
2015 APPENDIX

**Center for
Biofilm
Engineering**

Montana State
University Bozeman

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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 | CO₂ 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

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:
 2014–2015 CBE GRANT-FUNDED RESEARCH ACTIVITY

Research Area	Title	Principal Investigator	Funding Agency
Biofilm Mechanics	Exploring biofilm material properties with micromechanical tools	Wilking	NSF
Biofilm Mechanics	Characterizing microbial biofilms in water recovery systems using micromechanical tools **	Wilking	NASA
Biofilms in Nature	Clark Fork River biofilms	Fields	US Geological Survey
Education	Improving Montana community health through graduate education	Camper	NIH
Energy Solutions	Environmental responses to geologic CO ₂ sequestrations	Cunningham	DOE EPSCoR
Energy Solutions	Basic science of retention issues, risk assessment & measurement, monitoring & verification for geologic CO ₂ sequestrations	Cunningham	DOE
Energy Solutions	Sustainable coal bed methane (CBM) and biofuel production from algae grown in CBM produced water	Cunningham & Fields	MBRCT
Energy Solutions	Using biomineralization sealing for leakage mitigation in shale during CO ₂ sequestration	Gerlach	DOE
Energy Solutions	SEP collaborative research: Alkaliphilic microalgae-based sustainable & scalable processes for renewable fuels and products	Gerlach	NSF
Energy Solutions	Cultivation and characterization of cyanobacteria for a renewable organic fertilizer	Macur	American Indian Higher Education
Energy Solutions	Extremophilic fungal enzymes for degradation of lignocellulosic feedstocks	Macur	Sustainable Bioproducts
Energy Solutions	Lipid derived biofuels: Bicarbonate induced triacylglycerol accumulation in microalgae	Peyton	Church & Dwight
Energy Solutions	Direct conversion of agricultural wastes to biodiesel utilizing a unique extremophilic fungus - USD SBIR	Macur	Sustainable Bioproducts
Energy Solutions	Direct conversion of municipal wastes to biodiesel utilizing a unique extremophilic fungus - EPA SBIR	Macur	Sustainable Bioproducts
Environmental Substance Technologies	Low cost in situ NMR technologies for monitoring biological and geochemical processes in the subsurface	Codd	DOE
Environmental Substance Technologies	ZERT II - Cunningham Task II	Cunningham	DOE-ZERT
Environmental Substance Technologies	Microbial activity and precipitation at solution- mixing zones in porous media	Gerlach	DOE-ERSP
Environmental Substance Technologies	Using biomineralization sealing for leakage mitigation in shale during CO ₂ sequestration	Gerlach	MT Emergent Technologies

Environmental Substance Technologies	Cultivation and characterization of phototrophs for renewable organic fertilizer	Macur	DOE-AIREI
Environmental Substance Technologies	MSU selenium biogeochemistry investigation	Peyton	Teck Coal
Environmental Substance Technologies	Teck ART/MSU microbial selenium reduction and mining bioprocesses	Peyton	Teck Metals LTD
Environmental Substance Technologies	Cooperative research program on constructed wetland design and implementation	Stein	USFWS
Environmental Substance Technologies	Design and implementation of pilot vertical flow treatment wetland systems at Bridger Bowl	Stein	MT DEQ
Environmental Substance Technologies	Use of saturated/submerged rock fills for water quality management	Peyton	SRK Consulting
Environmental Substance Technologies	Saturated rock fill research program	Peyton	Teck Coal Ltd
Environmental Substance Technologies	Selenium bioremediation - Teck applied - 2015 bridge funding	Peyton	Teck Coal Ltd
Environmental Substance Technologies	Using biomineralization sealing for leakage mitigation in shale during CO ₂ sequestration	Gerlach	Montana Emergent Technologies
Environmental Substance Technologies	Nitrifying wastewater biofilms and the influence of emerging contaminants **	Lauchnor	US Geological Survey
Medical Biofilms	<i>Staphylococcus aureus</i> biofilms mediate keratinocyte apoptosis	Kirker	NIH
Medical Biofilms	Spatiotemporal distribution of oxygen in biofilm infections	Stewart	NIH
Medical Biofilms	Resensitization of bacteria in biofilms to antibiotics	Stewart	DOD (USAMRAA)
Methods Development	Development and use of standard methods for the growth, treatment, sampling and analysis of biofilm bacteria *	Goeres	US EPA
Modeling	CMG research	Klapper	NSF
Modeling	Predictive multiscale modeling of microbial consortia biofilms	Carlson	NIH
Physiology & Ecology	Collaborative research: Hydrodynamic controls on microbial community dynamics	Cunningham & Fields	NSF
Physiology & Ecology	Virtual institute for microbial stress & survival	Fields	DOE/LBNL
Physiology & Ecology	Molecular level characterization of dissolved organic carbon and microbial diversity in the WAIS Divide replicate core	Foreman	NSF

Physiology & Ecology	Role of IbpA in maintaining viability of <i>p. aeruginosa</i> biofilm persister cells* ¹	Franklin	NIH
Physiology & Ecology	Phototroph-heterotroph Interactions	Carlson	DOE/PNNL
Water Systems	Water, our voice to the future: Climate change adaptation and waterborne disease prevention on the Crow Reservation	Camper	Little Big Horn College

*Denotes a project running through a different MSU department, but involving collaboration with CBE researchers and/or use of CBE facilities.

¹MSU Department of Microbiology & Immunology

List of Acronyms

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
MBRCT	Montana Board of Research and Commercialization Technology
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NSF	National Science Foundation
USDA	U.S. Department of Agriculture
ZERT	Zero Emissions Research and Technology
MT DEQ	Montana Department of Environmental Quality
USFWS	U.S. Fish and Wildlife Service
DOD	U.S. Department of Defense
USAMRAA	U.S.A. Medical Research Acquisition Activity
EPSCoR	Experimental Program to Stimulate Competitive Research
ARRA	American Recovery and Reinvestment Act
LBNL	Lawrence Berkley National Lab
PNNL	Pacific Northwest National Laboratory
SBIR	Small Business Innovation Research

FY15 New CBE Research Grants (July 1, 2014 to June 30, 2015)

Sponsor	Title	PI	Period	Amount
NSF	Exploring biofilm material properties with micromechanical tools	Wilking	5 yrs	\$503,395
SRK Consulting	Use of saturated/submerged rock fills for water quality management	Peyton	1 yr	\$123,427
Teck Coal Ltd	Saturated rock fill research program	Peyton	9 mos.	\$212,401
US Geological Survey	Clark Fork River biofilms	Fields	1 yr	\$12,000
Teck Coal Ltd	Selenium bioremediation - Teck applied - 2015 bridge funding	Peyton	5 mos.	\$100,000
NIH	Predictive multiscale modeling of microbial consortia biofilms	Carlson	5 yrs	\$1,315,973
Little Big Horn College	Water, our voice to the future: Climate change adaptation and waterborne disease prevention on the Crow Reservation	Camper	3 yrs	\$352,540
Montana Emergent Technologies	Using biomineralization sealing for leakage mitigation in shale during CO ₂ Sequestration	Gerlach	2 yrs	\$240,086
Sustainable Bioproducts	Direct conversion of agricultural wastes to biodiesel utilizing a unique extremophilic Fungus - USD SBIR	Macur	7 mos.	\$28,891
Sustainable Bioproducts	Direct conversion of municipal wastes to biodiesel utilizing a unique extremophilic fungus - EPA SBIR	Macur	5 mos.	\$28,953
US EPA	Development and use of standard methods for the growth, treatment, sampling and analysis of biofilm bacteria *	Goeres	1 yr	\$38,000
	Total Grant Awards to CBE for FY2015			\$2,955,666
	* <i>Additional monies awarded in FY15 (budget increased by the amount listed)</i>			
US Geological Survey	Nitrifying wastewater biofilms and the influence of emerging contaminants **	Lauchnor	1 yr	\$15,000
NASA	Characterizing microbial biofilms in water recovery systems using micromechanical tools **	Wilking	8 mos.	\$50,364
	Total Biofilm Grant Awards for FY2015			\$3,021,030
	** <i>Denotes a project running through a different MSU department, but involving collaboration with CBE researchers and/or use of CBE facilities.</i>			

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RESEARCH:
 PUBLICATIONS
 June 2014–May 2015

2014 Publications

NOTE:

2014-001 through 2014-010 are listed in 2014 Appendix

Ammons MC, Tripet BP, **Carlson RP**, Kirker KR, **Gross MA**[‡], Stanisich JJ, Copié V, “Quantitative NMR metabolite profiling of methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* discriminates between biofilm and planktonic phenotypes,” *J Proteome Res.*, June 2014; 13(6): 2973–85. 2014-019

Bernstein HC, **Carlson RP**, Book chapter: “Design, construction, and characterization methodologies for synthetic microbial consortia,” Book title: Engineering and Analyzing Multicellular Systems: Methods and Protocols *Methods Mol Biol.*, 2014; 1151:49–68. 2014-017

Bray JM, Rassi EM, **Seymour JD**, **Codd SL**, “Magnetic resonance measurement of fluid dynamics and transport in tube flow of a near-critical fluid,” *Exp Fluids*, 2014; 55(7): 1777 2014-035

Brileya KA, **Camilleri LB**, **Fields MW**, Book chapter: “3D-fluorescence in situ hybridization of intact, anaerobic biofilm,” Book title: Engineering and Analyzing Multicellular Systems: Methods and Protocols *Methods Mol Biol.*, 2014; 1151:189–97. 2014-018

Brileya KA, **Camilleri LB**, Zane G M, Wall, JD, and **Fields, MW**, “Biofilm growth mode promotes maximum carrying capacity and community stability during product inhibition syntrophy,” *Frontiers in Microbiol.*, Dec 2014; 5:693. 2014-030

Brown JR, **Seymour JD**, Brox TI, Skidmore ML, Wang C, Christner BC, Luo BH, **Codd SL**, “Recrystallization inhibition in ice due to ice binding protein activity detected by nuclear magnetic resonance,” *Biotechnol Rep.*, Sept 2014; 3: 60–64. 2014-027

Chimileski S*, **Franklin MJ**, Papke RT, “Biofilms formed by the archaeon *Haloferax volcanii* exhibit cellular differentiation and social motility, and facilitate horizontal gene transfer,” *BMC Biol.*, August 2014, 12:65. 2014-025

Cunningham A, **Phillips AJ**, **Troyer E**[‡], **Lauchnor E**, **Hiebert R**, **Gerlach R**, Spangler L, “Wellbore leakage mitigation using engineered biomineralization,” *Energy Procedia*, 2014; 63: 4612–4619. 2014-028

Fields MW, **Hise A***, **Lohman EJ**, **Bell T**, **Gardner RD**, **Corredor L**, **Moll K**, **Peyton BM**, **Characklis GW***, **Gerlach R**, “Sources and resources: Importance of nutrients, resource allocation, and ecology in microalgal cultivation for lipid accumulation,” *Appl Microbiol Biotechnol.*, June 2014; 98(11): 4805–4816. 2014-011

Folsom J, **Parker A**, **Carlson R**, “Physiological and proteomic analysis of *Escherichia coli* iron-limited chemostat growth,” *J. Bacteriol.*, Aug 2014; 196(15): 2748–2761. 2014-015

Fridjonsson EO, **Seymour JD**, **Codd SL**, “Anomalous preasymptotic colloid transport by hydrodynamic dispersion in microfluidic capillary flow,” *Physical Review E Stat Nonlin Soft Matter Phys.*, July 2014; 90(1–1): 010301. 2014-021

Fridjonsson EO, **Codd SL**, **Seymour JD**, “Application of PFG–NMR to study the impact of colloidal deposition on hydrodynamic dispersion in a porous medium,” *Transp Porous Med.*, 2014; 103(1): 117–130 2014-036

Hamner S, Broadaway SC, Berg E, Stettner S, **Pyle BH**[#], Big Man N, Old Elk J, **Eggers MJ**, **Doyle J**, Kindness L, Good Luck B, Ford TE, **Camper AC**, “Detection and source tracking of *Escherichia coli*, harboring intimin and Shiga toxin genes, isolated from the Little Bighorn River, Montana,” *Int J Environ Health Res.*, 2014; 24(4): 341–362. 2014-022

Hunt KA, **Folsom JP**, **Taffs RL**, **Carlson RP**, “Complete enumeration of elementary flux modes through scalable demand-based subnetwork definition,” *Bioinformatics*, June 2014; 30(11): 1569–78. 2014-016

Lohman EJ, **Gardner RD**, **Halverson L**, **Peyton BM**, **Gerlach R**, “Carbon partitioning in lipids synthesized by *Chlamydomonas reinhardtii* when cultured under three unique inorganic carbon regimes,” *Algal Research*, 2014; 5: 171–180. 2014-033

Laurenco A, Coenye T, **Goeres DM**, Donelli G, Azevedo AS, Ceri H, Coelho FL, Flemming H-C, Juhna T, Lopes SP, Oliveira R, Oliver A, Shirliff ME, Sousa AM, Stoodley P, Pereira MO, Azevedo NF, “Minimum information about a biofilm experiment (MIABIE): Standards for reporting experiments and data on sessile microbial communities living at interfaces,” *Pathogens and Disease*, April 2014; 70(3): 250–256. 2014-013

Macinga D, Shumaker D, Edmonds S, Leslie R, **Parker A**, Arbogast J, "The relative influences of product volume delivery format and alcohol concentration on dry-time and efficacy of alcohol-based hand rubs," *BMC Infect. Dis.*, September 2014; 14:511. 2014-024

Mann EE, Mettetal MR, May RM, Drinker MC, Stevenson BC, Baiamonte VL, Marso JM, Dannemiller EA, **Parker AE**, Reddy ST, Sande MK, "Surface micropattern resists bacterial contamination transferred by healthcare practitioners," *J Microbiol Exp.*, 2014; 1(5):00032. 2014-031

Moll KM, Gardner RD, Eustance EO, **Gerlach R, Peyton BM**, "Combining multiple nutrient stresses and bicarbonate addition to promote lipid accumulation in the diatom RGd-1," *Algal Research*, July 2014; 5:7–15. 2014-014

Oja T, Blomqvista B, **Buckingham-Meyer K, Goeres D**, Vuorelac P, Fallarero A, "Revisiting an agar-based plate method: What the static biofilm method can offer for biofilm research," *J Microbiol Methods*, Dec 2014; 107:157–160. 2014-029

Parker AE, Walker DK, Goeres DM, Allan N, Olson ME, Omar A, "Ruggedness and reproducibility of the MBEC biofilm disinfectant efficacy test," *J Microbiol Methods*, 2014; 102:55–64. 2014-012

Rajeev L, Luning EG, **Altenburg S**, Zane GM, Baidoo EE, Catena M, Keasling JD, Wall JD, **Fields MW**, Mukhopadhyay A, "Identification of a cyclic-di-GMP-modulating response regulator that impacts biofilm formation in a model sulfate reducing bacterium," *Front Microbiol.*, July 2014; 5:382. 2014-026

Sarkisova SA, Lotlikar SR, Guragain M, Kubat R, Cloud J, **Franklin MJ**, Patrauchan MA, "A *Pseudomonas aeruginosa* EF-hand protein, EfhP (PA4107), modulates stress responses and virulence at high calcium concentration," *PLoS ONE*, June 2014; 9(2): e98985. 2014-023

Skorupa DJ, Castenholz RW, Mazurie A, Carey C, Rosenzweig F, McDermott TR, "In situ gene expression profiling of the thermoacidophilic alga *Cyanidioschyzon* in relation to visible and ultraviolet irradiance," *Environ Microbiol., Special Issue: Ecophysiology of Stress and Extremophile Lifestyles* June 2014; 16(6): 1627–1641. 2014-020

Smith HJ, Foreman CM, Ramaraj T, "Draft genome sequence of a metabolically diverse Antarctic supraglacial stream organism, *Polaromonas sp. strain CG9_12*, determined using pacific biosciences single-molecule real-time sequencing technology," *Genome Announc.*, Dec 2014; 2(6) e01242–14. 2014-032

Vogt SJ, Shaw CA, Maneval JE, Brox TI, Skidmore ML, **Codd SL, Seymour JD**, "Magnetic resonance measurements of flow-path enhancement during supercritical CO₂ injection in sandstone and carbonate rock cores," *J Petroleum Science and Eng.*, 2014; 122: 507–514 2014-034

2015 Publications

Ammons MC, Morrissey K, Triplet BP, Van Leuven JT, Han A, Lazarus GS, Zenilman JM, **Stewart PS, James GA**, Copie V "Biochemical association of metabolic profile and microbiome in chronic pressure ulcer wounds," *PLoS ONE*, 2015; 10(5). 2015-017

Benton HP, Ivanisevic J, Mahieu NG, Kurczyk ME, Johnson CH, **Franco L**, Rinehart D, Valentine E, Gowda H, Ubhi BK, Tautenhahn R, Gieschen A, **Fields MW**, Patti GJ, Siuzdak G, "Autonomous metabolomics for rapid metabolite identification in global profiling," *Anal Chem.*, 2015; 87(2): 884–891. 2015-007

Eggers MJ, Moore-Nall AL, Doyle JT, Lefthand MJ, Young SL, Bends AL, Crow Environmental Health Steering Committee, **Camper AK** "Potential health risks from uranium in home well water: An investigation by the Apsalooke (Crow) tribal research group," *Geosciences*, 2015; 5(1):67–94. 2015-011

Fritz B[±], Walker D, Goveia D[±], Parker A, Goeres D, "Evaluation of petrifilm aerobic count plates as an equivalent alternative to drop plating on R2A agar plates in a biofilm disinfectant efficacy test," *Curr Microbiol.*, 2015; 70(3): 450–456. 2015-004

Hwang C, Copeland A, Lucas S, Lapidus A, Barry K, Glavina Del Rio T, Dalin E, Tice H, Pitluck S, Sims D, Brettin T, Bruce DC, Detter JC, Han CS, Schmutz J, Larimer FW, Land ML, Hauser LJ, Kyrpides N, Lykidis A, Richardson P, Belieav A, Sanford RA, Loeffler FE, **Fields MW**, "Complete genome sequence of *Anaeromyxobacter sp. Fw109-5*, an anaerobic, metal-reducing bacterium isolated from a contaminated subsurface environment," *Genome Announc.*, Jan 2015; 3(1): e01449–14. 2015-009

Kahrilas GA, Blotevogel J, **Stewart PS**, Borch T, "Biocides in hydraulic fracturing fluids: A critical review of their usage, mobility, degradation, and toxicity," *Environ. Sci. Technol.*, 2015; 49(1): 16–32. 2015-001

Kesaano M*, **Gardner RD, Moll K, Lauchnor E, Gerlach R, Peyton BM**, Sims RC, "Dissolved inorganic carbon enhanced growth, nutrient uptake, and lipid accumulation in wastewater grown microalgal biofilms," *Bioresource Tech.*, March 2015; 180: 7–15. 2015-005

Kurczy ME, Zhu ZJ, Ivanisevic J, Schuyler AM, Lalwani K, Santidrian AF, David JM, Giddabasappa A, Roberts AJ, Olivos HJ, O'Brien PJ, Franco L, **Fields MW**, Paris LP, Friedlander M, Johnson CH, Epstein AA, Gendelman HE, Wood MR, Felding BH, Patti GJ, Spilker ME, Siuzdak G, "Comprehensive bioimaging with fluorinated nanoparticles using breathable liquids," *Nat Commun.*, Jan 2015; 6:5998. 2015-008

Lauchnor EG, Semprini L, Wood BD "Kinetic parameter estimation in *N. europaea* biofilms using a 2-D reactive transport model," *Biotechnol Bioeng*, 2015; 112(6): 1122–31. 2015-012

Lauchnor EG, Topp DM[±], Parker AE, Gerlach R, "Whole cell kinetics of ureolysis by *Sporosarcina pasteurii*," *J Appl Microbiol.*, Jun 2015; 118(6) 1321–32. 2015-014

McOliver CA, **Camper AK, Doyle JT, Eggers MJ**, Ford TE, Lila MA, Berner J, Campbell L, Donatuto J, "Community-based research as a mechanism to reduce environmental health disparities in American Indian and Alaska native communities," *Int J Environ Res Public Health*, 2015; 12(4):4076-4100. 2015-016

Otter JA, Vickery K, Walker JT, **de Lancey Pulcini E**, Stoodley P, Goldenberg SD, Salkeld JA, Chewins J, Yezli S, Edgeworth JD, "Surface-attached cells, biofilms and biocide susceptibility: Implications for hospital cleaning and disinfection," *J Hosp Infect.*, Jan 2015; 89(1):16–27. 2015-002

Phillips AJ, Eldring J, **Hiebert R, Lauchnor E**, Mitchell AC, **Cunningham A, Gerlach R**, Spangler L, "Design of a meso-scale high pressure vessel for the laboratory examination of biogeochemical subsurface processes," *J Petroleum Science and Engineering*, Feb 2015; 126: 55–62. 2015-003

Ramsay BD[#], Hwang C, Woo HL, Carroll SL, Lucas S, Han J, Lapidus AL, Cheng JF, Goodwin LA, Pitluck S, Peters L, Chertkov O, Held B, Detter JC, Han CS, Tapia R, Land ML, Hauser LJ, Kyrpides NC, Ivanova NN, Mikhailova N, Pagani I, Woyke T, Arkin AP, Dehal P, Chivian D, Criddle CS, Wu W, Chakraborty R, Hazen TC, **Fields MW**, "High-quality draft genome sequence of *Desulfovibrio carbinoliphilus* FW-101-2B, an organic acid-oxidizing sulfate-reducing bacterium isolated from uranium(VI)-contaminated groundwater," *Genome Announc.*, Mar 12, 2015; 3(2):e00092–15. 2015-010

Smith MB, Rocha AM, Smillie CS, Olesen SW, Paradis C, Wu L, Campbell JH, Fortney JL, Mehlhorn TL, Lowe KA, Earles JE, Phillips J, Techtmann SM, Joyner DC, Elias DA, Bailey KL, Hurt RA Jr, Preheim SP, Sanders MC, Yang J, Mueller MA, Brooks S, Watson DB, Zhang P, He Z, Dubinsky EA, Adams PD, Arkin AP, **Fields MW**, Zhou J, Alm EJ, Hazen TC, "Natural bacterial communities serve as quantitative geochemical biosensors," *MBio*. May 2015; 6(3):e00326-15. 2015-015

Trentin DS, Silva DB, Frasson AP, Rzhepishevskaya O, da Silva MV, **de Lancey Pulcini E, James G**, Soares GV, Tasca T, Ramstedt M, Giordani RB, Lopes NP, Macedo AJ, "Natural green coating inhibits adhesion of clinically important bacteria," *Scientific Reports*, Feb 2015; 5:8287. 2015-006

Washburn KE, Anderssen E, **Vogt SJ, Seymour JD**, Birdwell JE, Kirkland CM, **Codd SL**, "Simultaneous Gaussian and exponential inversion for improved analysis of shales by NMR relaxometry," *J Magn Reson.*, Jan 2015; 250: 7–16. 2015-013

Industrial or Federal Agency co-author
 * Previous Visiting Researcher
 # Previous staff/faculty
 ± Current/previous undergraduate student

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RESEARCH:
 PRESENTATIONS
 June 2014–May 2015

Chris Allen, PhD student, civil engineering, presented the poster, “Season and plant species effects on nutrient removal from domestic wastewater in treatment wetlands,” American Society of Civil Engineers Environmental and Water Resources Congress Portland, OR, May 31–June 6, 2014.

Mari Eggers, CBE postdoctoral researcher, and John Doyle, CBE project manager, as invited speakers presented “Community-based cumulative risk assessment of well water contamination: A tribal environmental health disparity,” Tribal College Librarians Annual Institute, Bozeman, MT June 2–6, 2014.

Chiachi Hwang, CBE industrial research scientist, as an invited speaker presented “Bacterial community changes with depth and metal geochemistry in spent ore gold heap leach,” Biohydrometallurgy conference, Falmouth, Cornwall, UK. June 6–16, 2014.

Robin Gerlach, associate professor, chemical and biological engineering, presented the following research at the 20th International Conference on Computational Methods in Water Resources (CMWR), Stuttgart, Germany. June 10–13, 2014:

Platform presentation: “Pore scale modeling of the microbially induced CaCO₃ precipitation process;”

Poster: “Using biomineralization sealing for leakage mitigation in shale.”

Trace Hobbs, undergraduate in chemical and biological engineering, was selected to present the poster “Development of a clinically relevant model flow system for observing struvite formation by *Proteus mirabilis* biofilms,” NIH, NIGMS Fifth Biennial National IDeA Symposium in Washington D.C., June 16–18, 2014.

Robin Gerlach, associate professor, chemical and biological engineering, presented the following research at the 5th International Conference on Porous Media and its Applications in Science, Engineering and Industry (ICPM V), Kona, HI, June 22–27, 2014:

Keynote presentation: “Biofilm-mediated mineral precipitation technology—from the microscale to the field-scale.”

Platform presentation: “Pore scale modeling of the microbially induced CaCO₃ precipitation process.”

Phil Stewart, CBE director, as an invited speaker presented the opening lecture “Biofilms Overview,” 4th International Practical Course in Biofilm Science, University of Minho, Braga, Portugal, June 30–July 3, 2014.

Elinor Pulcini, assistant research professor, chemical and biological engineering, presented the poster “Effects of boric acid and TOL-463 against biofilms formed by key vaginitis pathogens *Gardnerella vaginalis* and *Candida albicans*,” Infectious Diseases Society for Obstetrics and Gynecology (IDSOG) annual meeting, Stowe, VT, August 7–10, 2014.

The following CBE PhD students presented posters at the Ecosystems and Networks Integrated with Genes and Molecular Assemblies (ENIGMA) meeting at the Lawrence Berkeley National Laboratory in Berkeley, California, August 18–24, 2014:

Anna Zelaya, microbiology and immunology, “Intra- and inter-well variation for groundwater and sediment-associated microbial communities from background wells.”

Lauren Franco, microbiology and immunology, “Characterization of structures in *Desulfovibrio vulgaris* RCH1 biofilms under nutrient limiting conditions.”

Gregory Krantz, microbiology and immunology, “Growth physiology of *Desulfovibrio alaskensis* G20 under nutritionally limiting conditions on glass and steel surfaces.”

Matthew Fields, associate professor, microbiology and immunology, presented research at two roundtable sessions at the 15th International Symposium on Microbial Ecology (ISME-15), Seoul, Korea, August 24–28, 2014:

Roundtable: Engineering Microbial Consortia for Controllable Outputs
 Presentation: “Learning from nature to build synthetic systems.”

Roundtable: Biodegradation of Challenging Contaminants II
 Presentation: “Impacts of environmental contaminants on functional diversity of

groundwater microbial communities at a U(VI)-contaminated aquifer.”

The following CBE faculty presented their research at the Interscience Conference on Antimicrobial Agents and Chemotherapy (ICAAC), Washington, D.C. September 5–9, 2014:

Poster: “Antibiotic susceptibility of *Clostridium difficile* biofilms to Fidaxomicin,” presented by **Elinor Pulcini**, assistant research professor, chemical and biological engineering,

Invited talk: “The evolving science of biofilms and their role in device-related infections,” presented by **Phil Stewart**, CBE director and professor in chemical and biological engineering.

Garth James, CBE medical projects manager, presented the poster “Combined negative wound pressure therapy and instillation for killing methicillin-resistant *Staphylococcus aureus* biofilms on titanium surfaces in-vitro,” European Bone & Joint Infection Society Meeting, Utrecht, The Netherlands, September 9–14, 2014.

Darla Goeres, assistant research professor, chemical and biological engineering, presented the following research in October, 2014:

“Biofilm Methods Development Part 1: A discourse on parameters which influence biofilm growth, treatment, sampling and analysis,” International Bioremediation Research Group Meeting, Athens, Greece, October 2, 2014.

“There and back again: A biofilm researcher’s story,” ASTM E35.15 Committee Meeting, New Orleans, LA, October 7–10, 2014.

Otto Stein, professor, civil engineering, presented the following research IWA 14th International Conference on Wetlands Systems for Water Pollution Control, Shanghai, China, October 13–16, 2014:

“Temperature plant species and carbon loading effects on denitrification and nitrous oxide emissions in model treatment wetlands.” Co-authors: **Allen CR, Burr MD, Moss JJ, Spengler J.**

“Presence, pervasiveness, and persistence of *Escherichia coli* O157:H7 in treatment wetland systems,” Co-authors: **VanKempen-Fryling R, Camper AK.**

Al Parker, CBE bio-statistician, as an invited seminar speaker presented “Fast solutions to LARGE Bayesian linear models of 3-D confocal microscope images of

biofilms,” Department of Physics, Otago University, Dunedin, New Zealand, October 20, 2014.

Phil Stewart, CBE director, as an invited speaker presented “Busting biofilms,” Cleaning Products Conference, Washington D.C., November 9–12, 2014.

Al Parker, CBE bio-statistician, as an invited speaker presented “Method validation: A case study of the single tube biofilm method,” Conference on Recent Advances in Microbial Control, Society for Industrial Microbiology, San Francisco, November 12, 2014.

Sloane RealBird, master's student, health and human development, presented the poster “Impacts of historical trauma on chronic illness management,” American Public Health Association National Conference, New Orleans, LA, November 16–19, 2014.

Robin Gerlach, professor, chemical & biological engineering, presented the following research at the 20th annual Reservoir Microbiology Forum conference (RMF 2014), London, England, November 17–20, 2014:

Presentations: “Modeling the growth and chemistry of sulphate reducing biofilms,” and “Stimulation of coal-dependent methanogenesis with native microbial consortia from the Powder River Basin (USA).”

Poster: “Biofilm-mediated mineral precipitation technology—from the microscale to the field-scale.”

The following CBE researchers presented the following research at the American Geophysical Union (AGU) Conference, San Francisco, CA, December 12–18, 2014:

Adie Phillips, assistant professor, civil engineering, as an invited speaker presented “Microbially induced calcite precipitation (MICP)—A technology for managing flow and transport in porous and fractured media.”

Katie Davis, master's student, civil engineering, presented the poster, “Microbially-enhanced coal bed methane: Strategies for increased biogenic production.”

Benjamin Jackson, PhD candidate, mathematical sciences, as an invited speaker presented “Estimating parameters in a bacterial community using inverse methods,” American Mathematical Society and Mathematical Association of America (MAA-AMS) Joint Meeting, San Antonio, TX, January 9–15, 2015

The following CBE Researchers were both invited speakers at American Chemical Society (ACS) annual meeting in Denver, CO, March 22–27, 2015:

Juliana D'Andrilli, assistant research professor, chemical and biological engineering, presented “Antarctic ice-locked reservoirs of organic matter: Probing the bulk and molecular level chemical nature of organic matter by fluorescence spectroscopy and mass spectrometry.”

Heidi Smith, PhD student, land resources and environmental sciences, presented “Transformations in autochthonous DOM: An Antarctic supraglacial case study.”

Phil Stewart, CBE director, presented the following research in March 2015:

“Mechanics of microorganisms in biofilms,” presented at The Physics of Microorganisms meeting organized by the Institute of Physics, London, England, March 23, 2015.

“Biofilm control: Engineering science and modeling,” presented at Newcastle University, Newcastle Upon Tyne, England, March 20, 2015.

Elinor Pulcini, assistant research professor, chemical & biological engineering, as invited speaker presented “Targeting biofilm and biofilm disrupters,” at the Sexually Transmitted Infections Clinical Trials Group (STI CTG), Washington D.C., April 8–9, 2015.

Trace Hobbs, undergraduate student, chemical & biological engineering, present the poster “Investigation of the relationship between biofilm and mineral formation in a clinically relevant model flow system of the kidney,” 29th Annual National Conference on Undergraduate Research, Eastern Washington University, Cheney, WA, April 16–18, 2015.

Tianyu Zhang, assistant professor, mathematics, as a speaker presented “Mechanical aspects of biointerface,” 42nd International Conference on Metallurgical Coatings and Thin Films (ICMCTF), San Diego, CA, April 19–21, 2015.

Robin Gerlach, professor, chemical & biological engineering, presented the following research in May:

Invited talk: “Biofilm-mediated mineral precipitation technology—from the microscale to the field-scale,” University of Tübingen, Germany, April 24, 2015 and Shell, Rijswijk, Netherlands, May 27, 2015.

Poster presentation: “A revised model for microbially induced calcite precipitation—improvements and new insights,” 7th International Conference on Porous Media, Padova, Italy, May 18–21, 2015.

Invited talk: “Why Bioengineers need (to know about) bioinformatics and bioinformaticians,” University of Tübingen, Germany, May 20, 2015.

RESEARCH: NEWS HIGHLIGHTS

CBE awarded contract from the Department of Defense

Phil Stewart, CBE director, was awarded a contract from the US Department of Defense entitled “Resensitization of Bacteria in Biofilms to Antibiotics.” Stewart, the project director, will be joined by collaborating MSU investigators **Garth James**, associate research professor, chemical and biological engineering; **Brian Bothner**, associate professor, chemistry & biochemistry; and **Michael Franklin**, professor, microbiology and immunology. This interdisciplinary team will use transcriptomic and metabolomic approaches to elucidate changes in bacterial phenotypes in biofilms with the ultimate goal of devising interventions that restore antibiotic efficacy against bacteria in biofilms like those that form in chronic wounds.

MSU-CBE faculty and researcher awarded EPA grant to study water quality on Crow reservation

CBE-affiliated faculty member **Anne Camper**, Regents Professor, civil engineering, and **Mari Eggers**, CBE postdoctoral researcher, along with collaborators from Montana’s Little Big Horn College were awarded a \$900,000 three-year grant from the US EPA Office of Research and Development entitled “Climate Adaptation and Water Disease Prevention.” The project will integrate traditional ecological and community knowledge, scientific data, and climate models to describe existing and projected local climate, hydrologic and microbial water quality changes and their impacts on resources, Crow traditions, ecosystems, and community health. MSU’s Institute on Ecosystems is also a collaborator and John Doyle, water quality project director at Little Big Horn College, is the PI on the award.

CBE and Montana Emergent Technologies partner on contract from the Department of Energy

CBE and Montana Emergent Technologies (MET) were awarded a \$1M contract from the US Department of Energy (DOE). CBE-affiliated faculty member **Robin Gerlach**, associate professor, chemical and biological engineering, is the principal investigator on the contract titled “Using biomineralization sealing for leakage mitigation in shale during CO₂ sequestration.” Gerlach will be collaborating with project engineer **Randy Hiebert**, vice president of MET and researcher at the CBE. The project’s technology is based on the ability of microorganisms to produce calcium carbonate minerals to permanently seal leakage pathways. Additional MSU-CBE faculty collaborators are **Al Cunningham**, professor in civil engineering, and **Matthew Fields**, associate professor in microbiology. For more information about the project, go to: http://www.mt-emergent.com/Phase_II_Contract_Award.html

Proven in the field: Microbially induced fracture sealing

A successful field-scale experiment marked a significant milestone in CBE’s development and control of biofilm processes that mitigate unwanted leakage pathways near wells. The potential for upward leakage of gas and fluids through wells poses a major environmental risk, especially in depleted oil and gas reservoirs where large numbers of abandoned wellbores are often present. When compromised, the near-wellbore environment can become a key leakage pathway for CO₂, methane and fluids to migrate to the surface or into functional aquifers above, leading to potential atmospheric release of greenhouse gases or damage to drinking water aquifers. Click to read more:

<http://www.biofilm.montana.edu/news/2015/03/proven-field-microbially-induced-fracture-sealing.html>

RESEARCH:
 CBE Affiliated Faculty and Their Specialties, 2014–2015

NAME	DEPARTMENT	SPECIALTY
Jennifer Brown	Chemical & Biological Engineering	Rheology and biofilm mechanics
Mark Burr	Land Resources & Environ Sciences	Microbial community analysis
Anne Camper	Civil Engineering	Biofilms in environmental systems
Ross Carlson	Chemical & Biological Engineering	Metabolic engineering, metabolic networks
Connie Chang	Chemical & Biological Engineering	Microfluidics
Kevin Cook	Mechanical & Engineering Technology	Tool and machine design
Sarah Codd	Mechanical & Industrial Engineering	Magnetic resonance imaging
Al Cunningham	Civil Engineering	Subsurface biotechnology and bioremediation
Juliana D'Andrilli	Chemical & Biological Engineering	Physical and environmental chemistry
Jack Dockery	Mathematical Science	Mathematical models of biofilms
Matthew Fields	Microbiology	Physiology and ecology
Christine Foreman	Chemical & Biological Engineering	Microbial ecology in cold temperature environments
Michael Franklin	Microbiology	Molecular genetics, gene expression, alginate biosynthesis
Gill Geesey	Microbiology	Molecular and cellular interactions at interfaces
Robin Gerlach	Chemical & Biological Engineering	Environmental biotechnology and bioremediation
Darla Goeres	Chemical & Biological Engineering	Standardized biofilm methods
Marty Hamilton	Statistics	Applied biostatistical thinking
Jeff Heys	Chemical & Biological Engineering	Fluid-structure interactions
Garth James	Chemical & Biological Engineering	Medical biofilms
Erick Johnson	Mechanical & Industrial Engineering	Fluid mechanics
Lisa Kirk	Chemical & Biological Engineering	Treatment of mine effected water
Kelly Kirker	Chemical & Biological Engineering	Medical biofilms
Isaac Klapper	Mathematical Science	Mathematical modeling
Ellen Lauchnor	Civil Engineering	Environmental engineering
Zbigniew Lewandowski	Civil Engineering	Microsensors, chemical gradients, biofilm structure
Richard Macur	Chemical & Biological Engineering	Biofuels, geochemistry, geomicrobiology
Albert Parker	Mathematical Sciences	Mathematics and Statistics
Brent Peyton	Chemical & Biological Engineering	Environmental biotechnology and bioremediation
Adie Phillips	Civil Engineering	Environmental engineering
Elinor Pulcini	Chemical & Biological Engineering	Medical biofilms
Abbie Richards	Chemical & Biological Engineering	Environmental biotechnology
Rocky Ross	Computer Science	Web-based, active learning education
Joseph Seymour	Chemical & Biological Engineering	Magnetic resonance imaging
Otto Stein	Civil Engineering	Engineered waste remediation
Phil Stewart	Chemical & Biological Engineering	Biofilm control strategies
Paul Sturman	Civil Engineering	Biofilms in waste remediation and industrial systems
James Wilking	Chemical & Biological Engineering	Physical and material biofilm properties
Tianyu Zhang	Mathematics	Mathematical modeling

CBE Affiliated Faculty Awards & News

MSU 2015 Faculty Awards and Recognition

MSU-CBE faculty member **Abigail Richards**, associate professor in chemical and biological engineering, was among the winners of the top 2015 faculty awards at Montana State University. The annual awards honor achievement in faculty research, teaching, outreach, and creative projects. This year's awards were presented January 13, 2015 at the 4th annual MSU Spring Convocation.

Richards was the recipient of MSU's inaugural Spirit of Discovery Award. This award is for faculty members who have excelled in teaching and mentoring students in the Honors College. The awards were made possible by support from Dr. Lew and Liane Vadheim of Miles City. The Vadheims' son, Bryan, was MSU's first Marshall Scholar. The award provides a \$1,400 honorarium.

Read more about Richards and her award MSU faculty award recipients go to:

<http://www.montana.edu/news/12351/msu-honors-top-faculty-and-staff>

Jim Wilking wins NSF CAREER award

CBE faculty member **Jim Wilking**, assistant professor in MSU's Department of Chemical and Biological Engineering, was awarded a prestigious NSF CAREER award, the National Science Foundation's top award for young scientists. The Young Investigator CAREER Award provides \$503,396 over five years, which he will use to study the physical and material properties of biofilms. He will also use the award to develop teaching modules for after-school programs across Montana.

Read more about Wilking and his research at MSU News Service: <http://www.biofilm.montana.edu/news/2015/04/jim-wilking-wins-nsf-career-award.html>

CBE faculty member serves as guest editor of Microbial Ecology's special issue on biofilms

The CBE earned the guest editor role and cover photo of the July 2014 Special Issue on Biofilms of the journal Microbial Ecology. Dr. **Anne Camper**, a CBE affiliated faculty member and Regents Professor in MSU's Department of Civil Engineering served as guest editor of the special issue. The cover photo features an image obtained with a confocal scanning laser microscope (CSLM) taken by **Federica Villa**, CBE visiting postdoctoral researcher, and **Betsey Pitts**, CBE research scientist and microscope facilities manager. Read the full story at: <https://www.biofilm.montana.edu/news/2014/11/cbe-faculty-member-serves-guest-editor-microbial-ecology%E2%80%99s-special-issue-biofilms.html>

New MSU Faculty Appointments

Two CBE researchers were appointed to assistant professor faculty positions in MSU's Department of Civil Engineering. **Ellen Lauchnor**, postdoctoral researcher, and **Adie Phillips**, research engineer, joined the civil engineering department in August and began teaching classes this fall semester. Lauchnor's research areas are bioremediation, nitrification, and wastewater biofilms. Her office is located in Cobleigh 220. Phillips' research interest is biofilms in energy and bioremediation-related technologies. Her office is located in Cobleigh 215.

Dr. **Juliana D'Andrilli**, former CBE postdoctoral researcher, was appointed as an assistant research professor in MSU's Department of Chemical and Biological Engineering. D'Andrilli's specialty is organic matter characterization and biogeochemical cycling in marine, terrestrial, and glacial environments. Her current research areas are: organic matter evolution and cycling; Antarctic ice cores, lakes, and streams; and glacially-fed Montana lakes, rivers, and streams.

Dr. **Al Parker**, CBE's bio-statistician, was appointed assistant research professor in MSU's Department of Mathematical Sciences. Parker's research areas include modeling complex biofilm systems, application of Bayesian methods to solve biofilm inverse problems, and using highly efficient iterative samplers to analyze big data problems such as 3-D confocal scanning laser microscope (CSLM) movies. His work with the CBE Standardized Biofilm Methods team focuses on method development for the US Environmental Protection Agency (EPA) and ASTM International. Parker's current research is assessing the uncertainty in quantitative statistical measures calculated from CSLM images, and proposing optimal spatial and temporal resolutions when capturing CSLM images.

Dr. **Connie Chang**, former assistant research professor, has been appointed to an assistant professor faculty position. Chang's research interest is in droplet-based microfluidics, which is the creation and manipulation of tiny drops of fluid that

range from picoliters to nanoliters in volume. These drops are created at rates of thousands per second and can be used in applications such as biomaterials, ultra high-throughput screening of bacterial biofilm formation, single cell genomics, and directed evolution in biology. Chang joined MSU's chemical and biological engineering department in November 2013 from a postdoctoral position in the David Weitz laboratory at the School of Engineering and Applied Sciences at Harvard University.

Dr. **Lisa Kirk**, former CBE postdoctoral researcher, was appointed to an assistant research professor position. Kirk's research areas are: biofilms in mine waste rock, tailings, post-mine pit lakes and underground workings; biofilms in treatment of mine-affected water; in situ biological stabilization of nitrogen, sulfur, and metals including selenium.

Dr. **Kelly Kirker**, former CBE research scientist, was appointed to an assistant research professor position. Kirker's research interests are: Exploring how biofilms contribute to wound chronicity; developing new in vitro wound/biofilm models; evaluating antimicrobial properties of biomaterials; investigating anti-biofilm technologies for the health care field.

College of Engineering Awards

MSU's College of Engineering (COE) honored faculty and students at its annual awards luncheon on April 28, 2015. Two CBE affiliated faculty members received awards at the ceremony.

Al Cunningham, professor of civil engineering, received the COE 2015 award for Excellence in Research. **Ross Carlson**, associate professor of chemical and biological engineering, received the COE 2015 award for Excellence in Teaching.

Cunningham was honored as an internationally recognized researcher on the beneficial use of biofilms in porous media, working across disciplines, building strong collaborations with faculty, students, and industry partners. He has advised 14 PhD students and 16 master's students.

Carlson was recognized for his stellar teaching evaluations by his students and peers whether measured qualitatively or by the numbers. Despite being busy with research, and being asked to teach some of the most difficult and abstract material in a chemical engineering curriculum, Carlson engages and inspires students.

Read more about Cunningham and Carlson's contributions to MSU education and research at:

<http://www.biofilm.montana.edu/content/2015-college-engineering-awards>

CBE 2014 Outstanding Researcher Award

Dana Skorupa, CBE postdoctoral research associate, received the CBE Outstanding Researcher Award. Skorupa was recognized for her leadership on projects in heavy metal remediation and characterization of novel microorganisms. She was also acknowledged for her mentoring of CBE students in DNA extraction, sequencing, bioinformatics, enrichment cultures, and novel techniques. Skorupa's productivity, generosity, and readiness to take on new challenges exemplify the CBE spirit. The Outstanding Researcher Award is open to any CBE researcher or faculty member. The criteria for selection include research quality, teamwork, willingness to mentor others and willingness to contribute to CBE outreach efforts through the Montana Biofilm Meetings and workshops.

CBE Outstanding Faculty Awards

2015— Jim Wilking was awarded CBE's 2015 Outstanding Faculty Award. Wilking was recognized for his quick and enthusiastic engagement with the intellectual and team life of CBE, involvement of students in research, and in recognition of his NSF CAREER Award.

2014—CBE founding member **Al Cunningham**, professor of civil engineering, received the CBE Outstanding Faculty Award. Cunningham was awarded in recognition of his sustained productivity, collaboration, and leadership in interdisciplinary research related to the beneficial use of biofilms in porous media. He is currently a principal investigator for MSU's Zero Emissions Research and Technology Center (ZERT), a partnership between MSU, the University of West Virginia, and five DOE Laboratories focused on understanding the basic science of underground (geologic) storage of carbon dioxide.

EDUCATION:

Undergraduate Students: Summer 2014, Fall 2014, Spring 2015

*Graduating

‡ Native American

1. *Akyel, Arda	M	Chem & Bio Eng	Turkey
2. Almeida de Jesus, Aline (Gerlach)	F	Civil Engineering	Brazil
3. Avera, Erika (James)	F	Microbiology & Immunology	Grass Valley, CA
4. Bain, Matthew (Fields)	M	LRES	Missoula, MT
5. *Bender, Andrew (Codd)	M	Mech & Indust Eng	Moscow, ID
6. *Berglund, Emily (Wilking)	F	Chem & Bio Eng	Helena, MT
7. ‡*Bermel, Emily (Foreman)	F	Chem & Bio Eng (McNair Scholar)	Big Fork, MT
8. Berninghaus, Ashley (Gerlach)	F	Chem & Bio Eng (USP)	Poulsbo, WA
9. *Boucher, Logan (Macur)	M	Chem & Bio Eng	Laurel, MT
10. *Bozbiyik, Guner (Peyton)	F	Chem & Bio Eng	Turkey
11. Bronec, Hallie (Franklin)	F	Microbiology & Immunology	Geraldine, MT
12. Click, Randall (Gerlach)	M	Chem & Bio Eng (USP)	Lone Tree, CO
13. Cole, Patrick (James)	M	Chem/Biochem	Spokane, WA
14. Crawford, James (Peyton)	M	Chem & Bio Eng	Bozeman, MT
15. *Dahl, Spencer (Macur)	M	Chem & Bio Eng	Great Falls, MT
16. Dankworth, Piper (Fields)	F	Microbiology & Immunology	Carlsbad, CA
17. Dickerman, Grace (Walker)	F	Chem & Bio Eng	Cody, WY
18. Dos Santos, Tatyanna (Lauchnor/Gerlach)	F	Chem & Bio Eng	Brazil
19. Eickelberg, Makayla (James)	F	Chem & Bio Eng	Belgrade, MT
20. *Ertuna, Cagan (Peyton)	M	Chem & Bio Eng	Cyprus
21. *Evcil, Merve (Wilking)	F	Chem & Bio Eng	Turkey
22. *Everly, Dylan (Macur)	M	Chem & Bio Eng	Butte, MT when graduate??
23. Filanoski, Brooke (Phillips)	F	Chem & Bio Eng	Spokane, WA
24. Fox, Amy (Chang)	F	Chem & Bio Eng (USP)	Belgrade, MT
25. *Gokce, Merve (Wilking)	F	Chem & Bio Eng	Turkey
26. *Goldberg, Julia (James)	F	Chem & Bio Eng (USP)	Missoula, MT
27. *Gray, James (Carlson)	M	Chem & Bio Eng	Helena, MT
28. Hobbs, Trace (Gerlach)	M	Chem/Biochem (Hughes)	Kalispell, MT
29. *Kerins, Devon (Lauchnor)	F	Civil Eng	Helena, MT
30. *Kurtoglu, Furkan (Wilking)	M	Chem & Bio Eng	Turkey
31. Mayo, Melissa (Foreman)	F	Chem & Bio Eng	Belgrade, MT
32. Meagher, Michelle (Peyton/Skorupa)	F	Chem & Bio Eng	Idaho Falls, ID
33. Miller, Isaac (Fields)	M	Ecology	East Helena, MT
34. *Norton, Drew (Phillips)	M	Chem & Bio Eng	Olympia, WA
35. Obert, Kevin (Fields/Hwang)	M	Microbiology & Immunology	Billings, MT
36. Oeschger, Taylor (Seymour)	F	Chem & Bio Eng	Sacramento, CA
37. Ozcan, Safiye (Chang)	F	Chem & Bio Eng	Turkey
38. Pedersen, Stephen (Walker)	M	Chem & Bio Eng	Clayton, CA
39. Peters, Daniel (Gerlach)	M	Chem & Bio Eng	Butte, MT
40. Pintar, Kathryn (Carlson)	F	Chem & Bio Eng	Spokane, WA
41. Pratt, Shawna (Chang)	F	Chem & Bio Eng	Miles City, MT
42. Rao, Varsha (Codd/Seymour)	F	Chem & Bio Eng	Canada
43. *Reese, Taylor (Wilking)	M	Chem & Bio Eng	Great Falls, MT
44. Rehbein, Steven (Fields)	M	Chem/Biochem	Missoula, MT
45. *Richards, Amanda (Franklin)	F	Microbiology & Immunology	Salt Lake City, UT
46. Schrammeck, Ashley (Carlson)	F	Chem & Bio Eng	Hamilton, MT
47. Schultz, Johanna (Walker)	F	Chem & Bio Eng	Glasgow, MT
48. *Sherick, Matthew (Codd/Seymour)	M	Chem & Bio Eng (INBRE, Goldwater)	Hudson, WI
49. Sowell, Gage (Macur)	M	Chem & Bio Eng	Bozeman, MT
50. Summers, Jennifer (Walker)	F	Chem & Bio Eng	Conowingo, MD
51. Swain, Kyle (Walker)	M	Chem & Bio Eng	Burien, WA

52. Troyer, Eric (Gerlach)	M	Chem & Bio Eng	Hardin, MT
53. *Van Hoy, Martina (Wilking)	F	Chem & Bio Eng (McNair Scholar)	Eureka, MT
54. Vigers, Michael (Wilking)	M	Chem & Bio Eng	Boulder, CO
55. West, Cody (Phillips)	M	Civil Eng	Butte, MT
56. Westerhoff, Lilly (Macur/Richards)	F	Chem & Bio Eng	Worden, MT
57. *Yagci, Elif (Wilking)	F	Chem & Bio Eng	Turkey
58. Ying Wee, Shu (Foreman)	F	Chem & Bio Eng	Malaysia
59. Zhu, Sophie (Fields)	F	Microbiology & Immunology	Bozeman, MT

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Undergraduates Summary: 2014–2015

Department (Program)	Male	Female	Total
Chemical & Biological Engineering	18M	26F	44
Chemistry & Biochemistry	3M		3
Civil Engineering	1M	2F	3
Ecology	1M		1
Land Resources & Environ Sci (LRES)	1M		1
Mechanical & Industrial Engineering	1M		1
Microbiology & Immunology	1M	5F	6
Totals	26 M	33 F	59

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EDUCATION:

Graduate Students: Summer 2014, Fall 2014, Spring 2015

‡ Native American *Received degree

Masters Candidates

1. Bodle, Kylie (Lauchnor)	F	Environmental Eng	Camano Island, WA
2. ‡Doig, Lakotah (Fields)	F	Micro & Immunology	Gypsum, CO
3. *Halverson, Luke (Gerlach)	M	Chem & Bio Eng	Lansing, IA
4. *Hodgskiss, Logan (Cunningham/Fields)	M	Environmental Eng	Choteau, MT
5. *Markwardt, Stephen (Camper)	M	Civil Engineering	Ely, MN
6. ‡Martin, Christine (Camper/Eggers)	F	Health & Human Dev	Hardin, MT
7. Moss, Jefferson (Stein)	M	Civil Engineering	Colorado Springs, CO
8. Pedersen, Todd (Peyton)	M	Chem & Bio Eng	Poulsbo, WA
9. *‡Realbird, Sloane (Camper)	F	Health & Human Dev	Hardin, MT
10. Schaefer, Robert (Chang)	M	Chem & Bio Eng	Bothell, WA
11. Spengler, Justin (Carlson/Camper)	M	Chem & Bio Eng	Jacksonville, FL
12. Thane, Abby (Phillips)	F	Civil Eng	Missoula, MT
13. Yanardag, Sila (Franklin)	F	Chem & Bio Eng	Turkey
14. Zath, Geoffrey (Chang)	M	Chem & Bio Eng	Bend, OR

PhD Candidates

1. Akiyama, Tatsuya (Franklin)	M	Micro & Immunology	Japan
2. Allen, Chris (Stein)	M	Civil Engineering	Bozeman, MT
3. Corredor Arias, Luisa (Fields)	F	Micro & Immun (Fulbright)	Colombia
4. *Barnhart, Elliott (Fields)	M	Micro & Immunology	Broadus, MT
5. Beck, Ashley (Carlson)	F	Micro & Immunology	Corning, IA
6. Bell, Tisza (Fields/Peyton)	F	Micro & Immunology	Littleton, CO
7. Brame, Keenan (Camper)	M	LRES	Livingston, MT
8. *Burbank, Katherine (Peyton)	F	Chem & Biochem	Bozeman, MT
9. Camilleri, Laura (Fields)	F	Micro & Immunology	Ukiah, CA
10. *Connolly, James (Gerlach)	M	Chem & Bio Eng	Post Falls, ID
11. Davis, Katie (Gerlach)	F	Chem & Bio Eng	Green Creek, NC
12. *Serrano Figueroa, Luis (Richards)	M	Micro & Immunology	Puerto Rico
13. Franco, Lauren (Fields)	F	Micro & Immunology	Moorpark, CA
14. ‡Gordon, Melissa (Camper)	F	Nursing	Heart Butte, MT
15. Hunt, Kristopher (Carlson)	M	Chem & Bio Eng	Thorp, WI
16. Jackson, Benjamin (Klapper)	M	Mathematics	Sheridan, OR
17. Jackson, Matthew (Gerlach)	M	Chem & Bio Eng	Naples, FL
18. Jennings, Ryan (Carlson)	M	LRES	Lexington, SC
19. Kirkland, Catherine (Codd)	F	Civil Engineering	Bozeman, MT
20. Krantz, Gregory (Fields)	M	Micro & Immunology	Tinmouth, UT
21. Mailhiot, Sarah (James)	F	Chem & Bio Eng	Oak Forest, IL
22. McGill, Stacy (Carlson)	M	Micro & Immunology	Minor Hill, TN
23. Moll, Karen (Peyton)	F	Micro & Immunology	Fairport, NY
24. Pellizzaro, Aline (Fields)	F	Micro & Immunology	Brazil
25. Plaggemeyer, Sara (Camper)	F	Micro & Immunology	Big Timber, MT
26. Rathore, Muneeb (Peyton)	M	Chem & Bio Eng (Fulbright)	Pakistan
27. Schoen, Heidi (Carlson/Peyton)	F	Chem & Bio Eng	Geneva, IL
28. Schweitzer, Hannah (Fields)	F	Micro & Immunology	Chester, MT
29. ‡Show, Jennifer (Camper)	F	Nursing	Harlem, MT
30. Sidar, Barkan (Wilking)	M	Chem & Bio Eng	Istanbul, Turkey
31. Simkins, Jeffrey (Stewart)	M	Chem & Bio Eng	The Netherlands
32. Smith, Heidi (Foreman)	F	LRES	Westford, VT
33. *Tigges, Michelle (Foreman)	F	Chem & Biochem	Battle Lake, MN
34. *VanKempen-Fryling, Rachel (Camper)	F	Micro & Immunology	Grand Rapids, MI
35. White, Benjamin (Franklin/James)	M	Micro & Immunology	Grand Island, NE
36. Zambare, Neerja (Gerlach)	F	Chem & Bio Eng	India
37. Zelaya, Anna (Fields)	F	Micro & Immunology	Russellville, AR

EDUCATION:
 Graduate Students, 2014–2015

16: Chemical & Biological Engineering

MS: 6

- 5 M Halverson, Luke: MS, *Gerlach*
 Pederson, Todd: MS, *Peyton*
 Schaefer, Robert: MS, *Chang*
 Spengler, Justin: MS, *Carlson/Camper*
 Zath, Geoffrey: MS, *Chang*
 1 F Yanardag, Sila: MS, *Franklin*

PhD: 10

- 6 M Connolly, James: PhD, *Gerlach*
 Hunt, Kristopher: PhD, *Carlson*
 Jackson, Matthew: PhD, *Gerlach*
 Rathore, Muneeb: PhD, *Peyton*
 Sidar, Barkan: PhD, *Wilking*
 Simkins, Jeffrey: PhD, *Stewart*
 4 F Davis, Katie: PhD, *Gerlach*
 Mailhiot, Sarah: PhD, *James*
 Schoen, Heidi: PhD, *Peyton/Carlson*
 Zambare, Neerja: PhD, *Gerlach*

2: Chemistry & Biochemistry

PhD: 2

- 2 F Burbank, Katherine: PhD, *Peyton*
 Tigges, Michelle: PhD, *Foreman*

7: Civil / Environmental Engineering

MS: 5

- 3 M Hodgskiss, Logan: MS,
Cunningham/Fields
 Markwardt, Stephen: MS, *Camper*
 Moss, Jefferson: MS, *Stein*
 2 F Bodle, Kylie: MS, *Lauchnor*
 Thane, Abby: MS, *Phillips*

PhD: 2

- 1 M Allen, Chris: PhD, *Stein*
 1 F Kirkland, Catherine: PhD, *Codd*

2: Health & Human Development

MS: 2

- 2 F Martin, Christine: MS, *Camper*
 Realbird, Sloane: MS, *Camper*

3: Land Resources & Environmental Sciences

PhD: 3

- 2 M Brame, Keenan: PhD, *Camper*
 Jennings, Ryan: PhD, *Carlson*
 1 F Smith, Heidi: PhD, *Foreman*

1: Mathematical Sciences

PhD: 1

- 1 M Jackson, Benjamin: PhD, *Klapper*

18: Microbiology

MS: 1

- 1 F Doig, Lakotah: MS, *Fields*

PhD: 17

- 6 M Akiyama, Tatsuya: PhD, *Franklin*
 Barnhart, Elliott: PhD, *Fields*
 Serrano Figueroa, Luis: PhD, *Richards*
 Krantz, Gregory: PhD, *Fields*
 McGill, Stacy: PhD, *Carlson*
 White, Benjamin: PhD, *Franklin/James*
 11 F Corredor Arias, Luisa: PhD, *Fields*
 Beck, Ashley: PhD, *Carlson*
 Bell, Tisza: PhD, *Fields/Peyton*
 Camilleri, Laura: PhD, *Fields*
 Franco, Lauren: PhD, *Fields*
 Moll, Karen: PhD, *Peyton*
 Pellizzaro, Aline: PhD, *Fields*
 Plaggemeyer, Sara: PhD, *Camper*
 Schweitzer, Hannah: PhD, *Fields*
 VanKempen-Fryling, R.: PhD, *Camper*
 Zelaya, Anna: PhD, *Fields*

2: Nursing

PhD: 2

- 2 F Gordon, Melissa: PhD, *Camper*
 Show, Jennifer: PhD, *Camper*

TOTALS

Total Grads: 51

Total MS: 14 8 M / 6 F
 Total PhD: 37 16 M / 21 F

Total Male: 24
 Total Female: 27

EDUCATION:

Graduating with advanced degrees: June 2014–May 2015

Elliott Barnhart, PhD, Microbiology and Immunology, June 2014

In situ and enhanced coal-bed methane production from the Powder River Basin

Luke Halverson, MS, Chemical and Biological Engineering, July 2014

Biofuel production by two green microalgae utilizing wastewater and recycled nutrients for growth

Luis O. Serrano Figueroa, PhD, Microbiology and Immunology, October 2014

A study on amphiphilic siderophores detection, structure elucidation, and their iron-mediated vesicle self-assembly

James Connolly, PhD, Chemical and Biological Engineering, March 2015

Biofilm-induced carbonate precipitation at the pore-scale

Michelle Tigges, PhD, Chemistry and Biochemistry, March 2015

The application of mass spectrometry-based 'omics technologies to investigate environmental interactions of microbial systems

Logan Hodgskiss, MS, Civil Engineering, April 2015

Evaluation of a green alga isolate for growth and lipid accumulation in coal bed methane production water from the Powder River Basin

Rachel Van-Kempen Fryling, PhD, Microbiology and Immunology, April 2015

Understanding *Escherichia coli* O157:H7 presence, pervasiveness, and persistence in constructed treatment wetland Systems

Stephen Markwardt, MS, Civil Engineering, May 2015

Non-destructive assessment of household reverse osmosis water treatment membrane biofouling

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EDUCATION:

2015 MSU Student Research Celebration: CBE Participants

MSU's undergraduate and graduate students shared their research at the annual Student Research Celebration Thursday, April 9, 2015. Among the more than 200 students presenting their research, numerous students were connected with the Center for Biofilm Engineering.

Undergraduate Students (alpha by last name)

Andrew Bender: Mechanical & Industrial Engineering
 Mentors: **Sarah Codd, Joseph Seymour** — Mechanical & Industrial Engineering, Chemical & Biological Engineering
 "Characteristics of two-phase flow in porous media at low capillary numbers"

Emily Berglund: Chemical & Biological Engineering
 Mentor: **James Wilking** — Chemical & Biological Engineering
 "Force measurements of pluripotent stem cell differentiation in the development of viable three dimensional structures of large intestine organoids"

Emily Bermel: Chemical & Biological Engineering
 Mentor: **Christine Foreman** — Chemical & Biological Engineering
 "The effects of UV light on biofilm formation and pigment production of Antarctic *Janthinobacterium* sp. strain CG23_2 and a non-pigmented mutant"

Ashley Berninghaus: Chemical & Biological Engineering
 Mentors: **Brent Peyton, Robin Gerlach** — Chemical & Biological Engineering
 "Renewable biogas production from algal biomass using anaerobic digestate cultures acquired from municipal wastewater with varying carbon substrates"

Spencer Dahl: Chemical & Biological Engineering
 Mentors: **Rich Macur, Ellen Lauchnor** — Center for Biofilm Engineering, Civil Engineering
 "Degradation of recalcitrant compounds in waste water using fungal strain GS24"

Amy Fox: Chemical & Biological Engineering
 Mentor: **Connie Chang** — Center for Biofilm Engineering
 "Cells in gels: A microfluidics study of alginate droplets"

Merve Gokce and Elif Yagci: Chemical & Biological Engineering
 Mentor: **James Wilking** — Center for Biofilm Engineering
 "Extending colloidal templating techniques with new colloidal materials"

Julia Goldberg: Chemical & Biological Engineering
 Mentors: **Garth James, Elinor Pulcini, Kelly Kirker** — Center for Biofilm Engineering
 "Analysis of gene expression of *Pseudomonas aeruginosa* post exposure to atmospheric plasma using RNA sequencing"

Danielle Hanger: Psychology (CBE admin assistant)
 Mentor: Hutchison Keith — Psychology
 "Working memory capacity and deception"

Shelley Haug: Chemical & Biological Engineering
 Mentor: **Joseph Seymour** — Chemical & Biological Engineering
 "Self-diffusion coefficient model development for HPMCAS polymer/acetone binary mixtures and polymer concentration regime analysis using Nuclear Magnetic Resonance and rheology"

Trace Hobbs: Chemistry & Biochemistry
 Mentor: **Robin Gerlach** — Center for Biofilm Engineering
 "Investigation of the relationship between biofilm and mineral formation in a clinically relevant model flow system of the kidney"

Mason Weber, **Coltran Hophan-Nichols:** Computer Science (CBE IT assistant)
 Mentor: Clem Izurieta — Computer Science
 "Mobile application for equation recognition and manipulation"

Michelle Meagher: Chemical & Biological Engineering
 Mentors: **Brent Peyton, Dana Skorupa** — Chemical & Biological Engineering, Center for Biofilm Engineering
 "Phylogenetic analysis of novel thermophilic archaea and bacteria from an alkaline spring in Yellowstone National Park"

Taylor Oeschger: Chemical & Biological Engineering
 Mentor: **Joseph Seymour** — Chemical & Biological Engineering
 "Techniques for heterogeneous gelation of alginate solutions"

Shawna Pratt: Center for Biofilm Engineering
Mentor: **Connie Chang** — Chemical & Biological Engineering
“Development and applications of double emulsion microfluidics techniques”

Varsha Rao: Chemical & Biological Engineering
Mentors: **Sarah Codd, Joseph Seymour** — Mechanical & Industrial Engineering, Chemical & Biological Engineering
“Heterogeneous gelation of bacterial alginate strains FRD1 and FRD1153”

Taylor Reese: Chemical & Biological Engineering
Mentor: **James Wilking** — Center for Biofilm Engineering
“Active microrheology on *Pseudomonas aeruginosa*”

Amanda Richards: Microbiology & Immunology
Mentor: **Michael Franklin** — Microbiology & Immunology
“Fluorescent staining and imaging of the *Pseudomonas aeruginosa* PAO1 biofilm matrix material”

Gage Sowell: Chemical & Biological Engineering
Mentor: **Rich Macur** — Center for Biofilm Engineering
“Determination of optimal aeration rate and shear stress conditions for maximizing growth and lipid production by an extremophilic fungus”

Eric Troyer: Chemical & Biological Engineering
Mentors: **Ellen Lauchnor, Adrienne Phillips, Robin Gerlach** — Civil Engineering, Chemical & Biological Engineering
“Method to measure biomass entrapped during microbially induced calcium carbonate precipitation”

Shu Ying Wee: Chemical & Biological Engineering
Mentor: **Christine Foreman** — Chemical & Biological Engineering
“Chemotaxis of Antarctic and Arctic microbial life toward various carbon sources using a microfluidic capillary motility method”

EDUCATION:

2014–15 MSU student awards and news

Education Awards: 2014–2015 Undergraduate Awards

Seventeen CBE undergraduate students were awarded funding from the Howard Hughes Medical Institute, Montana’s IDeA Networks of Biomedical Research Excellence program (INBRE) and MSU’s Undergraduate Scholars program (USP) for their research projects in the 2014–2015 academic year. Read the full list of award recipients:

Howard Hughes Medical Institute

The Hughes Scholars program, funded by the Howard Hughes Medical Institute, supports active research and outreach by undergraduate students in areas related to biomedical/bioscience research. The program seeks Montana State University students who are considering careers in biomedical/bioscience research or a medical/health field, and who are dedicated, driven, and innovative.

The successful Hughes Scholar understands the critical nature of a well-rounded education, strong communication skills, and a commitment to providing science learning opportunities to others. Key to the Hughes Scholars fellowships is participation in a significant and meaningful project to reach out to populations through discovery-based and/or research-relevant science. This program differs from others at MSU in that supported projects have a clear methodology for imparting science information to a specific audience, and in a way that encourages young learners or other populations to be excited and intrigued by science.

Spencer Dahl, Chemical and Biological Engineering

Project: “Degradation of pharmaceuticals in waste water using fungal strain GS24”

Faculty mentor: **Rich Macur**, research assistant professor, Center for Biofilm Engineering

Montana INBRE Awards

Montana INBRE is a five-year award (2009-2014) by the National Institute of General Medical Sciences (NIGMS) division of the National Institutes of Health (NIH). The program focuses on increasing the biomedical research capacity of Montana by building research infrastructure, supporting faculty and student research, and fostering a state-wide collaborative network. MT INBRE is expanding its research into the field of health disparities, an area of great relevance to the state. INBRE positions Montana as a leader in biomedical research and significantly increases education, research, and, ultimately, employment opportunities in the state.

Varsha Rao, Chemical and Biological Engineering

Project: “Structure formation alginate gels studied using MRI”

Faculty mentor: **Sarah Codd**, professor, Mechanical and Industrial Engineering

Amanda Richards, Microbiology & Immunology

Project: “Imaging biofilm matrix material”

Faculty mentor: **Michael Franklin**, professor, Microbiology & Immunology

Taylor Reese, Chemical and Biological Engineering

Project: “Active and passive microrheology techniques for *Pseudomonas aeruginosa*”

Faculty mentor: **Jim Wilking**, assistant professor, Chemical and Biological Engineering

USP Awards

USP is one of the largest multidisciplinary undergraduate research programs at MSU. The program helps undergraduate students in all disciplines pursue research, scholarship, and creative projects. USP facilitates, supports, and promotes undergraduate research and scholarship by providing funding and logistical support directly to students.

Andrew Bender, Mechanical and Industrial Engineering

Project: "Two phase flow in porous media"

Faculty mentor: **Sarah Codd**, professor, Mechanical and Industrial Engineering

Emily Bermel, Chemical and Biological Engineering

Project: "The effects of UV light on biofilm formation and pigment production of Antarctic *Janthinobacterium sp.* Strain CG23_2 and a non-pigmented mutant"

Faculty mentor: **Christine Foreman**, associate professor, Chemical and Biological Engineering

Merve Gokce, Chemical and Biological Engineering

Project: "Extending colloidal templating techniques with new colloidal materials"

Faculty mentor: **Jim Wilking**, assistant professor, Chemical and Biological Engineering

Julia Goldberg, Chemical and Biological Engineering

Project: "Analyzing gene expression of *Pseudomonas aeruginosa* post exposure to atmospheric plasma"

Faculty mentor: **Garth James**, associate research professor, Center for Biofilm Engineering

Katherine Kent, Chemical and Biological Engineering

Project: "Rheo-NMR studies of polymer-particle dispersions with silicon dioxide nanoparticles"

Faculty mentor: **Jennifer Brown**, assistant professor, Chemical and Biological Engineering

Taylor Oeschger, Chemical and Biological Engineering

Project: "Production of microbial alginate from *P. Aeruginosa* and the formation of hydrogels"

Faculty Mentor: **Joseph Seymour**, professor, Chemical and Biological Engineering

Gage Sowell, Chemical and Biological Engineering

Project: "Determination of optimal aeration and sheer stress for maximum growth and lipid production by an extremophilic fungus"

Faculty mentor: **Rich Macur**, research assistant professor, Center for Biofilm Engineering

Shu-Ying Wee, Chemical and Biological Engineering

Project: "Chemotaxis of Antarctic and Arctic microbial life towards various carbon sources using a capillary motility method"

Faculty mentor: **Christine Foreman**, associate professor, Chemical and Biological Engineering

Lily Westerhoff, Chemical and Biological Engineering

Project: "Fungal conversion of lignocellulosic waste materials and naphthenic acid to lipids and ethanol"

Faculty mentor: **Rich Macur**, research assistant professor, Center for Biofilm Engineering

2015 MSU Awards for Excellence

Forty of Montana State University's top seniors and their faculty and staff mentors were recognized Tuesday, February 17, 2015 at the 33rd annual Awards for Excellence banquet held on the MSU campus.

The event is co-hosted by the MSU Alumni Association and the Bozeman Chamber of Commerce. Honored students were nominated by faculty in their college or department. Qualified seniors must have at least a 3.5 grade point average on a 4.0 scale, as well as demonstrated campus leadership and community service. The award-winning students each selected a mentor who will be honored with them at the event.

CBE undergraduate student **Varsha Rao**, chemical and biological engineering, was honored at the ceremony. Rao's mentor is CBE affiliated faculty member Joseph **Seymour**, professor in chemical and biological engineering.

View the full list of recipients at *MSU News Service*: <http://www.montana.edu/news/15367/annual-awards-for-excellence-to-honor-40-msu-students-and-their-mentors>

MSU Annual Day of Student Recognition

Two CBE undergraduate students were among the forty-one students honored at MSU's 92nd Annual Day of Student Recognition. The event recognizes student achievement in leadership, involvement in various campus-wide activities, and community service. Awards were presented at a reception held on Tuesday, April 16, 2015 on the MSU campus.

Spencer Dahl, chemical and biological engineering, received the Max Worthington Service Award. The award is presented to a senior man whose service to MSU has exemplified high scholarship, values, and concern for others. Dahl is from Carter, Montana. His CBE advisor is Dr. **Rich Macur**.

Kathryn Pintar, chemical and biological engineering, received the Erma Lessel Collins Junior Award. The award recognizes a new, junior Mortar Board member who best exemplifies campus and community service. Pintar is from Spokane, Washington. Her CBE advisor is Dr. **Ross Carlson**.

View the full list of honorees at MSU News: <http://www.montana.edu/news/15519/students-honored-at-msu-s-day-of-student-recognition>

MSU graduate awarded competitive masters scholarship from the University of Copenhagen

Blaine Fritz, an MSU graduate in chemistry and biochemistry, was awarded a highly competitive Lundbeck Foundation International Masters Scholarship, which is part of the University of Copenhagen's International Graduate Talent Program. The Lundbeck Foundation International Masters provides 2–4 scholarships to highly talented international applicants for a combined masters/PhD program.

Read about Fritz's work at the CBE at: <http://www.biofilm.montana.edu/news/2014/06/msu-graduate-awarded-competitive-masters-scholarship-university-copenhagen.html>

CBE graduate student receives MSU College of Engineering Award

Heidi Schoen, PhD candidate in chemical and biological engineering, was honored with the Raymond E. and Erin S. Schultz Emerging Fellowship award for the 2015–2016 academic year. The award is given to graduate students in MSU's Department of Chemical and Biological Engineering in recognition of high academic performance in coursework and grades, and history of receiving awards, grants, and scholarships. The award also recognizes research accomplishments evidenced by publications and presentations.

Schoen earned her bachelor's degree in chemical and biomolecular engineering from the University of Illinois at Urbana-Champaign. As a PhD candidate at MSU, she is studying fungal biofuels under the supervision of CBE-affiliated faculty member **Brent Peyton**, professor in chemical and biological engineering.

CBE Student Research Awards

Three CBE graduate students were selected to receive a travel award to deliver an oral presentation at the upcoming national meeting of the American Society of Microbiology (ASM) in New Orleans, Louisiana May 30–June 2, 2015. ASM's national meeting is the world's largest meeting of microbiologists.

Laura Camilleri, PhD student in microbiology & immunology, will present "Altered gene expression in a methanogenic, symbiotic biofilm." Supervisor: **Matthew Fields**, MSU-CBE professor in microbiology & immunology

Greg Krantz, PhD student in microbiology & immunology, will present “Electron donor limitation promotes metal corrosion by *Desulfovibrio alaskensis* biofilms.” Supervisor: **Matthew Fields**

Tatsuya Akiyama, PhD student in microbiology & immunology, will present “Regulation of hibernation promoting factor (hpf) and ribosome modulation factor (rmf) of *Pseudomonas aeruginosa* includes transcriptional and post-transcriptional mechanisms.” Supervisor: **Mike Franklin**, MSU-CBE professor in microbiology & immunology

Heidi Smith, MSU-CBE PhD student in land resources and environmental sciences, was awarded the Montana Academy of Sciences (MAS) annual Laurie Henneman Award for Best Graduate Student Research Presentation. Smith was recognized for her poster “Riverine dissolved organic matter decomposition and dynamics,” which she presented at the MAS annual meeting in Butte, Montana April 10–11, 2015. Smith’s supervisor is MSU-CBE faculty member Christine Foreman, associate professor, chemical & biological engineering.

Montana Academy of Sciences promotes scientific research and public understanding of science through student research grants, an annual scientific meeting, and an annual public symposium that highlights the role of science in our society.

2015 W.G. Characklis Outstanding Student Award

The CBE is proud to announce the 2015 W.G. Characklis Outstanding Student Award recipient—**Chris Allen**.

Allen, a PhD candidate in civil engineering, received his award in recognition of his exceptional management of his PhD program to improve the quality of his research, leadership on wetlands projects and mentoring of other students, and his commitment to service projects through Engineers Without Borders—all handled with gentlemanly generosity. Allen is an outstanding representative of the aims of the CBE.

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.

CBE Student Citizen Award

Ashley Beck, PhD candidate in microbiology, received the CBE Student Citizen Award. Beck was recognized for being a conscientious scientist and researcher with an eye for detail and analytic precision. She was praised for her selfless contributions to her lab group and beyond: through laboratory clean-up days, chemical inventories, ordering supplies, teaching, mentoring visiting researchers, and training other students.

The Student Citizen Award is open to any CBE student and recognizes the 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 2014

Montana State University, Roberts Hall 321, 4:10pm

Date	Speaker	Affiliation	Title/Topic
Aug 28	No Seminar—First Week of Classes		
Sept 4	No Seminar		
Sept 11	Dr. Marvin Whiteley	Professor, Molecular Biosciences, University of Texas at Austin	Microbial Facebook: Probing bacterial social networks during polymicrobial infection
Sept 18	Lauren Franco	PhD Student, Microbiology, MSU, CBE	Discerning the structural characteristics of an anaerobic sulfate-reducing biofilm
Sept 25	Dr. Mike SanClements	Deputy Director, Terrestrial Instrumentation Systems, National Ecological Observatory Network (NEON), Boulder, Colorado	Collaborating with NEON: An open source platform for research over the next three decades
Oct 2	Dr. Tim McDermott	Professor, Land Resources & Environmental Sciences, MSU	Genetics, physiology, and metabolomics associated with microbial oxidation of arsenic and antimony
Oct 9	Dr. Linda Figueroa	Associate Professor, Civil & Environmental Engineering, Colorado School of Mines, Golden, Colorado	Harnessing biogeochemical process to mitigate contaminant release from mine sites
Oct 16	Dr. Mike Gilmore	Professor, Ophthalmology, Harvard Medical School, Boston, Massachusetts	Evolution of <i>Enterococci</i> into multidrug resistant hospital pathogens
Oct 23	Dr. Valérie Copié	Professor, Chemistry & Biochemistry, MSU	NMR metabolomics: Applications to the global profiling of microbial metabolites
Oct 30	Heidi Smith	PhD Student, Land Resources & Environmental Sciences, MSU, CBE	The role of microbes in microbial synthesis and transformation of dissolved organic matter in glacial environments
Nov 6	Dr. Ellen Lauchnor	Assistant Professor, Civil Engineering, MSU, CBE	Ammonia oxidizing biofilms: Inhibition and gene expression
Nov 13	Dr. Joe Seymour	Professor, Chemical & Biological Engineering, MSU, CBE	Biopolymer dynamics and thermodynamics: Making structures in alginate gels
Nov 20	Catherine Kirkland	PhD Student, Chemical & Biological Engineering, MSU, CBE	Subsurface biofilm detection using low-field magnetic resonance
Nov 27	No Seminar – Thanksgiving		
Dec 4	No Seminar – Last week of classes		

EDUCATION:

CBE Seminar Series: Spring 2015

Montana State University, Roberts Hall 321, 4:10pm

Date	Speaker	Affiliation	Topic
Jan 15	No seminar—First week of classes		
Jan 22	Dr. Logan Schultz	CBE Postdoctoral Researcher	Crystal stabilization over geologic time: How do microbes do it?
Jan 29	No Seminar – CBE semi-annual rally		
Feb 5	Dr. Shinya Matsumoto	CBE Visiting Researcher	Detection and molecular mechanisms of dormant cells
Feb 12	Dr. Lewis Semprini	Distinguished Professor, Environmental Engineering, Oregon State University	Reduction dehalogenation of Trichloroethene (TCE) and Perchloroethene (PCE) in chemostat reactors continuous flow columns
Feb 26	Diane Walker Kelli Buckingham-Meyer	Research Engineer, Standardized Biofilms Methods Laboratory, CBE; Research Assistant, Standardized Biofilms Methods Laboratory, CBE	Transforming laboratory protocols into a quality system
March 5	Dr. Rosa Oliveira	CBE Visiting Researcher	Interactions between cariogenic bacteria: Susceptibility to chlorhexidine using a drip-flow reactor
Mar 12	No seminar—Spring break		
March 19	Dr. Federica Villa	CBE Visiting Researcher	Subaerial biofilms: New horizons in stone biodeterioration research
March 26	Dr. Stephanie McCalla	Assistant Professor, Chemical & Biological Engineering, MSU	An overview of biomedical assay development
April 2	Undergraduate Research Day	Jennifer Summers, Chemical & Biological Engineering, MSU, CBE	Sonication ruggedness of efficacy test in the single tube method
		Kathryn Pintar & Ashley Schrammeck, Chemical & Biological Engineering, MSU, CBE	Analysis of acetic acid substrate and inhibition kinetics in <i>Escherichia coli</i>
		Michelle Meagher, Chemical & Biological Engineering, MSU, CBE	Phylogenetic analysis of novel thermophilic archaea and bacteria from an alkaline spring in Yellowstone National Park
April 9	Heidi Schoen	PhD Student, Chemical & Biological Engineering, MSU, CBE	Endophytic fungal fermentation to produce biofuel and flavor hydrocarbons in liquid and solid state
April 16	Dr. Robert Jones	Asst. Professor, Development and Surgical Sciences, School of Dentistry, Univ. of Minnesota	Weight loss for oral biofilms
April 23	Dominik Ausbacher	CBE Visiting Researcher	β 2,2-amino acid derivatives developed from antimicrobial peptides: Biological activity and mechanism of action studies
Apr 30	No Seminar – Last week of classes		

TECHNOLOGY TRANSFER:
Industrial Associates, 2014–15
Bold, new *Small business member

3M
Accuratus Lab Services (formally ATS Labs)*
American Chemet*
Bard Access Systems
BASF
Baxter Healthcare
BCG Solutions
BP
Church & Dwight Company
Colgate-Palmolive
Curza*
Dow Corning Corporation
Dow Microbial Control
Ecolab
ExxonMobil
ICU Medical, Inc.
Johnson & Johnson Consumer & Personal Products
Kane Biotech*
KCI, An Acelity Company
Masco Corporation
NASA
NCH Corporation
Next Science
Novozymes
Procter & Gamble Company
Sani-Marc, Inc.
SANUWAVE Health*
Sealed Air Corporation
Sterilex*
STERIS
The Clorox Company
The Sherwin-Williams Company
W.L. Gore & Associates
Zimmer Biomet

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TECHNOLOGY TRANSFER:
 Montana Biofilm Meeting
 July 15–17, 2014

Monday, July 14

6:00–8:30 p.m.

Pre-registration and welcome reception

Larkspur Foyer, Hilton Garden Inn, Bozeman

Tuesday, July 15

7:30–8:00 a.m.

Registration and continental breakfast

Larkspur Foyer, Hilton Garden Inn

8:00–8:10

Introductory remarks

Larkspur Ballroom

Paul Sturman, CBE Industrial Coordinator

Tony Rook, Chair, CBE Industrial Associates; and Manager, Microbiology, The Sherwin-Williams Company

Phil Stewart, CBE Director

SESSION 1:

Biofilm Infection

8:10–8:20

Session Introduction

Phil Stewart, CBE

8:20–8:50

Biofilm model of delayed healing in the rabbit ear: Clinical implications of virulence, host response, and treatment

Thomas Mustoe, MD, Professor, Plastic Surgery, Northwestern University, Chicago, IL

8:50–9:20

Whack-a-mole, chess and the fight against chronic infections

Pradeep Singh, MD, Professor, Medicine & Microbiology, University of Washington, Seattle

9:20–9:50

Prosthetic joint infection update

Robin Patel, MD, and Chair, Division of Clinical Microbiology, College of Medicine, Mayo Clinic, Rochester, MN

9:50–10:20 Networking Break

10:20–10:50

Transport limitations in heterogeneous systems

Isaac Klapper, Professor, Temple University, Philadelphia, PA

10:50–11:20

Atmospheric plasma for annihilation of wound biofilms

Garth James, Assoc Research Professor, Chem & Biological Eng; CBE Medical Biofilm Laboratory Manager

11:20–11:50

Gel-entrapped *Staphylococcus aureus* as a model of biofilm infection

Breana Pabst, Research Assistant, CBE

12:00–1:00

Catered lunch, Hilton Garden Inn

SESSION 2:

Microscopy

1:00–1:30

Time-lapse confocal microscopy of gel-entrapped bacteria as models of infection

Betsey Pitts, Research Scientist and Microscope Facilities Manager, CBE

Visualization of cell surface interactions of environmental samples using confocal microscopy

Heidi Smith, PhD student, Land Resources & Environ Sci, CBE

1:30–1:55

Experience with the microscopy Treatment Flow Cell

Lindsey Lorenz, Research Assistant, CBE; *Kelli Buckingham-Meyer*, Research Assistant, CBE

1:55–2:20

FISH On! Optimization and utility of Fluorescence In Situ Hybridization (FISH) in detecting industry-relevant environmental microbes

Dana Skorupa, Postdoctoral Research Associate, CBE

CBE Open House: Lab

demonstrations and poster session

3:00–5:00

3rd Floor EPS Building, MSU

Wednesday, July 16

7:30–8:00 a.m.

Registration and continental breakfast

Larkspur Foyer, Hilton Garden Inn

SESSION 3:

DNA Sequencing in Practice

8:00–8:30

Sequencing: Trials & tribulations

Matthew Fields, Associate Professor, Microbiology, CBE

8:30–9:00

Molecular diagnosis of medical biofilm

Randy Wolcott, MD, Southwest Regional Wound Care Center, Lubbock, TX

9:00–9:30

Bacterial community changes with depth and metal geochemistry from mined material

Chiachi Hwang, Industrial Research Scientist, CBE

9:30-10:00

I did not know because I could not grow...the impact of molecular methods on microbial control in industrial systems

Vic Keasler, Senior RD&E Group Leader, Microbiology & Global Biotechnology Anchor, Ecolab

10:00-10:30 Networking Break

YOUNG INVESTIGATORS

10:30-11:00

Genetic requirements in spatially organized polymicrobial wound infection

Keith Turner, Postdoctoral Fellow, Center for Infectious Disease, University of Texas at Austin

11:00-11:30

Analyzing secondary metabolite production by 3D-printed bacterial populations using scanning electrochemical microscopy

Jodi Connell, Postdoctoral Fellow, Center for Infectious Disease, University of Texas at Austin

SPECIAL PRESENTATIONS

11:30-11:50

State of the CBE Address

Phil Stewart, CBE Director

11:50-12:00

Presentation of CBE awards

Phil Stewart, CBE Director

12:00-1:00

Catered lunch, Hilton Garden Inn

SESSION 4:

U.S. Regulatory Review

1:00-1:05

Session introduction

1:05-1:30

Biofilm claims for antimicrobial products: U.S. EPA regulatory perspective

Stephen Tomasino, Senior Science Advisor, U.S. EPA-OPP, Microbiology Laboratory Branch

1:30-1:50

FDA/CBE joint workshop recap

Phil Stewart, CBE Director

1:50-2:15

Biofilm claims-EPA rules and implications

John Wood, Senior Director, Agency Relations, Ecolab, Inc.

2:15-2:40

Biofilm test methods and impact on regulatory guidelines

LaShanda Glenn, Scientist, Procter & Gamble

2:40-3:10

Discussion: Paths forward for biofilm regulation

3:30-5:00

Business Meeting

6:00

Dinner/Banquet

Rockin' TJ Ranch, Bozeman

Thursday, July 17

7:30-8:00 a.m.

Continental breakfast

Hilton Garden Inn

SESSION 5:

New CBE Capabilities:

Micromechanics & Microfluidics

8:00-8:05

Session introduction

Phil Stewart, CBE Director

8:05-8:30

Mechanical properties of microbial biofilms

Jim Wilking, Asst Professor, Chem & Biological Eng, CBE

8:30-8:55

Drop-based microfluidics for biological applications:

From colloidal dispersions to high-throughput assaying

Connie Chang, Asst Research Professor, Chem & Biological Eng, CBE

SESSION 6:

Bacterial Survival in Industry and the Environment

8:55-9:00

Session Introduction

9:00-9:25

Hot water disinfection of planktonic and biofilm bacteria

Mark Pasmore, Research Manager, Baxter Healthcare Corporation
Diane Walker, Research Engineer, CBE

9:25-9:50

Systems analysis of iron-limited growth: Insights into pathogen metabolic acclimation to host

Ross Carlson, Assoc Professor, Chem & Biological Eng, CBE

9:50-10:15 Networking Break

10:15-10:40

Field-scale plugging of hydraulic fractures using ureolytic bacteria

Al Cunningham, Professor, Civil Eng, CBE; Robin Gerlach, Assoc Professor, Chem & Biological Eng, CBE; Adie Phillips, Research Engineer, CBE

10:40-11:10

Presence, pervasiveness, and persistence of wastewater pathogen *Escherichia coli* O157:H7 in model treatment wetlands

Rachel VanKempen-Fryling, PhD student, Microbiology, CBE

11:10-11:35

Monitoring *Chlorella* survival during algal biofuel production using a community ecology approach

Tisza Bell, PhD student, Microbiology, CBE

11:35-12:00

Biofouling on household reverse osmosis water treatment membranes

Stephen Markwardt, MS student, Environmental Eng, CBE

WORKSHOP:
 The Single Tube Method and Treatment Flow Cell Workshop
 July 14, 2014

9:00 a.m.–9:15 a.m.	Welcome and Group Introductions - <i>Phil Stewart, CBE Director</i>	EPS 323
9:15 a.m.–9:30 a.m.	An Introduction to Biofilms - <i>Paul Sturman</i>	EPS 323
9:30 a.m.–10:30 a.m.	A Component Approach to Standard Methods - <i>Darla Goeres</i>	EPS 323
10:30 a.m.–10:45 a.m.	<i>Morning Refreshments</i>	EPS 323
10:45 a.m.–11:45 a.m.	Single Tube Method ILS - <i>Al Parker</i>	EPS 323
11:45 a.m.–1:00 p.m.	<i>Lunch</i>	SUB 168
1:00 p.m.–2:00 p.m.	Hands-on Biofilms! Single Tube Method - <i>Diane Walker, Kelli Buckingham-Meyer, Lindsey Lorenz, Blaine Fritz, SBML Interns</i>	EPS 301
2:00 p.m.–2:15 p.m.	<i>Afternoon Refreshments</i>	EPS 323
2:15 p.m.–3:15 p.m.	Microscopy: Epi Viewing of Control z. Treated Biofilm - <i>Kelli Buckingham-Meyer, Diane Walker</i> Treatment Flow Cell with CSLM - <i>Lindsey Lorenz</i> Stereoscopic Views - <i>Blaine Fritz</i>	EPS 336
3:15 p.m.–3:30 p.m.	Treatment Flow Cell Movies - <i>Kelli Buckinham-Meyer, Lindsey Lorenz</i>	EPS 323
3:30 p.m.–3:45 p.m.	STM Ruggedness & Bias - <i>Blaine Fritz, Diane Walker</i>	EPS 301
3:45 p.m.–4:00 p.m.	Wrap-Up/Discussion	EPS 323

TECHNOLOGY TRANSFER:

Anti-Biofilm Technologies: Pathways to Product Development

February 11, 2015 Silver Spring, MD

Time	Title	Speaker
7:15 a.m.–8:00 a.m.	Registration and continental breakfast, Potomac Foyer & Salon II	
8:00 a.m.–8:10 a.m.	Welcome and opening remarks	Phil Stewart, CBE Director; Paul Sturman, CBE Industrial Coordinator; Leticia Vega, Vice-Chair, CBE Industrial Associates Program; Scientist, NASA
8:10 a.m.–8:15 a.m.	SESSION 1: Surface Disinfection Technologies Potomac Salon I Session Introduction	
8:15 a.m.–8:45 a.m.	Development and assessment of test methods for antimicrobial products— Emphasis on biofilm methods	Dr. Stephen Tomasino, Senior Science Advisor, EPA Office of Pesticide Programs
8:45 a.m.–9:15 a.m.	EPA’s regulatory perspective on biofilm claims	Mr. Marc Rindal, Microbiologist, EPA <i>(presented by Dr. S. Tomasino)</i>
9:15 a.m.–9:45 a.m.	Quantitative Microbial Risk Assessment (QMRA) for hard surface disinfectants	Dr. Michael Ryan, Assistant Teaching Professor, Civil, Architectural & Environmental Eng., Drexel University
9:45 a.m.–10:15 a.m.	BREAK, Potomac Salon II	
10:15 a.m.–10:45 a.m.	Agricultural applications of anti-biofilm compounds	Dr. Christian Melander, Professor, Chemistry, North Carolina State University
10:45 a.m.–11:15 a.m.	Biofilm removal	Dr. Phil Stewart
11:15 a.m.–12:00 p.m.	Session 1 wrap up and panel discussion	
12:00 p.m.–1:00 p.m.	Networking Lunch, Potomac Salon II	
1:00 p.m.–1:15 p.m.	SESSION 2: Medical Device Technologies Potomac Salon I Session Introduction	
1:15 p.m.–1:45 p.m.	The public health challenge of medical device biofilms	Dr. K. Scott Phillips, Regulatory Research Scientist, FDA Center for Devices & Radiological Health
1:45 p.m.–2:15 p.m.	Antimicrobial-containing medical devices: A perspective	Dr. Kapil Panguluri, Microbiologist/Team Leader, FDA Center for Devices & Radiological Health
2:15 p.m.–2:45 p.m.	Research challenges for clinical translation of antimicrobial device technologies	Dr. David Grainger, Professor, Department Chair, Pharmaceuticals and Pharmaceutical Chemistry, University of Utah
2:45 p.m.–3:15 p.m.	BREAK, Potomac Salon II	
3:15 p.m.–3:45 p.m.	Everything SLIPS: No bacteria left behind	Dr. Caitlin Howell, Technology Development Fellow, Wyss Institute for Biologically Inspired Engineering, Harvard University
3:45 p.m.–4:15 p.m.	Medical device technologies: Methods for assessing biofilm prevention	Dr. Darla Goeres, Manager, Standardized Biofilm Methods Laboratory, CBE
4:15 p.m.–5:00 p.m.	Session 2 wrap up and panel discussion	
5:30 p.m.–7:30 p.m.	Reception, Potomac Salon II	

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TECHNOLOGY TRANSFER: NEWS HIGHLIGHTS

CBE welcomes new members to its Industrial Associates Program

American Chemet is a manufacturer of cuprous oxide, cupric oxide, zinc oxide, copper powder, dispersion strengthened copper, copper oxide agricultural fungicides, and related products. Chemet is best known for its variety of copper oxides. Since the 1970's the company has produced both cuprous oxides and cupric oxides which are sold around the world for use in antifouling coatings, catalysts, agricultural applications, ceramics, copper chemical production and ferrite production. Colin Anderson is the CBE's designated representative at American Chemet. Read more about the company at: <http://www.chemet.com>

SANUWAVE Health, Inc. is an emerging leader in the development and commercialization of a high-energy and focused shock wave technology that is used in devices for the repair and regeneration of bones, muscles, tendons and skin, and for the separation of solids and fluid in non-medical systems. Iulian Cioanta is the CBE's designated representative at SANUWAVE Health. Read more about the company at: <http://www.sanuwave.com>

New Knowledge Sharing Articles (KSAs)

KSA-SM-15: Disinfectant test results: How to average across laboratories

The CBE Standard Biofilm Methods Lab (SBML) presented their fifteenth knowledge sharing article (KSA) on standardized methods "Disinfectant test results: How to average across laboratories." A comprehensive assessment of a disinfectant product often entails multi-laboratory testing, in which case the individual test outcomes may be averaged across the laboratories. This article is a review of techniques for averaging across laboratories.

We describe and compare popular averaging techniques and recommend the one that seems most appropriate in the context of disinfectant testing. The recommendation is based on the statistical literature and our many years of experience in analyzing data from multi-laboratory studies. We assume that all disinfectant tests conducted by all laboratories were judged by the study director to follow the pre-specified test protocol closely enough to justify calculation of an overall average.

View the [complete KSA series](#)

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TECHNOLOGY TRANSFER: Industry and Agency Interactions

Phil Stewart, professor, chemical and biological engineering, visited CareFusion to discuss the CBE Industrial Associate program, August 18, 2014.

Paul Sturman, CBE research engineer and industrial coordinator, presented “Biofilms on reverse-osmosis membranes,” at Dow Membrane Division, Minneapolis, Minnesota, September 8, 2014.

Jim Wilking, assistant professor, chemical and biological engineering, presented “Micromechanical techniques for the study of soft materials and films,” at The Sherwin-Williams Company, Cleveland, Ohio, September 9, 2014.

Connie Chang, assistant professor, chemical and biological engineering, presented “Microfluidic methods for creating materials and microparticles,” at The Sherwin-Williams Company, Cleveland, Ohio, September 17, 2014.

Paul Sturman, CBE research engineer and industrial coordinator, presented “Biofilm growth and disinfection in industrial water systems,” at Genentech, Vacaville, CA, October 29, 2014.

Susan Pungitore and **Michael Ruben** of Nice-Pak visited the CBE on November 19, 2014. Nice-Pak is the leading manufacturer of brand and retailer-brand wet wipes across consumer, healthcare, and foodservice business channels. Their visit included a tour and discussions with CBE director **Phil Stewart** and CBE industrial coordinator **Paul Sturman** about project testing and membership.

Dr. **Lisa Cooper** from Dow Microbial visited the Center on Tuesday, March 17, 2015. Cooper met with **Darla Goeres**, manager of the CBE standardized biofilm methods lab.

OUTREACH: News Highlight

Uncovering the monumental effects of biofilm

Federica Villa, a Center for Biofilm Engineering visiting researcher from Italy, is delving into the effects of biofilm on some iconic American monuments. A postgraduate researcher from the University of Milan, Villa came to CBE in 2013 for a two-year stay to conduct studies on biofilm samples she has collected from the Jefferson and Lincoln memorials in Washington, D.C., and the Federal Hall National Memorial in New York City. Villa's research is featured in the spring 2015 issue of MSU's *Mountains and Minds* magazine: <http://www.montana.edu/mountainsandminds/article.php?article=15537>

Visiting Researchers

Visiting Student Researchers

The CBE welcomed the following visiting students conducting research with faculty during the 2014–2015 year:

Andrew Keenan, undergraduate, Boise State University, Boise, Utah (summer 2014). Project: Engineering of a fluorescence detection microscope stand for droplet microfluidics and creating hydrogel microparticles for single cell encapsulation. Supervisor: **Connie Chang**, chemical and biological engineering, CBE.

Joshua Felicia, undergraduate, Little Bighorn College, Hardin, Montana (summer 2014). Project: Performing plant growth experiments in the field using nitrogen-fixing cyanobacteria as a biofertilizer. The field site is on the Crow Reservation near Wyola, Montana. Supervisor: **Rich Macur**, CBE.

Yeni Yung, PhD student, University of Illinois at Chicago, Illinois (summer 2014). Project: Learning basic biofilm culturing and analysis techniques. Mass spectroscopy imaging of biofilm proteome and metabolome for analysis of the CBE chronic wound model system. Supervisor: **Ross Carlson**, chemical and biological engineering, CBE.

Adam Hise, PhD student, University of North Carolina at Chapel Hill (summer 2014). Project: Algal research to further life-cycle and techno-economic analyses associated with the development of sustainable algal biorefineries. Supervisor: **Al Cunningham**, civil engineering.

Pia Herrling, PhD student, Karlsruhe Institute of Technology, Karlsruhe, Germany (summer 2014). Area of study: Diffusion in biofilms using NMR. Supervisor: **Sarah Codd**, mechanical and industrial engineering.

Cristina Catto' PhD student, University of Milan, Italy (summer 2014). Area of study: Medical biofilms. Supervisor: **Garth James**, CBE medical projects manager.

Erika J. Espinosa-Ortiz, PhD candidate (July 2014–January 2015). Hometown: Cuautitlán Izcalli, Mexico. Area of study/Home university: Environmental engineering and water technology, UNESCO-IHE, Delft, the Netherlands. Research at the CBE: Mycogenic production of elemental selenium nanoparticles. Supervisor: **Robin Gerlach**, associate professor, chemical and biological engineering.

Rosa Oliveira, PhD candidate (July 2014–April 2015). Hometown: Sao Paulo, Brazil. Area of study/Home university: Dentistry, Universidade Estadual Julio de Mesquita, Sao Paulo, Brazil. Research at the CBE: Development of biofilms in a drip flow reactor. Supervisor: **Garth James**, CBE medical projects manager and professor in chemical and biological engineering.

Raquel Ferrer, PhD candidate (October 2014–December 2015). Hometown: Getxo, Vizcaya, Spain. Area of study/Home university: Microbiology, Universidad de Navarra, Spain. Research at the CBE: Investigating combinations of antimicrobial peptides and antibiotics against biofilms of *Pseudomonas aeruginosa* grown in the CDC biofilm reactor. Supervisor: **Phil Stewart**, CBE director, professor, chemical and biological engineering.

Visiting Research Faculty/Staff

Dr. **Federica Villa** continued her second year working at the CBE. Villa is from the University of Milan and is working as a postdoctoral researcher in the lab of CBE director Phil Stewart. She was previously a visiting graduate student at the CBE in 2009. Villa is the recipient of a competitive Marie Curie International Fellowship. While at the CBE, she will pursue her project related to understanding how cyanobacterial biofilms contribute to deterioration of outdoor stone materials.

Dr. **Shinya Matsumoto** continued his work at the CBE under the direction of Phil Stewart. Matsumoto worked as a postdoctoral researcher with Stewart on dormancy and antimicrobial tolerance in biofilms. Matsumoto received his PhD in chemical engineering in 2009 from Waseda University in Tokyo. He has worked on aspects of biofilm-based wastewater treatment, individual-based biofilm modeling (with Cristian Picioreanu at Delft University of Technology), and persister cells. His current position is supported through a competitive fellowship from the Japanese Society for Promotion of Science.

Dr. **Greg Characklis**, professor in the Department of Environmental Sciences and Engineering at the School of Global Public Health at the University of North Carolina at Chapel Hill will be spending July and August at the CBE. Characklis will be working on two collaborative projects with CBE-affiliated faculty and MSU Algal Biofuels Research team—Robin Gerlach, associate professor in chemical and biological engineering, Brent Peyton, professor in chemical and biological engineering, and Matthew Fields, associate professor in microbiology and immunology.

Dr. **Merle de Kreuk** is an assistant professor in the Department of Water Management at Delft University of Technology in Delft, The Netherlands. She spent the summer working at the CBE with Matthew Fields, associate professor in microbiology and immunology. Dr. de Kreuk worked on biofilm techniques and analytical methods that can be applied to anaerobic biofilms.

Dr. **Kirsten Küsel** is the department chair of Aquatic Geochemistry in the Institute of Ecology at Friedrich Schiller University in Jena, Germany. While at the CBE, she worked with Matthew Fields on biofilm and molecular ecology techniques for microbial communities associated with solid matrices.

Dr. **Mike Gilmore** will be working at the CBE through December 2014. Dr. Gilmore is on sabbatical from Harvard Medical School where he holds a chaired position as a professor of ophthalmology. His training is in medical microbiology and one of his areas of expertise is antibiotic resistance of enterococci, staphylococci, and

streptococci. Dr. Gilmore will be working with CBE director Phil Stewart.

Dr. **Jennifer McIntosh** is working at the CBE through October 2014. Dr. McIntosh is a geochemist from the Department of Hydrology and Water Resources at the University of Arizona. She is a co-PI on an NSF-funded project that studies coal-bed methane and will be working on that project with co-PIs and CBE faculty members Matthew Fields, associate professor, microbiology and immunology, and Al Cunningham, professor, civil engineering.

Dr. **Dominik Ausbacher** is a visiting postdoctoral researcher from the Department of Pharmacy, UiT—The Arctic University of Norway. Ausbacher is investigating the anti-biofilm potency and mechanism of action of antimicrobial β 2,2-amino acid derivatives. He is working in collaboration with Darla Goeres, manager, CBE standardized biofilm methods laboratory, Phil Stewart, CBE director, and the Anti-Infective Research Laboratory, University of Helsinki, Finland. For more information on Ausbacher and his research, go to: <http://en.uit.no/ansatte/dominik.ausbacher>

Dr. **Melanie Blanchette** and **Mark Lund** from the Mine Water and Environment Research Centre (MiWER) at Edith Cowan University in Western Perth, Australia visited the Center April 3–April 15. Blanchette is a postdoctoral research fellow at MiWER. Her research focus is freshwater ecology including dryland rivers, tropical rivers, mine water, and environmental genomics. Lund is an associate professor in environmental management at Edith Cowan and a principal investigator at MiWER. His research interest is mine pit lakes, from remediation of acid mine drainage, through to the establishment and encouragement of biological communities and issues around their closure. During their visit they met with potential research collaborators and presented information on graduate student exchange opportunities at MiWER. Their CBE hosts were Matthew Fields, associate professor in microbiology and immunology and Lisa Kirk, assistant research professor, chemical and biological engineering.

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CBE Tours

On November 25, 2014, the Center hosted two tours of middle school students who were on MSU's campus participating in the Montana Science Olympiad competition. **Ann Willis**, CBE operations manager, led the tours through the following CBE labs—microfluidics, biofilm control, confocal microscopy, algal biofuels, and fracture sealing.

Science Olympiad is a national non-profit organization dedicated to improving the quality of K-12 science education, increasing male, female and minority interest in science, creating a technologically-literate workforce and providing recognition for outstanding achievement by both students and teachers. These goals are achieved by participating in Science Olympiad tournaments and non-competitive events, incorporating Science Olympiad into classroom curriculum and

attending teacher training institutes. Locally, 1,031 Montana students from 71 different schools and 88 different teams competed for spots in the national competition held in spring 2015 in Orlando, Florida.

On February 4, 2015 twenty administrators and technicians from the University of Tokyo visited the center. They were sponsored by MSU's Office of International Programs. Their CBE host was Dr. **Shinya Matsumoto**, CBE visiting researcher, under the supervision of Phil Stewart, professor in chemical and biological engineering.

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OUTREACH:

Web image library use 2014-15

Requests for CBE graphics were submitted from **32** of the U.S. states and Puerto Rico:

Arkansas	Idaho	Michigan	New York	Texas
Arizona	Illinois	Minnesota	North Carolina	Virginia
California	Indiana	Mississippi	Ohio	Washington
Colorado	Iowa	Montana	Oklahoma	Wisconsin
Connecticut	Louisiana	Nevada	Oregon	
Florida	Maryland	New Jersey	Pennsylvania	
Georgia	Massachusetts	New Mexico	Tennessee	

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

Algeria	Mexico
Australia	Netherlands
Belgium	New Zealand
Botswana	Norway
Brazil	Pakistan
Canada	Poland
Chile	Portugal
China	Saudi Arabia
Denmark	Scotland
Ecuador	Singapore
France	South Africa
Germany	Spain
India	Sweden
Ireland	Switzerland
Italy	Turkey
Japan	United Kingdom
Malaysia	Vietnam

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FACILITIES:

Center for Biofilm Engineering Facilities Overview

The CBE moved into the MSU's Engineering/Physical Sciences Building when it was built in 1997. The >20,000 ft² facility includes offices and conference rooms for faculty, staff, and students; two computer laboratories; and thirteen fully equipped research laboratories. The full-time CBE Technical Operations Manager oversees the research laboratories, provides one-on-one training for students, ensures safe laboratory practices, and maintains equipment. State-of-the-art instruments and equipment are available for use by all CBE faculty, staff, and students. General use areas include a microbiology lab, a media kitchen, an instrument lab, and an isolated radioactive isotope lab. Facilities of particular note are described below.

CBE labs continue sustainable practices

Collaborative efforts have been successful in replacing the use of highly toxic ethidium bromide (EtBr) with GelRed™ Nucleic Acid Gel Stain. This dye was developed by scientists at Biotium, Inc. with a goal of low toxicity, high sensitivity, and exceptional stability. This change is part of the CBE's continued effort to improve lab safety and support sustainable practices.

Mass spectrometry facility

In 2005 an equipment grant was awarded for an Environmental and Biofilm Mass Spectrometry Facility through the Department of Defense University Research Instrumentation Program (DURIP). The grant funded the acquisition of an Agilent 1100 series high performance liquid chromatography system with autosampler and fraction collector, an Agilent SL ion trap mass spectrometer, and an Agilent 6890 gas chromatograph (GC) with electron capture detector, flame ionization detector, and 5973 inert mass spectrometer. Since then, an Agilent 7500ce inductively coupled plasma mass spectrometer with autosampler, liquid, and gas chromatographic capabilities have been added as well as an additional Agilent 1100 series high performance liquid chromatography system with autosampler and an Agilent 6890 GC with autosampler and flame ionization detector. The chromatographs and mass spectrometers are very well suited for unknown compound identification and high sensitivity speciation measurements of organic and inorganic compounds; this equipment enhances the CBE's research capabilities significantly. The Environmental and Biofilm Mass Spectrometry Facility is operated as a user facility and allows access for academic and non-academic researchers.

Microsensor Laboratory

A specialized Microsensor Laboratory provides the capability of measuring microscale chemical and physical parameters within biofilms. 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 micropositioners for depth profiling. The microsensor lab also has instrumentation for measuring corrosion and other electrochemical phenomena associated with biofilms.

Microscope Facilities

The microscopy 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 and fluorescent confocal microscopy. The microscopy facilities include three separate laboratories—the Optical Microscopy Lab, the Confocal Microscopy Lab, and the Microscope Resource Room and Digital Imaging Lab—which are detailed below.

The **Optical Microscopy Lab** houses two 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. Other equipment in the Optical Microscopy Lab includes a Nikon SMZ-1500 barrel zoom stereomicroscope equipped with a color camera, a Leica CM1800 cryostat, a Zeiss Palm Laser Capture Dissection microscope and a dry ice maker.

The **Confocal Microscopy Lab** contains two fairly new (2011) 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 new 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 **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.

Computer Facilities

The CBE maintains several dedicated computational and data storage computers. CBE also provides workstations connected to the MSU College of Engineering (COE) computer network. A student computer laboratory offers six state-of-the-art PCs along with scanning and printing services.

Additionally CBE staff and students have access to COE maintained computational PCs and the centrally maintained computational cluster for data manipulation, mathematical modeling, and graphic image analysis.

SPECIALIZED CBE RESEARCH GROUPS

Ecology/Physiology Laboratory

The Ecology/Physiology Laboratory headed by Dr. Matthew Fields has general microbiology equipment, anaerobic gassing stations, Shimadzu UV-VIS spectrophotometer, Ultra-Centrifuge, biofilm reactors, protein and DNA electrophoresis, Qubit fluorometer, two Eppendorf Mastercylcers, incubators, laminar/fume hoods, microcentrifuges, table-top centrifuges, and a microcapillary gas chromatograph with dual TCDs. The lab has a light-cycle controlled photo-incubator as well as photo-bioreactors for the cultivation of algae and diatoms, and maintains one -20°C freezer and two -70°C freezers for sample storage.

This laboratory houses an Illumina MiSeq Sequencing System. 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 4 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).

Medical Biofilm Laboratory

The Medical Biofilm Laboratory (MBL) has earned a reputation for being a university lab that responds quickly to real world needs 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 research scientist, two technicians, and three undergraduate research assistants.

Currently, eight companies, including CBE Industrial Associates, sponsor MBL projects. The MBL is also collaborating with a small business on a Phase II Small Business Innovation Research (SBIR) grant. In addition, MBL principal investigator, Assistant Research Professor Dr. Kelly Kirker, is investigating staphylococcal biofilm induction of apoptosis in human epidermal cells, with funding from the National Institutes of Health (NIH). Other MBL projects include evaluating antimicrobial wound dressings, biofilm formation on biomedical polymers, testing novel toothpaste ingredients, 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.

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, refine, and publish quantitative methods for growing, treating, sampling, and analyzing biofilm bacteria. The SBML members work with international standard setting organizations (ASTM International, AOAC, IBRG, OECD, and 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 conducts laboratory research to support the development and standardization of test methods for measuring the performance of antimicrobial products—including those for biofilm bacteria—and provide statistical services related to EPA's Office of Pesticide Programs Antimicrobial Testing Program. In addition, they conduct applied and fundamental research experiments and develop testing protocols. Methods include: design of reactor systems to simulate industrial/medical systems; growing biofilm and quantifying cell numbers 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.

Microbial Ecology and Biogeochemistry Laboratory

Research in the Microbial Ecology and Biogeochemistry Laboratory lies at the intersection of microbial and ecosystem ecology 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 whole 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, they are interested in physiological adaptations to life in icy environments. Regardless of the environment, the group employs microbiological, limnological, biochemical and molecular biology approaches to investigate fundamental processes carried out by microbes.

OTHER Montana State University facilities available for collaborative research

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.

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. Both instruments in the facility are Bruker Avance instruments. The facility houses 250 MHz standard/wide bore and a 300 MHz wide/super-wide bore instruments for imaging and fluid dynamics applications. The imaging systems are capable of generating NMR image and transport data with spatial resolution on the order of 10 μm in a sample space up to 6 cm diameter.

MSU ICAL Laboratory

The Image and Chemical Analysis Laboratory (ICAL) in the Physics Department at Montana State University is located on the 3rd floor of the EPS Building, 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 to government and academic institutions and the private sector. Laboratory instrumentation is dedicated to the characterization of materials through high resolution imaging and spectroscopy. ICAL promotes interdisciplinary collaboration between the research, educational and industrial fields.

Current Instrumentation

- * 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
- * Microplotting System
- * 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/home/index.asp>

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