."

Ross Carlson, professor, chemical & biological engineering, *"In silico* Metabolic Design of Two-Strain Biofilm Systems Predicts Enhanced Biomass Production and Biochemical Synthesis."

Connie Chang, professor, chemical & biological engineer, was session chair for "Technologies for Understanding Microbial Interactions" and was invited to present "Drop Stabilization on a Chip (DropSOAC): Stabilizing Microfluidic Drops for Time-Lapse Quantification of Single-Cell Bacterial Physiology."

Brian Pettygrove, PhD Student, microbiology & immunology, invited speaker, **Philip Stewart**, professor, chemical & biological engineering, invited speaker, presented "Innate Immunity at the Biomaterial Interface."

Shawna Pratt, PhD Candidate, chemical & biological engineering, **Petria Russell**, undergraduate, chemical & biological engineering, "Microsphere Hydrogel Encapsulation to Identify Interactions in Chronic Wound Microbial Consortia."

Philip Stewart, professor, chemical & biological engineering, invited speaker, presented "Systems Biology for Biofilm Antibiotic Tolerance"

James Wilking, professor, chemical & biological engineering, was session chair for "Biophysical Properties of Microbes and Microbial Communities" and was invited to present "Microbial Biofilms: Structure, Transport, and Dynamics."

Geoffrey Zath, PhD Student, chemical & biological engineering, **Humberto Sanchez**, PhD Student, chemical & biological engineering, **Emma Loveday**, post-doctoral researcher, *"*High-Throughput Assaying of Individual Host-Pathogen Dynamics in Influenza A Virus Infection Using Drop-Based Microfluidics."

Jason Zeng, PhD Student, chemical & biological engineering, presented "Understanding Venture Capital Funding Decisions and Using Initial Funding to Build a Successful Startup" and "Printing Hydrogels with Living Bacterial Cultures for Use as Chemical Bioreactors."

Connie Chang, professor, chemical & biological engineering, presented "Examining heterogeneous populations of microbes at the single cell level using stabilized emulsions," at the City College of New York, New York City, NY, November 4-8, 2019.

The following CBE researchers presented research at the Reservoir Microbiology Forum (RMF), London, UK, November 18 – 25, 2019:

Robin Gerlach, professor, chemical & biological engineering, presented "Stimulating Microbial

Coalbed Methane Production – Results from Batch and Column Experiments."

Matthew Fields, CBE director, professor, microbiology & immunology, presented "Targeted Metagenomic Analysis of Recalcitrant Carbon Rich Coal Seams along a Vertical Sulfate Transition Zone."

Robin Gerlach, professor, chemical & biological engineering, presented "Stimulating Microbial Coalbed Methane Production – Results from Batch and Column Experiments" and "Using Ureolysis-Induced Calcium Carbonate Precipitation in the Field to Enhance Wellbore Integrity and Resource Recovery" at the 25th Reservoir Microbiology Forum (RMF) in London, United Kingdom, November 20-21, 2019.

Matthew Fields, CBE director, professor, microbiology & immunology, presented "Sustaining University-Industry Partnerships" at Stanford University, San Francisco, CA, December 3, 2019.

Connie Chang, assistant professor, chemical & biological engineering, and **Cati Carmody**, undergraduate researcher, mechanical engineering, presented their research at the 81st New England Complex Fluids Meeting, Harvard University, Cambridge, MA, December 6, 2019:

Connie, as an invited speaker, presented "Examining heterogeneous populations of microbes at the single cell level using stabilized emulsions."

Cati gave a short research presentation "Ballistic seed dispersal in leafy spurge. "

Robin Gerlach, professor, chemical & biological engineering, presented "Role of Biofilms, Organics and Urine Chemistry in the Formation of Kidney Stones – Different (Bio-)Chemistry Results in Different Minerals," at StoneLab Scientific Symposium in Linthicum, MD, December 7, 2019.

Luke McKay, assistant research professor, land resources and environmental sciences, presented "A dynamic sulfur cycle at suboxic, high-temperature vents in Yellowstone Lake is mediated by deeply-rooted thermophiles and their associated viruses," at Advancing Earth and Space Science (AGU) Fall Meeting in San Francisco, CA, December 8-13, 2019.

Matthew Fields, CBE director, professor, microbiology & immunology, presented "Identifying Causative Relationships and Active Populations in Polymicrobial Communities" at University of Virginia Medical Center, Charlottesville, VA, December 10, 2019.

Heidi Smith, assistant research professor, microbiology & immunology, presented "Core Values: Spatial Variation in Microbial Function, Activity, and Community Assembly in Groundwater and Sediment from a Contaminated Subsurface Aquifer," at the 2020 Genomic Sciences Program Annual Principal Investigator Meeting, Washington, DC, February 24–25, 2020.

Phil Stewart, Regents Professor, chemical & biological engineering, presented "Medical Implants, Infection, and Innate Immunity," at the Department of Orthopedic Surgery, University of California at Los Angeles, Los Angeles, CA, January 22, 2020.

The following CBE researchers presented their work at Biofilm Technologies: Pathways to Product Development, hosted by the Center for Biofilm Engineering in Arlington, VA, February 4–5, 2020:

Matthew Fields, CBE director, professor, microbiology & immunology: "CBE's role in regulation and product advancement."

Darla Goeres, assistant research professor, chemical & biological engineering: "Evaluating performance criteria for the cleanliness of reusable medical devices."

Garth James, assistant research professor, chemical & biological engineering: "In-vitro models of oral biofilms for evaluating antimicrobial susceptibility."

Phil Stewart, Regents Professor, chemical & biological engineering: "Risk factors for chronic biofilm infections on medical implants."

Diane Walker, CBE research engineer: "Dry biofilms: Challenges of recognition and eradication."

Roland Hatzenpichler, assistant professor, chemistry and biochemistry, was invited to present "Ecophysiology of uncultured sediment-dwelling microbes revealed by substrate analog probing," MicroSeminar, March 27, 2020. Watch on YouTube MicroSeminar is a web-based microbiology seminar series.

Phil Stewart, regents professor, chemical & biological engineering, was invited to present virtually "Implant infection and innate immunity," for the Max Planck Society, University of Marburg, Germany, May 7, 2020.

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RESEARCH:

CBE Affiliated Faculty and Their Specialties, 2019–2020

NAME	DEPARTMENT	SPECIALTY
Elliott Barnhart	Center for Biofilm Engineering	Environmental biotechnology
Roberta Amendola	Mechanical & Industrial Engineering	Material science and technology
Iwona Beech	Center for Biofilm Engineering	Biocorrosion and metal-microbe interactions
Diane Bimczok	Microbiology & Immunology	Immunology
Jennifer Brown	Chemical & Biological Engineering	Rheology and biofilm mechanics
Ross Carlson	Chemical & Biological Engineering	Metabolic eng., metabolic networks; chronic wounds
Connie Chang	Chemical & Biological Engineering	Microfluidics
Sarah Codd	Mechanical & Industrial Engineering	Magnetic resonance imaging
Kevin Cook	Mechanical & Industrial Engineering	Tool and machine design
Lewis Cox	Mechanical & Industrial Engineering	Polymer science; scanning probe microscopy
Al Cunningham	Civil Engineering	Subsurface biotechnology and bioremediation
Markus Dieser	Chemical & Biological Engineering	Ecology
Erika Espinosa-Ortiz	Chemical & Biological Engineering	Environmental technologies
Matthew Fields	Microbiology & Immunology	Environmental biofilms
Christine Foreman	Chemical & Biological Engineering	Microbial ecology in cold temperature environments
Michael Franklin	Microbiology & Immunology	Molecular genetics, gene expression, alginate biosynthesis; *Pseudomonas*
Robin Gerlach	Chemical & Biological Engineering	Environmental biotechnology and bioremediation
Darla Goeres	Chemical & Biological Engineering	Standardized biofilm methods
Martin Hamilton	Mathematical Sciences	Mathematics and statistics
Roland Hatzenpichler	Chemistry & Biochemistry	Microbial activity
Chelsea Heveran	Mechanical & Industrial Engineering	Biomechanics; biomimetic materials
Jeffrey Heys	Chemical & Biological Engineering	Fluid-structure interactions
Garth James	Chemical & Biological Engineering	Medical biofilms
Kelly Kirker	Chemical & Biological Engineering	Medical biofilms
Catherine Kirkland	Civil Engineering	Environmental technologies
Ellen Lauchnor	Civil Engineering	Wastewater Systems
Zbigniew Lewandowski	Civil Engineering	Microsensors, chemical gradients, biofilm structure
Scott McCalla	Mathematical Sciences	Applied dynamic systems
Luke McKay	Land Resources and Environ. Sciences	Biofilms in extreme environments, metagenomics
Rebecca Mueller	Chemical & Biological Engineering	Microbial ecology
Albert Parker	Mathematical Sciences	Mathematics and statistics

Brent Peyton	Chemical & Biological Engineering	Environmental biotechnology and bioremediation
Adrienne Phillips	Civil Engineering	Environmental biotechnology
Elinor Pulcini	Chemical & Biological Engineering	Medical biofilms
Abbie Richards	Chemical & Biological Engineering	Environmental biotechnology
Cecily Ryan	Mechanical & Industrial Engineering	Polymers & composites
Joseph Seymour	Chemical & Biological Engineering	Magnetic resonance imaging
Dana Skorupa	Chemical & Biological Engineering	Microbes in extreme environments
Heidi Smith	Microbiology & Immunology	Biology, imaging
Otto Stein	Civil Engineering	Engineered waste remediation
Phil Stewart	Chemical & Biological Engineering	Biofilm control strategies
Paul Sturman	Civil Engineering	Biofilms in waste remediation, industrial systems
Seth Walk	Microbiology & Immunology	Infectious diseases, microbial ecology and evolution
Stephan Warnat	Mechanical & Industrial Engineering	MEMS, sensors, and actuators
James Wilking	Chemical & Biological Engineering	Physical and material biofilm properties
Tianyu Zhang	Mathematical Sciences	Mathematical modeling

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RESEARCH:

NEWS HIGHLIGHTS

CBE researchers receive funding to purchase new equipment for imaging facility

MSU's Norm Asbjornson College of Engineering announced their selections for the 2020 Thorson Excellence in Engineering (TEER) Grants program. Four CBE researchers were awarded funds to purchase a Linkam LTSE420-P stage, which is compatible with the LabRam Confocal Raman Microscope within the CBE Imaging Facility.

This new piece of equipment will be available to MSU researchers across campus soon. CBE's existing Raman microscope provides detailed information about the chemical structure, phase and polymorphy, crystallinity, and molecular composition of biotic and abiotic substrates including microorganisms. With the addition of the new temperature-controlled, probe-compatible stage, real-time measurements of cell processes, chemical reactions, or material properties (across precise temperature ranges and gradients) in combination with Raman spectroscopy will be possible. The stage has an operating temperature between -196°C to 420°C and houses four ports for sensor integration to study electrical and/or physical properties of a sample. This stage configuration enables many applications from cryo- to thermal-biology, the design of micro-electrochemical sensors, material science, chemical and electrical engineering, geology, snow hydrology, to name a few.

CBE affiliated faculty **Christine Foreman** and **Markus Dieser** from chemical and biological engineering, **Stephan Warnat** from mechanical engineering, and **Heidi Smith** from microbiology and immunology, are working with Kevin Hammonds in civil engineering on the acquisition of this new piece of equipment.

The Thorson Excellence in Engineering Research (TEER) Grants Program was established in 2017 through the generosity of Donald R. Thorson, who earned his degree in chemical engineering from MSU's College of Engineering in 1949. Mr. Thorson's gift of $2.7 million has been set up as an endowment with yearly awards of $100,000 given to support MSU-NACOE research objectives.

CBE affiliated faculty member featured in book about women in workforce

When Connie Chang was in graduate school, a senior colleague told her to not expect to become a professor. He may have thought he was giving her a friendly reality check, Chang said, but the comment nonetheless illustrated the persistence of gender stereotypes that all too often undercut women's aspirations. Read the full article at MSU News

CBE faculty member part of NASA grant to research food production on deep-space missions

CBE affiliated faculty Ross Carlson, professor of chemical and biological engineering, is part of a grant awarded by NASA to research food sustainability on deep-space missions. Carlson will partner with local Bozeman company, Sustainable Bioproducts, LLC, on this work. Read more about this work at Parabolic Arc.

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Cheers! Goeres wins grant from Brewers Association

The Brewers Association announced Darla Goeres won a grant to research the "Evaluation of biofilm growth in chemically treated beer draught tubing." Goeres has a longstanding relationship with the nonprofit trade organization. The type of biofilm that can accumulate in beer tubing, while harmless, can adversely affect the flavor of the beer. The Brewers Association is "dedicated to small and independent American brewers," representing more than 5,000 breweries in the U.S., according to its website.

CBE faculty part of MSU research team set to improve water quality with new funding

As part of a statewide effort to advance research and education in water quality, three Montana State University research teams have won funding for projects that could lead to more affordable water monitoring, new treatment methods and better understanding of contamination sources. Read the complete article at MSU News

MSU researchers ramp up $6 million project seeking solutions to biofilm corrosion

The microbial gunk that forms in bathroom sink drains can be a slimy nuisance, but it pales in comparison to similar, more corrosive biofilms that cause billions of dollars in damage each year to oil pipelines and other infrastructure. Read more at MSU News

Phil Stewart named Montana University System Regents Professor

Widely respected biofilm researcher **Phil Stewart** of Montana State University was named a Montana University System Regents Professor, the most prestigious designation attainable by a professor in the system.

CBE's Connie Chang is a pioneer of microfluidics

Mountains & Minds, MSU's flagship research publication, features Connie Chang's groundbreaking work in the emerging field of microfluidics. Chang, an assistant professor of chemical and biological engineering, is a CBE-affiliated faculty member. Microfluidics enables scientists to perform chemical reactions, assay molecules for diagnostics, or other scientific processes cheaper and faster than their full-scale counterparts.

CBE biostatistician Al Parker helps data tell its stories

Since 2008, **Albert Parker**, PhD, has been helping researchers and industrial associates discover deeper meaning in their data. He has a highly specialized skill set that many bioscience-based research centers in academia and industries alike don't have. Read more

MSU researcher co-authors paper that raises awareness of microbes' importance to climate change

CBE affiliated faculty member **Christine Foreman**, associate professor in chemical and biological engineering, was featured by MSU News for her paper in Nature Reviews Microbiology that calls for greater attention to microbes when studying global climate change.

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CBE Affiliated Faculty & Staff Awards & Appointments

2020 MSU Norm Asbjornson College of Engineering Awards

The Norm Asbjornson College of Engineering honored two CBE-affiliated faculty with 2020 faculty awards. **Adrienne (Adie) Phillips** received the NACOE Excellence in Research Award, and **Ellen Lauchnor** won the Excellence in Outreach Award. Both researchers are faculty members in MSU's Department of Civil Engineering and were nominated by its department head Craig Woolard.

Woolard cited Phillips' voluminous output in his letter nominating her for the Excellence in Research Award. "Since joining our faculty in 2014, Dr. Phillips has consistently been one of the Department and College's most productive scholars," Woolard wrote. "The significance of her work, her unique ability to apply fundamental principles to engineering problems at all scales, and her extraordinary ability to collaborate with scientists, engineers and professionals from all backgrounds make her an ideal choice for this award." He specifically cited Phillips' work in utilizing microbial technologies to remediate or mitigate environmental problems, such as using biocement to seal leaking oil and gas wells. "Her research productivity since arriving at MSU includes submitting 24 proposals as PI or Co-PI with 15 proposals funded; securing approximately $7.17 million in external research funding from highly competitive national funding organizations like the Department of Energy and the state of Montana." Phillips has also co-invented three patented processes.

"Dr. Lauchnor has been a leader in MSU's Expanding Your Horizons workshop," Woolard wrote in his letter nominating Lauchnor for the Excellence in Outreach award. "She has developed a water-treatment demonstration that reflects her research interest and teaching expertise in water quality. She has involved her student researchers, both graduate and undergraduate, in these outreach efforts to excite K-8 students about engineering. Combining outreach that involves students characterizes Dr. Lauchnor's work at MSU. She has incorporated outreach into her graduate classes providing her students with hands-on experience with field investigations, data collection and engineering analysis at actual sites in Montana undergoing contaminant investigation and clean up. As part of her outreach activities, Dr. Lauchnor has worked with local consultants and the EPA Superfund program treating mine waste from a site in Montana. Dr. Lauchnor has also integrated research into outreach to Montana's tribal communities."

2020 CBE Outstanding Faculty Award

Heidi Smith received the CBE 2020 Outstanding Faculty Award. Heidi was recognized for her indisputable commitment to interdisciplinary research and education, and the CBE industrial program in her role as our Bio-Imaging Facility Manager. Heidi is steadfast in seeking funding to elevate the quality of the center's microscopy equipment. Most notably, she secured nearly $1.7 million to upgrade the facility. Heidi is an intelligent and curious researcher who confidently trains and mentors students and researchers across multiple academic disciplines on imaging techniques. She is committed to creating imaging opportunities for students and industrial members. Heidi is also a productive early-career research faculty member, having published 22 peer-reviewed papers, including two in *Nature* journals.

2020 Outstanding Researcher Award

CBE acknowledged **Kristen Brileya's** contributions to research by bestowing onto her its 2020 Outstanding Researcher Award. From a team, research, and business standpoint, one would be hard pressed to find a more collaborative, intelligent, and committed member of the CBE staff than Kristen.

In her role as the technical operations manager, Kristen's commitment to the CBE is undeniable, and her drive and natural curiosity propel the level of research taking place here. She brings a high level of intelligence and organization to her interactions with companies, and always makes herself available to students, faculty, and staff. Kristen is committed to creating a safe work environment, ensures that labs have what they need, and assists faculty, staff, and students with a solution-oriented attitude. Finally, we recognize Kristen for providing laboratory logistics expertise, in a very short timeframe, in support of a COVID testing site.

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New Staff

Laura Merante joined the CBE as its accounting analyst. She is responsible for the center's accounts payable and receivable functions. Laura joined MSU in 2016 working for the Allen Yarnell Center for Student Success as a program coordinator. Prior to that, she enjoyed traveling and working in different areas of the country and the world. A graduate of University of Colorado, Laura is glad to be back in the Rocky Mountains enjoying the abundant opportunities for hiking and skiing.

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EDUCATION:

Undergraduate Students: Summer 2019, Fall 2019, Spring 2020

*Graduating ‡Native American

1. *Anderson, Rebekah (Foreman)	F	Chemical & Biological Engineering	Golden, CO
2. Bedwell, Sierra (Fields)	F	Microbiology & Immunology	S. Lake Tahoe, CA
3. Blossom, Tallis (Goeres)	F	Chemical & Biological Engineering	Helena, MT
4. Brasier, Whitney (Goeres)	F	Cell Biology & Neuroscience	Erie, CO
5. Burr, Mary (Lauchnor)	F	Civil Engineering	Anchorage, AK
6. Butler, Brooke (Lauchnor)	F	Civil Engineering	Billings, MT
7. Carmody, Caitlin (Wilking)	F	Mechanical & Industrial Engineering	Butte, MT
8. Corey, Isabella (Kirkland)	F	Civil & Environmental Engineering	Eagle, ID
9. Cummings, Atticus (Wilking)	M	Directed Interdisciplinary Studies	Bozeman, MT
10. Dreesbach, Hannah (Fields)	F	Microbiology & Immunology	Helena, MT
11. Driesler, Matthew (Warnat)	M	Mechanical & Industrial Engineering	Terrance, CA
12. *Du, Martina (Carlson)	F	Chemical & Biological Engineering	Kent, WA
13. DuBois, Camryn (Gerlach)	F	Mechanical & Industrial Engineering	Lake Stevens, WA
14. Espinal, Michael (Phillips)	M	Mechanical & Industrial Engineering	Vacaville, CA
15. Fenton, Jacob (Carlson)	M	Chemical & Biological Engineering	Menommie, WI
16. *Frische, Lora (Wilking)	F	Chemical & Biological Engineering	Beaverton, OR
17. *Gulyavskaya, Anastasia (Peyton)	F	Chemical & Biological Engineering	Cleveland, OH
18. Gurney, James (Gerlach)	M	Plant Sciences & Plant Pathology	Pleasanton, CA
19. Gutenberger, Gretchen (Gerlach)	F	Chemical & Biological Engineering	Menomonee Falls, MI
20. *‡Hershman, Seth (Gerlach)	NB	Chemical & Biological Engineering	Arlee, MT
21. Hemmah, Ashlyn (Peyton)	F	Civil & Environmental Engineering	Leads, SD
22. *John, Ethan (Wilking)	M	Chemical & Biological Engineering	Essex, VT
23. King, Felicia (Foreman)	F	Mechanical & Industrial Engineering	Santa Cruz, CA
24. Langton, Kaely (Phillips)	F	Civil Engineering	Woodville, WA
25. Leonard, Michelle (Goeres)	F	Microbiology & Immunology	Eureka, MT
26. *Lewis, Christian (Peyton)	M	Chemical & Biological Engineering	Gig Harbor, WA
27. Martinson, Anna (Phillips)	F	Chemical & Biological Engineering	Gig Harbor, WA
28. McAlpine, Kelly (Phillips/Espinosa-Ortiz)	F	Plant Sciences & Plant Pathology	Simsbury, CT
29. McCoy, Quintin (Foreman)	M	Chemical & Biological Engineering	Bend, OR
30. ‡*Meier, Kelsey (Goeres)	F	Microbiology & Immunology	Billings, MT
31. *Mettler, Madelyn (Peyton/Goeres)	F	Chemical & Biological Engineering	Littleton, CO
32. *Morris, Garrett (Goeres)	F	Mechanical & Industrial Engineering	Missoula, MT
33. Morris, Kate (Lauchnor)	F	Civil Engineering	Kansas City, KS
34. Newby, Audrey (James)	F	Microbiology & Immunology	Eau Claire, WI
35. Newhart, Alyssa (James)	F	Chemical & Biological Engineering	Helena, MT
36. Ostrem, Kathleen (Wilking)	F	Ecology	Wilmette, IL
37. *Parks, Kendall (Gerlach)	F	Chemical & Biological Engineering	Vancouver, WA
38. Pearson, Jack (Foreman)	M	Directed Interdisciplinary Studies	Evergreen, CO
39. Pirtz, Matalin (Chang)	F	Chemical & Biological Engineering	Billing, MT
40. Rosenblum, Amy (Lauchnor)	F	Civil Engineering	Basking Ridge, NJ
41. Rotert, Jacob (Stewart)	M	Chemical & Biological Engineering	Everett, WA
42. Russell, Petria (Chang)	F	Chemical & Biological Engineering	Lake Tapps, WA
43. Snyder, Derek (Stein)	M	Civil Engineering	San Jose, CA
44. Smith, Hannah (Fields)	F	Microbiology & Immunology	Helena, MT
45. ‡Stewart, Tillie (Lauchnor)	F	Microbiology & Immunology	Lodge Grass, MT
46. Strautmanis, Uve (Fields)	F	Microbiology & Immunology	Cedarburg, MT
47. Taylor, Molly (Gerlach)	F	Civil Engineering	Bozeman, MT
48. *Trudgeon, Benjamin (Foreman)	M	Chemical & Biological Engineering	Grand Rapids, MI
49. Turner, Evan (Goeres)	M	Chemical & Biological Engineering	Honolulu, HI
50. Valenzuela, Mary (Lauchnor/Eggers)	F	Microbiology & Immunology	Soldotna, AK

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Undergraduates Summary: 2019–2020

Department	Male	Female	Non-Binary	Total
Cell Biology & Neuroscience		1F		1
Chemical & Biological Engineering	7M	12F	1 NB	20
Civil Engineering	1M	8F		9
Directed Interdisciplinary Studies (Honors College)	2M			2
Ecology	1M			1
Mechanical & Industrial Engineering	2M	4F		6
Microbiology & Immunology		9F		9
Plant Sciences & Plant Pathology	1M	1F		2
Totals	**14M**	**35F**	**1NB**	**50**

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EDUCATION:

Graduate Students: Summer 2019, Fall 2019, Spring 2020

‡ Native American *Received degree

Masters Candidates

1.	Ajayi, Kehinde (Wilking)	M	Mathematical Sciences	Lagos, Nigeria
2.	Bowman, Tucker (Stein)	M	Civil & Environmental Engineering	Highland Ranch, CO
3.	*Erturk, Berrak (Peyton)	F	Chemical & Biological Engineering	Istanbul, Turkey
4.	*Daily, Ryanne (Phillips)	F	Civil & Environmental Engineering	Great Falls, MT
5.	Golichnik, Joseph (Espinosa-Ortiz)	M	Civil & Environmental Engineering	Neenah, WI
6.	Karcher, Paul (Stein)	M	Civil & Environmental Engineering	Cut Bank, MT
7.	Koenig, Heidi (Stewart)	F	Chemistry & Biochemistry	Everett, WA
8.	Kronz, Shannon (Kirkland)	F	Civil & Environmental Engineering	N. Olmsted, OH
9.	Neubauer, Michael (Warnat)	M	Mechanical & Industrial Engineering	Rogers, MN
10.	Massey, KaeLee (Fields)	F	Chemical & Biological Engineering	Billings, MT
11.	McCarthy, Cameron (Lauchnor)	F	Civil & Environmental Engineering	Roanoke, VA
12.	McGlennen, Matthew (Warnat)	M	Microbiology & Immunology	Edina, MN
13.	*Messmer, Mitch (Foreman)	M	Chemical & Biological Engineering	Hillsboro, OR
14.	*Paine, Kyle (Lauchnor)	M	Civil & Environmental Engineering	Ludington, MI
15.	Panighetti, Robert (Stein)	M	Civil & Environmental Engineering	Cedarburg, WI
16.	*Platt, George (Gerlach/Fields)	M	Chemical & Biological Engineering	Eagle River, AK
17.	*Pratt, Shawna (Chang)	F	Chemical & Biological Engineering	Miles City, MT
18.	*Proudfoot, Dylan (Lauchnor)	M	Civil & Environmental Engineering	Fairmont, WV
19.	*Sykes, Jordan (Lauchnor)	M	Civil & Environmental Engineering	Brevard, NC
20.	Thomae, Madelyn (Warnat)	F	Mechanical & Industrial Engineering	Ashland, OH
21.	Thompson, Luke (Stein)	M	Civil & Environmental Engineering	Littleton, CO

PhD Candidates

1.	Abassi, Reha (Wilking)	M	Chemical & Biological Engineering	Istanbul, Turkey
2.	Akyel, Arda (Gerlach)	M	Chemical & Biological Engineering	Istanbul, Turkey
3.	Anjum, Sobia (Gerlach)	F	Chemical & Biological Engineering	Punjab, Pakistan
4.	Arnold, Adrienne (Carlson)	F	Microbiology & Immunology	Charleston, WV
5.	Bodle, Kylie (Kirkland)	F	Civil & Environmental Engineering	Camano Island, WA
6.	Cicha, Calvin (Gerlach)	M	Microbiology & Immunology	Isanti, Minnesota
7.	Christian, William (Hatzenpichler)	M	Chemistry & Biochemistry	Grand Rapids, MI
8.	*Corredor-Arias, Luisa (Fields)	F	Microbiology & Immunology	Pereira, Colombia
9.	Fredrickson, Jacob (Chang)	M	Chemical & Biological Engineering	Puyallup, WA
10.	LeFevre, Thomas (Wilking)	M	Chemical & Biological Engineering	Escanaba, MN
11.	Lynes, Mackenzie (Hatzenpichler)	F	Chemistry & Biochemistry	Cleveland, OH
12.	Goemann, Hannah (Peyton)	F	Microbiology & Immunology	Wells, MN
13.	Hoffman, Carter (Chang)	M	Chemical & Biological Engineering	Carlsbad, CA
14.	Jackson, Matthew (Gerlach)	M	Chemical & Biological Engineering	Naples, FL
15.	Keller, Lisa (Fields)	F	Microbiology & Immunology	Knoxville, MT
16.	Kilic, Ayse Bengisu (Lauchnor)	F	Chemical & Biological Engineering	Istanbul, Turkey
17.	*Krantz, Gregory (Fields)	F	Microbiology & Immunology	Tinmouth, VT
18.	Koepnick, Hannah (Peyton)	F	Chemical & Biological Engineering	Sherman, TX
19.	Kohtz, Anthony (Hatzenpichler)	M	Chemistry & Biochemistry	Omaha, NE
20.	Miller, Isaac (Fields)	M	Microbiology & Immunology	East Helena, MT
21.	McGill, Lee (Stacy) (Carlson)	M	Microbiology & Immunology	Minor Hill, TX
22.	Moll, Karen (Peyton)	F	Microbiology & Immunology	Fairport, NY
23.	Pettygrove, Brian (Stewart)	M	Chemical & Biological Engineering	Leesburg, VA
24.	Pratt, Shawna (Chang)	F	Chemical & Biological Engineering	Miles City, MT
25.	Rathore, Muneeb (Peyton)	M	Chemical & Biological Engineering	Punjab, Pakistan
26.	Reichart, Nicholas (Hatzenpichler)	M	Chemistry & Biochemistry	Bel Air, MD
27.	Robinson, Emily (Wilking)	F	Microbiology & Immunology	Portland, OR
28.	Sanchez, Humberto (Chang)	M	Chemical & Biological Engineering	Corona, CA
29.	Schaible, George (Hatzenpichler)	M	Chemistry & Biochemistry	Missoula, MT
30.	Thomas, Mallory (Chang)	F	Microbiology & Immunology	Elkhart, IN

31.	Thornton, Isaak (Wilking)	M	Mechanical & Industrial Engineering	Great Falls, MT
32.	*Walsh, Danica (Stewart)	F	Chemistry & Biochemistry	Olympia, WA
33.	*Zambare, Neerja (Gerlach)	F	Chemical & Biological Engineering	Maharashtra, India
34.	Zath, Geoffrey (Chang)	M	Chemical & Biological Engineering	Bend, OR
35.	Zeng, Jason (Wilking)	M	Chemical & Biological Engineering	Novato, CA

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EDUCATION:
Graduate Students, 2019–2020

20: Chemical & Biological Engineering

MS: 5

2 M Platt, George: MS, *Fields*
Messmer, Mitchell: MS, *Foreman*

3 F Erturk, Berrak: MS, *Peyton*
Massey, KaeLee: MS, *Fields*
Pratt, Shawna: MS, *Chang*

PhD: 15

10 M Abbasi, Reha: PhD, *Wilking*
Akyel, Arda: PhD, *Gerlach*
Fredrickson, Jacob: PhD, *Chang*
Hoffman, Carter: PhD, *Chang*
Jackson, Matthew: PhD, *Gerlach*
LeFevre, Thomas: PhD, *Wilking*
Rathore, Muneeb: PhD, *Peyton*
Sanchez, Humberto: PhD, *Chang*
Zath, Geoffrey: PhD, *Chang*
Zeng, Jason: PhD, *Wilking*

5 F Anjum, Sobia: PhD, *Gerlach*
Kilic, Ayse Bengisu: PhD, *Lauchnor*
Koepnick, Hannah: PhD, P*eyton*
Pratt, Shawna: PhD, *Chang*
Zambare, Neerja: PhD, *Gerlach*

7: Chemistry & Biochemistry

MS: 1

1 F Koenig, Heidi: MS, *Stewart*

PhD: 6

4 M Christian, William: PhD, *Hatzenpichler*
Kohtz, Anthony: PhD, *Hatzenpichler*
Reichart, Nicholas: PhD, *Hatzenpichler*
Schaible, George: PhD, *Hatzenpichler*

2 F Lynes, Mackenzie: PhD, *Hatzenpichler*
Walsh, Danica: PhD, *Stewart*

12: Civil / Environmental Engineering

MS: 11

8 M Bowman, Tucker: MS, *Stein*
Golichnik, JT: MS, *Espinosa-Ortiz*
Karcher, Paul: MS, *Stein*
Paine, Kyle: MS, *Lauchnor*
Panighetti, Robert: MS, *Stein*
Proudfoot, Dylan: MS, *Lauchnor*
Sykes, Jordan: MS, *Lauchnor*
Thompson, Luke: MS, *Lauchnor*

3 F Daily, Ryanne: MS, *Phillips*
Kronz, Shannon: MS, *Kirkland*
McCarthy, Cameron: MS, *Lauchnor*

PhD: 1

1 F Bodle, Kylie: PhD, *Kirkland*

1: Mathematical Sciences

MS: 1

1 M Ajayi, Kehinde: MS, *Wilking*

4: Mechanical & Industrial Engineering

MS: 3

2 M McGlennen, Matthew: MS, *Warnat*
Neubauer, Michael: MS, *Warnat*

1 F Thomae, Madelyn: MS, *Warnat*

PhD: 1

1 M Thornton, Isaak: PhD, *Wilking*

12: Microbiology & Immunology

PhD: 12

5 M Cicha, Calvin: PhD, *Gerlach*
Krantz, Gregory: PhD, *Fields*
McGill, Stacy: PhD, *Carlson*
Miller, Isaac: PhD, *Fields*
Pettygrove, Brian: PhD, *Stewart*

7 F Arnold, Adrienne: PhD, *Carlson*
Corredor-Arias, Luisa: PhD, *Fields*
Goemann, Hannah: PhD, *Peyton*
Keller, Lisa: PhD, *Fields*
Moll, Karen: PhD, *Peyton*
Robinson, Emily: PhD, *Wilking*
Thomas, Mallory: PhD, Chang

TOTALS

Total Grads: 56

Total MS: 21	13 M / 8 F
Total PhD: 35	19 M / 16 F

Total Male: 33
Total Female: 23

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EDUCATION:

Graduating with advanced degrees: June 2019–May 2020

George Platt, MS, Chemical & Biological Engineering, MSU, July 2019
Investigation of field relevant parameters for microbially enhanced coalbed methane scale up

Ryanne Daily, MS, Chemical & Biological Engineering, MSU, July 2019
A study of bio-mineralization for the application of reducing leakage potential of geologically stored CO_2

Luisa Corredor-Arias, PhD, Microbiology & Immunology, MSU, Nov 2019
Understanding physiological adaptations, metabolic potential and ecology in a novel photoautotrophic alga for biofuel production

Greg Krantz, PhD, Microbiology & Immunology, MSU, Nov 2019
The biofilm matrix in sulfate-reducing bacterial biofilms: Potential roles for electron mediators and large proteins

Berrak Erturk, MS, Chemical & Biological Engineering, MSU, Nov 2019
Sodium bicarbonate amendment for enhanced astaxanthin production from *Haematococcus pluvialis*

Danica Walsh, PhD, Chemistry & Biochemistry, MSU, Mar 2020
Design, synthesis and evaluation of novel antimicrobials for the eradication of biofilms

Neerja Zambare, PhD, Chemical & Biological Engineering, MSU, Apr 2020
Microbially induced calcium carbonate precipitation: Meso-scale optimization and micro-scale characterization

Mitch Messmer, MS, Chemical & Biological Engineering, MSU, April 2020
Spectral Signs of Life in Ice (SLICE)

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EDUCATION:

Student News and Awards

MSU 97th Annual Day of Student Recognition

Ellie Jackson, an MSU-CBE undergraduate student in cell biology and neuroscience, was among the thirty-five students honored in April for MSU's 97th Annual Day of Student Recognition. The event recognized student achievement in leadership, involvement in various campus-wide activities, and community service. Ellie received the Outstanding Sophomore Leadership Award, which recognizes a sophomore who demonstrates notable leadership skills and values. Ellie, a Bozeman native, is active in several service organizations in the community and on campus. She holds leadership roles in the HEART Initiative and the Health Professions Club. She also serves as a Child Advancement Project (CAP) mentor, has volunteered at Bozeman Health, and has engaged in service activities with Alpha Omicron Pi and Breaks Away trips. Ellie's CBE advisor is Dr. Connie Change, assistant professor in chemical and biological engineering. Congratulations to Ellie!

Due to the coronavirus pandemic, an in-person ceremony for this event was not possible but a video honoring the awardees is available on the MSU Office of Student Engagement Facebook page and on its website.

CBE PhD graduate earns prestigious fellowship at Pacific Northwest National Laboratory

Neerja Zambare, a former CBE student in MSU's Department of Chemical and Biological Engineering who successfully defended her PhD dissertation in April, has accepted the distinguished Linus Pauling Fellowship at the Pacific Northwest National Laboratory. "I knew [the fellowship] was highly competitive, and if I got it, I would get to work with some of the leading microscopes and experts in the world, which would be a fantastic way to start a career in microscopy and microanalysis," she says. Zambare's dissertation was titled "Microbially induced calcium carbonate precipitation: Meso-scale optimization and micro-scale characterization." While at the CBE, Zambare worked in Robin Gerlach's lab where her research exposed her to advanced microscopy techniques and microanalysis, which she says will play an integral part in her career.

CBE faculty guide students seeking plastic-degrading microbes in Yellowstone

CBE-affiliated faculty members **Dana Skorupa** and **Brent Peyton** led 11 undergraduates into Yellowstone's back country to collect and grow hot spring microorganisms that may be capable of breaking down plastics. Read about this important research project in *Explore Big Sky* newspaper.

MSU-CBE undergraduate documents microplastic in precipitation

The general public often cites two bits of information about snowflakes: each has six appendages, and the crystal pattern of their structures are as unique as a human fingerprint. Research led by CBE-affiliated undergraduate **Bekah Anderson** offers startling new information that may also get people talking: some snowflakes contain microplastic fiber.

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CBE Student Awards

2020 W.G. Characklis Outstanding Graduate Student Award

CBE awarded the 2020 W.G Characklis Outstanding Graduate Student Award to **Isaak Thornton & Tom LeFevre,** both PhD candidates in chemical and biological engineering. Tom and Isaak were recognized for their contributions to research innovation through exceptional fabrication work supporting the COVID-19 testing efforts at MSU. During the COVID-19 pandemic, both men promptly responded to the need to fabricate lab supplies and equipment for testing efforts, working long hours, without additional pay, and without sacrificing their PhD projects. Tom and Isaak's work supported the testing operations of several faculty and contributed significantly to the efficiency of MSU's testing programs. Both men's efforts had a real impact on campus safety and the health of our community. Most notably, Isaak took the lead on the first COVID-related project on campus, designing and 3-D-printing nasal swabs due to a nationwide shortage. On a site visit to campus, U.S. Rep. (now Governor) Greg Gianforte said he was struck by how engineering students contributed so significantly to the projects.

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

2020 CBE Student Lab Citizen Award

Brian Pettygrove, PhD student in microbiology and cell biology, received the CBE's Student Lab Citizen Award. Brian was recognized for being consistently hardworking, respectful of property, considerate of his lab workers, and attentive to safety. He is always willing to help others, serving on the CBE Seminar Series Organizing Committee, the Operations Committee, and regularly trains new students. And, importantly, Brian collaborates amiably at the CBE and across campus. He not only demonstrates his deep commitment to excellence in research, Brian is also a responsible, respectful, and conscientious member of the CBE community. In short, he is an outstanding ambassador for lab etiquette at the CBE. Brian has great attention to detail and is an incredibly resourceful, independent scientist.

The Student Lab Citizen Award is open to any CBE student and recognizes a student's exceptional responsibility and good citizenship in his or her work at the CBE. Attributes that are considered in selecting awardees include: attention to laboratory safety and cleanliness, considerate use of shared spaces, respect for equipment and proper protocols, willingness to help fellow students and staff, strong work ethic, and commitment to CBE goals. The award is presented in honor of John Neuman, the CBE's Technical Operations Manager from 1994–2008 and was established by John's family after his death in 2011.

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EDUCATION:

CBE Seminar Series: Fall 2019

Montana State University, Roberts Hall, 312A 4:10 p.m.

Date	Speaker	Affiliation	Title/Topic
Aug 29	Dr. Yakir Ophir	Research Scientist, Biotechnology, Israel Institute for Biological Research	The laboratory of environmental microbiology and biotechnology: An overview of biofilm, biofouling, bio-corrosion and bioremediation research
Sep 5	Dr. William Harcombe	Assistant Professor, Biological Sciences, University of Minnesota	The impact of structure and antibiotics on eco-evolutionary dynamics in a microbial consortium
Sep 12	Dr. Huyen Bui	Research Scientist, Chemical & Biological Engineering, MSU, CBE	Characterization of cross-domain interactions in high pH/high alkalinity algal cultures for biofuel production
Sep 19	Dr. Connie Chang	Assistant Professor, Chemical and Biological Engineering, MSU, CBE	Examining heterogeneous populations of microbes at the single cell level using stabilized emulsions
Sep 26	Dr. Catherine Kirkland	Assistant Professor, Civil Engineering, MSU, CBE	Exploring aerobic granular sludge with magnetic resonance: Progress and future directions
Oct 3	Dr. James McGrath	Professor, Biomedical Engineering, University of Rochester Medical Center	Ultrathin silicon membranes and their application to biosensing and tissue chips
Oct 10	Dr. Phil Stewart	Distinguished Prof., Chemical & Biological Engineering, MSU, CBE	Medical implants, infection, and innate immunity
Oct 17	Dr. Catherine Zabinski	Professor, Land Resources and Environmental Sciences, MSU	Belowground Ecology: Making Sense of Plant Microbe Interactions
Oct 24	Dr. Robert Quinn	Assistant Professor, Biochemistry & Molecular Biology, Michigan State University	Lungs, Germs and Steel: Fighting the cystic fibrosis lung microbiome
Oct 31	No Seminar		
Nov 7	Hannah Goemann	PhD student, Microbiology & Immunology, MSU, CBE	Making sense of the mess: The role of biofertilizers in sustainable agriculture
Nov 14	Undergraduate Research Day	Bekah Anderson	Characterization of microplastic in precipitation
		Lora Frische	3D Printing human sinuses
Nov 21	MaryClare Rollins	Research Associate; Lab Manager, Wiedenheft Lab, Microbiology & Immunology, MSU	CRISPR defense and viral counter-defense
Nov 28	No Seminar- Thanksgiving Holiday		
Dec 5	No Seminar- Last Week of Classes		

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EDUCATION:

CBE Seminar Series: Spring 2020

Montana State University, Linfield Hall 301, 4:10pm

Date	Speaker	Affiliation	Title/Topic
Jan 9	No Seminar		
Jan 16	Dr. Emma Loveday Geoffrey Zath	Postdoctoral Scholar, CBE PhD Student, Chemical & Biological Engineering, MSU, CBE	High-throughput quantification of influenza A virus using drop-based qRT-PCR
Jan 23	Dr. Robin Gerlach	Professor, Chemical & Biological Engineering, MSU, CBE	Biofilms and minerals: From engineered biomineralization applications to studying the role of biofilms in urinary tract stone formation
Jan 30	Dr. Jed Eberly	Assistant Professor, Agronomy & Soil Microbiology, MSU, Central Ag Research Center	Aptamers for environmental sensing
Feb 6	Wilking Lab	Montana State University, CBE	Soft materials and beyond
Feb 13	Dr. Darla Goeres Diane Walker	Associate Research Professor, Chemical & Biological Engineering, MSU; PI, CBE Standardized Biofilm Methods Lab Research Engineer, CBE	Evaluating performance criteria for the cleanliness of reusable medical devices Dry biofilms: challenges of recognition and eradication
Feb 20	Dr. Phil Stewart Dr. Garth James	Regents Professor, Chemical & Biological Engineering, MSU, CBE Associate Research Professor, Chemical & Biological Engineering, MSU; PI, CBE Medical Biofilms Lab	Risk factors for chronic biofilm infections on medical implants In-vitro models of oral biofilms for evaluating antimicrobial susceptibility
Feb 27	No Seminar- 3 Minute Thesis		
Mar 5	Rachel Kratofil	PhD Student, Immunology, University of Calgary	Monocytes are critical for tissue repair following a *Staphylococcus aureus* foreign-body skin infection
Mar 12	Dr. Ellen Lauchnor	Assistant Professor, Civil & Env. Engineering, MSU, CBE	Use of biomineralization in remediation applications
Mar 19	Remaining seminar schedule cancelled due to shutdown related to COVID-19 pandemic		

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TECHNOLOGY TRANSFER:

Industrial Associates, 2019–20

Bold, new *Small business member

3M
Abradem Corp*
American Chemet*
ASP
Baxter Healthcare
BioMendics, LLC
Chem-Aqua
Church & Dwight Company
Clorox
Decon7 Systems*
DeLaval
ICU Medical, Inc.
Lonza
Masco Corporation
Next Science
Novozymes
Olympus
Perfectus Biomed
PPG Industries
Procter & Gamble Company
PureLine Systems*
Quest Medical
SANUWAVE Health*
Sharklet Technologies*
Smith & Nephew
Solvay
Sterilex*
STERIS
The Sherwin-Williams Company
Zimmer Biomet

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TECHNOLOGY TRANSFER:

Montana Biofilm Meeting
July 16–18, 2019

Monday July 15
6:00–8:30 pm
Registration & welcome reception
Larkspur Foyer, Hilton Garden Inn Bozeman

Tuesday July 16
7:30–8:00 am
Registration & continental breakfast
Larkspur Foyer, Hilton Garden Inn

8:00–8:10
Introductory remarks
Larkspur Ballroom
Matthew Fields, CBE Director
Paul Sturman, CBE Industrial Coordinator
Laura Wahlen, Research Scientist, Baxter Healthcare

SESSION 1:
Biofilm Methods

8:10–8:40
Proposed standard method for antimicrobial urinary catheters: ruggedness test results
Darla Goeres, Associate Research Professor, Chemical & Biological Eng., MSU; PI, Standardized Biofilm Methods Laboratory, CBE

8:40–9:10
Monitoring hand hygiene and its effects on healthcare-associated infections (HAI)
Al Parker, Biostatistician, CBE; Asst. Research Professor, Mathematical Sciences, MSU

9:10–9:40
Product-specific method development to assess microbial contamination
Chris Jones, Director of R&D, Sharklet Technologies

9:40–10:10 Networking Break

10:10–10:40
Interlaboratory study results for the Drip Flow Reactor
Diane Walker, Research Engineer, CBE

10:40–11:10
Understanding your production facility's microbiome using 16S metagenomics
Michele Sayles, Executive Director, Food Safety and Quality, Diamond Pet Foods

11:10–11:35
CBE Address
Matthew Fields

Poster Pitches
11:35–12:00
Presented by CBE researchers

12:00–1:00
Lunch, Hilton Garden Inn

SESSION 2:
Wound Biofilms

1:00–1:30
Architecture and phylogenetic structure of chronic wound biofilms
Garth James, Associate Research Professor, Chemical & Biological Eng., MSU; PI, Medical Biofilms Laboratory, CBE

1:30–2:00
Integrating symptom science with innovative molecular measures: Focus on understanding the trajectory of healing vs. non healing in chronic venous leg ulcers
Joyce Stechmiller, Associate Professor, Behavioral Nursing Science, University of Florida

2:00–2:30
Shifting the Paradigm: Chronic wounds are chronic infections caused by biofilm
Randall Wolcott, MD, Medical Director, Southwest Regional Wound Center

3:00–5:00
CBE Open House: Poster session and lab demonstrations
3rd Floor Barnard Hall, MSU
Schedule available onsite

Wednesday July 17
7:30–8:00 am
Registration & continental breakfast
Larkspur Foyer, Hilton Garden Inn

SESSION 3:
Alternative Biocides

8:00–8:30
Sustaining product microbial quality in a dynamic environment
Chuck Pettigrew, Principal Scientist, Procter & Gamble

8:30–9:00
Modern solutions for product protection
Ed Rolls, Global Account Director, Cosmetic Ingredients Division, Symrise

9:00–9:30
Supplier Perspective: Alternatives for preservation
Julie Vaughn Biege, Global Business Development Director, Industrial Products;
Rosanna Stokes, Business Development Manager, Consumer Products, Emerald Kalama Chemicals

9:30–10:00
Biocidal-free future in EU. Wood protection and coating. Why and how?
Berit Lindegaard, Product Mgr., Danish Technological Inst.

10:00–10:30 Networking Break

10:30–11:00
HCPA Microbiology Preservative Subcommittee (MPS): Supporting and enhancing the microbiological quality of consumer, household, and industrial products
Tony Rook, R&D Associate Director, Microbiology, The Sherwin-Williams Co.

11:00–11:30
The design, synthesis, and evaluation of new classes of antimicrobials for the control of biofilms
Tom Livinghouse, Professor, Chem. & Biochem., MSU

11:30–11:50
Presentation of CBE awards
Matthew Fields
11:50–1:00
Lunch, Hilton Garden Inn

SESSION 4:
Young Investigators

1:00–1:30
Oral biofilm-stimulated human gingival epithelium differentially regulates inflammatory responses in co-cultured immune cells
Jason Brown, Research Assistant, University of Glasgow Dental School

1:30–2:00
Investigation of synovial fluid induced *Staphylococcus aureus* aggregate development and its impact on surface attachment and biofilm formation
Matthew Pestrak, Graduate Research Associate, Microbial Infection & Immunity, The Ohio State University

2:00–2:30
Evolution of *P. aeruginosa* in a chronic burn wound model
Erin Gloag, Postdoctoral Researcher, Microbial Infection & Immunity, The Ohio State University

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2:30–3:00
CBE-NBIC scientific and collaborative opportunities
Jeremy Webb, Professor, Microbiology, University of Southampton; Co-Director, National Biofilms Innovation Center

3:30-5:00
Business Meeting
Hilton Garden Inn
6:00
Dinner
Hart Ranch, Gallatin Gateway

Thursday July 18
7:30–8:00 am
Registration & cont. breakfast
Larkspur Foyer, Hilton Garden Inn

SESSION 5:
Biofilms and Host Response

8:00–8:30
Mechanics of biofilm infection
Phil Stewart, Professor, Chemical & Biological Engineering, MSU, CBE

8:30–9:00
Early recruitment of neutrophils prevents *Staphylococcus aureus* biofilm formation
Brian Pettygrove, PhD Student, Microbiology & Immunology, MSU, CBE

9:00–9:30
***P. aeruginosa* and *S. aureus* biofilms and adaptations during chronic infections**
Dan Wozniak, Professor, Microbial Infection & Immunity, The Ohio State University

9:30–10:00
Breaking down the immunobiology of implant fibrosis/foreign body response
Joshua Doloff, Asst. Professor, Biomedical Engineering, Materials Sci. & Engineering, Johns Hopkins University School of Medicine

10:00–10:30 Networking Break

SESSION 6:
Biofilms in Space

10:30–11:00
Development of nanoengineered materials for organisms (NEMO) to resist biofilm formation in space
Kasthuri Venkateswaran, Senior Research Scientist, California Institute of Technology, JPL

11:00–11:30
Management of biofilms in the operation of the ISS water recovery and management system
Layne Carter, ISS Water Subsystem Manager, NASA

11:30–12:00
Design considerations for mitigating biofilm growth on the ISS and future missions
Mononita Nur, Aerospace Engineer, NASA

12:00–12:10
Meeting wrap-up

***1:30-4:30**
NASA Session
Join our NASA speakers and attendees for a brainstorming session on maintaining wastewater systems for extended space flight
Larkspur Ballroom A, Hilton Garden Inn

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WORKSHOP:

BIOFILM GROWTH REACTORS: The Drip Flow Reactor (DFR) and The NEW! Industrial Surfaces Biofilm Reactor (ISBR) July 15, 2019

8:00 – 8:30	Welcome – *Matthew Fields, CBE Director* • Group introductions Workshop Overview – *Paul Sturman*	323 BH
8:30 – 10:15	Statistical Analysis of Standard Methods – *Al Parker* Biofilm Growth Reactors – *Diane Walker* Modifications to the DFR Method – *Elinor Pulcini*	323 BH
10:15 – 10:30	*Morning Refreshments*	323 BH
10:30 – 11:30	Design and Fabrication of Biofilm Reactors – *Darla Goeres & Stephen Pedersen, BST**	323 BH
11:30 - 11:45	Workshop Group Photos Outside (weather permitting)	
11:45 - 1:00	*LUNCH*	Rendezvous Dining Hall

Laboratory Rotations:

A. DFR & Modifications – *Kelsey Meier, Elinor Pulcini & Laura Boegli* — 316 BH
B. ISBR – *Maddie Mettler & Darla Goeres* — 324 BH
C. Imaging DFR Biofilms – *Steve Fisher* — 326/7 BH
D. Microscopy & the ISBR Surfaces – *Heidi Smith* — 326/7 BH

	Group 1	Group 2	Group 3	Group 4
1:00 - 1:45	A	B	C	D
1:45 - 2:30	B	C	D	A
2:30 - 2:45	*Afternoon Refreshments*			323 BH
2:45 - 3:30	C	D	A	B
3:30 - 4:15	D	A	B	C
4:15 – 4:30	Wrap-Up/Discussion			323 BH

**BioSurface Technologies Corporation, Bozeman, MT*

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TECHNOLOGY TRANSFER:

Biofilm Technologies: Pathways to Product Development
February 5-6, 2020 Arlington, VA
Hyatt Regency Crystal City

Tuesday February 4

7:30-8:00 am
Registration & Cont. Breakfast Regency Foyer

8:00–8:15 am
Introductory remarks
Matthew Fields, CBE Director
Paul Sturman, CBE Industrial Coord.
Regency F Ballroom

SESSION 1
Perspectives on Biofilm, Regulation, and Research

8:35-9:20 am
Medical biofilms: Insights from the first two decades of the millennium
Robin Patel, Chair, Division of Clinical Microbiology, Professor, Microbiology & Medicine, Mayo Clinic

9:20-9:55 am
Moving towards meaningful standards for preclinical performance testing of anti-biofilm medical devices and combination products
Scott Phillips, Regulatory Research Scientist, Center for Device & Radiological Health, US FDA

9:55–10:20 am Break

10:25-11:00 am
Antimicrobial method development initiatives
Steve Tomasino, Senior Scientist, Office of Pesticide Programs,
US EPA

11:00-11:30 am
Biofilm claims, who cares?
A commercial perspective
Elaine Black, Senior Regulatory Manager, Ecolab

11:30-12:00 pm
An innovative company's perspective on biofilm regulation
Matt Myntti, Chief Technology Officer, Next Science

12:00–1:00 pm
Lunch, Regency E Ballroom

SESSION 2
Food-Related Biofilms

1:00-1:35 pm
Dry biofilms: Challenges of recognition and eradication
Diane Walker, Research Eng., CBE

1:35-2:10 pm
Evaluation of the effect of chlorine dioxide gas and a liquid probiotic application on hydrated and dehydrated biofilms
Michele Sayles, Executive Director, Food Safety & Quality, Diamond Pet Foods

2:10-2:45 pm
Persistent vs. transient listeria monocytogenes in food processing facilities: What makes the difference?
Dumitru Macarisin, Research Microbiologist, Center for Food Safety & Applied Nutrition,
US FDA

2:45-3:15 pm Break
Sponsored by Decon7 Systems

3:15-3:50 pm
Control of microbial hazards on low moisture processing equipment through non-aqueous cleaning and sanitation
Elizabeth Grasso-Kelley, Assistant Professor, Food Science & Nutrition, Illinois Institute of Technology

3:50-4:25 pm
Drinking water pipeline and premise plumbing decontamination of Bacillus globigii
James Goodrich, Senior Science Advisor, Wide Area & Infrastructure Decontamination Branch, US EPA

5:00 pm Networking Reception
Chesapeake View Room

Wednesday February 6

7:30-8:00 am
Registration & Cont. Breakfast Regency Foyer
Meeting, Regency F Ballroom

SESSION 3
Biofilm Infection
8:00-8:35 am
Risk factors for chronic biofilm infections on medical implants
Phil Stewart, Regents Professor, Chemical & Bio. Eng., MSU, CBE

8:35–9:10 am
Lighting up the lung:
Developing optical tools for real-time, point-of-care detection of lung disease in the clinic
Bethany Mills, Postdoctoral Researcher, Optical Imaging PROTEUS Hub, University of Edinburgh Queens Medical Research Institute

9:10–9:45 am
A regulatory overview of infection control medical devices
Yongqing Chen, Scientific Regulatory Reviewer/Biologist, Center for Device & Radiological Health, US FDA

9:45–10:20 am Break

10:20-10:55 am
Use of the hollow fiber infection model to study emergence of resistance using humanized pharmacokinetic profile of antibiotics
Tesfalem Zere, ORISE Research Fellow, Center for Drug Evaluation & Research, US FDA

10:55-11:30 am
Busting biofilms—winning the war in wounds
Greg Schultz, Professor, Obstetrics & Gynecology, College of Medicine, University of Florida

11:30-12:00 pm
Development and characterization of complex wound biofilm models
Petra Kohler-Riedi, Senior Research Specialist, 3M

12:00–1:00 pm
Lunch, Regency E Ballroom

SESSION 4
Oral Biofilm
1:00-1:35 pm
In vitro models of oral biofilms for evaluating antimicrobial susceptibility
Garth James, Associate Research Professor, Chemical & Biological Engineering, MSU; PI, Medical Biofilms Laboratory, CBE

1:35-2:10 pm
Targeting oral biofilms using nanotechnology
Hyun (Michel) Koo, Professor, Orthodontics; Director, Center for Innovation & Precision Dentistry, School of Dental Medicine, University of Pennsylvania

2:10-2:45 pm
Oral biofilm models for testing mechanical disruption on structure and community
Paul Stoodley, Professor, Microbial Infection and Immunity, Ohio State University

2:45–3:15 pm Break

SESSION 5
Reusable Medical Devices
3:15-3:45 pm
Evaluating performance criteria for the cleanliness of reusable medical devices
Darla Goeres, Associate Research Professor, Chemical & Biological Eng., MSU; PI, Standardized Biofilm Methods Laboratory, CBE

3:45-4:15 pm
Quality control of endoscope reprocessing: Three-hospital clinical study using rapid, point-of-reprocessing methods to detect protein and biofilm
Sang Won Lee, PhD Student, Biomedical & Chemical Engineering, Syracuse University

4:15–4:45 pm
Medical devices containing antimicrobials–A regulatory perspective
Ramesh Panguluri, Microbiologist/Team Lead, Disinfection, Reprocessing and Personal Protection Equipment Devices Team, Center for Device & Radiological Health, US FDA

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TECHNOLOGY TRANSFER:

NEWS HIGHLIGHTS

CBE industrial associate earns antibiofilm efficacy claim

CBE industrial associate Next Science, a biotechnology company, received notification from the Environmental Protection Agency that its hospital cleaner surface disinfectant LMN8 has been accepted for registration. The product has also received clearance to include a claim for effectiveness against biofilm on its labeling. Unlike disinfectants such as bleach, LMN8 is a non-toxic product that uses patented technology to eliminate biofilm-based bacteria by attacking the biofilm matrix to expose the bacteria within, making it more vulnerable to attack and eradication. The product's effectiveness against many types of bacteria, including *S. aureus* and *E. coli*, has been validated by clinical testing, Food and Drug Administration clearances, and more than 130,000 patient treatments since 2017. The EPA requires antibiofilm products pass a standardized testing method developed by the CBE prior to including an efficacy claim on its label.

CBE member awarded $17M for drug development to treat cystic fibrosis

CBE industrial associate Microbion, a clinical-stage pharmaceutical company located in Bozeman, was awarded more than $17 million in grant funding to complete preclinical and Phase 1 clinical studies of its inhaled antimicrobial medication pravibismane for treating cystic fibrosis (CF) patients with lung infections. Read more on Microbion's website

CBE welcomed new members to its Industrial Associates Program:

Novozymes**,** a global biotechnology company headquartered in Bagsværd outside of Copenhagen, Denmark, joined the Center for Biofilm Engineering's Industrial Associate program in April 2020. Their focus is the research, development and production of industrial enzymes, microorganisms, and biopharmaceutical ingredients. Novozymes becomes the 31st company currently participating in the innovative CBE Industrial Associate program. Novozymes previously was a CBE Industrial Associate from 2005 to 2016. The CBE designated representative from Novozymes is **Lorena Gonzalez Palmen**.

LivaNova, a medical supply company with 4,000 employees worldwide, became an Industrial Associate of the Center for Biofilm Engineeringin November 2019. LivaNova is recognized globally as a leader in cardiovascular and neuromodulation solutions designed to create meaningful healthcare products and therapies. LivaNova manufactures heart-lung machines and, according to its website, is recognized as the world's #1 cardiopulmonary bypass company. It also manufactures "a truly sutureless" aortic valve replacement known commercially as Perceval®. LivaNova also develops medical device solutions for people affected by drug-resistant epilepsy and treatment-resistant depression.

BioMendics is dedicated to the treatment of acute wounds, burns, antibiotics and inflammatory skin conditions. The company's lead product in development, TolaSure™, is a patented topical gel containing small-molecule liquid crystals that help promote all phases of the healing process. **Karen McGuire** is the CBE designated representative.

Perfectus Biomed is a GLP-compliant and UKAS accredited ISO 17025 contract testing laboratory. They provide standard and customized microbiology testing services to a variety of sectors including wound care, medical devices, cosmetics, disinfectants, and oral care. **Samantha Westgate** is the CBE designated representative.

Quest Medical manufactures medical devices, including heater/cooler units that regulate blood temperature and circulation during open heart surgery. **Jan Hodges** is the CBE designated representative.

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TECHNOLOGY TRANSFER:

Industry and Agency Interactions

CBE Visits to Industry/Agencies

Heidi Smith, CBE imaging core manager, and **Paul Sturman**, CBE industrial coordinator, were invited to present at Sherwin- Williams, Cleveland, OH, September 10-12,2019:

Heidi Smith presented: "CBE Imaging Capabilities: An Overview."
Paul Sturman presented: "Biofilm growth, visualization and response to antimicrobial treatment."

Paul Sturman as an invited speaker present "Biofilm growth and response to antimicrobial treatment," during L'Oreal's Hygiene Week in Newark, NJ, Oct 1-3, 2019.

Matthew Fields, CBE director, was invited to participate in the Tri-Service Microbiome Conference Oct. 23, at the Air Force Research Laboratory in Dayton, OH. The Tri-Service Microbiome Consortium (TSMC) was established in 2017 to enhance collaboration, coordination, and communication of microbiome research among Department of Defense (DoD) organizations. The TSMC aims to serve as a forum for sharing information related to DoD microbiome research, policy, and applications, to monitor global advances relevant to human health and performance, to identify priority objectives, and to facilitate Tri-Service (Army, Navy, and Air Force) collaborative research. Matthew presented "Identifying causative relationships and active populations in polymicrobial communities."

Neerja Zambare, MSU-CBE PhD student in chemical and biological engineering, received an MSU Dean's Professional Advancement Grant to conduct microanalysis on microbially produced calcium carbonate precipitates at the Environmental and Molecular Sciences Laboratory at Pacific Northwest National Laboratory Oct. 27–30 in Richland, Washington.

Industry/Agency Visits to CBE

Dimitris Tsintikidis, Joanna Ptasinski, Meriah Arias-Thode, and Rob George from the Naval Information Warfare Center visited the center. Their CBE host was Matthew Fields. (Dec. 17, 2019)

Robert Kokoska, US Army Research Office. CBE host: Matthew Fields. (Dec. 5, 2019)

Takashi Abe and **Takashi Kinebuchi**, Olympus. CBE host: Paul Sturman. (Nov. 19, 2019)

Steve Reese, Idaho National Laboratory. CBE host: Paul Sturman (Oct. 31, 2019

Patricia Falcone, **Rita Foster**, and **Chenlin Li** from the Idaho National Laboratory and **Tonya Nichols** from the US EPA visited the center. Their CBE host was Matthew Fields. (Oct. 7, 2019)

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OUTREACH:

News Highlights

Final COST Action AMiCi conference, Krakow, Poland

Matthew Fields, CBE director and professor of microbiology & immunology, as a committee member presented "U.S. perspectives on antimicrobial coatings," at the final COST Action AMiCi conference, Krakow, Poland, February 18–20, 2020. COST is the longest-running European framework supporting trans-national cooperation among researchers, engineers, and scholars across Europe. AMiCI stands for Anti-Microbial Coating Innovations to prevent infectious disease. The group's aim is to evaluate the impact of (introducing) antimicrobial coatings in healthcare, the spread of infections and on the efficacy in fighting healthcare associated infections and bacterial resistance to current antibiotics. Matthew was invited to join COST AMiCi as a U.S. collaborator.

MSU Science Day for 5th Graders

Faculty and students provided hands-on learning for MSU's annual Science Day for 5th Graders event held February 27, 2020. The day-long event was held on MSU's campus and aims to help fifth graders learn more about science in a fun and easy-to-understand format. Several CBE students and faculty showcased their research through a variety of engaging demonstrations and experiments.

Adie Phillips, assistant professor in civil engineering, and **Arda Akyel**, PhD student in chemical and biological engineering, demonstrated the process of biomineralization and how it can solve real-world problems. Adie and her team are engineering calcium carbonate, a common compound found in rocks, to form a cement that can seal cracks in oil and gas wells.

Rebecca Mueller, assistant research professor in chemical and biological engineering, used food to demonstrate the complexity of the organisms in Yellowstone National Park. She handed out multi-dyed cupcakes, which were made to represent the different microbial layers of bacteria in Yellowstone, with green as the top layer representing light-seeking organisms, and different colors beneath representing different types of chemical reactions within the organism.

Shawna Pratt, PhD student in chemical and biological engineering, helped the fifth graders build electrical circuits using Play-dough. They attached wires to forms of dough and connected batteries to power small LED lights and small buzzers.

Journal highlights CBE history, biofilm research

The open-source research journal *Biofilm* highlighted the history of the Center for Biofilm Engineering in a comprehensive article "The establishment of the CBE launched biofilms as a field of specialized research." The article focuses on the history of biofilm research, which began in earnest in 1990 when the National Science Foundation awarded Montana State University a $7.2 million grant to establish a biofilm-focused Engineering Research Center on its campus. The NSF ERC grant was the largest grant in the school's 96-year history. The CBE is celebrating the 30th anniversary of its founding throughout 2020.

Biofilm Bash: Researchers publish paper on 'the future of biofilm research'

In May 2019, twenty-nine of the world's leading biofilm researchers met in Leavenworth, Washington to identify the most fertile areas for future research. Invited researchers from Australia, Belgium, Denmark, the Netherlands, Portugal, the United Kingdom, and the United States were present, including Matthew Fields, Darla Goeres, and Phil Stewart from the Center for Biofilm Engineering. Read about the future of biofilm research at Biofilm

Faculty connect with Asian biofilm researchers

Al Parker, CBE biostatistician, visited China to present on biofilms and statistics at two conferences. He gave an invited talk "Bayesian analysis and design of experiments of biofilms over space and time," at the 5th International Symposium on Inverse Problems, Design and Optimization on Sept. 25, in Tianjin, China. He then partnered with Drs. Birthe Kjellerup and Paul Stoodley to present a workshop "Biofilm reactor systems, analytical tools and reproducibility," at the 2nd International Conference on Biofilms, Oct. 10 in Guangzhou, China. He also gave a talk at that conference titled "After the biofilm: bacterial transfer, infections and hand hygiene in a healthcare environment."

CBE builds on collaboration with University of Stuttgart

Al Cunningham, professor emeritus in MSU's Department of Civil Engineering, was awarded a Mercator Fellowship from SFB 1313 at the University of Stuttgart. Al is a founding member of the CBE and serves on the CBE Executive Committee, which is responsible for coordinating center research, education, and industry projects.

SFB 1313 is an interdisciplinary Collaborative Research Centre at Stuttgart, consisting of four major project areas—free flow and porous-media flow, fracture propagation and fluid flow, fluid-solid phase change and benchmarks, computing, and visualization. The center is funded by the by the German Research Foundation (DFG). The SFB 1313 team consists of 48 researchers from 18 different institutes at Stuttgart and partner universities.

Mercator Fellowships enable an intensive, long-term project-based collaboration between researchers from both domestic and foreign institutions. Al, along with Dr. Robin Gerlach in MSU's Chemical and Biological Engineering Department and Dr. Adie Phillips in MSU's Civil Engineering Department, have been instrumental in the long-standing collaboration between the work groups of Holger Class and Rainer Helmig at Stuttgart and the center. The intensive scientific exchange has resulted in a number of high-ranked joint publications.

Al's fellowship will focus on porosity-permeability relations and experiments will partly be conducted at the CBE. The team will investigate dynamic changes in porosity and associated changes in pore-water-velocity distributions with MRI and XRCT in order to determine permeability changes. Experiments on salt precipitation during evaporation and Microbially-Induced Calcite Precipitation (MICP) in porous glass-bead systems will be carried out using micro-fluidic cells.

CBE Faculty provide guidance to graduate review panel at University of Porto

Darla Goeres, associate research professor in chemical and biological engineering, and **Matthew Fields**, CBE director, were invited to participate in a graduate student review session hosted by the Biofilm Engineering Lab at the University of Porto, in Porto, Portugal June 9–15, 2019. Goeres and Fields were part of an audience that provided feedback to graduate students on their research presentations. The two were also invited to give a talk to the group. Goeres presented "Effective technical presentations," and Fields presented "Metabolic interactions and activity partitioning in a methanogenic, interdomain biofilm."

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OUTREACH:

Visiting Researchers

Visiting Faculty

Scott Wade, associate professor, Swinburne University, Melbourne, Australia
Home department: Telecommunications, Electrical, Robotics, and Biomedical Engineering
Area of study: Corrosion and investigating microbially influenced corrosion (MIC) and the development of new sensing systems.
CBE host: Matthew Fields, CBE director
Visiting July 2019–December 2019

Visiting Student Researcher

Ondřej Chlumský, PhD student
Home university: University of Chemistry & Technology, Prague, Czech Republic
Research focus: Interaction of nanoparticles modified by natural compounds with biofilms of pathogenic microorganisms.
CBE host: Jim Wilking, assistant professor, chemical and biological engineering
Visiting March 2020-August 2020

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OUTREACH:

Web image library use 2019–2020

Total image downloads: **238**

Requests for CBE graphics were submitted from **27** of the U.S. states:

Alabama	Indiana	New York
Arizona	Louisiana	North Carolina
Arkansas	Maryland	Ohio
California	Massachusetts	Pennsylvania
Colorado	Michigan	South Dakota
Florida	Minnesota	Tennessee
Georgia	Missouri	Texas
Idaho	Montana	Virginia
Illinois	New Jersey	Washington

There were requests from an additional **34** countries:

Afghanistan	Chile	Netherlands
Andorra	China	New Zealand
Argentina	Czech Republic	Norway
Australia	Denmark	Portugal
Austria	Finland	Russia
Azerbaijan	France	Singapore
Bahamas	Germany	Switzerland
Bangladesh	India	Turkey
Belgium	Iran	United Arab Emirates
Bosnia and Herzegovina	Ireland	United Kingdom
Brazil	Japan	
Canada	Mexico	

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FACILITIES:

Facilities Overview

Located in Barnard Hall next to the Strand Union Building, the Center for Biofilm Engineering comprises more than 20,000 square feet, and includes offices and conference rooms for faculty, staff, and students; a computer lab; and 15 fully equipped research laboratories and at least 9 additional directly affiliated laboratory spaces. CBE Core Facility labs include an analytical instrument lab, a microbiology lab with media preparation area and autoclaves, microscope facilities, as well as an isolated radioactive isotope lab with liquid scintillation counter. See below for a comprehensive list of shared equipment available.

Analytical and Molecular Core

The analytical core lab is a dedicated space with instruments that are maintained by the CBE Technical Operations Manager. Users including students, staff and faculty are trained to prepare their samples and standards, run instruments, analyze data and troubleshoot data analysis and methods by the TOM. There are three gas chromatographs with detectors including Mass Spectrometer, Thermal Conductivity and tandem thermal conductivity/Flame Ionization for analysis of permanent gases, ethylene/acetylene or fatty acid methyl esters on the MS detector. Liquid chromatography capabilities are extensive with two instruments that can be configured for various analysis including amino acids, organic acids, alcohols, carbohydrates, cannabinoids, industrial compounds of interest and photosynthetic pigments. The more basic system includes tandem Variable Wavelength Detector (UV) and Refractive Index Detector with a high-pressure quaternary pump. The more advanced HPLC has a temperature controlled, programmable autosampler for performing pre-column derivatizations in the sample needle, for detection with the highly sensitive and tunable multi-channel Fluorescence Detector. There is a dedicated Anion Ion Chromatography system and Total Carbon Analyzer that is configured for either non-purgeable organic carbon or dissolved inorganic carbon measurements. Spectrophotometers in the core are capable of visible and fluorescence measurements in vessels including cuvettes, test tubes and microwell plates. The plate reader can also measure luminescence as perform kinetic time scans. For small measurements a microbalance is available as well as a micro pH meter that can measure pH in as little as 10uL.

The primary molecular core lab includes advanced instrumentation for nucleic acid, extraction and detection, including an Illumina MiSeq Sequencing System as described in further detail below. The molecular core also includes an Agilent 2100 Bioanalyzer, MP Biomedical FastPrep 24 beadbeater and Oxford Nanopore Technologies MinION real-time sequencing device. A molecular satellite station includes two thermocyclers, a gel running and imaging station, and spectrophotometers for nucleic acid quantification. **Contact:** Kristen Brileya

Microscope Core

The microscopy and chemical imaging facilities are coordinated by the Microscopy Facilities Manager who maintains the equipment and trains and assists research staff and students in capturing images of in situ biofilms via optical microscopy, fluorescent and Raman confocal microscopy. The microscopy facilities include four separate laboratories—the Optical Microscopy Lab, the Confocal Microscopy Lab, the Chemical Imaging Lab, and the Microscope Resource Room and Digital Imaging Lab—which are detailed below.

The Optical Microscopy Lab houses a newly acquired Leica Thunder widefield microscope optimally configured for allow real-time, high-sensitivity, high-throughput imaging. This microscope is equipped with a cMOS Camera, a Tunable multiline LED Light Source, an ultraprecise, triggerable stage, has complete Hardware Synchronization and is fully enclosed to maintain temperatures between ambient 5-50□C (± 0.1°C), humidity (specifically designed to prevent condensation), and CO2/Air or hypoxic/hyperoxia conditions, and real time computational removal of out of focus background and increased imaging depth of thicker specimens. The acquisition speed is nearly five times faster than a conventional Confocal Scanning Laser Microscope (CSLM). Experiments that would normally take hours to visualize on a CSLM can be accomplished in minutes by the widefield Thunder microscope. For example, to image 96 wells, one position per well, 10 z-planes per well, and three channels per well would take only 3.5 min on the proposed THUNDER imager system. This system is ideally configured for improved live cell viability for longer term imaging studies due to advanced 'under microscope' incubation capabilities and reduced phototoxicity and photobleaching by limiting light doses.

An upright, Leica DM6 fluorescent microscope that is a fully automated with constant color temperature and fully automated transmitted light- and fluorescence axis, with motorized Z-focus.

A Nikon Eclipse E-800 research microscopes which are used for transmitted light and epi-fluorescent imaging. Both microscopes are equipped with Photometrics MYO cooled CCD cameras and use Universal Imaging Corporation's MetaVue software (v 7.4.6) for digital image acquisition. We have a large collection of fluorescence filter cubes for the Nikons, including those optimized for the following fluorescent stains: FITC (gfp), TRITC (propidium iodide), DAPI, CTC, ELF-97, CY5, cfp, and we also have a B2E cube. Both Nikons are equipped with Nomarski/DIC, and we have a 100x oil phase contrast objective and condenser especially for use with imaging spores.

A Leica LMD6 Laser Microdissection System equipped with a color camera, fluorescence filter cubes (FITC, TRITC, DAPI), and a UV laser for sample dissection.

A GAN210 Optical Coherence Tomography (OCT) imaging system. OCT is a high resolution, non-contact, non-invasive, and non-fluorescent based technique that is well suited for imaging thick specimens. The OCT light source centered around 930 nm with a bandwidth >100 nm and has a scan rate of up to 36 kHz with an axial field of view of 2.9 mm / 2.2 mm. Depending on the scan objective the field of view (FOV) and resolution can be adjusted and vary between a larger FOV of 16x16 mm^2 at 12 µm resolution, and a FOV of 10x10 mm^2 with a higher resolution of 8 µm.
Additionally, within the Optical Microscopy Lab is a Leica M 205 FA computer-controlled stereomicroscope and a Leica DFC3000G fluorescence camera. This stereoscope can be used to image samples using fluorescence, brightfield with or without polarization or Rotterman contrast, and reflected white light. The software will also allow a z-stack of images to be collected and recombined using simple deconvolution. Other equipment in the Optical Microscopy Lab includes a Nikon SMZ-1500 barrel zoom stereomicroscope equipped with a color camera, a Leica cryostat, and a dry ice maker.

The Confocal Microscopy Lab contains two Leica SP5 Confocal Scanning Laser Microscopes (CSLMs). One is an inverted confocal microscope with 405, 488, 561 and 633 nm laser excitation lines. It is equipped with a tandem scanner, so it can be switched from standard scanning mode to operate in Resonant Scanner mode, which enables scanning at exceptionally high frequencies for fluorescent imaging. This faster scanning is necessary for most live cell imaging (note: "live cell imaging" doesn't generally refer to imaging bacterial cells, but rather mammalian cells and processes). This inverted SP5 also includes a heated stage with an environmental control chamber (i.e. it can be used to provide an enclosed CO2 atmosphere), and a motorized stage with Mark-and-Find and image tiling capabilities.

The second SP5 is an upright confocal microscope, also with 405, 488, 561 and 633 nm lasers, a motorized stage, Mark-and-Find, and tiling capabilities. This upright has a removable heated chamber that encloses the entire microscope, so that larger, incubated flow cell systems can be accommodated over long periods of time. This enables high-resolution time-lapse monitoring of biofilm development, treatment and detachment phenomena. Additionally, this microscope is equipped with Fluorescence Lifetime Imaging (FLIM) capability, which is also referred to as Single Molecule Detection.

The CSLM is capable of imaging biofilms on opaque surfaces, so a wide variety of materials can be used in the experimental flow cells. As biofilm formation proceeds in an experiment, representative areas of the colonized surface are scanned with the use of the automatic stage. Digital data is collected from sequential scans, and stored data can be viewed in the x, y, z coordinates to yield a 3-dimensional image of the biofilm architecture. Quantitative and qualitative information about biofilm architecture can be retrieved easily from examination of CSLM data, in both the x-y and x-z planes, and the existence or absence of structural features, such as microcolonies and water channels, can be determined.

The Chemical Imaging Laboratory contains two Raman Microscopes. One is a Horiba LabRam HR Evolution NIR that is dedicated to studying the molecular composition of a sample. This is a fully integrated high resolution Raman microscope for confocal Raman analysis, optimized for the visible to IR range (400nm-2500nm) microscope. Includes confocal Raman microscope with an automated xyz-stage with fast-mapping capabilities, transfer optics, stigmatic spectrometer equipped with two gratings (600 and 1800 l/mm gratings), multichannel air-cooled CCD detector, and computer package with the latest version of the LabSpec6 software and the KnowItAll Raman spectra library, Horiba edition. It is equipped with 532nm 100mW laser, HeNe 633nm laser, 785nm 90mW laser, and 10x, 50x, 100x, 20xLWD and 50xLWD objectives. The second Confocal Raman Microscope is dedicated to studying the metabolic activity of single microbial cells as well as a cell's health/disease state. This is a modified Horiba LabRam Evolution Confocal Raman microscope and is equipped with a 500mW 532nm laser, a 100mW 785nm laser, ultra-low frequency filters for stokes and anti-stokes measurements, an air-cooled open electrode CCD, a deep-cooled back-illuminated EMCCD multichannel detector, 300 and 1800 gr/mm grating, an automated xyz-stage with fast-mapping capabilities, filter sets for FITC, CY3, DAPI, and Cy5, 10x, 50x, 63x (long working distance), and 100x objectives, and a CaptuR laser trapping (1,500mW, 1,064nm) system (=optical tweezer). The computer workstation is equipped with the latest version of the LabSpec6 software with an integrated multivariate analysis module, a particle finder

module, as well as a KnowItAll Raman spectra library, HORIBA Edition.

The Microscope Resource Room / Digital Imaging Lab is where CBE researchers examine and reconstruct the stacks of image data they have collected using our image analysis software. For quantitative analysis, such as intensity or particle-size measurements, we use Universal Imaging Corporation's MetaMorph software. We use Bitplane's Imaris software for computer-intensive data analysis like particle tracking and for qualitative analysis—for example, putting together a stack of 200 red and green flat images to get a 3-dimensional image of a biofilm microcolony that can be rotated in space and examined from every angle. The lab consists of three dedicated computers, a server for storing large files, CD and DVD burners and readers, and a color printer. In addition to providing CBE students, staff, and researchers with an imaging workplace, the resource room gives us a place to hold group tutorials and WebEx group software training sessions.

Contact for Microscopy Core: Heidi Smith

Specialized CBE Laboratories

Ecology/Physiology Laboratory

The Ecology/Physiology Laboratory led by Dr. Matthew Fields has general microbiology equipment, anaerobic gassing stations in two lab spaces, Ultra-Centrifuge, Anaerobic Chamber, biofilm reactors, protein and DNA electrophoresis, Qubit fluorometer, two Eppendorf Mastercylcers, and a microcapillary gas chromatograph with dual TCDs. The lab has light-cycle controlled photo-incubators as well as photo-bioreactors for the cultivation of algae and diatoms.

This laboratory houses an Illumina MiSeq Sequencing System in its shared molecular core area. The MiSeq desktop sequencer allows the user to access more focused applications such as targeted gene sequencing, metagenomics, small genome sequencing, targeted gene expression, amplicon sequencing, and HLA typing. This system enables up to 15 Gb of output with 25 M sequencing reads and 2x300 bp read lengths by utilizing Sequencing by Synthesis (SBS) Technology. A fluorescently labeled reversible terminator is imaged as each dNTP is added, and then cleaved to allow incorporation of the next base. Since all four reversible terminator-bound dNTPs are present during each sequencing cycle, natural competition minimizes incorporation bias. The end result is true base-by-base sequencing that enables the industry's most accurate data for a broad range of applications. The method virtually eliminates errors and missed calls associated with strings of repeated nucleotides (homopolymers). **Contact:** Sara Altenburg

Medical Biofilm Laboratory

The Medical Biofilm Laboratory (MBL) has earned a reputation for being a university lab that focuses on industrially relevant medical research in the area of health care as it relates to biofilms. Dr. Garth James (PhD, microbiology), Randy Hiebert (MS, chemical engineering), and Dr. Elinor Pulcini (PhD, microbiology) have been the innovative leaders and managers of this respected, flexible, and adaptable lab group. The MBL team also includes a full-time Associate Research Professor, a Research Professional, a Research Associate, and two Undergraduate Research Assistants.

Currently, eighteen companies, including CBE Industrial Associates, sponsor MBL projects. These projects include evaluating antimicrobial wound treatments and dressings, prevention of biofilm formation on medical devices, evaluation of biofilm formation in endoscopes, testing endodontic irrigants, evaluating virus transfer from surfaces, and testing biofilm prevention and removal agents. The MBL is a prime example of integration at the CBE, bringing together applied biomedical science, industrial interaction, and student educational opportunities. **Contact**: Garth James

Standardized Biofilm Methods Laboratory

The Standardized Biofilm Methods Laboratory (SBML) was designed to meet research and industry needs for standard analytical methods to evaluate innovative biofilm control technologies. SBML staff and students develop, validate, and publish quantitative methods for growing, treating, sampling, and analyzing biofilm bacteria. The SBML members work with international standard setting organizations (ASTM International, ISO) on the approval of biofilm methods by the standard setting community. Under a contract with the U.S. Environmental Protection Agency (EPA), the SBML provides statistical services relevant to the EPA's Office of Pesticide Programs Microbiology Laboratory Branch to assess the performance of antimicrobial test methods—including those for biofilm bacteria. The SBML received funding from the Burroughs Wellcome Foundation to develop a method for assessing the prevention of biofilm on surface modified urinary catheters that was approved in 2021 as ASTM Standard Test Method E3321. In addition, they conduct applied and fundamental research experiments and develop testing protocols for product specific applications. Methods include: design of reactor systems to

simulate industrial/medical systems; growing biofilm and quantifying microbial abundances and activity; testing the efficacy of chemical constituents against biofilms; and microscopy and image analysis of biofilms. SBML staff offer customized biofilm methods training workshops for CBE students, collaborators, and industry clients. **Contact:** Darla Goeres

Microbial Ecology and Biogeochemistry Laboratory

Research in the Microbial Ecology and Biogeochemistry Laboratory (www.foremanresearch.com) lies at the intersection of microbial ecology and engineering and uses a combination of field and laboratory studies, as well as approaches ranging from the single-cell to the community level. Staff in this lab are interested in understanding how the environment controls the composition of microbial communities and how, in turn, those microbes regulate ecosystem processes such as nutrient and organic matter cycling. Ongoing research examines carbon flux through microbial communities, with the long-term goal of improving predictions of carbon fate (metabolism to CO2, sequestration into biomass, long-term storage in ice) in the context of a changing environment. Additionally, the lab is interested in physiological adaptations to life in extreme environments, biofilms in space, microbial biosurfactants, genomics and spectral detection of organic compounds. **Contact**: Christine Foreman

Environmental Sensing Laboratory

Sensors are essential for understanding and predicting environmental changes by measuring biological, chemical, and physical properties. The Warnat laboratory develops microfabricated sensor systems that allow *in situ* measurements with a high spatial and temporal resolution in various harsh environments such as water systems, snow and ice, soil, or maple syrup lines. Sensors can be integrated into microfluidic environments that allow measurements of ultra-small volumes and simultaneous visualization of biological processes on the sensor surfaces using high-resolution microscopy. Ongoing research examines in collaboration with CBE colleagues how fabricated sensor systems can be integrated into various biofilm-forming environments to detect initial biofilm attachment and provide an electrical feedback signal for potential biofilm mitigation strategies. **Contact:** Stephan Warnat

Microfluidics Laboratory

Dr. Connie Chang runs a soft materials and microfluidics laboratory to study microbes (bacteria, biofilms, and viruses). Dr. Chang is applying drop-based microfluidics—the creation and manipulation of picoliter-sized drops of fluid—for high-throughput screening and assaying in biology. Her lab is developing novel tools for quantifying the behavior of individuals and how they can collectively contribute to large-scale population dynamics. Ongoing projects within her group include the screening of persister and dormant bacteria cells in biofilms and the study of influenza evolution and population dynamics.

Dr. Chang has shared laboratory space in the CBE and an individual laboratory space in the Chemistry and Biochemistry Building (CBB) at MSU. The laboratory spaces include common space for equipment, chemical storage, freezers and reagents. The lab is outfitted with a qPCR machine and also includes a dedicated a room for epifluorescence microscopy and a custom built microscope stand (200 square feet). The lab contains all the equipment and instrumentation necessary for fabrication of new devices, microfluidics handling, PCR, and cell culture. **Contact:** Connie Chang

Bioprocess and Biofilm Technology Laboratory

Dr. Gerlach oversees the Bioprocess and Biofilm Technology Laboratory (BBTL), which is a set of laboratories focusing on the development of engineering applications, relevant for industry, the environment and medicine. The BBTL develops and improves engineering processes based on the use of traditional chemical, biological and mechanical process-schemes through combination with biofilm- and biomineralization-specific aspects. Work in the BBTL cuts across all domains of life with current foci on fungi, algae, and -of course- bacteria and archaea. The BBTL was essential in the development and commercialization of a biocement-based well-sealing technology (BioSqueeze®) and is currently focusing on the development of biocement-based infrastructure materials. Algal biofuel and bioproduct generation are additional research and development topics with a current focus on high pH/high alkalinity adapted extremophiles as well as the capture of carbon dioxide directly from the air. The BBTL facilitates fundamental and applied research, and has specialized equipment available that includes small and large-scale, high pressure and high temperature bio- and biofilm-reactors and incubators capable of supporting (photo)autotrophic and heterotrophic growth experimentation, porous media micromodels, flowcells, etc. suited for the cultivation of biofilms and microorganisms, Gas Chromatographs with Mass Spectrometric (GC-MS), electron capture (ECD) and flame ionization detectors (FID), an elemental analyzer (EA), a Thermal Gravimetric Analyzer (TGA), a Raman microspectroscopy instrument, a Fourier-Transform Infrared (FTIR) spectrometer, an ion chromatograph, an automated titrator, fluorescence and absorbance plate readers, as well as all necessary standard chemical analysis and cultivation capabilities necessary for biofilms and microbe cultivation, including capabilities for the

cultivation of microaerophilic or anaerobic microbes (modified Hungate setup and anaerobic glovebag). The use of advanced molecular biology techniques including next generation sequencing for community analyses, metagenomics and transcriptomics are applied routinely in combination with next generation physiology techniques. **Contact**: Robin Gerlach

Microsensor Laboratory

The Microsensor Laboratory provides the capability of measuring microscale chemical and physical parameters within biofilms, microbial mats and other compatible environments. The Microsensor Laboratory has the capability to measure spatial concentration profiles using sensors for oxygen, pH, hydrogen sulfide, nitrous oxide and some custom-made electrodes. All electrodes are used in conjunction with computer-controlled micromanipulators for depth profiling. A Leica stereoscope is used to visualize the sensors while positioning them on the biofilm surface. The laboratory has experience with diverse microsensor applications including biofilms in wastewater, catheters and hollow fiber membrane systems in addition to algal and fungal biofilms. **Contact:** Kristen Brileya

Environmental Microbiology Lab

The research activities of the Environmental Microbiology Lab headed by Dr. Roland Hatzenpichler focuses on microbial ecophysiology, the study of the physiology of microorganisms with respect to their habitat. We are interested in how the activity of the "uncultured majority" – the large number of microbes that evades cultivation under laboratory conditions – impacts humans and the environment on a micron to global scale. We are convinced that only by gaining an understanding of microbes directly in their habitats researchers will be able to elucidate the mechanisms of microbial interactions with the biotic and abiotic world. To accomplish these goals, we apply an integrative approach that bridges the two extremes of the microbial scale bar: the individual cell and the whole community.

Very broadly, the research questions our lab addresses are: (1) who is doing what (linking phylogenetic identity and physiological function), (2) what are the abiotic and biotic factors controlling microbial in situ activity, (3) how does this activity affect the environment and ultimately humans, (4) what are the limits to metabolism in terms of energy, space, and time, and (5) how can we discover novel structures and functions within uncultured microbial lineages?

Our approach to these problems is inherently multi-disciplinary and multi-scaled. In order to address previously unrecognized physiologies and cellular interactions of uncultured microbes, we employ a unique combination of metagenomics (as hypotheses generator), high-through-put metabolic screening via substrate analog probing (to identify geochemical and biotic parameters driving ecology), and single cell resolved stable isotope probing via Raman microspectroscopy or nano-scale secondary ion mass spectrometry (to identify specific growth-sustaining substrates). These culture-independent approaches are complemented by mesocosm experiments run under close to *in situ* conditions and targeted cultivation efforts. Because, together, these approaches target the whole microbiome as well as the individual cell we typically do not depend on samples enriched in a target population, as is often necessitated in ecological studies. Our main study sites are sediments from a variety of geothermal, deep-sea, and coastal habitats. **Contact**: Roland Hatzenpichler

CBE Computer Facilities

The CBE maintains several dedicated computational and data storage computer systems including 6 high performance data and image analysis workstations and servers in addition a 143TB allocation on centrally maintained high throughput backed up high availability storage systems. The center provides personal workstations for staff and graduate students that are connected to the MSU computer network. A student computer laboratory offers nine state-of-the-art PCs along with scanning and printing services. Additionally, CBE staff and students have access to the centrally maintained computational cluster for data manipulation, analysis, and mathematical modeling. This cluster consists of 77 nodes with a total of 1300 hyper-threaded cores and 22 teraflops of computing power.

OTHER Montana State University facilities available for collaborative research

Montana Nanotechnology (MONT) Facility

The MONT facility was formed from a $3 million NSF grant awarded to MSU in September of 2015. This collaborative facility includes the Montana Microfabrication Facility (MMF), the Imaging and Chemical Analysis Lab (ICAL), the CBE, the MSU Mass Spectrometry facility, and the Center for Bio-Inspired Nanomaterials. MONT provides researchers from academia, government and companies large and small with access to university facilities with leading-edge fabrication and

characterization tools, instrumentation and expertise within all disciplines of nanoscale science, engineering and technology. **Contact:** David Dickensheets

MSU Nuclear Magnetic Resonance (NMR) Facility

A state-of-the-art NMR facility is available on campus on a recharge basis for research projects. This facility is a 5-minute walk from the College of Engineering and CBE laboratories. All the instruments in the facility are Bruker Avance instruments. The facility houses 300, 500 and 600 MHz NMR instruments for high resolution spectroscopy analysis. **Contact:** Valerie Copie

MSU Magnetic Resonance Microscopy (MRM) Facility

A state-of-the-art MRM facility is available on a recharge basis for research projects. This facility is located in the College of Engineering in the same building as the Center for Biofilm Engineering. Instruments in the facility are Bruker Avance III 250 MHz standard/wide bore and 300 MHz wide/super-wide bore spectrometers with Microimaging probes for each configuration. The facility provides measurements of NMR relaxation and diffusion to characterize molecular dynamics, *e.g*. for microscale EPS gel structure characterization and mesoscale MR imaging of heterogeneity in molecular dynamics and bulk scale transport phenomena and fluid dynamics. The imaging systems are capable of generating MRI and transport data with spatial resolution on the order of 10 µm in a sample space up to 6 cm diameter in opaque samples. **Contacts:** Sarah Codd and Joe Seymour

MSU ICAL Laboratory

The Imaging and Chemical Analysis Laboratory (ICAL) in the Physics Department at Montana State University is located on the 3rd floor of Barnard Hall, adjacent to the Center for Biofilm Engineering. ICAL is a user-oriented facility that supports basic and applied research and education in all science and engineering disciplines at MSU. The laboratory provides access to state-of-the-art equipment, professional expertise, and individual training for government and academic institutions and the private sector. Laboratory instrumentation is dedicated to the characterization of materials via high-resolution imaging and spectroscopy. ICAL promotes interdisciplinary collaboration between the research, educational and industrial fields,education, and industry; and the strengthening of existing cooperation between the physical, biological, and engineering sciences by providing critically needed analytical facilities. These facilities are open to academic researchers.

ICAL currently contains eleven complementary microanalytical systems:

- Atomic Force Microscope (AFM)
- Field Emission Scanning Electron Microscope (FE SEM)
- Scanning Electron Microscope (SEM)
- Small-Spot X-ray Photoelectron Spectrometer (XPS)
- Time-of-Flight Secondary Ion Mass Spectrometer (ToF-SIMS)
- X-Ray Powder Diffraction Spectrometer (XRD)
- Scanning Auger Electron Microprobe (AUGER)
- Epifluorescence Optical Microscope
- Critical Point Drying
- Video Contact Angle System

For more information on each system, see the ICAL web site at: http://www.physics.montana.edu/ical/

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