

2008 APPENDIX

*to the
Center for Biofilm Engineering
Annual Report*

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2007 Publications

Ayati BP and Klapper I, “A multiscale model of biofilm as a senescence-structured fluid,” *Multiscale modeling and simulation: A SIAM Interdisciplinary Journal*, 2007; 6:347–365. **Abstract 07-024**

Alpkvist E and Klapper I, “Description of mechanical response including detachment using a novel particle model of biofilm/flow interaction,” *Water Science Technology*, 2007; 55(8-9):265–273. **Abstract 07-025**

Alpkvist E and Klapper I, “A multidimensional multispecies continuum model for heterogeneous biofilm development,” *Bull Math Biol*, 2007; 69(2):765–789. **Abstract 07-018**

Boyd ES, Cummings DE, and Geesey GG, “Mineralogy influences structure and diversity of bacterial communities associated with geological substrata in a pristine aquifer,” *Microb Ecol*, 2007; 54(1):170–182. **Abstract 07-032**

Buckingham-Meyer K, Goeres DM, and Hamilton MA, “Comparative evaluation of biofilm disinfectant efficacy tests,” *J Microbiol Methods*, 2007; 70(2):236–244. **Abstract 07-016**

Clark ME, Edelmann RE, Duley ML, Wall JD, and Fields MW, “Biofilm formation in *Desulfovibrio vulgaris* Hildenborough is dependent upon protein filaments,” *Environ Microbiol*, 2007; 9(11):2844–2854. **Abstract 07-019**

Desrosiers M, Myntti M, and James G, “Methods for removing bacterial biofilms: In vitro study using clinical chronic rhinosinusitis specimens,” *Am J Rhinol*, 2007; 21(5):527–532. **Abstract 07-026**

Foreman CM, Sattler B, Mikucki JA, Porazinska DL, and Priscu JC, “Metabolic activity and diversity of cryoconites in the Taylor Valley, Antarctica,” *J Geophys Res Biogeosciences*, 2007; 112(G04S32): 1–11. **Abstract 07-027**

Garo E, Eldridge GR, Goering MG, deLancey Pulcini E, Hamilton M, Costerton JW, and James GA, “Asiatic acid and corosolic acid enhance the susceptibility of *P. aeruginosa* biofilm to tobramycin,” *Antimicrob Agents Chemother*, 2007; 51(5):1813–1817. **Abstract 07-002**

Kirisits MJ, Margolis JJ, Purevdorj-Gage BL, Vaughan B, Chopp DL, Stoodley P, and Parsek MR, “Influence of the hydrodynamic environment on quorum sensing in *Pseudomonas aeruginosa* biofilms,” *J Bacteriol*, 2007; 189(22):8357–8360. **Abstract 07-031**

Klapper I, Gilbert P, Ayati BP, Dockery J, and Stewart PS, “Senescence can explain microbial persistence,” *Microbiology*, 2007; 153(11):3623–3630. **Abstract 07-022**

Lewandowski Z and Beyenal H, “Fundamentals of biofilm research,” CRC Press Inc Lewis Publishers Boca Raton, (Available for purchase at CRC Press) Book review by Robert Palmer, *J Microbiol Meth*, 2007; 71:347–349. **Abstract 07-014**

Lewandowski Z, Beyenal H, Meyers J, and Stookey D, “The effect of detachment on biofilm structure and activity: The oscillating pattern of biofilm accumulation,” *Water Science & Technology*, 2007; 55(8-9):429–436. **Abstract 07-023**

Marsili E, Beyenal H, Di Palma L, Merli C, Dohnalkova A, Amonette JE, and Lewandowski Z, “Uranium immobilization by sulfate-reducing biofilms grown on hematite, dolomite, and calcite,” *Environ Sci Technol*, 2007; 41(24):8349–8354. **Abstract 07-021**

Meers P, Malinin V, Lee J, Neville M, Sardaryan G, James G, Fisher S, and Perkins WR, “*Pseudomonas* biofilm penetration and activity of liposomal Amikacin (Arikace™),” *Pediatric Pulmonology*, 2007; 42(S30):322–323. *Special Issue: 21st Annual North American Cystic Fibrosis Conference* **Abstract 07-030**

Patrauchan MA, Sarkisova SA, and Franklin MJ, “Strain-specific proteome responses of *Pseudomonas aeruginosa* to biofilm-associated growth and to calcium,” *Microbiology*, 2007; 153(11):3838–3851. **Abstract 07-029**

Stein OR, Borden DJ, Hook PB, and Jones WL, “Seasonal influence on sulfate reduction and metal sequestration in sub-surface wetlands,” *Wat Res*, 2007; 41(15):3440–3448. **Abstract 07-017**

RESEARCH : PUBLICATIONS

Wu W, et al., "In situ bioreduction of uranium (VI) in situ and stability of immobilized uranium: Impact of dissolved oxygen," *Environ Sci Technol*, 2007; 41:5716–5723. **Abstract 07-028**

2008 Publications

Christner BC, Morris CE, Foreman CM, Cai R, and Sands DC, "Ubiquity of biological ice nucleators in snowfall," *Science*, 2008; 319 (5867):1214. **Abstract 08-006**

Dowd SE, Sun Y, Secor PR, Rhoads DD, Wolcott BM, James GA, and Wolcott RD, "Survey of bacterial diversity in chronic wounds using pyrosequencing, DGGE, and full ribosome shotgun sequencing," *BMC Microbiol*, 2008; 8(1):43. **Abstract 08-007**

Geesey GG and Mitchell AC, "Need for direct measurements of coupled microbiological and hydrological processes at different scales in porous media systems," *J Hydrologic Eng*, 2008; 13(1): 28–36. **Abstract 08-001**

Geesey GG, Borch T, and Reardon CL, "Resolving biogeochemical phenomena at high spatial resolution through electron microscopy," *Geobiology*, 2008; 6:263–269. **Abstract 08-012**

Geier H, Mostowy S, Cangelosi GA, Behr MA, and Ford TE, "Autoinducer-2 triggers the oxidative stress response in *Mycobacterium avium* leading to biofilm formation," *Appl Environ Microbiol*, 2008; 74(6):1798–1804. **Abstract 08-017**

Hochwalt P, Zhao G, Underwood R, Usui M, Singh P, Stewart P, Olerud J, and Fleckman P, "Development of a chronic wound in a diabetic (db/db) mouse by infection with biofilm," *J Investigative Dermatology*, 2008; 128(S1):S195 Meeting Abstract 1168. **Abstract 08-016**

James GA, Swogger E, Wolcott R, deLancey Pulcini E, Secor P, Sestrich J, Costerton JW, and Stewart PS, "Biofilms in chronic wounds," *Wound Repair and Regeneration*, 2008; 16:37–44. **Abstract 08-002**

Klonowska A, Clark ME, Thieman SB, Giles BJ, Wall JD, and Fields MW, "Hexavalent chromium reduction in *Desulfovibrio vulgaris* Hildenborough causes transitory inhibition of sulfate reduction and cell growth," *Appl Microbiol Biotechnol*, 2008; 78(6):1007–1016. **Abstract 08-011**

Kim J, Pitts B, Stewart PS, Camper A, and Yoon J, "Comparison of antimicrobial effect on biofilm of chlorine, silver ion and tobramycin," *Antimicrob Agents Chemother*, 2008; 52(4):1446–1453. **Abstract 08-003**

Khot PD, Suci PA, and Tyler BJ, "*Candida albicans* viability after exposure to amphotericin B: assessment using metabolic assays and colony forming units," *J Microbiol Methods*, Mar 2008; 72(3):268–274. **Abstract 08-015**

Korenblum E, Sebastián GV, Paiva MM, Coutinho CM, Magalhães FC, Peyton BM, and Seldin L, "Action of antimicrobial substances produced by different oil reservoir *Bacillus* strains against biofilm formation," *Appl Microbiol Biotechnol*, 2008; 79(1):97–103. **Abstract 08-013**

Lenz AP, Williamson K, Pitts B, Stewart PS, and Franklin MJ, "Localized gene expression in *Pseudomonas aeruginosa* biofilms," *Appl Environ Microbiol*, 2008; May 16 [Epub ahead of print]. **Abstract 08-014**

Meers P, Neville M, Malinin V, Scotto AW, Sardaryan G, Kurumunda R, Mackinson C, James G, Fisher S, and Perkins WR, "Biofilm penetration, triggered release and in vivo activity of inhaled liposomal amikacin in chronic *Pseudomonas aeruginosa* lung infections," *J Antimicrobial Chemotherapy*, 2008; 61(4):859–868. **Abstract 08-010**

Stewart PS and Franklin MJ, "Physiological heterogeneity in biofilms," *Nat Rev Microbio*, 2008; 6(3):199–210. **Abstract 08-005**

Takenaka S, Trivedi HM, Corbin A, Pitts B, and Stewart PS, "Direct visualization of spatial and temporal patterns of antimicrobial action within model oral biofilms," *Appl Environ Microbiol*, 2008; 74(6):1869–1875. **Abstract 08-004**

PRESENTATIONS:

June 1 – December 31, 2007

John Lennox and **Jeffrey Ashe** presented the poster “Biofilms as biobarriers,” 14th Annual American Society for Microbiology Conference for Undergraduate Educators, University at Buffalo, SUNY North Campus, Buffalo, NY, May 18–20, 2007. John Lennox is from Penn State Altoona and is co-editor on *Biofilms: The Hyptertextbook*, an NSF-funded education project. They also presented the poster at the American Society for Microbiology General Meeting, Metro Toronto Convention Centre, Toronto, Ontario, Canada, May 21–25, 2007.

Marty Hamilton presented “The 6-log performance standard for quantitative sporicidal efficacy tests,” EPA FIFRA Scientific Advisory Panel, Arlington, Virginia, July 17, 2007.

Melinda Clark presented the poster “Structural role for flagella in biofilm formation and stability in *Desulfovibrio vulgaris* Hildenborough,” 2007 Environmental Subsurface Science Symposium, Utah State University, Logan, Utah, July 25, 2007. *She won second place in the poster competition.*

Melinda Clark presented “Responses of *Desulfovibrio vulgaris* to physiological constraints,” 2007 Environmental Subsurface Science Symposium, Utah State University, Logan, Utah, July 25, 2007.

Chiachi Hwang presented the poster “Changes in microbial community structure during bio-stimulation for uranium reduction,” 2007 Environmental Subsurface Science Symposium, Utah State University, Logan, Utah, July 25, 2007. *She won third place in the poster competition.*

Chiachi Hwang presented “Bacterial communities stimulated for uranium bio-reduction display temporal concordance along controlled flow paths,” 2007 Environmental Subsurface Science Symposium, Utah State University, Logan, Utah, July 25, 2007.

Anitha Sundararajan presented the poster “Proteins involved in oxygen sensing and metabolism are important for biofilms in *Shewanella oneidensis* MR-1,” 2007 Environmental Subsurface Science Symposium, Utah State University, Logan, Utah, July 25, 2007.

Phil Stewart presented “Diffusion of macromolecules and antimicrobial agents in biofilm,” at the National Institute for Dental and Craniofacial Research, Bethesda, Maryland, July 27, 2007.

Joseph Seymour, as an invited speaker, presented “Biopolymer and water dynamics in microbial biofilm extracellular polymeric substance,” EUCHEM Conference Structure Dynamics in Soft Condensed Matter, Fiskebäckskil, Sweden, August 20–22, 2007.

Markus Dieser presented the poster “Microbial diversity and the role of bacterial pigments as cryo- or UV- protectants in Pony Lake, Antarctica,” Society of International Limnology Meeting, Montreal, Canada, August 12–18, 2007. Authors: Dieser M, and Foreman C. *Markus won best student poster presentation and received a \$250 award.*

Abbie Richards presented “Novel iron reducing siderophores produced by a soda lake *Halomonas sp.*,” Halophiles 2007 Congress, University of Essex, Colchester, England, September 2–6.

Amber Broadbent presented the poster “Quantifying velocity and mass transfer in Taylor-Couette flow,” 9th International Conference on Magnetic Resonance Microscopy, Aachen, Germany, September 3–7, 2007. She won the conference poster award. She competed against 125 other posters and was awarded nuclear magnetic resonance textbooks.

Sara Codd presented as invited speaker “Biopolymer and water dynamics in microbial biofilm extracellular polymeric substance,” 9th International Conference on Magnetic Resonance Microscopy, Aachen, Germany, September 3–7, 2007.

Tyler Brosten presented the poster “NMR velocity phase encoded measurements within unidirectional tapered-pore ceramic structures,” 9th International Conference on Magnetic Resonance Microscopy, Aachen, Germany, September 3–7, 2007.

RESEARCH : PRESENTATIONS

Jennifer R. Brown presented the poster “NMR measurement of irreversibility and particle migration in dilute sheared brownian suspensions,” 9th International Conference on Magnetic Resonance Microscopy, Aachen, Germany, September 3–7, 2007.

Einar Orn Fridjonsson presented the poster “The study of flow and particle distribution in a bifurcation using dynamic NMR microscopy,” 9th International Conference on Magnetic Resonance Microscopy, Aachen, Germany, September 3–7, 2007.

Jennifer Hornemann presented the poster “Analysis of biofilm extracellular polymeric Substance (EPS) Diffusion,” 9th International Conference on Magnetic Resonance Microscopy, Aachen, Germany, September 3–7, 2007. Authors: Brown J, Codd S, Lysova A, and Seymour J.

Betsey Pitts presented “Microscopy of biofilms at the CBE,” Procter & Gamble Company, Rusham Park Technical Centre, Egham, England, September 12, 2007.

Anne Camper presented a WEBINAR: “Water quality: Biofilm formation in clean water lines,” September 13, 2007. The Webinar was sponsored by the Cosmetic, Toiletry and Fragrance Association (CTFA) and there were approximately fifty participants.

Storm Shirley and **Brent Peyton** presented a poster “Use of inosine containing primers for rapid resolution of microbial diversity from thermophilic hot springs in Yellowstone National Park,” Thermophiles Conference, Bergen City, Norway, September 24–27, 2007.

Paul Sturman presented “Biofilms in biocorrosion,” Society of Petroleum Engineers (SPE), Calgary, Alberta, Canada, October 1–4, 2007.

Phil Stewart presented “Alternative strategies to controlling biofilms,” Colgate-Palmolive symposium, Boston, Massachusetts, October 8–11, 2007.

Phil Stewart presented “Biofilms, daptomycin, and persistent infections,” Cubist Pharmaceuticals, Boston, Massachusetts, October 9, 2007.

Darla Goeres presented “Understanding the importance of biofilm in treated recreational water venues,” Texas Environmental Health Association Annual Educational Conference, Austin, Texas, October 18, 2007.

Kelli Buckingham-Meyer presented “Biofilm methods for standardization,” American Society for Testing and Materials Committee Meeting, Tampa, Florida, October 30–November 2, 2007.

Andreas Nocker presented “Live-dead distinction in molecular diagnostics,” QIAGEN AG, Hilden, Germany, December 4, 2007.

John Lennox and **Jeffrey Ashe** presented the poster “Biofilms as biobarriers” at the National Association of Biology Teachers, Professional Development Conference, Hyatt Regency, Atlanta, Georgia, November 28–December 1, 2007. John Lennox is from Penn State Altoona and is co-editor on *Biofilms: The Hyptertextbook*, an NSF-funded education project.

PRESENTATIONS: January 1–May 31, 2008

Zbigniew Lewandowski presented “The concept of stratified biofilms relates results of measurements at the microscale to the biofilm reactor performance at the macroscale,” Biofilm Technologies Conference, International Water Association, Singapore, January 8–10, 2008. He also was co-chair of Session 1: Biofilm Structure along with Dr. Sanjay Swarup, National University of Singapore, Singapore.

Garth James presented “The role of biofilms in wound infection,” Wound Healing Conference, Paris, France, January 25–30, 2008.

Kristen Brileya, **Natasha Mallette**, **Reed Taffs** and **John Aston** presented the poster “Case study in geobiological systems: In silico analysis of material and energy flow in a hot spring microbial mat,” MSU Department of Graduate Studies Molecular Bioscience Recruitment Program, Bozeman, Montana, February 29, 2008. Authors: Brileya K, Aston J, Carlson R, Fields M, Gerlach R, Inskeep W, Jay Z, Klatt C, Mallette N, McGlynn S, Montross S, Skidmore M, Taffs R, Ward D.

RESEARCH : PRESENTATIONS

Stewart Clark presented the poster “Comparing the behavior of *Salmonella typhimurium*: Biofilm vs. planktonic,” MSU Department of Graduate Studies Molecular Bioscience Recruitment Program, Bozeman, Montana, February 29, 2008.

Markus Dieser presented the poster “Microbial diversity and the role of bacterial pigments as cryo- and-UV- protectants in Pony Lake, Antarctica,” MSU Department of Graduate Studies Molecular Bioscience Recruitment Program, Bozeman, Montana, February 29, 2008. Authors: Dieser M, Foreman C.

Andy Mitchell and **Robin Gerlach** presented the poster “Bioremediation and the role of mixed pollution: TNT and Cr(VI),” MSU Department of Graduate Studies Molecular Bioscience Recruitment Program, Bozeman, Montana, February 29, 2008. Authors: Ballor NR, Gerlach, R.

Andy Mitchell and **Robin Gerlach** presented the poster “Isolation of cellulose degrading microorganisms and their influence on contaminant mobility and reduction,” MSU Department of Graduate Studies Molecular Bioscience Recruitment Program, Bozeman, Montana, February 29, 2008. Authors: Field EK, VanEngelen M, Peyton BM, Lee B, Apel WA, Gerlach R.

Andy Mitchell and **Robin Gerlach** presented the poster “Biofilm enhanced subsurface sequestration of supercritical CO₂,” MSU Department of Graduate Studies Molecular Bioscience Recruitment Program, Bozeman, Montana, February 29, 2008. Authors: Mitchell AC, Phillips AJ, Hiebert R, Gerlach R, Kaszuba J, Hollis WK, Cunningham AB.

Catherine VanEngelen presented the poster “Alkaline hydrolysis and biotransformation of TNT by thermoalkaliphiles from Yellowstone National Park,” MSU Department of Graduate Studies Molecular Bioscience Recruitment Program, Bozeman, Montana, February 29, 2008. Authors: Albaugh-VanEngelen C, Peyton BM, Gerlach R.

Robin Gerlach presented “Oxidation-reduction reactions influencing the transformation of mixed contaminants in the presence of zero valent iron and biofilms,” Pittcon Conference, New Orleans, Louisiana, March 1–6, 2008.

Zbigniew Lewandowski presented “Microbial fuel cells—from laboratory studies to applications” and “Optimizing power generation by microbial fuel cells,” Ocean Sciences Meeting, Orlando, Florida, March 2–7, 2008.

Al Cunningham presented “Microbially enhanced carbon storage” at a workshop on Numerical Models for Carbon Dioxide Storage in Geological Formations, Stuttgart, Germany, April 2–4, 2008.

Phil Stewart presented a three-day workshop on biofilm control at the University of Concepción in Concepción, Chile, April 7–9, 2008. This event was a continuation of interaction between the CBE and the biofilm group in Concepción led by Homero Urrutia. The two groups have hosted reciprocal workshops and visits regularly since 2001. Dr. Stewart lectured to approximately 40 attendees on topics of: issues in biofilm control, antimicrobial tolerance in biofilms, and alternative strategies for biofilm control.

Kelly Kirker presented “*Staphylococcus aureus* biofilms prevent scratch wound closure in vitro,” at the Society Advance Wound Care Meeting San Diego, California, April 24–27, 2008.

Elinor deLancey Pulcini presented “Biofilms and the biodiversity of slime,” at the American Society for Clinical Laboratory Scientists (ASCLS), Idaho Spring Convention, Pocatello, Idaho, April 17–19, 2008.

Phil Stewart was invited to present “Quorum sensing inhibition as an alternative biofilm control strategy,” at Ecolab in Eagan, Minnesota, May 8, 2008.

Zbigniew Lewandowski was invited as a keynote speaker to present “Quantifying mass transport, structure, and microbial activity in biofilms,” at The First Israeli Conference on Biofilms in Water and Food Industries, Israel Institute of Technology, Technion, Haifa, Israel, May 15, 2008.

RESEARCH : PROJECTS

2007–2008 CBE Research Projects

Research Area	Title	Principal Investigator	Funding Agency
Biofilm Control / Antimicrobials	Kodak antimicrobial surface patent Development	Camper, Stewart Sturman	Kodak
Bioelectrochemistry	Microbial fuel cells to power submersed electronic devices	Lewandowski	ONR
Bioremediation	Subsurface biofilm barriers for enhanced geologic sequestration of supercritical CO ₂	Cunningham Spangler	DOE/ZERT
Bioremediation	Mechanistically based field scale models of uranium biogeochemistry from up-scaling pore-scale experiments and models ²	Seymour Codd	DOE
Bioremediation	Mobility of source zone heavy metals and radionuclides: The mixed roles of fermentative activity on fate and transport of U and Cr	Gerlach Peyton	DOE
Bioremediation	Seasonal, operational, and plant effects on oxygen potential and microbial responses influencing constructed wetland performance	Stein	USDA
Bioremediation	Biocomplexity: Biogeochemical cycling of heavy metals ²	Peyton	NSF
Bioremediation	INRA subsurface biotechnology and bioremediation research initiative	Cunningham	INRA
Bioremediation	Identification of molecular and cellular responses of <i>Desulfovibrio vulgaris</i> biofilms under culture conditions relevant to field conditions for bioreduction of heavy metals	Fields	DOE
Bioremediation	Genome sequencing of multiple <i>Anaeromyxobacter</i> species: Comparative genomics for insight into the ecophysiology, genetics and evolution of metal-reducing and halorespiring bacteria	Fields	DOE
Bioremediation	Rapid deduction of stress pathways in metal reducing bacteria	Fields	DOE via University of Oklahoma
Bioremediation	Effects of groundwater chemistry on the distribution of soil microorganisms in natural media	Fields	ORNL
Bioremediation	Subsurface biotechnology	Fields	INRA
Education	Biofilms: The Hypertextbook	Cunningham Ross	NSF
Education	Partners in Science Program	Pulcini	MJ Murdock Charitable Trust
Industrial and Environmental Water Systems	Health implications of biofilms in drinking water systems	Camper Cunningham	DOD/ARO

RESEARCH : PROJECTS

Research Area	Title	Principal Investigator	Funding Agency
Industrial and Environmental Water Systems	Towards sustainable materials for drinking water infrastructure	Camper	NSF
Industrial and Environmental Water Systems	Synthesis document on the state of science of molecular techniques for application to the drinking water industry	Camper Burr Nocker	AwwaRF
Industrial and Environmental Water Systems	Biodegradation of HAAs in distribution systems	Camper	AwwaRF via University of Minnesota
Industrial and Environmental Water Systems	Investigation of the mode of action of stannous chloride as an inhibitor of lead corrosion	Camper	AwwaRF via University of Minnesota
Industrial and Environmental Water Systems	Effect of nitrification on corrosion in the distribution system	Camper	AwwaRF via Virginia Tech
Medical Biofilms	The role of biofilms in the pathogenesis of otorrhea	Stewart	NIH via Allegheny-Singer
Medical Biofilms	<i>Staphylococcus aureus</i> and production of toxic shock syndrome toxin	Lewandowski	Procter & Gamble
Medical Biofilms	Transcutaneous devices permitting skin cell attachment	Stewart James	NIH via University of Washington
Medical Biofilms	Mobilization of <i>Candida albicans</i> biofilms	Suci	NIH
Medical Biofilms	Healing chronic wounds by controlling microbial biofilm	Stewart James	NIH
Medical Biofilms	Non-invasive clinical device that is effective in clearing persistent infections in prosthetic knee implants	McLeod	Allegheny-Singer MTBRC
Medical Biofilms	Novel chemical analysis of the biofilm-biomaterial interface	Carlson	NIH via University of Illinois
Natural Organic Matter	Collaborative proposal: Biogeochemistry of dissolved organic matter in Pony Lake, Ross Island ³	Foreman	NSF
Natural Organic Matter	Paleorecords of biotic and abiotic particles in polar ice cores ³	Foreman Priscu	NSF
Physiology & Ecology	A genomes-to-geochemical analysis of geothermal features in Yellowstone National Park ⁴	Gerlach, Peyton, Inskeep, McDermott, Fields	NASA
Physiology & Ecology	Biocomplexity in metal contaminated sediments of Lake Coeur d'Alene ²	Peyton	NSF
Physiology & Ecology	Bacterial pigments: Examining their potential role as cryo- and ultraviolet radiation protectants	Foreman	MSGC-NASA
Physiology & Ecology	Virtual Institute for Microbial Stress & Survival	Fields	Lawrence Berkley National Lab
Physiology & Ecology	Methanogenesis in subglacial environments --- biosignatures of extraterrestrial life	Mitchell	MSGC-NASA

RESEARCH : PROJECTS

Physiology & Ecology	Metabolic engineering of <i>Alicyclobacillus acidocaldarius</i> for lactic acid production from biomass derived Monosaccharides	Carlson	INL
Standardized Biofilm Methods	Antimicrobial test methodology	Goeres	EPA
Standardized Biofilm Methods	Research support for the development and manufacturing of a rapid biofilm analysis test kit	Goeres Cunningham	MTBRC
Structure-Function	Gene expression in <i>Pseudomonas aeruginosa</i> during biofilm development ^{*1}	Franklin	NIH
Structure-Function	ADVANCE Fellows Award: NMR microscopy of structure-function relationships and microfluidics in biofilms and cellular suspensions ^{*2}	Codd	NSF
Structure-Function	Cohesive strength and detachment of bacterial biofilms	Stewart	NSF via University of Minnesota

* 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

²MSU Department of Chemical and Biological Engineering

³MSU Department of Land Resources & Environmental Sciences

⁴MSU Thermal Biology Institute

List of Acronyms

ARO	Army Research Office
AwwaRF	American Water Works Association Research Foundation
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
INL	Idaho National Lab
INRA	Inland Northwest Research Alliance
MSGC	Montana Space Grant Consortium
MTBRC	Montana Board of Research and Commercialization
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NSF	National Science Foundation
ONR	Office of Naval Research
ORNL	Oak Ridge National Laboratory
TBI	Thermal Biology Institute (MSU)
USDA	U.S. Department of Agriculture
ZERT	Zero Emissions Research and Technology

RESEARCH : CURRENT COLLABORATORS

2007–2008 Current Research Collaborators

Collaborators	Title	PI, Research Area	Funding Agency	Project Dates
Ray Hozalski, University of Minnesota	Cohesive strength and detachment of bacterial biofilms	Stewart, Structure-Function	NSF	9/1/07–8/31/10
Ray Hozalski, University of Minnesota	Biodegradation of HAAs in distribution systems	Camper, Industrial and Drinking Water	AwwaRF via Univ of Minnesota	1/9/06–2/22/09
Ray Hozalski, University of Minnesota	Investigation of the mode of action of stannous chloride as an inhibitor of lead corrosion	Camper, Industrial and Drinking Water	AwwaRF via Univ of Minnesota	1/1/06–1/1/09
Phil Fleckman, John Olerud, University of Washington	Transcutaneous devices permitting skin cell attachment	Stewart, James Medical Biofilms	NIH via Univ of Washington	5/1/05–4/30/07
Adam Arkin, Terry Hazen, Jay Keasling, Lawrence Berkeley National Lab, CA	Virtual institute for microbial stress and survival	Fields, Physiology & Ecology	Lawrence Berkley National Lab	10/1/07–9/30/12
James Gossett, Cornell University, NY	Advisor to Laura Jennings	Bioremediation	Cornell University	09/15/05–
Marc Edwards, Virginia Polytechnic	Effect of nitrification on corrosion in the distribution system	Camper, Industrial and Drinking Water	AwwaRF via Virginia Tech	1/1/07–8/31/08
William Apel, Brady Lee, Idaho National Laboratory	Mobility of source zone heavy metals and radionuclides: The mixed roles of fermentative activity on fate and transport of U and Cr	Gerlach, Peyton, Bioremediation	DOE	12/15/06–12/14/08
Brady Lee, Frank Roberto, Idaho National Laboratory	Metabolic engineering of <i>Alicyclobacillus acidocaldarius</i> for lactic acid production from biomass derived monosaccharides	Carlson, Physiology & Ecology	INL	2/26/08–12/31/10
Luke Hanley, University of Illinois	Novel chemical analysis of the biofilm-biomaterial interface	Carlson, Medical Biofilms	NIH via Univ of Illinois	7/16/07–4/30/09
Phil Jardine, Oak Ridge National Laboratory, TN Tracy Bank, University of Buffalo, NY	Effects of groundwater chemistry on the distribution of soil microorganisms in natural media	Fields, Bioremediation	ORNL	3/8/07–9/30/09
Phil Fleckman, John Olerud, University of Washington Randy Wolcott, Southwest Regional Wound Care Center	Healing chronic wounds by controlling microbial biofilm	Stewart, James, Medical Biofilms	NIH	9/1/06–8/31/10
Haluk Beyenal, Washington State University	Microbial fuel cells to power submersed electronic devices	Lewandowski, Bioelectrochemistry	ONR	12/15/05–6/30/09
Zhili He, Jizhong Zhou, University of Oklahoma	Rapid deduction of stress pathways in metal reducing bacteria	Fields, Bioremediation	DOE	3/1/07–2/29/09

RESEARCH : CURRENT COLLABORATORS

Collaborators	Title	PI, Research Area	Funding Agency	Project Dates
Jizhong Zhou, University of Oklahoma Judy Wall, University of Missouri	Identification of molecular and cellular responses of <i>Desulfovibrio vulgaris</i> biofilms under culture conditions relevant to field conditions for bioreduction of heavy metals	Fields, Bioremediation	DOE	1/2/07–9/14/08
Ron Sims, Utah State University Steve Billingsley, Inland Northwest Research Alliance, ID	INRA subsurface biotechnology and bioremediation research initiative	Cunningham, Bioremediation	INRA	6/1/06–5/31/08
Garth Ehrlich, Allegheny Singer Research Institute	The role of biofilms in the pathogenesis of otorrhea	Stewart, Medical Biofilms	NIH via Allegheny- Singer	12/1/03–11/30/08
Garth Ehrlich, Allegheny Singer Research Institute	Non-invasive clinical device that is effective in clearing persistent infections in prosthetic knee implants	McLeod, Medical Biofilms	Allegheny- Singer MTBRC	7/1/07–5/31/08 8/1/07–7/31/09
Andre Nantel, McGill University, Canada	Mobilization of <i>Candida albicans</i> biofilms	Suci, Medical Biofilms	NIH	4/1/06–3/31/09

* 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

²MSU Department of Chemical and Biological Engineering

³MSU Department of Land Resources & Environmental Sciences

⁴MSU Thermal Biology Institute

List of Acronyms

ARO	Army Research Office
AwwaRF	American Water Works Association Research Foundation
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
INL	Idaho National Lab
INRA	Inland Northwest Research Alliance
MSGC	Montana Space Grant Consortium
MTBRC	Montana Board of Research and Commercialization
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NSF	National Science Foundation
ONR	Office of Naval Research
ORNL	Oak Ridge National Laboratory
TBI	Thermal Biology Institute (MSU)
USDA	U.S. Department of Agriculture
ZERT	Zero Emissions Research and Technology

RESEARCH : ASSOCIATED FACULTY

CBE Associated Faculty and Their Specialties, 2007–2008

NAME	DEPARTMENT	SPECIALTY
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
Sarah Codd	Mechanical & Industrial Engineering	Magnetic resonance imaging
Al Cunningham	Civil Engineering	Subsurface biotechnology and bioremediation
Jack Dockery	Mathematical Science	Mathematical models of biofilms
Matthew Fields	Microbiology	Physiology and ecology
Tim Ford	Microbiology	Drinking water, public health microbiology
Christine Foreman	Land Resources & Environ Sciences	Microbial ecology in cold temperature environments
Michael Franklin	Microbiology	Molecular genetics, gene expression, alginate
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
Tom Hughes	Cell Biology & Neuroscience	Fluorescent proteins, genetically encoded biosensors
Garth James	Chemical & Biological Engineering	Medical biofilms
Warren Jones	Civil Engineering	Water distribution systems
M.M. Taimur Khan	Center for Biofilm Engineering	Environmental engineering
Isaac Klapper	Mathematical Science	Mathematical modeling
Zbigniew Lewandowski	Civil Engineering	Microsensors, chemical gradients, biofilm structure
Tom Livinghouse	Chemistry & Biochemistry	Organic synthesis, signaling analogues
Timothy McDermott	Land Resources & Environ Sciences	Biofilms in extreme environments
Bruce McLeod	Electrical & Computer Engineering	Bioelectric effect
David Miller	Mechanical & Industrial Engineering	Experimental mechanics
Andy Mitchell	Civil Engineering	Geomicrobiology
Andreas Nocker	Center for Biofilm Engineering	Molecular microbiology
Brent Peyton	Chemical & Biological Engineering	Environmental biotechnology and bioremediation
Barry Pyle	Microbiology	Environmental, water, and food microbiology
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
Peter Suci	Microbiology	Fungal biofilms

EDUCATION : UNDERGRADUATE STUDENTS

Undergrads: Summer 2007, Fall 2007, Spring 2008

1. Akabari, Ratilal (Z. Lewandowski)	M	Microbiology	India
2. Allen, Chris (W. Jones)	M	Civil Engineering	California
3. Alniemi, Saba (E. Pulcini)	F	Biomedical Science	Bozeman, MT
4. Beck, Nicholas (D. Walker)	M	Chemical & Biological Engineering	Baker, MT
5. Bozeman, Jared (B. Peyton)	M	Cell Biology & Neuroscience	Bozeman, MT
6. Casey, Jennifer (M. Fields)	F	Chemical & Biological Engineering	Bozeman, MT
7. Donovan, Conrad (H. Beyenal)	M	Electrical & Computer Engineering	Helena, MT
8. Floener, Jenifer (O. Stein)	F	Civil Engineering	Bozeman, MT
9. Geer, Lindsey (D. Walker)	F	Chemical & Biological Engineering	Bozeman, MT
10. Gengler, Jon (P. Stewart)	M	Ag Biotechnology	Helena, MT
11. Goeres, Shannon (D. Goeres)	F	Civil Engineering	Kalispell, MT
12. Guggiana, Drago (A. Camper)	M	Chemical & Biological Engineering	Copiapo, Chile
13. Harrer, Travis (A. Richards)	M	Chemical & Biological Engineering	Great Falls, MT
14. Hartman, Andrea (E. Pulcini)	F	Chemical & Biological Engineering	Belgrade, MT
15. Hedegaard, Aaron (R. Carlson)	M	Chemical & Biological Engineering	Sidney, MT
16. Hellekson, Stacey (W. Jones)	F	Civil Engineering	Bozeman, MT
17. Helzer, Bryan (Z. Lewandowski)	M	Microbiology	Bozeman, MT
18. Hilyard, Alex (D. Goeres)	M	Business	Conrad, MT
19. Hisey, Bennett (A. Camper)	M	Civil Engineering	Bozeman, MT
20. Horn, Daniel (C. Foreman)	M	Land Resources & Environmental Sci.	Harlem, MT
21. Hoyt, Kathryn (S. Codd)	F	Chemical & Biological Engineering	Bellingham, WA
22. Humphreys, Bryan (D. Walker)	M	Chemical & Biological Engineering	Missoula, MT
23. Jara, Mateo (R. Ross)	M	Computer Science	Black Eagle, MT
24. Larson, Pattee (M. Fields)	F	Microbiology	Helena, MT
25. Lyles, Jennifer (M. Fields)	F	Microbiology	Bozeman, MT
26. Martin, Elizabeth (E. Pulcini)	F	Nursing (Bridges)	Hardin, MT
27. Nelson, Sara (T. Khan)	F	Cell Biology & Neuroscience	Kalispell, MT
28. Oksness, Garret (E. Pulcini)	M	Microbiology	Bozeman, MT
29. Popovitch, Paul (A. Richards)	M	Chemical & Biological Engineering	Bozeman, MT
30. Ready, Tiffany (D. Goeres)	F	Microbiology	Bozeman, MT
31. Rice, Jonathan (R. Carlson)	M	Chemical & Biological Engineering	Miles City, MT
32. Samuelson, Derrick (E. Pulcini)	M	Chemical & Biological Engineering	Bozeman, MT
33. Schicktanz, Laura (E. Pulcini)	F	Microbiology	Billings, MT
34. Schroeder, Melissa (O. Stein)	F	Land Resources & Environmental Sci.	Dorris, CA
35. Schultz, Logan (R. Gerlach)	M	Chemical & Biological Engineering	Chelan, WA
36. Swanson, Daniel (M. Burr)	M	Civil Engineering	Bozeman, MT
37. Unterreiner, Benjamin (B. Pitts)	M	Chemical & Biological Engineering	Kalispell, MT
38. Williamson, JeriLynn (B. Peyton)	F	Chemical & Biological Engineering	Billings, MT
39. Zuroff, Trevor (R. Carlson)	M	Chemical & Biological Engineering	Bozeman, MT

EDUCATION : UNDERGRADUATE STUDENTS

Graduating Fall 2007/Spring/Summer 2008

Saba Alniemi, May 31, 2008
Shannon Goeres, May 31, 2008
Andrea Hartman, December 14, 2007
Stacey Hellekson, May 31, 2008
Bryan Helzer, May 31, 2008
Alex Hilyard, May 31, 2008
Kathryn Hoyt, December 14, 2007
Jonathan Rice, December 14, 2007
Logan Schultz, May 31, 2008

Undergraduates Summary: 2007-2008

<u>Discipline / Program</u>	<u>Male</u>	<u>Female</u>	<u>Total</u>
Ag Biotech	1		1
Biomedical Science		1	1
Business	1		1
Cell Biology & Neuroscience	1	1	2
Chem & Bio Eng	11	5	16
Civil Engineering	3	3	6
Computer Science	1		1
Electrical & Comp Eng	1		1
Land Res. & Env Sci	1	1	2
Microbiology	3	4	7
Nursing (Bridges)		1	1
Totals	23	16	39

EDUCATION : GRADUATE STUDENTS

Grads: Summer 2007, Fall 2007, Spring 2008

1. Aldrich, Steve (MS Candidate, R. Ross)	M	Computer Sci	Bozeman, MT
2. Ba, Sidy (MS Candidate, W. Jones)	M	Env Eng	Bamako, Mali
3. Barua, Sutapa (MS Candidate, B. Peyton)	F	Chem & Bio Eng	Dhaka, Bangladesh
4. Behnke, Sabrina (MS Candidate, A. Camper)	F	Microbiology	Voerde, Germany
5. Bernstein, Hans (MS Candidate, R. Carlson)	M	Chem & Bio Eng	Kalispell, MT
6. Biebel, Stacy (MS Candidate, A. Cunningham)	F	Chem & Bio Eng	Livingston, MT
7. Brindle, Eric (MS Candidate, P. Stewart)	M	Mech & Ind Eng	Bozeman, MT
8. Coward, Kristin (MS Candidate, W. Jones)	F	Microbiology	Anchorage, AK
9. Harmon, Rance (MS Candidate, R. Ross)	M	Computer Sci	Bozeman, MT
10. Pannier, Andy (MS Candidate, R. Gerlach)	M	Microbiology	Bozeman, MT
11. Richard, Jessica (MS Candidate, M. Franklin)	F	Microbiology	Wuppertal, Germany
12. Sandvik, Elizabeth (MS Candidate, B. McLeod)	F	Chem & Bio Eng	Rapid City, SD
13. Schultz, Rickey (MS Candidate, O. Stein)	M	Env Eng	Ocean Spgs, MS
14. Sutton, Michael (MS Candidate, B. Towler)	M	Mech & Ind Eng	Billings, MT
15. Taylor, Carrie (MS Candidate, O. Stein)	F	Land Res & Env Sci	Columbus, IN
16. Taffs, Reed (MS Candidate, R. Carlson)	M	Civil Engineering	Helena, MT
17. Trasky, Trevor (MS Candidate, W. Jones)	M	Env Eng	Anchorage, AK
18. Wheeler, Laura (MS Candidate, A. Cunningham)	F	Chem & Bio Eng	Helena, MT
1. Aston, John (PhD Candidate, B. Peyton)	M	Chem & Bio Eng	Bozeman, MT
2. Bowen, Kara (PhD Candidate, M. Fields)	F	Molecular Biosci	Bozeman, MT
3. Brileya, Kristen (PhD Candidate, M. Fields)	F	Microbiology	Bozeman, MT
4. Chambless, Jason (PhD Candidate, P. Stewart)	M	Chem & Bio Eng	Austin, TX
5. Clark, Melinda (PhD Candidate, M. Fields)	F	Microbiology	Beloit, OH
6. Clark, Stewart (PhD Candidate, A. Camper)	M	Microbiology	South Africa
7. Davison, William (PhD Candidate, P. Stewart)	M	Chem & Bio Eng	Ballantine, MT
8. Dieser, Markus (PhD Candidate, C. Foreman)	M	Land Res & Env Sci	Walchsee, Austria
9. Encarnacion, Gem (PhD Candidate, A. Camper)	F	Microbiology	The Philippines
10. Faulwetter, Jennifer (PhD Candidate, M. Burr)	F	Microbiology	Morgan Hill, CA
11. Field, Erin (PhD Candidate, R. Gerlach)	F	Microbiology	Deep River, CT
12. Fridjonsson, Einar (PhD Candidate, J. Seymour)	M	Chem & Bio Eng	Iceland
13. Grabinski, Kevin (PhD Candidate, A. Camper)	M	Civil Engineering	East Helena, MT
14. Hornemann, Jennifer (PhD Candidate, S. Codd)	F	Chem & Bio Eng	Bozeman, MT
15. Hwang, Chiachi (PhD Candidate, M. Fields)	F	Microbiology	Taiwan
16. Jennings, Laura (PhD Candidate, A. Cunningham)	F	Civil Engineering	Helena, MT
17. Karmacharya, Amresh (PhD Candidate, Z. Lew)	M	Microbiology	Nepal
18. Kirk, Lisa (PhD Candidate, B. Peyton)	F	Land Res & Env Sci	Bozeman, MT
19. Klayman, Benjamin (PhD Candidate, A. Camper)	M	Civil Engineering	San Diego, CA
20. Mallette, Natasha (PhD Candidate, R. Gerlach)	F	Chem & Bio Eng	Fayetteville, AR
21. O'Shea, Kelly (PhD Candidate, M. Fields)	F	Molecular Biosci	Colorado Spg CO
22. Rahman, Mohammad Shahedur (PhD, A. Camper)	M	Civil Engineering	Rangpur, Bangladesh
23. Secor, Pat (PhD Candidate, E. Pulcini)	M	Cell Bio & Neurosci	Bozeman, MT
24. Shirley, Storm (PhD Candidate, B. Peyton)	M	Microbiology	Belgrade, MT
25. Sundararajan, Anitha (PhD Candidate, M. Fields)	F	Microbiology	India
26. Van Engelen, Catherine (PhD Candidate, B. Peyton)	F	Chem & Bio Eng	Lake City, PA
27. Van Engelen, Michael (PhD Candidate, B. Peyton)	M	Chem & Bio Eng	Spokane, WA

EDUCATION : GRADUATE STUDENTS

Graduate Students, 2007–2008

1: Cell Biology & Neuroscience

PhD: 1M Secor, Pat (PhD Candidate, E. Pulcini)

13: Chemical & Biological Engineering

MS: 5 Barua, Sutapa (MS Candidate, B. Peyton)
1 M Bernstein, Hans (MS Candidate, R. Carlson)
4 F Biebel, Stacy (MS Candidate, A. Cunningham)
Sandvik, Elizabeth (MS Candidate, B. McLeod)
Wheeler, Laura (MS Candidate, A. Cunningham)

PhD: 8 Aston, John (PhD Candidate, B. Peyton)
5 M Chambless, Jason (PhD Candidate, P. Stewart)
3 F Davison, William (PhD Candidate, P. Stewart)
Fridjonsson, Einar (PhD Candidate, J. Seymour)
Hornemann, Jennifer (PhD Candidate, S. Codd)
Malette, Natasha (PhD Candidate, R. Gerlach)
Van Engelen, Catherine (PhD Candidate, B. Peyton)
Van Engelen, Michael (PhD Candidate, B. Peyton)

8: Civil / Environmental Engineering

MS: 4M Ba, Sidy (MS Candidate, W. Jones)
Schultz, Rickey (MS Candidate, O. Stein)
Taffs, Reed (MS Candidate, R. Carlson)
Trasky, Trevor (MS Candidate, W. Jones)
PhD: 4 Grabinski, Kevin (PhD Candidate, A. Camper)
3 M Jennings, Laura (PhD Candidate, A. Cunningham)
1 F Klayman, Benjamin (PhD Candidate, A. Camper)
Rahman, Mohammad Shahedur (PhD, A. Camper)

2: Computer Science

MS: 2M Harmon, Rance (MS Candidate, R. Ross)
Aldrich, Steve (MS Candidate, R. Ross)

3: Land Resources & Environmental Sciences

MS: 1 F Taylor, Carrie (MS Candidate, O. Stein)
PhD: 2 Dieser, Markus (PhD Candidate, C. Foreman)
1 M Kirk, Lisa (PhD Candidate, B. Peyton)
1 F

2: Mechanical & Industrial Engineering

MS: 2M Brindle, Eric (MS Candidate, P. Stewart)
Sutton, Michael (MS Candidate, B. Towler)

13: Microbiology

MS: 4 Behnke, Sabrina (MS Candidate, A. Camper)
1M Coward, Kristin (MS Candidate, W. Jones)
3F Pannier, Andy (MS Candidate, R. Gerlach)
Richard, Jessica (MS Candidate, M. Franklin)
PhD: 9 Brileya, Kristen (PhD Candidate, M. Fields)
2M Clark, Melinda (PhD Candidate, M. Fields)
7F Clark, Stewart (PhD Candidate, A. Camper)
Encarnacion, Gem (PhD Candidate, A. Camper)
Faulwetter, Jennifer (PhD Candidate, M. Burr)
Field, Erin (PhD Candidate, R. Gerlach)
Hwang, Chiachi (PhD Candidate, M. Fields)
Shirley, Storm (PhD Candidate, B. Peyton)
Sundararajan, Anitha (PhD Candidate, M. Fields)

2: Molecular Bioscience

PhD: 2FBowen, Kara (PhD Candidate, M. Fields)
O'Shea, Kelly (PhD Candidate, M. Fields)

TOTALS

Total Grads: 44
Total MS: 18 10 M / 8 F
Total PhD: 26 12 M / 14 F
Total Male: 22
Total Female: 22

EDUCATION : GRADUATE STUDENTS

Graduating with advanced degrees, 2007–2008

Sidy Ba, MS, Environmental Engineering, Montana State University, May 2008:

“Breakthrough of indicator organisms from slow sand filters as part of a drinking water production system for sub-Saharan Africa”

Sutapa Barua, MS, Chemical Engineering, Montana State University, June 2007:

“Microbial diversity and zinc toxicity to *Pseudomonas* sp. from Coeur d’Alene river sediment”

Jason D. Chambless, PhD, Chemical and Biological Engineering, Montana State University, February 2008:

“A 3D computer model investigation of biofilm detachment and protection mechanisms”

William Marshall Davison, PhD, Chemical and Biological Engineering, Montana State University, January 2008:

“Spatial and temporal patterns of antimicrobial action against *Staphylococcus epidermidis* biofilms”

Henriette Geier, PhD, Microbiology, Montana State University, April 2008:

“Environmental and genetic factors leading to *Mycobacterium avium* biofilm formation”

Kevin Grabinski, MS, Environmental Engineering, Montana State University, July 2007:

“Pathogen transport and capture in a porous media biofilm reactor”

Benjamin J. Klayman, PhD, Environmental Engineering, Montana State University, June 2007:

“A quantitative description at multiple scales of observation of accumulation and displacement patterns in single and dual-species biofilms”

Jessica Richard, MS, Microbiology, Montana State University, May 2008:

“The two-component signal transduction systems of *Pseudomonas aeruginosa*”

Rickey Schultz, MS, Environmental Engineering, Montana State University, December 2007:

“Influence of pollutant loading rate on seasonal performance of model constructed wetlands”

Mike Sutton, MS, Environmental Engineering, Montana State University, March 2008:

“Quantifying the viscoelastic properties of treated and untreated *Pseudomonas aeruginosa* and *Staphylococcus epidermidis* biofilms using a rheological creep analysis”

EDUCATION : STUDENT AWARDS

2007–2008 Student Awards and Honors

Amber Broadbent, PhD candidate in chemical and biological engineering, won the Conference Poster Award for “Quantifying velocity and mass transfer in Taylor-Couette flow” at the 9th International Conference on Magnetic Resonance Microscopy, in Aachen, Germany, September 3–7, 2007. She competed against 125 other poster presentations.

Melinda Clark, PhD candidate in microbiology, won second place in the poster competition for “Structural role for flagella in biofilm formation and stability in *Desulfovibrio vulgaris* Hildenborough” at the 2007 Environmental Subsurface Science Symposium, Utah State University, Logan, UT, July 25, 2007.

Markus Dieser, PhD candidate in land resources and environmental sciences, won Best Student Poster Presentation and an award of \$250 for “Microbial diversity and the role of bacterial pigments as Cryo- or UV-protectants in Pony Lake, Antarctica” at the Society of International Limnology Meeting in Montreal, August 12–18, 2007. Authors were Markus Dieser and Christine Foreman.

Jennifer Hornemann, PhD candidate in chemical and biological engineering, won the February 2008 TAC’s Best Poster Award for “Magnetic resonance microscopy diffusion study of biofilm EPS.” Industrial attendees voted on the posters presented at the CBE’s open house and poster session.

Chiachi Hwang, PhD candidate in microbiology, won third place in the poster completion for “Changes in microbial community structure during biostimulation for uranium reduction” at the 2007 Environmental Subsurface Science Symposium, Utah State University, Logan, UT, July 25, 2007.

Laura Jennings, PhD candidate in environmental engineering, was awarded the 2008 Characklis Award. The award was presented to Laura at the CBE’s winter Technical Advisory Conference by Nancy Characklis. The W.G. Characklis Award was created in honor of the center's founder and is presented to a CBE PhD student based on his or her contributions in research, education, outreach, and industrial interaction. Laura regularly organized outreach activities for K-12 students, has been one of the CBE seminar series organizers, and has team-taught the University Studies Course UNIV 125CS “Microbes in the Environment” course (taught by CBE-PhD students to non-science or -engineering undergraduate students). Her research work elucidates oxidative DCE transformation processes by combining microarray, proteomics, and chromatography-mass spectrometry techniques.

Tiffany Ready, undergraduate in microbiology, was awarded the R.G. Martin Award. This award is given every three years; the student receiving this award is selected by a committee of faculty members of the Department of Microbiology. Students are selected based on their overall classroom performance, their initiative in seeking opportunities to make original contributions to the field, and their efforts to disseminate accurate information about the field. This scholarship has been made available through the generosity Richard G. Martin.

2007–2008 Scholarships and Fellowships

Natasha Mallette, **Reed Taffs** and **John Aston**, PhD candidates in chemical and biological engineering, were recipients of a two-year Integrative Graduate Education and Research Training (IGERT) Fellowship in August 2007. This fellowship is awarded to those interested in focusing on the geomicrobiology of complex microbiological systems and bringing together expertise in hydrodynamics, geochemistry, microbial ecology, biochemistry, and genomics.

Melissa Schroeder, undergraduate in land resources and environmental sciences, was awarded the Erskine Excellence in Agriculture Scholarship and the Margaret Gina Sachs Memorial Scholarship.

Daniel Swanson, undergraduate in microbiology, was awarded the E.R. Dodge Scholarship.

EDUCATION : STUDENT AWARDS

Trevor Trasky, graduate student in environment engineering, was awarded the Mary & Robert Sanks Graduate Fellowship.

Carrie Taylor, master's candidate in land resources and environmental sciences, was named a Big Sky Institute Science and Society Fellow for 2007–2008. The award is funded by the National Science Foundation Graduate Teaching Fellows in K12 Education (GK12) program. Carrie's application was chosen on the basis of a strong research record and extensive experience in communicating research to diverse groups of people. She received a stipend of \$30,000 for one year, with an additional \$10,500 cost-of-education allowance to offset tuition and fees, books, and supplies. Carrie is conducting research on constructed wetlands with her mentors Otto Stein, Paul Hook, and Cathy Zabinski.

EDUCATION : SEMINAR SERIES

2007 CBE Fall Seminar Series

Date	Speaker	Title
29 Aug 2007	First week of classes	No seminar
06 Sep 2007	Dr. Dave Ward MSU Professor, Land Resources and Environmental Sciences	Genomic and metagenomic analysis of a hot spring microbial mat community
13 Sep 2007	Dr. Sarah Codd CBE Assistant Professor, Mechanical and Industrial Engineering	Biopolymer and water dynamics in microbial biofilm extracellular polymeric substance
20 Sep 2007	Dr. Garth James CBE Research Scientist	Medical biofilm laboratory (MBL) summary
27 Sep 2007	Robert S. Maier U.S. Army Engineering Research and Development Center Vicksburg, Mississippi	Modeling NMR experiments with pore-scale simulation
04 Oct 2007	Dr. Mike Semmens Professor of Civil Engineering, University of Minnesota	Biofilm cohesiveness measurement using a novel atomic force microscopy methodology
11 Oct 2007	Melinda Clark PhD Candidate, Microbiology	The physiological state of <i>Desulfovibrio vulgaris</i> biofilms
18 Oct 2007	Dr. James Folsom CBE Postdoctoral Research Assistant	<i>Listeria monocytogenes</i> biofilms: Strain variation and chlorine resistance
25 Oct 2007	Dr. Carrie Harwood Professor of Microbiology, University of Washington	The role of oxygen and c-di-GMP on biofilm formation by <i>Pseudomonas aeruginosa</i>
01 Nov 2007	Dr. Joe (Jizhong) Zhou Presidential Professor, Department of Botany and Microbiology; Director, Institute for Environmental Genomics (IEG), University of Oklahoma	Microbial functional genomics, genomics technologies and environmental applications
08 Nov 2007	Dr. Andy Mitchell CBE Assistant Research Professor	Requirement for outer-membrane c-type cytochromes for anaerobic growth of <i>Shewanella</i> <i>oneidensis</i> MR-1 on hematite

EDUCATION : SEMINAR SERIES

15 Nov 2007	Dr. Tony Romeo Professor, Department of Microbiology and Immunology, Emory University School of Medicine	Dispensing the glue: Identification and regulation of a biofilm adhesion
22 Nov 2007	Thanksgiving	No seminar
29 Nov 2007	No seminar	No seminar
06 Dec 2007	Last week of classes	No seminar

EDUCATION : SEMINAR SERIES

2008 CBE Spring Seminar Series

Date	Speaker	Title
17 Jan 2008	Phil Stewart, Director and Paul Sturman, Coordinator of Industrial Development	Pre-TAC Talk
24 Jan 2008	No Seminar	No Seminar
31 Jan 2008	Dr. Sergio Morales Postdoctoral Research Assistant, University of Montana, Missoula	Validation of current 16S based phylogenetic analysis of complex bacterial communities
07 Feb 2008	Technical Advisory Conference (TAC)	TAC
14 Feb 2008	Laura K. Jennings PhD Candidate, Civil and Environmental Engineering, Cornell University	Proteomic, transcriptomic, and metabolomic analyses of cis-Dichloroethene degradation in <i>Polaromonas sp.</i> JS666
21 Feb 2008	Dr. Robin Gerlach MSU Associate Professor, Chemical and Biological Engineering Department	Bioremediation, bioenergy, carbon sequestration, and mass spectrometry - How does all this fit into the CBE?
28 Feb 2008	Dr. Luis Actis Professor and Chair Department of Microbiology, Miami University	<i>Acinetobacter baumannii</i> . A sticky blood-smelling human pathogen
06 Mar 2008	Dr. Isaac Klapper Professor, Mathematical Sciences Department, MSU	Modeling material aspects of biofilms
13 Mar 2008	Spring Break	No Seminar
20 Mar 2008	University Holiday	No Seminar
27 Mar 2008	Dr. Marc Edwards MacArthur Fellow, 2007, Charles P. Lunsford Professor of Civil and Environmental Engineering, Virginia Tech	The research challenge of premise plumbing
03 Apr 2008	No Seminar	No Seminar

EDUCATION : SEMINAR SERIES

10 Apr 2008	Dr. Ross Carlson Assistant Professor, Department of Chemical and Biological Engineering, MSU	Limitations of quorum sensing interference and biofilm control in <i>Escherichia coli</i>
17 Apr 2008	Dr. Mark Burr Research Scientist, CBE	Microbial community studies in constructed wetlands, biofilm reactors, and soils
25 Apr 2008	Dr. Chuck Gerba Professor, Department of Soil, Water and Environmental Science, University of Arizona, Tucson	Quantitative microbial risk assessment: Gambling with germs
01 May 2008	Last week of classes	No Seminar

EDUCATION : BIOFILMS COURSE

UNIV 125: Microbes in the Environment

Fall 2007

Class Meeting: Tuesdays and Thursdays 2:10-3:25; EPS 323

Instructors: Willy Davison

Jennifer Faulwetter

Erin Field

Laura Jennings

Mike VanEngelen

Course Coordinator: Al Cunningham

Office Hours: Wednesdays 9:30-10:30am; 335 EPS or 338 EPS (Mike only)

Course Description

During the semester, students will explore contemporary issues related to microorganisms in the environment through a series of lectures and hands-on activities. Topics will include microbes in the environmental, industrial, and medical settings. Examples include the beneficial role microbes play in treating waste water, making beer, wine, cheese and other food products as well as problems caused by microbes in medical infections, hot tubs, drinking water, and other industrial systems. Completing this course will advance a student's awareness and appreciation of scientific thought, critical thinking and improve communication skills.

Course Goals

At the end of the course, students should be able to:

- Orally communicate ideas clearly and effectively
- Write a scientific-style research paper
- Give a scientific-style presentation
- Understand the role microbes play in natural and industrial processes
- Understand the role microbes play in human disease
- Read and interpret popular science articles

Evaluation

Exams – 35%

Quiz 1 – 5%
Quiz 2 – 7.5%
Quiz 3 – 7.5%
Final Exam – 15%

Written Assignments– 30%

Module 1 – 10%
Module 2 – 10%
Module 3 – 10%

Project – 25%

Intro – 5%
Final Presentation – 10%
Final Paper – 10%

Typical Curve:

97-100 **A+**
93-97 **A**
90-93 **A**
87-89 **B+**
83-87 **B**
80-83 **B-**
77-79 **C+**
73-77 **C**
70-73 **C**
67-69 **D+**
63-67 **D**
60-63 **D**
<60 **F**

Note:

Final curve will be based on overall class performance...

EDUCATION : BIOFILMS COURSE

UNIV 125: Microbes in the Environment

Fall 2007

Class Participation – 10%

Extra Credit: Extra credit may be earned in order to raise a student's grade a maximum of 2% (i.e., B+ to an A-). Extra credit may be earned a number of ways, including attending on-campus seminars, summarizing relevant news/journal articles; opportunities will be announced in class.

Estimated Topics, by date

Introduction

- Aug 28 – Milestones in Microbiology
- Aug 30 – Overview of Microbiology Applications
- Sep 4 – Cell Biology
- Sep 6 – Metabolism

Module I - Environmental

- Sep 11 – Microbial Ecology
- Sep 13 – Prokaryotic Diversity I
- Sep 18 – Prokaryotic Diversity II
- Sep 20 – Eukaryotic Diversity
- Sep 25 – Microbes in Extreme Environments
- Sep 27 – Biogeochemical Cycling
- Oct 2 – Drinking Water
- Oct 4 – Wastewater

Module II - Medical

- Oct 9 – 40-min in-class Environmental Exam.....Intro to Medical Micro
- Oct 11 – Symbiosis
- Oct 16 – Immunity
- Oct 18 – Sterilization, Disinfection & Antisepsis
- Oct 23 – Hand Washing Lab
- Oct 25 – Antibiotics
- Oct 30 – Microbial Control, cont'd
- Nov 1 – Dental Microbiology

Module III - Industrial

- Nov 6 – 40-min in-class Medical Micro Exam..... Intro to Food Micro
- Nov 8 – Food Spoilage/Food Poisoning
- Nov 13 – Food Production/Fermentation
- Nov 15 – Dairy Microbiology
- Nov 20 – Overview of Industrially Relevant Microbial Processes
- Nov 27 – Beneficial Microbial Processes
- Nov 29 – Detrimental Microbial Processes

Dec 4 – Presentations

Dec 6 – Presentations

Dec 11 – FINAL EXAM 2:00-3:50PM

INDUSTRY : INDUSTRIAL ASSOCIATES

Current Industrial Membership (June 1, 2007–May 31, 2008)

ORGANIZATION	TYPE OF INDUSTRY	NUMBER OF YEARS OF SUPPORT
3M	Healthcare	07,08
Bausch & Lomb	Healthcare	07,08
Bridge Preclinical Testing Services	Testing Laboratory	07,08
Cardinal Health (formerly enturia, Inc.)	Healthcare	07,08
Church & Dwight Co., Inc.	Household Products	02,03,04,05,06,07,08
Ciba Specialty Chemicals	Specialty Chemicals	07,08
Colgate-Palmolive	Household Products	00,01,02,03,04,05,06,07,08
ConvaTec	Healthcare	07,08
Covidien (formerly Tyco Healthcare)	Healthcare	98,99,00,01,02,03,04,05,06,07,08
Cubist*	Pharmaceutical	08
The Dow Chemical Company	Specialty Chemicals	90,91,92,93,94,95,98,99,00,01,02,03,04,05,06,07,08
Ecolab, Inc.	Specialty Chemicals	05,06,07,08
Embryo Corporation	Testing Laboratory	07,08
Ethox International*	Testing Laboratory	08
Glanbia Nutritionals*	Healthcare	08
GlaxoSmithKline	Pharmaceutical	04,05,06,07,08
Kimberly-Clark*	Healthcare	08
Masco Corporation	Household Products	05,06,07,08
Mölnlycke Health Care	Healthcare	07,08
NASA	Government Lab	05,06,07,08
NovaBay Pharmaceuticals, Inc.	Pharmaceutical	05,06,07,08
Novozymes A/S	Healthcare	05,06,07,08
Procter & Gamble Company	Household Products	07,08
QuoNova LLC*	Pharmaceutical	08
Reckitt Benckiser	Household Products	07,08
Rohm and Haas*	Specialty Chemicals	08
Sandia National Laboratories	National Laboratory	07,08
Stryker Orthobiologics*	Healthcare	08

INDUSTRY : INDUSTRIAL ASSOCIATES

ORGANIZATION	TYPE OF INDUSTRY	NUMBER OF YEARS OF SUPPORT
Targanta Therapeutics, Corp.*	Pharmaceutical	08
Unilever	Household Products	06,07,08
W.L. Gore & Associates	Healthcare	97,98,99,00,01,02,03,04,05,06,07,08
Whirlpool Corporation	Household Products	06,07,08

*New members in 2007-2008

New CBE Industrial Associates

Cubist Pharmaceuticals is a biopharmaceutical company focused on developing and commercializing anti-infective therapies for the acute care environment.

Ethox International distributes more than 80 brand-name hospital products in almost every country in the world, and is the only contract service provider able to offer one source for medical and pharmaceutical needs worldwide.

Glanbia Nutritionals focuses on the expert delivery of science-based nutritional solutions. With production facilities located in Idaho, New Mexico, and Ireland, Glanbia delivers a wide range of specialty whey protein isolates, whey protein concentrates, whey fractions, milk proteins, dairy calcium and other nutritional ingredients.

For 135 years **Kimberly-Clark** has provided consumers worldwide with solutions that improve their health, hygiene, and well-being. It is a global company, employing over 55,000 people.

Based in Melbourne, Florida, **QuoNova** was established in December 2006 with the aim of developing a proprietary quorum sensing blocker (QSB) technology for commercialization. In August 2007 QuoNova Europe GmbH was established in Munich to support the company's global efforts in exploitation of the technology platform, with special focus on human healthcare applications.

Rohm and Haas has been delivering on innovation since 1909 by pairing creativity with sound knowledge, making it possible for companies to meet ever-changing market demands. More than 16,500 Rohm and Haas professionals develop specialty and performance materials for customers in more than 100 facilities with operations in 27 countries.

Stryker Orthobiologics has invested over 20 years of clinical research in developing a wide range of biological technologies that hold the promise of regeneration and healing for patients suffering from bone, cartilage and soft tissue injuries and defects. Stryker offers biomaterials and regenerative biological products for clinical specialties including trauma, spine, craniomaxillofacial and joint replacement.

Targanta Therapeutics Corporation is a biopharmaceutical company focused on the development and commercialization of innovative antibiotics to treat serious infections in the hospital and other institutional settings.

Center for Biofilm Engineering

07/23/07

Monday July 23

6:00–8:30 p.m.
**Pre-registration and
welcome reception**
Hilton Garden Inn, Bozeman

Tuesday July 24

7:30–8:30 a.m.
**Registration and
continental breakfast**
Hilton Garden Inn reception area

8:30–8:45
Introductory remarks
Larkspur Ballroom
Paul Sturman, CBE Industrial
Coordinator
Ruth Cutright, W.L. Gore,
TAC Chair
Phil Stewart, CBE Director

SESSION 1: **Wound Biofilms**

8:45–8:50
Session introduction
Garth James, Medical Projects
Manager, CBE

8:50–9:15
Biology of wound healing
John Olerud, MD, Professor of
Dermatology, University of
Washington

9:15–9:45
Advances in wound microbiology
Philip Bowler, Director,
Anti-Infectives & Microbiology,
Wound Therapeutics Global
Development Centre, ConvaTec,
Flintshire, UK

9:45–10:00
**Overview of the Center for Wound
Biofilm Research**
Phil Stewart

10:00–10:30 Break

10:30–10:50
In vitro models of wound biofilms
Garth James

10:50–11:10
**Preclinical modeling:
Studies on wound healing**
Stephen Davis, Research Associate
Professor of Dermatology,
University of Miami, Miller School
of Medicine

11:10–11:30
Biofilm models in acute wounds
Patricia Mertz, Professor of
Dermatology, University of
Miami, Miller School of Medicine

11:30–12:00
Biofilm based wound care
Randy Wolcott, MD,
Southwest Regional Wound Care
Center

12:00–1:00
Lunch at the Hilton Garden Inn

SESSION 2: **Special Presentations**

1:00–1:30
State of the CBE: 2007
Phil Stewart

1:30–2:00
**Regulatory presentation:
An update on federal activities**
Stephen Tomasino, Senior Scientist,
US EPA-OPP Microbiology
Laboratory, Fort Meade, Maryland

2:00–2:30
**Caserna, nanowires, signal
vesicles and flying buttresses:
Baroque architecture in biofilms**
Bill Costerton, Director, Center for
Biofilms, School of Dentistry,
University of Southern California

2:30–2:50 Break

2:50–3:20
**Biocide industry: Past, present
and future challenges for
biocontrol**
Michael V. Enzien, Senior Research
& Development Specialist, DOW
Biocides, The Dow Chemical
Company

SESSION 3: **Biofilm Behavior and Control**

3:20–3:40
**Examination of scCO₂ effects
against *Bacillus mojavensis*
biofilms**

Adie Phillips, Research
Engineer, CBE

3:40–4:00
**Influence of EPS and natural
organic matter on biofouling of
microfiltration membranes
coupled with powdered activated
carbon (PAC)**

Mohiuddin Md. Taimur Khan,
Assistant Research Professor, CBE

4:00–4:20
**Investigations of dormant cells
in *Pseudomonas aeruginosa*
biofilms**

Brenda Grau, Postdoctoral
Researcher, CBE

SESSION 4: **Biofilm Methods**

4:20–4:45
**Methods of assessing efficacy of
antimicrobial surfaces: A review**
Diane K. Walker, Research
Engineer, CBE

4:45–5:10
**Transcriptomes and proteomes:
Identification of physiological
constraints related to biofilm
growth**
Matthew Fields, Assistant Professor,
Microbiology, Montana State
University

7:30–9:00
**Evening Session:
Biofilm Methods Advisory
Committee**

INDUSTRY : TECHNICAL ADVISORY CONFERENCE : SUMMER 2007

Wednesday July 25

7:30–8:30 a.m.
**Registration and
continental breakfast**
Hilton Garden Inn

Special Presentation

8:30–9:30
**Predatory prokaryotes: Thinking
outside the bug**

Daniel Kadouri, Assistant Professor,
Department of Oral Biology &
the Center for Oral Infectious
Diseases, University of Medicine
and Dentistry of New Jersey,
Newark

SESSION 5: **Biofilms in Water Venues**

9:30–9:40
Session introduction

Darla Goeres, Senior Research
Engineer, CBE

9:40–10:10
**Disease outbreaks in recreational
water**

Michael J. Beach, Acting Associate
Director for Healthy Water,
National Center for Zoonotic,
Vector-Borne and Enteric
Diseases, Centers for Disease
Control and Prevention

10:10–10:40 Break

10:40–11:10
**Drinking water issues in
developing countries**

Tim Ford, Department Head,
Microbiology, Montana State
University

11:10–11:35
**Drinking water treatment
strategies and regulations**

Anne Camper, Professor of Civil
Engineering, CBE

11:35–12:00
**Understanding the importance of
biofilm in recreational water**
Darla Goeres

Lunch: On your own

2:00–4:00
**Laboratory open house exposition
and poster session**

CBE Laboratories, 3rd Floor, EPS
Building

3:30–5:00
TAC Business Meeting
108 EPS Building, MSU

6:00–9:00
Dinner at the Rock'n TJ Ranch,
Bozeman

Thursday July 26

7:30–8:30 a.m.
**Registration and
continental breakfast**
Hilton Garden Inn

SESSION 6: **Microscopy**

8:30–8:45
Session introduction & new stains

Betsy Pitts, Research
Associate, CBE

8:45–9:05
**Examination of tissue specimens
for biofilms**

Alessandra Agostinho, Research
Scientist, CBE

9:05–9:25
**Use of laser capture
microdissection microscopy and
qRT-PCR to characterize gene
expression in biofilms**

Ailyn Lenz, PhD Candidate,
Microbiology, Montana State
University

9:25–9:45
**Extended lifetime of unstable GFP
in *Escherichia coli* colony biofilm**
Audrey Corbin, Research
Associate, CBE

9:45–10:05
**Film Fest: Movies of biofilm
obliteration, annihilation, doom
and destruction**

Willy Davison, PhD Candidate,
Chemical Engineering, Montana
State University

10:05–10:30 Break

SESSION 7: **Fungal Biofilms**

10:30–10:55
**Functional subpopulations in
Candida albicans biofilms**

Peter Suci, Assistant Research
Professor, Plant Sciences,
Montana State University

10:55–11:20
**Small novel molecules inhibit
signaling pathways and hyphal
formation in *Candida albicans***

Kurt Toenjes, Assistant Professor,
Department of Biological and
Physical Sciences, MSU–Billings

Special Presentation

11:20–11:50
**Highlights from the ASM Biofilms
2007 Conference**
Phil Stewart

11:50–12:00
Meeting Wrap-Up

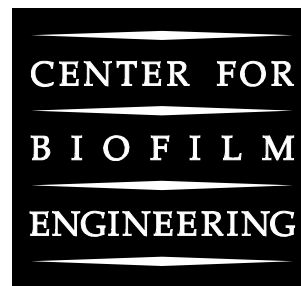
NEXT TAC:

Feb. 7-8, 2008

Biofilm Methods Workshop

Basics Option

July 23, 2007

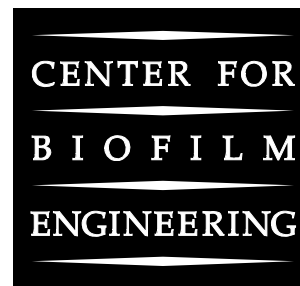


- 9:00 – 9:45** **Welcome, Introductions** – Paul Sturman, **EPS 323**
Using Scanning Electron Microscopy (SEM) to Study Biofilm –
Matthew Fields, **EPS 323**
- 9:45 – 10:30** **Standardized Biofilm Methods** – Darla Goeres, Marty Hamilton, Standardize a
research method for routine use; Experimental design; Statistics. **EPS 323**
- 10:30 – 10:45** **Coffee Break/Discussion**
- 10:45 – 12:00** **Biofilm Growth Reactors** – Diane Walker, Kelli Buckingham-Meyer, Lindsey
Lorenz, SBM Interns **EPS 337**
- 12:00 – 1:15** **LUNCH** – Habit Restaurant, MSU Campus
- 1:15 - 2:30** **Biofilm Reactor Protocol: Set-up, Inoculation, Sampling and Analysis** –
Diane Walker, Kelli Buckingham-Meyer, Lindsey Lorenz, SBM Interns **EPS 337**
- 2:30 – 3:30** **Cryosectioning and Microscopy of Biofilms** – Betsey Pitts, Alessandra
Agostinho **EPS 326/327**
- 3:30 – 4:15** **Scanning Electron Microscopy** – Steve Fisher, **ICAL EPS 339**
- 4:15 – 5:00** **Wrap-up/Discussion and Selected CBE Presentations:**
Adie Phillips – “Supercritical CO₂ Challenges.” **EPS 302**
- Shannon Goeres – Bioresources Engineering Undergraduate, “Fun with Pipes.”
EPS 301
- Wrap-Up, Discussion** – Paul Sturman, **EPS 323**

Biofilm Methods Workshop

Advanced Option

July 23, 2007



- 9:00 – 9:45** **Welcome, Introductions – Paul Sturman, EPS 323**
Using Scanning Electron Microscopy (SEM) to Study Biofilm – Matthew Fields, EPS 323
- 9:45 – 11:00** **A Fractionation Method for Assessing Differential Gene Expression in Colony Biofilms – Brenda Grau, EPS 312**
- 11:00 – 11:15** **Coffee Break/Discussion**
- 11:15 – 12:00** **Cryosectioning and Microscopy – Alessandra Agostinho and Betsey Pitts EPS 326**
- 12:00 – 1:15** **LUNCH – Habit Restaurant, MSU Campus**
- 1:15 - 2:15** **A Laser Dissection Method for Assessing Differential Gene Expression in Biofilms/ Tour of MicroArray Facility – Mike Franklin, Kate McInnerney, Cooley Lab**
- 2:15 – 3:00** **SEM Imaging of CDC Reactor Biofilms – Steve Fisher ICAL, EPS 339**
- 3:00 – 3:30** **Mass Spectrometry at the CBE – Robin Gerlach, EPS 329**
- 3:30 – 4:15** **Image Analysis – Betsey Pitts, EPS 317**
- 4:15 – 5:00** **Selected CBE Presentations:**
Adie Phillips – “Supercritical CO₂ Challenges” EPS 302

Shannon Goeres – Bioresources Engineering Undergraduate, “Fun with Pipes” EPS 301
- Wrap-Up, Discussion – Paul Sturman, EPS 323**

Center for Biofilm Engineering

02/01/08

Tuesday February 5

6:00–8:00 p.m.
**Pre-registration and
welcome reception**
Hilton Garden Inn, Bozeman

Wednesday February 6

7:30–8:30 a.m.
**Registration and
continental breakfast**
Hilton Garden Inn reception area

8:30–8:45
Introductory remarks
Larkspur Ballroom
Paul Sturman, CBE Industrial
Coordinator
Ruth Cutright, W.L. Gore,
TAC Chair
Phil Stewart, CBE Director

Keynote Presentation

8:45–9:30
**Biofilm dispersal: Molecular
mechanisms to control strategies**
Jeremy Webb, School of Biological
Sciences, University of
Southampton, UK

SESSION 1: Industrial Biofilm Investigations

9:30–9:35
Session Introduction
Paul Sturman

9:35–10:10
**Overview of biofilm detachment
mechanisms**
Brent Peyton, Professor,
Chemical & Biological
Engineering, CBE

10:10–10:40 Break

10:40–11:05
**Biofilms in bioenergy and carbon
sequestration**
Robin Gerlach, Associate Professor,
Chemical & Biological
Engineering, CBE

11:05–11:30
**Biocontrol studies at Novozymes
Biologicals**
Sarah McHatton, Novozymes

11:30–12:00
**Transcriptomics and molecular
techniques for biofilm
investigation in industrial systems**
Matthew Fields, Assistant Professor,
Microbiology, CBE

12:00–1:00
Lunch at the Hilton Garden Inn

SESSION 2: Visualizing Biofilms

1:00–1:10
Session Introduction
Phil Stewart

1:10–1:35
**A quantitative description at
multiple scales of observation of
accumulation and displacement
patterns in single- and dual-
species biofilms**
Anne Camper, Professor, Civil
Engineering, CBE

1:35–2:00
**Recent advances in cellular
automata modeling of
multispecies biofilm systems**
Al Cunningham, Professor, Civil
Engineering, CBE

2:00–2:30
**Fluorescence hyperspectral
imaging of biofilms**
Howland Jones, Sandia National
Laboratories

2:30–3:00
**Direct visualization of
antimicrobial action within
model oral biofilms**
Phil Stewart

Poster Session & Laboratory Open House

3:30–5:30
CBE Laboratories, 3rd Floor EPS
Building, MSU

Dinner: Restaurant of your choice

7:30–9:00 Hilton Garden Inn
**Evening Session:
Biofilms Methods Advisory
Committee Meeting**

Thursday February 7

7:30–9:00 a.m.
TAC Business Meeting (Industrial
Associate Representatives) with
breakfast, Larkspur Ballroom
8:00–9:00 a.m.
Continental breakfast
Hilton Garden Inn reception area

SESSION 3: Health Care-Related Biofilms

9:00–9:10
Session Introduction
Garth James, CBE Medical Projects
Manager

9:10–9:40
**Bacterial biofilms contribute to
pathogenesis of chronic
rhinosinusitis (CRS): A new target
for therapy**
Martin Desrosiers, Associate
Professor, Department of
Otolaryngology, University of
Montreal, Canada

9:40–10:10
**Molecular characterization of
wound biofilm communities**
Pat Secor, PhD Candidate,
Cell Biology & Neuroscience, MSU

10:10–10:30
**Biofilm wound infection in a
diabetic (db/db) mouse**
Phillip Hochwalt, Department of
Medicine, University of
Washington

10:30–11:00 Break

11:00–11:30
**Staphylococcus aureus biofilms
prevent scratch wound closure in
vitro**
Kelly Kirker, Research Scientist,
CBE

11:30–12:00
**Production of cell-cell signaling
molecules by biofilm bacteria
isolated from human chronic
wounds**
Alex Rickard, Assistant Professor,
Biological Sciences, Binghamton
University, Binghamton, NY

12:00–12:10 Meeting Wrap up



Center for Biofilm Engineering

Basic Biofilm Methods Workshop

Feb 5, 2008

- 9:00 – 9:30** Welcome & Introductions – Paul Sturman **EPS 323**
- 9:30 – 10:30** **Biofilm Growth Reactors & Demo** – Diane Walker, Kelli Buckingham-Meyer, Lindsey Lorenz, Jackie Hilyard, Shannon Goeres, Alex Hilyard **EPS 337**
- 10:30 – 11:00** Morning Refreshments
- 11:00 – 12:00** **Biofilm Reactor Protocol: Hands-on Sampling and Analysis** – Diane Walker, Kelli Buckingham-Meyer, Lindsey Lorenz, Jackie Hilyard, Shannon Goeres, Alex Hilyard **EPS 337**
- 12:00 – 1:15** LUNCH – Habit Restaurant, MSU Campus
- 1:15 - 2:00** **Standardizing a Research Method for Routine Use** – Darla Goeres, Marty Hamilton **EPS 323**
- 2:00 – 2:30** **Staining Biofilms** – Diane Gray* **EPS 323**
- Group A:*
2:30 – 3:15 **Microscopy of Biofilms** – Betsey Pitts, Diane Gray, Willy Davison, Liz Sandvik, Kelly Kirker, Pat Secor, Alessandra Agostinho **EPS 326/327**
- 3:30 – 4:15** **Scanning Electron Microscopy** – Steve Fisher **ICAL EPS 339**
- 3:15 – 3:30** Afternoon Refreshments
- Group B:*
2:30 – 3:15 **Scanning Electron Microscopy** – Steve Fisher **ICAL EPS 339**
- 3:30 – 4:15** **Microscopy of Biofilms** – Betsey Pitts, Diane Gray, Willy Davison, Liz Sandvik, Kelly Kirker, Pat Secor, Alessandra Agostinho **EPS 326/327**
- 4:15 – 5:00** **Lab Show & Tell:**
- **Treatment of Biofilms Using Direct Current** – Liz Sandvik **EPS 302**
 - **Reduction of Hexavalent Chromium by *Desulfovibrio vulgaris* Biofilms Under Steady State Conditions** – Melinda Clark **EPS 336**
- Wrap-Up/Discussion** – Paul Sturman **EPS 323**

*Special guest instructor from Molecular Probes/Invitrogen

OUTREACH : VISITING RESEARCHERS

Visiting Researchers, CBE 2007–2008

Diana Amari—a graduate student from CBE PhD alumnus David Davies' lab in Binghamton, NY—joined Anne Camper's drinking water research group for the summer of 2007. Diana worked with Pat Secor, Lynne Leach, and Andreas Nocker on a project that examines differences in 2D protein patterns between organisms grown in a single-species biofilm and grown in multi-species biofilms.

Dr. Virginia Anderson of Towson State University, Maryland—a collaborator on the CBE's NSF-sponsored *Biofilms: The Hypertextbook* project (grant numbers 0089397 and 0618744)—visited the CBE during the first week of November. Dr. Anderson, whose specialty is educational assessment and evaluation, attended one session of a class that has been using the Hypertextbook prototype and worked with local grant team members Rocky Ross, Al Cunningham, and Diane Williams to produce materials and instruments for ongoing teaching and learning evaluation of the Hypertextbook.

Sonia Porta Banderas, research scholar from Valencia, Spain, worked in the Biofilm Control lab from October through December 2007. Sonia works for Ainia Centro Tecnológico in Valencia, where she is a microbiological technician. She came to the CBE to learn biofilm methods related to food microbiology and was funded by a grant from the Spanish government.

Eliora Bujari, an undergraduate student in environmental engineering from Manhattan College in New York, joined visitor Chris Groth to work on a project investigating the effects of biofilm formation on porous media hydrodynamics during the summer of 2007.

Abdoulaye Camara, visiting from Bamako, Mali, worked in CBE labs from June 2006 to September 2007. He collaborated with Mark Burr, Andreas Nocker, Lynne Leach, and Jennifer Faulwetter in the Industrial and Environmental Water Systems lab headed by Anne Camper.

Gregory Characklis, associate professor of environmental engineering from the University of North Carolina—Chapel Hill, was a visiting faculty member at the CBE during the summer of 2007. He conducts research in the area of pathogen transport in storm water runoff systems. He brought four of his students for several days to present their research and to explore the Center's research and education programs. As the son of the Center's founding director W.G. (Bill) and Nancy Characklis, Greg has historical ties to the Center.

Chris Groth, a master's candidate in environmental engineering from Manhattan College in New York, visited the Center during the summer of 2007. Chris set up model porous media reactors to continue CBE studies on the effect of biofilm formation on porous media hydrodynamics. He worked with Robin Gerlach, chemical and biological engineering, and Al Cunningham, civil engineering. Chris' work at Manhattan College is under the supervision of Robert Sharp (a CBE PhD graduate in 1995).

Kim Harris, a researcher at Procter & Gamble in Egham, UK, came to the CBE to work with Betsey Pitts on biofilm microscopy and to talk with other CBE researchers about biofilm growth and imaging techniques.

John Lennox, professor emeritus, microbiology, Penn State Altoona, came to the CBE for the month of April in 2008 to work on biofilm education projects. As a co-editor, John is committed to bringing the biofilm concept into the undergraduate science and engineering curriculum and he contributed to the success of the *Biofilms: The Hypertextbook* project (grant numbers 0089397 and 0618744). During this visit, John collaborated with Rocky Ross and Al Cunningham on the hypertextbook project and also prepared material to present at the American Society for Microbiology Undergraduate Conference, May 31–June 1, 2008.

Hung Nguyen, a graduate student from Washington State University, Pullman WA, worked with Zbigniew Lewandowski and **Haluk Beyenal**, assistant professor of chemical engineering and bioengineering, WSU, Pullman. Together, the three put on a week-long biofilms summer school in the summer of 2007.

OUTREACH : VISITING RESEARCHERS

Susana Sánchez, a PhD candidate in microbiology from the University of Navarra, Spain, worked in the Biofilm Control lab from May 1 to September 30, 2007. With her expertise in peptides, Susana evaluated the ability of antimicrobial peptides—a natural class of antimicrobial agents—to control biofilm formation by the opportunistic pathogen *Pseudomonas aeruginosa*.

Priscilla Sossa, a PhD candidate in microbiology from the University of Antofagasta, Chile, returned to the CBE for a research visit in 2007.

Lourdes Jiménez Taracido, a graduate student from the University of Cádiz in Spain studying marine consortia and biofilms, worked with the CBE's Biofilm Control lab and with Ross Carlson's lab for the three months during the summer of 2007. Lourdes developed an AI2 quorum sensing reporter system for *E. coli*.

OUTREACH : BIOFILM MECHANICS WORKSHOP

2007 Initiative: Interdisciplinary Research Retreat Biofilm Mechanics Workshop

June 28-30, 2007
Montana State University Campus
Bozeman, Montana

A workshop review, by Phil Stewart

Early summer can be a beautiful time in Montana, and so it was at the end of June 2007 when the Center for Biofilm Engineering (CBE) hosted a workshop on the topic of biofilm mechanics on the Montana State University campus. This event brought together twenty-six participants from Montana, Texas, Florida, New York, Minnesota, Pennsylvania, North Carolina, Canada, Germany, and the Netherlands to share ideas and recent results about what holds microbial biofilms together and how these biological assemblages can be understood as mechanical structures that deform, move, and flow. The meeting was informal, convivial, and collaborative in spirit. Technical presentations were interspersed with discussion sessions. The modest size of the group and relaxed atmosphere helped make the questioning and discussion particularly unfettered, creative, and leavened with humor. The group dined together in the cellar of an attractive restaurant in historic downtown Bozeman, and a free afternoon allowed for some fishing, hiking, beer sipping, and project planning. We are indebted to Isaac Klapper for conceiving this event and organizing the program.

The interdisciplinary nature of the group was obvious at lunch one day when our table of five included a physicist, a chemical engineer, two microbiologists, and an electrical engineer. Also represented among the workshop participants were mathematicians, civil engineers, mechanical engineers, a biomedical engineer and a biochemist.

Rather than encapsulate specific talks, let me just summarize here some of the themes, hypotheses, and ideas that emerged in the course of the workshop:

- Biofilm cohesion is realized through multiple polymers and multiple cohesive forces.
- Specific polysaccharides are distributed heterogeneously in the biofilm matrix; these can be localized via lectin staining and microscopy.
- Abiotic components (precipitates, corrosion products, dead white blood cells, etc.) are significant in real-world systems and likely contribute to the material properties of biofilms.
- Biofilm should not be a prison; biological pathways for dispersion of cells from a biofilm are being elucidated.
- Biofilm properties are being probed and forces measured by pushing and pulling on biofilms with ingenious instrumental adaptations of atomic force microscopes, micropipette cantilevers, magnetic resonance microscopes, and fluid jets.
- These measurements point to microscale heterogeneity in the distribution of EPS and in local mechanical properties.
- Fluid-biofilm interactions give rise to drag, lift, detachment, channeling, differential effects during antimicrobial treatment, and also to complex motions of the biomass such as oscillation, mixing, and rolling.
- Cells compete for space and displace their neighbors as bacteria grow inside a biofilm.

OUTREACH : BIOFILM MECHANICS WORKSHOP

- Modelers are tackling biofilm mechanics by simulating a network of interconnected, breakable springs or by describing the biofilm as a compressible fluid subjected to combined attractive and repellant forces.

One of my visions for the CBE is that this center will serve as a meeting ground where researchers can come together to brainstorm and network for mutual benefit. I would like to thank all of the Biofilm Mechanics Workshop participants for helping to make this an example of this spirit of sharing and synthesis. I am inspired by the success of this event to seek ways to continue regular workshops of this kind.

Participant List

Recep Avci, Physics, MSU, Bozeman, MT

Bruce Ayati, Mathematics, Southern Methodist University, Dallas, TX

Sarah Codd, Mechanical & Industrial Engineering & CBE, MSU, Bozeman, MT

Nick Cogan, Mathematics, Florida State University, Tallahassee, FL

Al Cunningham, Civil Engineering & CBE, MSU, Bozeman, MT

David G. Davies, Biological Sciences, Binghamton University, Binghamton, NY

Willy Davison, Chemical & Biological Engineering & CBE, MSU, Bozeman, MT

Jack Dockery, Mathematical Science & CBE, MSU, Bozeman, MT

John Dutcher, Physics, University of Guelph, Guelph, ON, Canada

Hans-Curt Flemming, Biofilm Centre, University of Duisburg-Essen, Duisburg, Germany

Michael Franklin, Microbiology & CBE, MSU, Bozeman, MT

Gill Geesey, Microbiology & CBE, MSU, Bozeman, MT

Robin Gerlach, Chemical & Biological Engineering & CBE, MSU, Bozeman, MT

Raymond M. Hozalski, Civil Engineering, University of Minnesota, Minneapolis, MN

Jennifer Hornemann, Chemical & Biological Engineering & CBE, MSU, Bozeman, MT

Isaac Klapper, Mathematical Science & CBE, MSU, Bozeman, MT

Ben Klayman, Civil & Environmental Engineering & CBE, MSU, Bozeman, MT

Bertram Manz, Magnetic Resonance Imaging, Fraunhofer-Institut für Biomedizinische Technik, St. Ingbert Germany

Thomas R. Neu, Helmholtz Centre for Environmental Research, Magdeburg, Germany

Ekaterina Paramonova, Biomedical Engineering, University Medical Center Groningen and University of Groningen, Groningen, The Netherlands

Joseph Seymour, Chemical & Biological Engineering & CBE, MSU, Bozeman, MT

Phil Stewart, Chemical & Biological Engineering & CBE, MSU, Bozeman, MT

Paul Stoodley, Center for Genomic Sciences, Allegheny-Singer Research Institute, Pittsburgh PA

Zhiyong Suo, Physics, Montana State University, Bozeman, MT

Michael Sutton, Center for Biofilm Engineering & CBE, MSU, Bozeman, MT

Ahmed Touhami, Physics, University of Guelph, Guelph, ON, Canada

Daniel Wozniak, Microbiology & Immunology, Wake Forest University School of Medicine, Winston-Salem, NC

OUTREACH : IMAGE USE REQUESTS

Image Use Requests

Web requests for educational use of CBE images were received from 18 countries outside the US:

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- South Africa
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- Nebraska
- Nevada
- New Jersey
- New York
- North Carolina
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- South Carolina
- South Dakota
- Tennessee
- Texas
- Utah
- Vermont
- Virginia
- Washington
- West Virginia
- Wisconsin

CBE PROGRAM & FACILITIES

2008 CBE Program and Facilities

Center for Biofilm Engineering Program Overview

Montana State University's Center for Biofilm Engineering (CBE) offers an ideal setting for the interdisciplinary, collaborative research that is the basis for its worldwide reputation in the field of biofilms. Graduate and undergraduate students work under the guidance of the CBE's multidisciplinary faculty in contiguous laboratories to solve problems associated with biofilms in industry, medicine, and the environment. The CBE's standing in the international research community attracts visiting students and faculty from all parts of the world, providing a culturally diverse and stimulating academic environment.

Established in 1990 with a grant from the National Science Foundation, the CBE became a member of the elite Engineering Research Centers program. The NSF-ERC program was created to increase U.S. industrial competitiveness and to re-invent science and engineering education in U.S. universities. In order to promote achievement of the ERC program goals, the NSF-ERC program called for the contribution of significant support from ERC universities and industrial partners. The Center for Biofilm Engineering drew support from the State of Montana, Montana State University–Bozeman, and the industrial partners gathered during its pre-1990 work as the Institute for Process Analysis. After its 11-year period of NSF-ERC grant support drew to a close, the CBE built on the foundation of its many years of successful government-university-industry collaboration in pursuit of its vision as a world leader in fundamental research, science and engineering education, industrially relevant technology, and the synthesis of biofilm-related information.

The mission of the Center for Biofilm Engineering is to advance the basic knowledge, technology and education required to understand, control, and utilize biofilm processes.

The CBE has identified goals in four areas of activity. **In the area of research, the CBE's goal is to do leading edge fundamental research to elucidate the mechanisms at work in bacterial biofilms.** The CBE has been a leader in defining the structure and function of biofilms on surfaces, in understanding the antimicrobial resistance mechanisms of biofilm, and in identifying the role of signal molecules in controlling bacterial behavior. To the naked eye, biofilms simply look like slimy matter, but researchers at the CBE have demonstrated that they are actually multicellular attached communities, with primitive circulatory systems and a measure of cellular specialization. Understanding these fundamental biofilm characteristics and activities presents opportunities for developing more effective strategies to control biofilms in industrial settings. **The second goal of the CBE is to make its research relevant to real systems, where the information can be useful.** Industrial partnerships help to keep the ultimate focus of CBE research on real-world applications. Technology transfer at the CBE involves not only information, but methods and technology development. The CBE even has a laboratory specifically designated to develop these methods—the Standardized Biofilm Methods laboratory (SBM). **The CBE's third goal is to sustain productive interdisciplinary undergraduate and graduate education programs involving team research on industrially relevant projects.** Education is at the heart of the CBE's success. Undergraduates and graduate students are fully integrated into the development, design and implementation of research projects at the CBE, spanning a wide range of biofilm topics and applications. Hundreds of students from a dozen MSU departments have contributed to CBE research over the years. Many have graduated to take positions in industry and academia, continuing to be active and influential in the biofilm field. The most recent goal of the CBE is to provide educational **outreach**. The CBE's outreach efforts include workshops, symposiums, training, Internet resources, and a new initiative to produce an electronic, interactive 'hypertextbook' on biofilms to supplement undergraduate science and engineering education.

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 state-of-the-art research laboratories. The CBE Technical Operations Manager oversees the research

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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 note are described below.

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 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 has also been added. 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 laboratory maintains a microsensor fabrication and testing area that includes electrode pullers, microscopes, and grinding machines. All of these electrodes are used in conjunction with computer-controlled micropositioners for depth profiling, and a computer-controlled x-y table for mapping parameters in a horizontal plane. 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 microscopes, which are used for transmitted light and epi-fluorescent imaging of biofilms. Both microscopes are equipped with cooled CCD fluorescent cameras, a video camera, and a color camera; they use Universal Imaging Corporation's MetaVue software for digital image acquisition. One of the microscopes uses manually-switched filter blocks for epi-fluorescence and the other uses an electronically controlled filter wheel and shutter. Images collected on the Nikons range from pictures of *in situ* biofilms as they accumulate over time on glass tubing to FISH (Fluorescence *In Situ* Hybridization)-probed, cryosectioned colony biofilms.
- The **Optical Microscopy Lab** also includes a Nikon SMZ-1500 Stereo Zoom Microscope, with a magnification range from roughly 7.5 to 110X. The stereo scope gives researchers stunning, 3-dimensional views of biofilms on a more macroscopic scale than can be achieved with other microscopes. Finally, the lab includes a Leica CM 1850 cryostat which is used to cut very thin sections (usually 5 micrometers) of frozen biofilm.
- The **Confocal Microscopy Lab** contains two Leica upright Confocal Scanning Laser Microscopes (CSLM). The Leica configuration is ideal for continuous monitoring of biofilm formation and detachment phenomena because it causes only minimal specimen damage due to heating and allows for high-resolution time-lapse monitoring of the biofilm. 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

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biofilm formation proceeds in each 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 three-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.

- Our TCS-NT confocal has three laser lines available for fluorescence excitation: 488, 568 and 633 nm. The second, new, confocal system is a Leica TCS-SP2 AOBS with an add-on: a Spectra Physics MaiTai 2-photon infra-red laser and detector. With this new system we can image a biofilm, then switch between AOBS confocal mode and 2-photon mode—we only need to switch detectors and lasers. The AOBS system uses no excitation or emission filters, so it offers extreme flexibility in wavelength selection; it includes seven available laser lines for excitation (458, 476, 488, 496, 514, 543 and 633nm). The MaiTai gives us still another unique imaging capability. It has been established that in tissue-like materials 2-photon imaging provides much greater resolution, especially in the z-direction. We have seen that the MaiTai can image biofilms three to four times deeper than the AOBS or any other 1-photon confocal. So, for imaging thick or dense biofilms, the MaiTai is the perfect tool.
- 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 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, SCSI drives 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.

Flow Cytometry Facility

The flow cytometry facility is available for research staff to investigate physical and/or chemical properties of disaggregated biofilm cells in suspension. This facility is an excellent complement to the microscope facility in that biofilms may be examined *in situ* under the microscope and then later disaggregated for single-cell examination in the flow cytometer. This instrument has a wide variety of uses from examining heterogeneous populations, to counting cells, to sorting specific populations within a sample.

The facility is equipped with a Becton Dickinson FACSAria flow cytometer. Housed with three lasers, a 405 nm, 488 nm and a 633 nm, the FACSAria is able to detect up to seven different fluorochromes, plus forward and side scatter simultaneously. High-speed sorting is also a feature of the FACSAria. Two- and four-way sorting can be performed as well as sorting into 96-well plates.

Computer Facilities

CBE staff and students have access to personal computers connected to the MSU College of Engineering computer network. A student computer laboratory offers twelve state-of-the-art PCs along with scanning and printing services. In addition, the CBE maintains computational PCs, and a computational server for data manipulation, mathematical modeling, and graphic image analysis.

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SPECIALIZED CBE LABORATORIES

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 currently includes five full-time research scientists, three technicians, one graduate student, and four undergraduate research assistants.

Activity in the MBL has expanded substantially during recent years. Seventeen companies, including CBE Industrial Associates, currently sponsor MBL projects. The MBL is also performing research in support of two NIH-funded grants. Projects include examining the role of biofilms in chronic wound infections, evaluating biofilm formation on biomaterials, and testing medical devices. 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 (SBM)** was designed to meet research and industry needs for standard analytical methods to evaluate innovative biofilm control technologies. SBM staff and students develop, refine, and publish quantitative methods for growing, treating, sampling, and analyzing biofilm bacteria. The SBM members work with international standard setting organizations on the approval of biofilm methods by the standard setting community. Under a contract with the U.S. Environmental Protection Agency (EPA), the SBM will conduct 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. SBM staff offer customized biofilm methods training workshops for CBE students, collaborators, and industry clients.

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.

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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 MSU was established in order to promote interdisciplinary collaboration in research, education, and industry, and to strengthen existing cooperation between the physical, biological, and engineering sciences by providing critically needed analytical facilities. These facilities are open to academic researchers.

A new critical point dryer—jointly purchased in 2007 by the CBE and the Image & Chemical Analysis Laboratory—has been set up in the ICAL lab for the processing of biological samples for electron microscopy. This equipment allows our researchers to remove water from soft samples without distorting the sample.

The ICAL currently contains seven complementary microanalytical systems:

Atomic Force Microscope (AFM)

Auger Scanning Electron Microprobe (Auger)

Field Emission Scanning Electron Microscope (FESEM)

Scanning Electron Microscope (SEM)

Time of Flight Secondary Ion Mass Spectrometer (SIMS)

Small-Spot X-ray Photoelectron Spectrometer (XPS)

X-Ray Powder Diffraction Spectrometer (XRD)

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