

Center for Biofilm Engineering

2007 Annual Report

APPENDIX

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2006 Publications

Borriello, G., L. Richards, G.D. Ehrlich, and P.S. Stewart, "Arginine or Nitrate Enhances Antibiotic Susceptibility of *Pseudomonas aeruginosa* in Biofilms," Antimicrob. Agents Chemother., 50(1):382-384 (2006) **Abstract 06-002**

Brady, R.A., J.G. Leid, A.K. Camper, J.W. Costerton, and M.E. Shirtliff, "Identification of *Staphylococcus aureus* Proteins Recognized by the Antibody-Mediated Immune Response to a Biofilm Infection," Infect. Immun., 74(6):3415-3426 (2006) **Abstract 06-014**

Burr, M.D., S.J. Clark, C.R. Spear, and A.K. Camper, "Denaturing Gradient Gel Electrophoresis (DGGE) can Rapidly Display the Bacterial Diversity Contained in 16S rDNA Clone Libraries," Microb. Ecol., 51(4):479-486 (2006) **Abstract 06-006**

Carlson, R. and F. Srienc, "Effects of Recombinant Precursor Pathway Variations on poly[(R)-3-hydroxybutyrate] Synthesis in *Saccharomyces cerevisiae*," J. Biotechnol., 124(3):561-573 (2006) **Abstract 06-023**

Chambless, J.D., S.M. Hunt and P.S. Stewart, "A Three-Dimensional Computer Model of Four Hypothetical Mechanisms Protecting Biofilms from Antimicrobials," Appl. Environ. Microbiol., 72(3):2005-2013 (2006) **Abstract 06-009**

Choi, D.W., C.J. Zea, Y.S. Do, J.D. Semrau, W.E. Antholine, M.S. Hargrove, N.L. Pohl, E.S. Boyd, G.G. Geesey, S.C. Hartsel, P.H. Shafe, M.T. McEllistrem, C.J. Kisting, D. Campbell, V. Rao, A.M. de la Mora, and A.A. DiSpirito, "Spectral, Kinetic, and Thermodynamic Properties of Cu(I) and Cu(II) Binding by Methanobactin from *Methylosinus trichosporium* OB3b," Biochemistry, 45(5):1442-1453 (2006) **Abstract 06-024**

Christner, B.C., G. Royston-Bishop, C.M. Foreman, B.R. Arnold, M. Tranter, K.A. Welsh, W.B. Lyons, A.I. Tsapin, M. Studinger, and J.C. Priscu, "Limnological Conditions in Subglacial Lake Vostok, Antarctica," Limnol. Oceanogr., 51(6):2485-2501 (2006) **Abstract 06-019**

Fux, C.A., M. Quigley, A.M. Worel, C. Post, S. Zimmerli, G. Ehrlich, and R.H. Veeh, "Biofilm-Related Infections of Cerebrospinal Fluid Shunts," Clin. Microbiol. Infect., 12(4):331-337 (2006) **Abstract 06-001**

Hu, J.-F., E. Garo, M.G. Goering, M. Pasmore, H.-D. Yoo, T. Esser, J. Sestrich, P.A. Cremin, G.W. Hough, P. Perrone, Y.-S.L. Lee, N.T. Le, M. O'Neil-Johnson, J.W. Costerton and G.R. Eldridge, "Bacterial Biofilm Inhibitors from *Diospyros dendo*," J. Nat. Prod., 69(1):118-120 (2006) **Abstract 06-010**

Khot, P.D., P.A. Suci, L.R. Miller, R.D. Nelson, and B.J. Tyler, "A Small Subpopulation of Blastospores in *Candida albicans* Biofilms Exhibit Resistance to Amphotericin B Associated with Differential Regulation of Ergosterol and β -1,6-glucan Pathway Genes," Antimicrob. Agents Chemother., 50:3708-3716 (2006) **Abstract 06-017**

Komlos, J., A.B. Cunningham, A.K. Camper, and R.R. Sharp, "Effect of Substrate Concentration on Dual-Species Biofilm Population Densities of *Klebsiella oxytoca* and *Burkholderia cepacia* in Porous Media," Biotechnol. Bioeng., 93(3):434-442 (2006) **Abstract 06-003**

Marion, K., J. Freney, G. James, E. Bergeron, F.N.R. Renaud, and J.W. Costerton, "Using an Efficient Biofilm Detaching Agent: An Essential Step for the Improvement of Endoscope Reprocessing Protocols," J. Hosp. Infect., 64(2):136-142 (2006) **Abstract 06-020**

Menicucci, J., H. Beyenal, E. Marsili, R. Angathevar Veluchamy, G. Demir and Z. Lewandowski, "Procedure for Determining Maximum Sustainable Power Generated by Microbial Fuel Cells," Environ. Sci. Technol., 40(3):1062-1068 (2006) **Abstract 06-011**

Nocker, A. and A.K. Camper, "Selective Removal of DNA from Dead Cells of Mixed Bacterial Communities by Use of Ethidium Monoazide," Appl. Environ. Microbiol., 72(3):1997-2004 (2006) **Abstract 06-005**

Nocker, A., C.-Y. Cheung, and A.K. Camper, "Comparison of Propidium Monoazide With Ethidium Monoazide for Differentiation of Live vs. Dead Bacteria by Selective Removal of DNA From Dead Cells," J. Microbiol. Meth., 67(2):310-320 (2006) **Abstract 06-016**

RESEARCH : PUBLICATIONS

Priscu, J.C., B.C. Christner, C.M. Foreman and G. Royston-Bishop, "Biological Materials in Ice Cores," In: Encyclopedia of Quaternary Science, Elias, S.A. (ed), Elsevier, UK, Volume 2. Elsevier, UK. Pp. 1156-1166. (2006) **Abstract 06-004**

Rabinovitch, C. and P.S. Stewart, "Removal and Inactivation of *Staphylococcus epidermidis* Biofilms by Electrolysis," Appl. Environ. Microbiol., 72(9):6364-6366 (2006) **Abstract 06-012**

Stein, O.R., J.A. Biederman, P.B. Hook, and W.C. Allen, "Plant Species and Temperature Effects on the k-C* First-Order Model for COD Removal in Batch-Loaded SSF Wetlands," Ecol. Eng., 26(2):100-112 (2006) **Abstract 06-018**

Tomasino, S.F. and M.A. Hamilton, "Modification to the AOAC Sporidicidal Activity of Disinfectants Test (Method 966.04): Collaborative Study," Journal of AOAC International, 89(5):1373-1397 (2006) **Abstract 06-007**

Wlaschin, A.P., C.T. Trinh, R. Carlson, and F. Srienc, "The Fractional Contributions of Elementary Modes to the Metabolism of *Escherichia coli* and Their Estimation from Reaction Entropies," Metabolic Eng., 8(4):338-352 (2006) **Abstract 06-022**

Zhang, B., R. Carlson, and F. Srienc, "Engineering the Monomer Composition of Polyhydroxyalkanoates Synthesized in *Saccharomyces cerevisiae*," Appl. Environ. Microbiol., 72(1):536-543 (2006) **Abstract 06-021**

2007 Publications

Alpkvist, E. and I. Klapper, "A Multidimensional Multispecies Continuum Model for Heterogeneous Biofilm Development," Bull. Math. Biol., 69(2):765-789 (2007) **Abstract 07-018**

Chambless J.D., P.S. Stewart, "A 3D Computer Model Analysis of Three Hypothetical Biofilm Detachment Mechanisms," Biotechnol. Bioeng., 97(6):1573-1584 **Abstract 07-001**

Cunningham, A.B., R.S. Sharp, F. Caccavo Jr., and R. Gerlach, "Effects of Starvation on Bacterial Transport Through Porous Media," Adv. Water Resour., 30(6-7):1583-1592 **Abstract 07-011**

Garo, E., G.R. Eldridge, M.G. Goering, E. DeLancey Pulcini, M.A. Hamilton, J.W. Costerton, and G.A. James, "Asiatic Acid and Corosolic Acid Enhance the Susceptibility of *Pseudomonas aeruginosa* Biofilms to Tobramycin," Antimicrob. Agents Chemother., 51(5):1813-1817 (2007) **Abstract 07-002**

Goeres, D.M., L.R. Loetterle, and M.A. Hamilton, "A Laboratory Hot Tub Model for Disinfectant Efficacy Evaluation," J. Microbiol. Meth., 68:184-192 (2007) **Abstract 07-003**

Hamner, S., S.C. Broadaway, V.B. Mishra, A. Tripathi, R.K. Mishra, E. Pulcini, B.H. Pyle, and T.E. Ford, "Isolation of Potentially Pathogenic *Escherichia coli* O157:H7 from the Ganges River," Appl. Environ. Microbiol., 73(7):2369-2372 (2007) **Abstract 07-012**

Horswill A.R., P. Stoodley, P.S. Stewart, M.R. Parsek, "The Effect of the Chemical, Biological, and Physical Environment on Quorum Sensing in Structured Microbial Communities," Anal. Bioanal. Chem., 387(2):371-380 (2007) **Abstract 07-004**

Khan, M.Md.T., S. Takizawa, W.L. Jones, H. Katayama, F. Kurisu, A.K. Camper, and S. Ohgaki, "Powdered Activated Carbon and Biofiltration Improve MF Performance: Part I," Membrane Technology, (5):259-271 (2007) **Abstract 07-013**

Khan, M.Md.T., S. Takizawa, W.L. Jones, H. Katayama, F. Kurisu, A.K. Camper, and S. Ohgaki, "Powdered Activated Carbon and Biofiltration Improve MF Performance: Part II," Membrane Technology, (6) :259-271 (2007) **Abstract 07-015**

Rani, S.A., B. Pitts, H. Beyenal, R.A. Veluchamy, Z. Lewandowski, W.M. Davison, K. Buckingham-Meyer, and P.S. Stewart, "Spatial Patterns of DNA Replication, Protein Synthesis and Oxygen Concentration Within Bacterial Biofilms Reveal Diverse Physiological States," J. Bacteriol., 189(11):4223-4233 (2007) **Abstract 07-005**

Seymour, J.D., J.P. Gage, S.L. Codd, and R. Gerlach, "Magnetic Resonance Microscopy of Biofouling Induced Scale Dependent Transport in Porous Media," Adv. Water Resour., 30(6-7):1408-1420 (2007) **Abstract 07-006**

RESEARCH : PUBLICATIONS

Stewart, P.S., S.A. Rani, E. Gjersing, S.L. Codd, Z. Zheng, and B. Pitts, "Observations of Cell Cluster Hollowing in *Staphylococcus epidermidis* Biofilms," Lett. Appl. Microbiol., 44(4): 454-457 (2007) **Abstract 07-007**

Suci, P.A., D.L. Berglund, L. Liepold, S. Brumfield, B. Pitts, W. Davison, L. Oltrogge, K.O. Hoyt, S. Codd, P.S. Stewart, M. Young, and T. Douglas, "High-Density Targeting of a Viral Multifunctional Nanoplatfrom to a Pathogenic, Biofilm-Forming Bacterium," Chem. Biol., 14(4):387-398 (2007) **Abstract 07-008**

Tomasino, S.F. and M.A. Hamilton, "Comparative Evaluation of Two Quantitative Test Methods for Determining the Efficacy of Liquid Sporicides and Sterilants on a Hard Surface: A Precollaborative Study," J. AOAC International, 90(2):456-464 (2007) **Abstract 07-009**

Towler, B.W., A. Cunningham, P. Stoodley, and L. McKittrick, "A Model of Fluid-biofilm Interaction Using a Burger Material Law," Biotechnol. Bioeng., 96(2):259-271 (2007) **Abstract 07-010**

2006-07 Undergraduate Authors

Burr, M.D., S.J. Clark, **C.R. Spear**, and A.K. Camper, "Denaturing Gradient Gel Electrophoresis (DGGE) can Rapidly Display the Bacterial Diversity Contained in 16S rDNA Clone Libraries," Microb. Ecol., 51(4):479-486 (2006) **Abstract 06-006**

Rabinovitch, C. and P.S. Stewart, "Removal and Inactivation of *Staphylococcus epidermidis* Biofilms by Electrolysis," Appl. Environ. Microbiol., 72(9):6364-6366 (2006) **Abstract 06-012**

Suci, P.A., D.L. Berglund, L. Liepold, S. Brumfield, B. Pitts, W. Davison, L. Oltrogge, **K.O. Hoyt**, S. Codd, P.S. Stewart, M. Young, and T. Douglas, "High-Density Targeting of a Viral Multifunctional Nanoplatfrom to a Pathogenic, Biofilm-Forming Bacterium," Chem. Biol., 14(4):387-398 (2007) **Abstract 07-008**

PRESENTATIONS:

April 19–December 31, 2006

Phil Stewart, as invited speaker presented “Controlling Biofilms” to Unilever Home & Personal Care researchers in Rolling Meadows, IL, April 19, 2006.

Otto Stein presented, “Sulfur Cycling in Sub-Surface Constructed Wetlands,” 6th Workshop on Nutrient Cycling and Retention in Natural and Constructed Wetlands, May 30–June 3, 2006. Třeboň, Czech Republic. Co-authors are: Stein, OR, Sturman PJ, Kröpfelová L, and Vymazal J.

Al Cunningham presented “Microbially Enhanced Geologic Sequestration of Supercritical CO₂,” Conference on Carbon Sequestration, Washington, DC, May 8–10, 2006.

Phil Stewart as an invited speaker presented “Biofilm Infections and Antimicrobial Tolerance,” Kimberly-Clark Corporation, Roswell, GA, May 11–12, 2006.

Mohiuddin MD Taimur Khan presented a poster “Heterogeneity and Distribution of Biofilm on Reverse Osmosis and Nanofiltration Membranes in Rotating Disk Reactor System,” North American Membrane Society NAMS - 2006 Conference, Chicago, IL, May 12–17, 2006. Co-authors are: Mickols W, Niu J, DOW/FilmTec; Moll D, The DOW Chemical Company; Camper A, Montana State University.

Kelli Buckingham-Meyer presented a poster “Technique to Visualize Extracellular Polymeric Substance in Biofilms Grown under Different Shear Conditions,” American Society of Microbiology General Meeting, Orlando, FL, May 21–23, 2006.

Andreas Nocker-Einsiedler, presented the poster “Differentiation of Live vs. Dead Bacteria by Selective Removal of DNA from Dead Cells,” American Society of Microbiology General Meeting, Orlando, FL, May 21–23, 2006.

Brent Peyton presented a poster “Reductive Transformation of Metals and Organics by Gram Positive Environmental Isolates of the Genus *Cellulomonas*,” American Society of Microbiology General Meeting, Orlando, FL, May 21–23, 2006. Co-authors are: Gerlach R, Apel W, Sivaswamy V, Smith W, Newby D, Roberto F, Viamajala S, Barnes J, Borch T

Otto Stein presented, “Temperature, Plants and Oxygen: How Does Season Affect Constructed Wetland Performance?,” Institute of Sanitary Engineering and Water Pollution Control, BOKU University of Natural Resources and Applied Life Sciences, Vienna, Austria, May 22, 2006.

Paul Sturman presented “Microbial Control in Oil Production: New Technologies and Where They Fit with Existing Strategies,” Dow Chemical, Buffalo Grove, IL, June 8, 2006.

Paul Sturman presented a poster titled “Standard Method to Assess Antimicrobial Efficacy in Dental Unit Waterlines,” International Association of Dental Research Conference, Brisbane, Australia, June 28–July 1, 2006.

Christine Foreman presented “Hydrocarbon Degradation in the Permanent Ice Cover of Lake Fryxell, Antarctica” and a poster titled “Changes in Bioavailability and Chemical Properties During Photolysis of Pony Lake Dissolved Organic Matter,” Subcommittee on Antarctic Research, Open Science meeting, Hobart, Tasmania (Australia), July 10–14, 2006.

Phil Stewart gave an invited presentation “Treating Oral Biofilms with Antimicrobials,” to Colgate-Palmolive, Newark, NJ, July 11, 2006.

Phil Stewart presented “Antimicrobial Tolerance in Microbial Biofilms,” Centers for Disease Control (CDC) in Atlanta, GA, July 28, 2006.

Christoph Fux, CBE clinician collaborator, presented “Biofilm-Related Infections: In Vivo Questions— In Vitro Answers?” Montana State University, August 2, 2006.

Darla Goeres presented “Understanding the Potential for Bias in Biofilm Log Reduction Calculations” to the Antimicrobials Division of the EPA in Arlington, VA, on August 2, 2006.

Darla Goeres presented “Biological Reactors: Tools for Growing Biofilm in the Laboratory” to the Office of Pesticide Program (OPP) of the EPA in Ft. Meade, MD, on August 3, 2006.

Phil Stewart presented “The Biofilm Infection Hypothesis,” 1st International Symposium on Wound Healing and Technology (WHAT I), University of Washington, Seattle, WA, August 28, 2006.

RESEARCH : PRESENTATIONS

Randy Wolcott, CBE clinician collaborator, presented “Biofilm Based Wound Care,” 1st International Symposium on Wound Healing and Technology (WHAT I), University of Washington, Seattle, WA, August 28, 2006.

Phil Stewart as an invited speaker presented “Anti-Biofilm Properties of Chitosan-Coated Surfaces,” American Chemical Society 232nd National Meeting & Exposition, San Francisco, CA, September 10–14, 2006.

Joe Seymour as invited speaker presented a seminar titled “Characterization of Structure and Scale Dependent Hydrodynamic Dispersion in Porous Media Using Magnetic Resonance Microscopy: Percolation, Biofouling, and Fractional Dynamics” at the Department of Chemical Engineering at Columbia University in New York City, September 19, 2006.

Darla Goeres presented a talk titled “Understanding the Importance of Biofilms in Recreational Water” at the World Aquatic Health Conference in Austin, TX, on September 21, 2006. In attendance were individuals from public health organizations, academia, and industry.

Zbigniew Lewandowski chaired a session and presented “The Effect of Detachment on Biofilm Structure and Activity: Oscillating Pattern of Biofilm Accumulation,” at Biofilm Systems VI, Amsterdam, The Netherlands, September 24–27, 2006. Co-authors of the paper are: Beyenal H, Myers J, and Stookey D.

Otto Stein presented “On Fitting the k-C* First Order Model to Batch Loaded SSF Wetlands,” 10th Conference on Wetland System for Water Pollution Control, Lisbon, Portugal, September 25–29, 2006. Proc. 10th Inter. Conf. on Wetland Systems for Water Pollution Control. Sept. 25–29, 2006. Lisbon, Portugal. Pgs. 1447-1454. Otto chaired a session on Heavy Metals Removal and also served on the scientific committee for the conference.

Joe Seymour as invited speaker presented a seminar titled “Magnetic Resonance Microscopy of Hierarchical Transport: What can spatial resolution of molecular properties tell us about biofilms, colloids, porous media and membranes?” at the School of Polymer, Textile and Fiber Engineering at Georgia Tech University in Atlanta, Georgia, October 2, 2006.

Phil Stewart and **Paul Sturman** gave an “Introduction to Biofilms,” workshop to Bausch & Lomb, Rochester, New York, October 3, 2006. Topics addressed included: understanding biofilm control, laboratory biofilm growth systems and analyses, techniques of biofilm analysis, and CBE interaction with industry.

Zbigniew Lewandowski presented a poster titled “Factors Affecting Toxic Shock Syndrome Toxin (TSST-1) Expression in *Staphylococcus aureus* Biofilms,” 2006 Annual Meeting Infectious Diseases Society of America, Toronto, Canada, October 13–16, 2006.

Phil Stewart as an invited speaker presented “Alternative Strategies for Controlling Biofilms” at the 2006 American Association of Pharmaceutical Scientists (AAPS) Annual Meeting and Exposition, San Antonio, Texas, October 29–November 2, 2006.

Zbigniew Lewandowski as invited speaker presented “Recent Advances in Marine Antifouling,” International Biodegradation and Biodegradation Conference, Chennai, India, October 29–November 12, 2006.

Andreas Nocker presented “Molecular Monitoring of Disinfection Efficacy,” Water Quality Technology Conference, Denver, CO, November 5–11, 2006.

M.S. Rahman presented “Investigation of Nitrification and Corrosion in Domestic Plumbing System,” Water Quality Technology Conference, Denver, CO, November 5–11, 2006.

Anne Camper as invited speaker presented “Biofilms in Industrial Water Systems,” HPC NA Fall Hygiene Unilever Symposium, Trumbull, CT, November 14–16, 2006.

Phil Stewart presented “Illustrated Wonders of the Microbial World” at Longfellow Elementary School, November 16, 2006.

Christine Foreman presented “Opportunities for Cold Temperature Research in the College of Engineering” to the MSU Native American student seminar “Designing our Community,” November 21, 2006.

RESEARCH : PRESENTATIONS

Sarah Codd as an invited speaker presented “Magnetic Resonance Microscopy Analysis of Biofilm Polymer Dynamics and Bioreactor Transport,” at the MRS in Boston, November 27, 2006.

Zbigniew Lewandowski as an invited speaker presented “Mass Transport and Microbial Activity in Biofilms: Advances and Remaining Challenges,” University of Washington, Pullman, November 27, 2006.

Phil Stewart as an invited speaker presented “Mechanisms of Antibiotic Tolerance in Staphylococcal Biofilms,” at the Biofilm-Material Interactions Symposium H which is held within the Fall 2006 Materials Research Society meeting in Boston, MA, November 29–30, 2006.

Markus Dierer presented a poster “Microbial Metabolic Activity and Bioavailability of Dissolved Organic Matter Under the Impact of Intense UV Radiation in Pony Lake, Antarctica,” American Geophysical Union’s Fall Meeting, San Francisco, CA, December 11, 2006. Poster co-authors were Foreman C, McKnight D, Miller P, Chin Y.

Christine Foreman presented “Geomicrobiology of a Supraglacial Stream on the Cotton Glacier, Victoria Land, Antarctica,” American Geophysical Union’s Fall Meeting, San Francisco, CA, December 11, 2006. Co-authors were Morris C and Cory R.

PRESENTATIONS: January 1–May 31, 2007

Anne Camper, Ben Klayman, and Andreas Nocker helped teach a workshop titled “Biotechnology of Plant-Associated Microbes: Practical Applications for Agricultural, Forestry, Food, and Environmental Sciences,” at the University of Concepción, Chile, January 8–19, 2007. The workshop was organized by former CBE visitors Kathy Sossa, Homero Urrutia Briones, and Cindy Morris. **Anne Camper** presented “The Impact of Biofilms on Bacterial Biology and Ecology: Medicine, Industry, Water Resources, Food, and Agriculture,” and “Cell-to-Cell Signaling among microorganisms: An overview.” **Andreas Nocker** presented “Gene Ecology”: Genetic Islands and Horizontal Gene Transfer.” **Anne Camper** and **Benjamin Klayman** presented “Pathogen Capture: Microbial Interactions Leading to and Inhibiting Disease and Its Potential in Plant Disease Control.”

All three presented extensively in the workshop, “Research Tools/Techniques and Design of Laboratory Model Systems.”

Anne Camper presented “Overview of Available Information on Biofilm Microbiology, Growth, and Release,” EPA’s Total Coliform Rule/Distribution System Technical Workshop, Washington, DC, January 30–February 1, 2007.

Matthew Fields presented two posters: “*Desulfovibrio vulgaris* Responses to Hexavalent Chromium at the Community, Population, and Cellular Levels” and “Changes in Microbial Community Structure During Biostimulation for Uranium Reduction at Different Levels of Resolution” at the GTL and Genomics Workshop, sponsored by the US- DOE, Rockville, MD, February 12–14, 2007.

Otto Stein as invited speaker presented “Temperature, Plants, and Oxygen: How Does Season Affect Constructed Wetland Performance?” Institut de Recherche en Biologie Végétale, University of Montreal, Montreal, Canada, February 16, 2007.

Otto Stein presented “Constructed Wetlands for Water Quality Improvement,” at the Workshop Instruction 2007 MSU Engineering Festival, Bozeman, MT, March 1, 2007.

Phil Stewart was a Session Chair for the session on “Prevention and Treatment of Biofilms,” at the Biofilm 2007 Conference in Quebec City, Canada, March 25–29, 2007. As an invited speaker Phil presented “Visualizing Killing in Biofilms.”

Garth James as an invited speaker presented “Biofilms in Chronic Wounds,” at the Biofilm 2007 Conference in Quebec City, Canada, March 25–29, 2007.

POSTER PRESENTATIONS: ASM Biofilm 2007, Quebec City March 25–29, 2007

“Spatial Patterns of DNA Replication, Protein Synthesis and Oxygen Concentration within Bacterial Biofilms Reveal Diverse Physiological States,” Abdul Rani S, Pitts B, Beyenal H, Veluchamy RA, Lewandowski Z, Buckingham-Meyer K, Stewart PS*.

RESEARCH : PRESENTATIONS

“A 3D Computer Model Analysis of Three Hypothetical Biofilm Detachment Mechanisms,” Chambless JD, Stewart PS*.

“*Escherichia coli* O157:H7 Forms Biofilm in Co-culture with *Pseudomonas aeruginosa*, but Not Alone,” Klayman BJ*, Stewart PS, Camper AK.

“Development of a Rapid Molecular Technique for Detection of HAA Degradors in Drinking Water Distribution Systems,” Leach LH*, Zhang P, Camper AK.

“Localized Gene Expression along Vertical Transects of *Pseudomonas aeruginosa* Biofilms,” Lenz AP, Williamson K, Pitts B, Stewart PS, Franklin MJ.

“Visualization of Antimicrobial Action in *Staphylococcus epidermidis* Biofilms,” Davison WM*, Stewart PS.

“Optimal Strategy to Control Both Active and Dormant Cells in Biofilm with Various Antimicrobial Agents,” Kim J*, Nam C, Franklin M, Hahn M, Yoon J.

Molecular Analysis of Chronic Wound Biofilms,” Secor PR*, deLancey Pulcini E, Wolcott R, James G, Stewart P.

“Role of Flagella in Mature Biofilms of *Desulfovibrio vulgaris* Hildenborough,” Clark ME*, Edelman RE, Duley ML, He Z, Zhou J, Fields MW.

“Development of Fluorescent Reagent Combinations Specific to Biofilm Components,” Pitts B*, Gray D, Stewart P.

“Spatial Patterns of DNA Replication, Protein Synthesis and Oxygen Concentration within Bacterial Biofilms Reveal Diverse Physiological States,” Abdul Rani S, Pitts B, Beyenal H, Veluchamy RA, Lewandowski Z, Buckingham-Meyer K, Stewart PS*.

“Modeling Biofilms as Viscoelastic Materials,” Klapper I*, Alpkvist E, Hill D.

“Investigations of Dormant Cells in *Pseudomonas aeruginosa* Biofilms,” Richards LA, Grau BL*, Ehrlich GD, and Stewart PS.

“Multispecies Biofilm Development on Space Station Heat Exchanger Core Material,” Pyle BH*,

Vega LM, Roth SR, Pickering KD, Alvarez PJ, Roman MC.

“Characterization of *Escherichia coli* Biofilm Detachment in Mixed Species Biofilms Grown in Capillary Flow Cells,” Volden P*, Klayman B, Camper A.

“Biofilm Formation as a Mycobacterial Stress Response,” Geier H*, Mostowy S, Behr MA, Ford TE.

“The Necessary Information Is in Oasis,” Phillips A, Gerlach R*, Hiebert R, James G, Spangler L, Cunningham AB.

“A Multi-scale Model of Biofilm as a Senescence-Structured Fluid,” Ayati BP*, Klapper I.

“Mobile System for Spectral Imaging of Reflectance and Fluorescence from Environmental Samples at Various Spatial Scales,” Polerecky L*, Bissett A, Suci P, Stoodley P, de Beer D.

“Removal and Control of Biofilms in Dental Unit Waterlines Using Electrolyzed Water,” Agostinho AM, Sturman P, Lambie J, Camper A, deLancey Pulcini E, James G*.

“Biofilms in Chronic Wounds,” James GA*, Wolcott R, Swogger E, deLancey Pulcini E, Secor P, Sestrich J, Costerton JW, Stewart PS.

“The Use of the Drip Flow Reactor as a Dental Biofilm Model System,” deLancey Pulcini E*, James G, Hilblom E.

“Contribution of Oxygen to *Staphylococcus epidermidis* Biofilm Development and Antibiotic Susceptibility,” Cotter JJ, O’Gara JP, Stewart PS, Pitts B, Casey E.

End of ASM Biofilm 2007 Poster Presentations

Sara E. Nelson, M.M. Taimur Khan, and Anne Camper presented “Immobilized Chitosan-Coated Beads for Biogrowth Control and Water Purification” at the Undergraduate Scholars Conference, Bozeman, MT, April 10, 2007.

Garth James presented “Biofilm: A New Concept in Chronic Wound Pathophysiology” at Sharp Healthcare’s Fifth Annual Symposium on Wound Management, San Diego, CA, April 13, 2007.

RESEARCH : PRESENTATIONS

Martin Desrosiers, MD, presented the following at the Combined Otolaryngology Spring Meeting (<http://www.cosm.md/societies/societies.html>) in San Diego, April 26–29, 2007, and won first prize for basic science: “Methods for Removing Bacterial Biofilms: In Vitro Study Using Clinical Chronic Rhinosinusitis Specimens,” Martin Desrosiers, MD, Centre Hospitalier de l’Université de Montréal and McGill University Health Center, Montreal, Quebec, Canada; Matthew Myntti, PhD, Medtronic ENT, Jacksonville, Florida; Garth James, PhD, Center for Biofilm Engineering, Montana State University, Bozeman, Montana.

Garth James presented “Microscopic and Molecular Analyses of Chronic Wound Biofilms” at the 20th Annual Symposium on Advanced Wound Care and Wound Healing Society Meeting in Tampa, FL, April 28–May 1, 2007.

Mohammad Rahman presented “Influence of Chlorine Residual and Alkalinity on Copper Corrosion and Biofilm Communities in Domestic Plumbing Systems” at the MSAWWA/MWEA Annual Conference, Butte, MT, May 9–11, 2007.

Anne Camper presented “Biogrowth Control in Drinking Water Systems” at the University of California, Los Angeles, CA, May 14, 2007.

Taimur Khan presented “Influence of EPS and NOM on the Biofouling of Microfiltration (MF) Membrane Coupled with a High-Dose of PAC During the Treatment of Surface Water” at the North American Membrane Society Conference, Orlando, FL, May 15, 2007. Co-authors are Khan MMT, Ohgaki S, Takizawa S, and Camper AK.

Phil Stewart as an invited speaker presented “Survival Strategies of Pathogens in Biofilms and Their Control” at the symposium on Biofilms in Medicine and the Environment, University of Ottawa, Ontario, Canada, May 17–19, 2007.

Al Cunningham presented “The Significance of Biofilms in Biotechnology” at the 2007 BioPerspectives Conference, Cologne, Germany, May 17–June 1.

Chiachi Hwang presented the poster “Changes in Bacterial Community Structure During Stimulation for Uranium Bioremediation” at the American Society of Microbiology General Conference, Toronto, Ontario, Canada, May 23, 2007.

Jennifer Faulwetter presented the poster “Constructed Wetland Rhizosphere Microbial Community Analysis Using Group-Specific Primers and Denaturing Gradient Gel Electrophoresis” at the American Society of Microbiology General Conference, Toronto, Ontario, Canada, May 24, 2007.

Mark Burr presented the poster “PCR/DGGE Using ‘Universal’ 16S rDNA primers Has Limited Resolution for Soil Bacterial Community Analysis” at the American Society of Microbiology General Conference, Toronto, Ontario, Canada, May 25, 2007. Co-authors are Burr MD, Faulwetter JL, Camara A, Nocker A, Clark SJ, and Camper AK.

Anne Camper presented the poster “Optimizing Flow Cytometry to Detect Viable but Non-Culturable, Viable-Culturable, and Membrane-Damaged Bacteria” at the American Society of Microbiology General Conference, Toronto, Ontario, Canada, May 25, 2007. Co-authors are Khan MMT, Burr MD, and Camper AK.

Melinda Clark presented the poster “Structural Role for Flagella in Biofilm Formation and Stability in *Desulfovibrio vulgaris Hildenborough*,” at the American Society of Microbiology General Conference, Toronto, Ontario, Canada, May 25, 2007.

Taimur Khan presented the poster “Optimizing Flow Cytometry to Detect Viable but Non-Culturable, Viable-Culturable and Membrane-Damaged Bacteria” at the American Society of Microbiology General Conference, Toronto, Ontario, Canada, May 25, 2007. Co-authors are Khan MMT, Burr MD, and Camper AK.

Anitha Sundararajan presented the poster “Two PAS Domain Protein Mutants Suggest that Both Oxygen Sensing and Metabolism are Important for Biofilm Formation in *Shewanella oneidensis* MR-1” at the American Society of Microbiology General Conference, Toronto, Ontario, Canada, May 25, 2007.

Anne Camper gave a seminar “Internal Causes of Water Quality Degradation and Their Consequences” at the AwwaRF Distribution System Planning Meeting, Denver, CO, May 29–31, 2007.

RESEARCH : PROJECTS

2006–2007 CBE Research Projects

Research Area	Title	Principal Investigator	Funding Agency
Biofilm Control / Antimicrobials	Control of Biofilms by Natural Products	Costerton James	NIH via SBIR with Sequoia Sciences
Biofilm Control / Antimicrobials	Modeling Antibiotic Resistance of Biofilm Bacteria	Stewart	NIH
Biofilm Control / Antimicrobials	Kodak Antimicrobial Surface Patent Development	Camper/Stewart Sturman	Kodak
Biofilm Control / Antimicrobials	Ultrasonic Release of Antibiotics from Hydrogels for Biofilm Control	Stewart	NSF
Biofilm Control / Antimicrobials	Testing Anti-Biofilm Enzymes	Stewart James	NSF via SBIR with Diversa
Biofilm Control / Antimicrobials	Controlling Oral Biofilms	Stewart	Colgate-Palmolive
Bioelectrochemistry	Microbial Fuel Cells to Power Submersed Electronic Devices	Lewandowski	ONR
Bioremediation	Subsurface Biofilm Barriers for Enhanced Geologic Sequestration of Supercritical CO ₂	Cunningham	DOE/ZERT
Bioremediation	Mechanistically-Based Field Scale Models of Uranium Biogeochemistry from Upscaling Pore-Scale Experiments and Models ²	Seymour Codd	DOE
Bioremediation	Biofilm Remediation of Contaminated Army Sites	Gerlach	DOD via SSTR with Center for Innovation
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

RESEARCH : PROJECTS

Research Area	Title	Principal Investigator	Funding Agency
Bioremediation	Rapid Deduction of Stress Pathways in Metal Reducing Bacteria	Fields	DOE
Bioremediation	Effects of Groundwater Chemistry on the Distribution of Soil Microorganisms in Natural Media	Fields	ORNL
Bioterrorism	Health Implications of Biofilms in Drinking Water Systems	Camper, Cunningham	DOD/ARO
Industrial and Drinking Water Treatment	Towards Sustainable Materials for Drinking Water Infrastructure	Camper	NSF
Industrial and Drinking Water	Synthesis Document on the State of Science of Molecular Techniques for Application to the Drinking Water Industry	Camper Burr Nocker	AwwaRF
Industrial and Drinking Water	Biodegradation of HAAs in Distribution Systems	Camper	AwwaRF via University of Minnesota
Industrial and Drinking Water	Investigation of the Mode of Action of Stannous Chloride as an Inhibitor of Lead Corrosion	Camper	AwwaRF via University of Minnesota
Industrial and Drinking Water	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	Costerton Veeh	NIH via Allegheny-Singer
Medical Biofilms	Pneumococcal Biofilms in Otitis Media	Stewart/ Costerton Veeh	NIH via Allegheny-Singer
Medical Biofilms	Molecular Analysis of Pathogens in Otitis Media by PCR	Stewart/Costerton Veeh	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	Analysis of Wound Biofilms	James	Southwest Regional Wound Care Center
Medical Biofilms	Healing Chronic Wounds by Controlling Microbial Biofilm	Stewart James	NIH
Microbial Ecology	A Genomes to Geochemical Analysis of Geothermal Features in Yellowstone National Park	Gerlach, Peyton, Inskeep, McDermott	TBI
Microbial Ecology	Biocomplexity in Metal Contaminated Sediments of Lake Coeur d'Alene	Peyton	NSF
Microbial Ecology	Bacterial Pigments: Examining their Potential Role as Cryo- and Ultraviolet Radiation Protectants	Foreman	MSGC-NASA

RESEARCH : PROJECTS

Research Area	Title	Principal Investigator	Funding Agency
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	NSF
Standardized Biofilm Methods	Development of Routine Bias Checks at the Removal and Disaggregation Steps When Testing the Efficacy of an Antimicrobial Against Surface-Associated Bacteria	Hamilton Goeres	EPA
Standardized Biofilm Methods	Research Support for the Development and Manufacturing of a Rapid Biofilm Analysis Test Kit	Goeres Cunningham	MTBRC
Structure-Function	Microbial Biofilm Development	Stewart	Keck
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
Education	Biofilms: The Hypertextbook	Cunningham	NSF

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

List of Acronyms

API	American Petroleum Institute
ARO	Army Research Office
AwwaRF	American Water Works Association Research Foundation
DOD	Department of Defense
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
INRA	Inland Northwest Research Alliance
Keck	W.M. Keck Foundation
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
SBIR	Small Business Innovation Research
TBI	Thermal Biology Institute (MSU)
USDA	United States Department of Agriculture
ZERT	Zero Emissions Research and Technology

RESEARCH : FACULTY

CBE Associated Faculty and Their Specialties, 2006–2007

NAME	DEPARTMENT	SPECIALTY
Haluk Beyenal	Chemical & Biological Engineering	Biochemical engineering
Mark Burr	Land Resources & Environmental Sci.	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
Bill Costerton	Microbiology	Biofilms in microbial pathogenicity
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 & Environmental Sci.	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
Garth James	Chemical & Biological Engineering	Medical biofilms
Warren Jones	Civil Engineering	Water distribution systems
Taimur Khan	Center for Biofilm Engineering	Environmental engineering
Issac 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 & Environmental Sci.	Biofilms in extreme environments
Bruce McLeod	Electrical & Computer Engineering	Bioelectric effect
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
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
Rick Veeh	Center for Biofilm Engineering	Bacterial identification using oligonucleotide probes

2006–2007 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 multi-disciplinary 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 gunk, 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 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

RESEARCH : PROGRAM & FACILITIES

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 trains and assists research staff and students in capturing images of *in situ* biofilms via optical microscopy and fluorescent confocal microscopy, and maintains the equipment. 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 vary from those 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** includes 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 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

RESEARCH : PROGRAM & FACILITIES

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 two computational servers for data manipulation, mathematical modeling, and graphic image analysis.

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 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. Fifteen 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 of 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. 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.

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

RESEARCH : PROGRAM & FACILITIES

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)

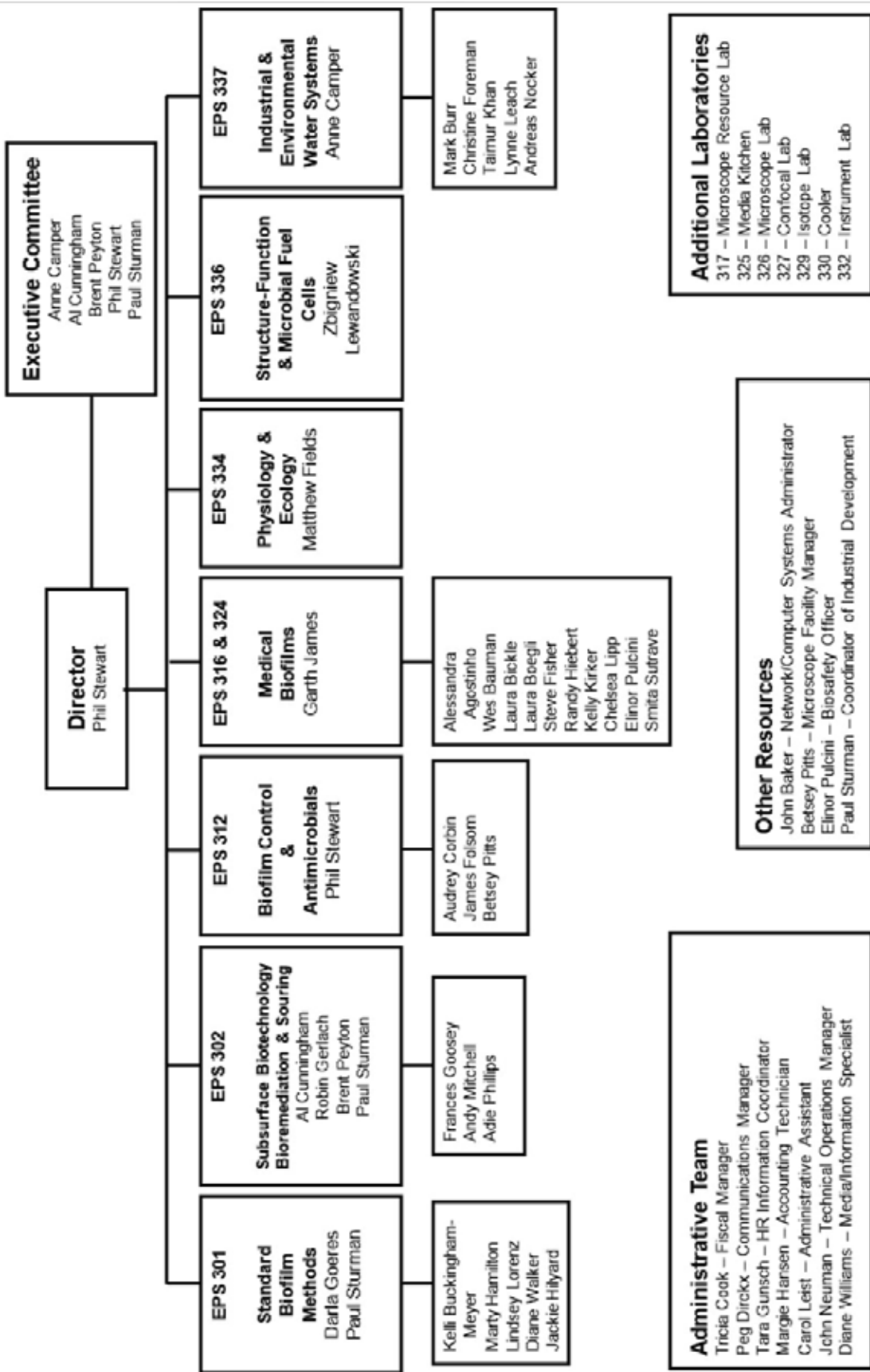
Time of Flight Secondary Ion Mass Spectrometer (SIMS)

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>.

Center for Biofilm Engineering – Organizational Chart Oct-2007



EDUCATION : GRADUATE STUDENTS

CBE Graduate Students: June 1, 2006–May 31, 2007

SUMMARY:

BY DEPARTMENT

Graduates pursuing degrees in 9 departments

Chem. & Bio. Eng:	6 MS (4F/2M) / 11 PhD (3F/8M) /	17 Total
Chemistry/Biochem:	1 MS (1M) 1 PhD (1M)	2 Total
Civil / Environ. Eng.:	6 MS (1F/5M) / 3 PhD (1F/2M) /	9 Total
Computer Science:	2 MS (2M) 1 PhD (1M)	3 Total
Geology	1 MS (1F)	1 Total
LRES		1 PhD (1M) 1 Total
Mathematics		1 PhD (1F) 1 Total
Mech. & Indus. Eng:	1 MS (1M)	1 Total
Microbiology	2 MS (2F) / 10 PhD (7F/3M)	12 Total

47 TOTAL GRAD

STUDENTS BY GENDER

Masters students: 8 Female / 11 Male / 19 Total

PhD students: 12 Female / 16 Male / 28 Total

20 F / 27 M / 47 Total

CHEMICAL & BIOLOGICAL ENGINEERING

<u>MS</u>			<u>4F / 2M</u>
F	Suriani Abdul Rani	Stewart	Degree: August, 2006
F	Sutapa Barua	Peyton	
F	Elizabeth Sandvik	McLeod	
F	Laura Wheeler		
M	Jace Harwood	Cunningham	
M	Reed Taffs	Carlson	
<u>PhD</u>			<u>3F / 8M</u>
F	Abigail Aiken-Richards	Peyton	
F	Catherine Albaugh	Peyton	
F	Jennifer Morrow	Codd	
M	John Aston	Peyton	
M	Jason Chambless	Stewart	
M	Willy Davison	Stewart	
M	Einar Fridjonsson	Seymour	
M	Justin Gage	Seymour	
M	James Moberly	Peyton	
M	Lee Richards	Stewart	Degree: August, 2006
M	Mike VanEngelen	Peyton	

CHEMISTRY / BIOCHEMISTRY

<u>MS</u>			<u>4F / 2M</u>
M	Caol Huff	Livinghouse	Degree: December, 2006
<u>PhD</u>			<u>1M</u>
M	Pat Secor	James	

CIVIL / ENVIRONMENTAL ENGINEERING

<u>MS</u>			<u>1F / 5M</u>
F	Kristin Coward	Jones	
M	Wes Bauman	Camper	Degree: May, 2007
M	Peter Gammelgard	Towler	Degree: August, 2006
M	Kevin Grabinski	Camper	
M	Rickey Schultz	Stein	
M	Sidy Ba	Jones	

EDUCATION : GRADUATE STUDENTS

PhD			1F / 2M
F	Laura Jennings	Gossett / Cunningham	
M	Ben Klayman	Camper	
M	Shahed Rahman	Camper	
<hr/>			
COMPUTER SCIENCE			
MS			2M
M	Rance Harmon	Ross	
M	Steve Aldrich	Ross	
PhD			1M
M	Robert Hunt	Cunningham	
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GEOLOGY			
MS			1F
F	Carrie Taylor	Stein	
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LAND RESOURCES & ENVIRONMENTAL SCIENCES			
PhD			1M
M	Markus Dieser	Foreman	
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MATHEMATICS			
PhD			1F
F	Barbara Szomolay	Klapper	
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MECHANICAL & INDUSTRIAL ENGINEERING			
MS			1M
M	Michael Sutton	Jones	
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MICROBIOLOGY			
MS			2F
F	Sabrina Behnke	Camper	
F	Jessica Richard	Franklin	
PhD			7F / 3M
F	Sharon Chang	Pyle	
F	Melinda Clark	Fields	
F	Jennifer Faulwetter	Stein	
F	Erin Field	Gerlach	
F	Henriette Geier	Ford	
F	Chiachi Hwang	Fields	
F	Anitha Sundararajan	Fields	
M	Stewart Clark	Camper	
M	Amresh Karmacharya	Ford	
M	Storm Shirley	Peyton	

2006–07 Graduates

“Spatial Heterogeneity in *Pseudomonas aeruginosa* Biofilms and How It Affects Antibiotic Tolerance,” Thesis Defense by Lee A. Richards, PhD Candidate in Chemical and Biological Engineering, Montana State University, June 2006.

“Retention of a Model Pathogen in a Porous Media Biofilm,” Thesis Defense by Wesley Bauman, MS Candidate in Environmental Engineering, Montana State University, April 2007.

“Pathogen Transport and Capture in a Porous Media Biofilm Reactor,” Thesis Defense by Kevin Grabinski, M.S. Candidate, Environmental Engineering, Montana State University, July 2007.

“A Quantitative Description at Multiple Scales of Observation of Accumulation and Displacement Patterns in Single and Dual-Species Biofilms,” Thesis Defense by Benjamin J. Klayman, PhD Candidate, Environmental Engineering, Montana State University, June 2007.

EDUCATION : UNDERGRADUATE STUDENTS

CBE Undergraduate Students: June 1, 2006–May 31, 2007

SUMMARY:

BY DEPARTMENT

Undergraduates from 9 departments

Business:	1M	1 Total
Cell Biology & Neuroscience:	5F / 2M	7 Total
Chemistry	1M	1 Total
Chemical & Biological Engineering:	4F / 11M	15 Total
Civil Engineering	1F / 1M	2 Total
Electrical Engineering	1M	1 Total
LRES	1F	1 Total
Mechanical Engineering:	1M	1 Total
Microbiology	3F	3 Total
Nursing	1F	1 Total

33 TOTAL UG STUDENTS

BY GENDER

15 Females / 18 Males

Business

M Alex Hilyard

Cell Biology & Neuroscience

F Saba Alniemi: USP, Garth James
F Heidi Cicon
F Lindsey Danreuther
F Chelsea Lipp
F Sara Nelson: USP, Taimur Khan
M Joseph Peila
M Paul Volden

Chemistry

M Jeffrey Ashe

Chemical & Biological Engineering

F Stacey Biebel
F Andrea Hartman
F Kathryn (Katie) Hoyt: USP, Sarah Codd
F Kathleen Koch
M Nicholas Beck
M Hans Bernstein: USP, Garth James
M Rob Fell
M Robert Fortenberry
M Peter Haun
M Bryan Humphreys
M Jonathan Rice
M Derrick Samuelson
M Logan Schultz: USP, Robin Gerlach
M Joseph Sibbert
M Alan (Matt) Weeden

Civil Engineering

F Shannon Goeres
M Bryan Close

Electrical Engineering

M Conrad Donovan

EDUCATION : UNDERGRADUATE STUDENTS

Land Resources and Environmental Sciences

F Melissa Schroeder

Mechanical Engineering

M Trey Riddle

Microbiology

F Rafaella Pulcini

F Laura Schicktanz

F Jacqueline Whitaker

Nursing

F Elizabeth Martin

Additional MSU USP students working on biofilm projects with CBE-associated faculty:

F Mita Patel: USP, Barry Pyle, Microbiology

F Sarah Mallowney: USP, Brent Peyton, Chemical & Biological Engineering

EDUCATION : STUDENT AWARDS & HONORS

2006–2007 Student Awards and Honors

Fellowship Award

Pat Secor received an IDeA Networks of Biomedical Research Excellence (INBRE) fellowship to assist him in pursuing his graduate degree in Cell Biology and Neuroscience. Pat is the CBE's first graduate student to be getting a degree in Cell Biology and Neuroscience, thus forging new connections with this department. Pat will be advised by Dr. Tom Hughes.

Honor Society Inductions & Fellowship Nominee

Ben Klayman and Stewart Clark were initiated into The Honor Society of Phi Kappa Phi on April 21, 2006. Elizabeth Sandvik was the MSU nominee for a Phi Kappa Phi Graduate Fellowship at the same ceremony. Nicholas Beck and Benjamin Unterreiner were inducted on April 9th into the Alpha Epsilon Delta, the world's largest honor society for premedical education. The 38 MSU students inducted are all in pre-medical or pre-dental programs, carry a grade point average of 3.2 or higher and have completed three or more semesters of work at MSU.

Undergraduate co-author in the media

Cinnamon Spear, an undergraduate co-author of the CBE paper cited below, received attention in the Howard Hughes Medical Institute News in June, 2006. The article and sidebar discussed Cinnamon's involvement in the CBE and how the Howard Hughes Medical Institute has supported her endeavors at Montana State University.

“From the Reservation to the Research Lab”

June 01, 2006

Howard Hughes Medical Institute News

“Denaturing Gradient Gel Electrophoresis (DGGE) can Rapidly Display the Bacterial Diversity Contained in 16S rDNA Clone Libraries”

Burr, MD, Clark SJ, Spear CR, and Camper AK

Microb. Ecol., in press (2006) Published Online 28 April 2006

ASM Graduate Research Fellowship

The American Society for Microbiology (ASM) selected Ailyn Lenz from Montana State University as a 2006–2009 award recipient of the Robert D. Watkins Graduate Research Fellowship. Lenz is awarded up to \$19,000 annual stipend for three years to conduct research.

The Watkins fellowship seeks to increase the number of graduate students from underrepresented groups completing doctoral degrees in the microbiological sciences. The program is aimed at highly competitive students who are enrolled in a PhD program and have completed their graduate coursework in the microbiological sciences. Fellows and their mentors are required to be members of ASM. Fellows are required to present at the ASM General Meeting annually, if their abstract is accepted, and to attend the ASM Kadner Institute, formerly known as the ASM Graduate and Postdoctoral Summer Institute in Preparation for Careers in Microbiology one time during the three-year tenure of the fellowship.

Michael Franklin, Microbiology, is Ailyn Lenz's mentor. The title of her research is “Localized Gene Expression Profiles of *P. aeruginosa* Biofilms in Respon.”

EDUCATION : STUDENT AWARDS & HONORS

W.G. Characklis Award 2007

Stewart Clark, graduate candidate in microbiology, was recognized for his leadership role and valuable contributions to the CBE. This award is made each year to the Ph.D. student who best exemplifies the spirit of cooperation, research leadership, and collaboration within the CBE.

Stewart's nomination letter contained the following description of his contributions:

In the spirit of cooperation, whenever there is a need for volunteer work within the CBE, Stewart is there. He has assisted with the CBE's undergraduate core course and has been on the seminar organizing committee. Whenever there is a need for someone to assist with social functions, the TAC meetings, or other activities, he is there. During the recent laboratory space swap, he was tireless in organizing and coordinating the move and also did a great deal of the work. He has been a key player in the organization and proper functioning of the CBE's molecular biology facility. He gives freely of his microbiology and molecular biology expertise to everyone within the organization and is always willing to take the time to train anyone who needs assistance. All of this is done with a sense of grace, style, and sincerity that is unequalled.

Morris Udall Native American Congressional Internship

Katie Hoyt was awarded a Morris Udall Native American congressional internship to Washington DC in the summer of 2007. Katie, a senior in Chemical & Biological Engineering, has been funded by an INBRE Undergraduate scholarship to work in the CBE on research with Peter Suci, Sarah Codd, and Phil Stewart. The Morris K. Udall Foundation funds 12 Native Americans or Alaska Natives each summer for a 10-week internship in Washington, DC.

MSU Excellence Awards

Forty-two of Montana State University's top seniors and their faculty or staff mentors were recognized Tuesday, February 13, 2007, at the 25th annual Awards for Excellence Banquet. Honored students are nominated by faculty in their college or department. Saba Alniemi, biomedical science undergraduate, was nominated by the College of Letters and Science for this award. Saba is working on a project in the CBE's Medical Biofilms Laboratory to examine the effects of bacteriophage on *Staphylococcus aureus* biofilms.

Big Sky Institute Science and Society Fellow for 2007–2008

Carrie Taylor 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 will receive a stipend of \$30,000 for one year: July 1, 2007 through June 30, 2008. In addition, there is a \$10,500 cost-of-education allowance that can be used to offset tuition, fees, books, and supplies. Carrie is working towards a masters degree in geology; her mentor is Otto Stein.

EDUCATION : SEMINAR SERIES

2006 CBE Fall Seminar Series

Date	Speaker	Title
07 Sep 2006	Shoji Takenaka CBE Visiting Researcher	The Advantages of Two-Photon Laser Microscopy and Dental Biofilms
14 Sep 2006	Jared Leadbetter California Institute of Technology, Professor Environmental Microbiology	Quorum Sensing Signal Decay by <i>Pseudomonas aeruginosa</i>
21 Sep 2006	Lynne Leach CBE Postdoctoral Researcher	The Physiological Role of Pyridine-2,6-dithiocarboxylic acid (PDTC) in Carbon Tetrachloride Degrading Strains of <i>Pseudomonas spp.</i>
28 Sep 2006	Henriette Geier MSU, Ph.D. Candidate, Microbiology	Quorum Sensing and Biofilm Formation in <i>Mycobacterium avium</i>
05 Oct 2006	Jason Chambless MSU, PhD Candidate, Chemical & Biological Engineering	A 3D Computer Model Analysis of Three Hypothetical Biofilm Detachment Mechanisms
12 Oct 2006	Frank Rosenzweig University of Montana	Das Hefeperspiel: Life History and Genomics of Immobilized Yeast
19 Oct 2006	Brenda Grau CBE Postdoctoral Researcher	Phase Variation in <i>Vibrio vulnificus</i> : Identification and Characterization of the Rugose Variant
26 Oct 2006	Phil Stewart MSU, Center Director, Professor, Chemical & Biological Engineering	Control Lab Update
02 Nov 2006	Adrienne Phillips & Al Cunningham CBE Staff and Professor, Civil Engineering	Geologic CO ₂ Sequestration: Opportunity for Biofilm Research
09 Nov 2006	Abbie Richards WSU, PhD Candidate, Chemical & Biological Engineering	Characterization of Siderophores Produced by Halo-Alkaliphilic Bacteria
16 Nov 2006	Rockford Ross MSU Professor, Computer Science	The Geeks Amongst Us: Biofilm Education, Hypertextbooks, and Computational Collaborations
30 Nov 2006	Peg Dirckx CBE, Visual Communications	Effective Research Poster Preparation & Presentation

EDUCATION : SEMINAR SERIES

2007 CBE Spring Seminar Series

Date	Speaker	Title
25 Jan 2007	Peg Dirckx CBE Visual Communications	Effective Technical Presentation
01 Feb 2007	Phil Stewart, Director and Paul Sturman, Coordinator of Industrial Development	TAC Preparation
15 Feb 2007	Elinor Pulcini	The Day Microbes Stood Still
22 Feb 2007	Mary Cloninger, MSU Chemistry	Glycodendrimers
01 Mar 2007	Kevin Grabinski MS candidate, Civil & Environmental Engineering	Pathogen Capture Mechanisms in Porous Media
08 Mar 2007	Anne Camper, Professor, Civil Engineering; Associate Dean of College of Engineering	Name that Lab...an Overview
22 Mar 2007	Kelly Kirker CBE Research Scientist	Tissue Engineering and Wound Healing
05 Apr 2007	Shankar Chellam Associate Professor, Dept. of Civil & Environmental Engineering, University of Houston	Bacterial Fouling of Microfiltration Membranes: Mechanisms and Control
12 Apr 2007	Ken Kemner Environmental Research Division, Argonne National Laboratory	Using Hard X-ray Synchrotron Radiation to Investigate Mineral-Metal-Microbe Interactions
19 Apr 2007	Robert Sharp Associate Professor, Civil and Environmental Engineering, Manhattan College, NY	A "Glowing" Review of Subsurface Biofilm Research at Manhattan College
26 Apr 2007	Tim Ford, Professor & Dept Head, Microbiology, MSU	From Bozeman to Nanjing: Shared Challenges in Environmental Health

EDUCATION : COURSE SYLLABUS

UNIV 125: Microbes in the Environment

Fall 2007

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

Web Page: www.erc.montana.edu/~wdavison/UNIV125/index.html

Instructors: **Willy Davison** wdavison@erc.montana.edu **Jennifer Faulwetter** jfaulwetter@erc.montana.edu **Erin Field** efield@erc.montana.edu

Laura Jennings ljennings@erc.montana.edu **Mike VanEngelen** mvanEngelen@coe.montana.edu

Course Coordinator: **Al Cunningham** al_c@erc.montana.edu

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

Typical Curve:

Exams – 35%	97-100	A+
Quiz 1 – 5%	93-97	A
Quiz 2 – 7.5%	90-93	A-
Quiz 3 – 7.5%	87-89	B+
Final Exam – 15%	83-87	B
Written Assignments– 30%	80-83	B-
Module 1 – 10%	77-79	C+
Module 2 – 10%	73-77	C
Module 3 – 10%	70-73	C-
Project – 25%	67-69	D+
Intro – 5%	63-67	D
Final Presentation – 10%	60-63	D-
Final Paper – 10%	<60	F
Class Participation – 10%		

Note:

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

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

TECHNOLOGY TRANSFER : INDUSTRIAL ASSOCIATES

Current Industrial Membership (June 1, 2006–May 31, 2007)

ORGANIZATION	TYPE OF INDUSTRY	NUMBER OF YEARS OF SUPPORT
3M	Healthcare	07
American Air Liquide, Inc.	Healthcare/Food Safety	05,06,07
Aramco Services Company	Petroleum	87,88,89,90,91,92,93,94,95,96,97, 98,99,00,01,02, 03,04,05,06,07
Bausch & Lomb	Healthcare	07
Bridge PreClinical Testing Services	Testing Laboratory	07
Church & Dwight Co., Inc.	Household Products	02,03,04,05,06,07
Ciba Specialty Chemicals	Specialty Chemicals	07
Colgate-Palmolive	Household Products	00,01,02,03,04,05,06,07
ConvaTec	Healthcare	07
Dow Chemical Company	Specialty Chemicals	90,91,92,93,94,95,98,99,00,01,02, 03,04,05,06,07
DuPont	Specialty Chemicals	95,96,97,98,00,03,04,05,06,07
Ecolab, Inc.	Specialty Chemicals	05,06,07
Embryo Corporation	Testing Laboratory	07
enturia, Inc	Healthcare	07
GlaxoSmithKline	Pharmaceutical	04,05,06,07
Masco	Household Products	05,06,07
Mölnlycke Health Care	Healthcare	07
NASA	Government Lab	05,06,07
NovaBay Pharmaceuticals, Inc.	Pharmaceutical	05,06,07
Novozymes North America, Inc.	Healthcare	05,06,07
Procter & Gamble	Household Products	07
Reckitt Benckiser	Household Products	07
Sandia National Laboratories	National Laboratory	07
Tyco Healthcare (formerly Kendall Healthcare Products Company)	Healthcare	98,99,00,01,02,03,04,05,06,07
Unilever	Household Products	06,07
W.L. Gore & Associates	Healthcare	97,98,99,00,01,02,03,04,05,06,07
Whirlpool Corporation	Household Products	06,07

Center for Biofilm Engineering

06/19/06

Monday June 19

6:00–7:30 p.m.

**Pre-registration and
welcome reception**
GranTree Inn
North 7th Ave, Bozeman

Tuesday June 20

7:30–8:30 a.m.

**Registration and
continental breakfast**
Strand Union Building (SUB)
Ballrooms B & C

8:30–8:45

Introductory remarks
SUB Ballroom D
Paul Sturman, CBE Industrial
Coordinator
Mel Czechowski, Church &
Dwight, TAC Chair
Phil Stewart, CBE Director

SESSION 1: **Antimicrobial Surfaces**

8:45–9:30

**Antimicrobial surfaces in
perspective—a review**
Ross Carlson, Assistant
Professor of Chemical and
Biological Engineering, CBE

9:30–10:05

N-halamine biocidal coatings
Dave Worley, Professor and
Interim Chair, Department of
Chemistry, Auburn University,
Auburn, Alabama

10:05–10:30

**Control of biofilm accumulation on
chitosan-coated surfaces**
M.M. Taimur Khan, Research
Assistant Professor, CBE

10:30–11:00 Break

11:00–11:25

Testing antimicrobial surfaces
Garth James, Medical Projects
Manager, CBE

11:25–12:00

**Textiles and antimicrobial
testing**
Mark Fornalik, Specialty Materials
Group, Kodak Research Labs

12:00–1:00

Lunch, catered
SUB Ballroom C

SPECIAL PRESENTATION

1:00–1:30

State of the CBE
Phil Stewart, CBE Director

SESSION 2: **Biofilms in Food and Food Processing**

1:30–2:00

**Session introduction:
Biofilms in the food industry:
Friend or foe?**
Stewart Clark, Ph.D. Candidate,
Microbiology, CBE

2:00–2:30

**Exploiting competitive
microorganisms to control
foodborne pathogens at the
source**
Mike Doyle, Director, Center for
Food Safety, University of
Georgia, Griffin, Georgia

2:30–2:50

**Biofilms on produce and
household surfaces: Microscopic
imaging and microbial community
analysis**
Rick Veeh, Senior Research
Associate, CBE

2:50–3:20

**Biofilms in the food processing
environments**
Amy Wong, Professor of Food
Microbiology, University of
Wisconsin–Madison

3:20–3:50 Break

SESSION 3: **Biofilm Methods**

3:50–4:15

Session introduction:
Darla Goeres, Research
Engineer, CBE
Log reduction calculations
Marty Hamilton, Professor
Emeritus, Statistics, CBE

4:15–4:30

**Measuring the bias in log
reduction calculations that
result from cell wash-off
during treatment**
Alex Hilyard, Standard Biofilm
Methods (SBM) Intern, CBE

4:30–4:45

**Checking the biofilm removal
and disaggregation steps:
A feasibility study**
Kelli Buckingham-Meyer, Research
Assistant, CBE

4:45–5:00

**A new standard method:
The drip flow reactor with
*Staphylococcus aureus***
Jackie Whitaker, Standard Biofilm
Methods (SBM) Intern, CBE

Poster Session

5:10–6:30

Ballrooms B & C

EPA Feedback Session

6:30–7:30

Ballroom D

TECHNOLOGY TRANSFER : CONFERENCE AGENDAS

Wednesday June 21

7:30–8:30 a.m.
Registration and continental breakfast
Strand Union Building
Ballrooms B & C

SESSION 4: **Industrial Water Treatment**

8:30–8:40
Session introduction
Anne Camper, Professor, Civil Engineering, CBE; Associate Dean for Research and Graduate Studies, MSU

8:40–9:00
Microbially influenced corrosion of copper
Mohammad Shahedur Rahman, Ph.D. Candidate, Civil Engineering, CBE

9:00–9:20
Immobilizing pathogens in a biofilm trap
Wes Bauman, M.S. Candidate, Civil Engineering, CBE

9:20–9:50
Inorganic particle transport in biofilms
Anne Camper

9:50–10:20 Break

10:20–10:50
Controlling localized corrosion in a complex cooling water system
Mike Dorsey, Senior Specialist, DuPont

SESSION 5: **Microscopy**

10:50–11:10
Session introduction:
Recently acquired equipment:
The stereo microscope
Betsey Pitts, Research Associate/Facilities Manager, Microscopy, CBE

11:10–11:40
Using fluorescent proteins to assess biofilm growth
Ben Klayman, Ph.D. Candidate, Environmental Engineering, CBE

11:40–12:10
Application of AFM to bacterial investigations
Recep Avci, Director, Image and Chemical Analysis Laboratory, Physics Department, MSU

12:10–1:00
Lunch, catered
SUB Ballrooms B & C
REGULATORY PRESENTATION

1:00–1:40
Regulatory methods: Recommendations for a suitable method for biofilm disinfectants
Stephen Tomasino, Senior Scientist, US EPA—OPP Microbiology Laboratory, Environmental Science Center

3:15–5:15
TAC Business Meeting
Springhill Pavilion

6:00–8:00
Dinner, catered
Springhill Pavilion

Thursday June 22

7:30–8:30 a.m.
Registration and continental breakfast
Strand Union Building
Ballrooms B & C

SESSION 6: **Environmental Biofilms**

8:30–8:40
Session introduction
Al Cunningham, Professor, Civil Engineering, CBE

8:40–9:15
Transformation of pure-culture and mixed-population biofilms with genes of value for bioremediation
Ron Crawford, Professor of Microbiology, University of Idaho, Moscow, Idaho

9:15–9:45
Selective removal of DNA from dead bacteria and molecular monitoring of disinfection efficacy
Andreas Nocker, Research Assistant Professor, CBE

9:45–10:15
Electron transport in engineered biofilms
Robin Gerlach, Research Assistant Professor, CBE

10:15–10:45 Break

10:45–11:10
Determinants of bacterial cell surface physicochemistry and architecture
Andrew Neal, Savannah River Ecology Laboratory, Aiken, South Carolina

11:15–11:50
Bacterial nanowires: Electrically conductive filaments and their implications for energy transformation and distribution in natural and engineered systems
Jeffrey McLean, Biological Sciences Division, Pacific Northwest National Laboratory

11:50–12:00
Session and meeting wrap-up

02/07/07

**Wednesday
February 7****6:00–8:00 p.m.****Pre-registration and
welcome reception**
Hilton Inn, Bozeman
take North 19th Ave.
to 2023 Commerce Way**Thursday
February 8****7:30–8:30 a.m.****Registration and
continental breakfast**
Strand Union Building (SUB)
Ballrooms B & C**8:30–8:50****Introductory remarks**
SUB Ballroom D
Paul Sturman, CBE Industrial
Coordinator
Ruth Cutright, WL Gore,
TAC Chair
Phil Stewart, CBE Director
Robert Marley, Dean, College
of Engineering**SESSION 1:
Medical/Oral Biofilms****8:50–9:00****Session Introduction**
Garth James, Medical
Projects Manager, CBE**9:00–9:50****Keynote Presentation:**
**The role of autoinducer-2 in the
development of oral multi-species
biofilms**
Alex Rickard, Assistant Professor,
Dept. of Biological Sciences,
Binghamton University,
State University of New York**9:50–10:15*****In vitro* models of oral biofilm**
Elinor deLancey Pulcini,
Research Manager, Medical
Biofilm Laboratory, CBE**10:15–10:45 Break****10:45–11:00****Role of biofilms in chronic wounds**
Garth James, Medical Projects
Manager, CBE**11:00–11:20****Molecular biology of chronic
wound biofilms**
Pat Secor, PhD Candidate,
Cell Biology, CBE**11:20–12:00****Biomaterials and bacteria:
Strategies for medical devices**
Buddy Ratner, Director,
University of Washington
Engineered Biomaterials (UWEB)**12:00–1:00****Lunch, catered****SESSION 2:
Biofilm Ecology****1:00–1:10****Session introduction**
Anne Camper, Professor,
Civil Engineering, CBE**1:10–1:30****Heterogeneity and distribution of
biofilm on reverse osmosis and
nanofiltration membranes**
M.M. Taimur Khan, Research
Assistant Professor, CBE**1:30–1:50*****Escherichia coli* O157:H7 requires
colonizing partner for biofilm
formation and development**
Ben Klayman, PhD Candidate,
Environmental Engineering**1:50–2:10****Retention of a model
pathogen in a porous media
biofilm**
Wesley Bauman, MS Candidate,
Environmental Engineering, CBE**SESSION 3:
Biofilm Methods****2:10–2:20****Session Introduction**
Darla Goeres, Senior Research
Engineer, CBE**2:20–2:40****Using flow cytometry to
distinguish between live
and dead cells**
Anne Camper, Professor,
Civil Engineering, CBE;
Associate Dean of Research,
COE**2:40–3:00 Break****3:00–3:25****Use of propidium monoazide for
live-dead distinction in microbial
ecology**
Andreas Nocker, Research
Assistant Professor, CBE**3:25–3:45****Magnetic resonance microscopy
analysis of biofilm polymer
dynamics and bioreactor transport**
Sarah Codd, Assistant
Professor, Mechanical and
Industrial Engineering**SESSION 4:
Regulatory Session****3:45–3:50****Session introduction:**
Paul Sturman**3:50–4:15****Regulatory methods: The
registration and efficacy
evaluation of biofilm disinfectants**
Marcus Rindal, Microbiologist, Office
of Pesticide Programs, EPA**4:15–4:40****Antimicrobial-coated medical
devices: Regulatory perspective**
Chiu Lin, Division Director,
Anesthesiology, General Hospital
Infection Control and Dental
Devices, Center for Devices and
Radiological Health, FDA**4:40–5:00****Strategic plan for creating
standardized biofilm methods**
Darla Goeres, Senior Research
Engineer, CBE**5:00 - 5:05****Hypertextbook update**
Rocky Ross, Professor, Computer
Science

TECHNOLOGY TRANSFER : CONFERENCE AGENDAS

Poster Session

5:00–6:00

Hors d'oeuvres & Beverages,
Ballrooms B & C

6:00–7:00

Dinner, catered, Ballrooms B & C

7:00–8:00

Biofilm Methods Advisory Committee
Meeting

**Friday
February 9**

7:30–9:00 a.m.

**TAC Business Meeting
(Industrial Associate
Representatives) w/breakfast**
Strand Union Building Room 275

SESSION 5: Biofilm Control

9:00–9:10

Session introduction
SUB Ballroom D
Phil Stewart, Director, CBE

9:10–10:00

**Activities of ceragenins in
eradicating biofilms and
preventing biofilm formation**
Paul Bennett Savage, Professor,
Department of Chemistry and
Biochemistry, Brigham Young
University, Utah

10:00–10:30

**Analysis of antibiotic tolerance
mechanisms in staphylococcal
biofilms**

Suriani Abdul Rani, recent MS
graduate, Chemical and Biological
Engineering; NovaCal
Pharmaceuticals

10:30–11:00 Break

11:00–11:25

**Visualization of antimicrobial
action in biofilms**

Willy Davison, PhD Candidate,
Chemical and Biological
Engineering, CBE

11:25–11:50

**A 3D computer model analysis of
three hypothetical biofilm
detachment mechanisms**

Jason Chambless, recent PhD
graduate, Chemical and Biological
Engineering, CBE

11:50–12:00

Meeting wrap-up

OUTREACH : INRA SYMPOSIUM



INRA Subsurface Biotechnology and Bioremediation Symposium and Workshop June 22-23, 2006

Thursday June 22

8:00 am
Registration and Continental Breakfast
Student Union Building (SUB) Ballrooms B&C

8:30 - 9:15 (SUB Ballroom D)
Transformation of Pure-Culture and Mixed-Population Biofilms with Genes of Value for Bioremediation
Ron Crawford (University of Idaho)

9:15 - 9:45
Selective removal of DNA from dead bacteria and molecular monitoring of disinfection efficacy
Andreas Nocker (Montana State University)

9:45 - 10:15
Electron Transport in Engineered Biofilms
Robin Gerlach (Montana State University)

10:15 - 10:45 Break

10:45 - 11:15
Determinants of bacterial cell surface physicochemistry and architecture
Andrew Neal (Savannah River Ecology Laboratory)

11:15 - 12:00 pm
Bacterial Nanowires: Extracellular Electron Transport in Metal Reducing Bacteria, Biofilms, and Microbial Fuel Cells
Jeff McLean (Pacific Northwest National Laboratory)

12:00 -1:30
Catered Lunch with Speaker (SUB Ballroom D)
Aerobic Oxidation of Vinyl Chloride and cis-1,2-Dichloroethene — Bioremediation Perspectives
Jim Gossett (Cornell University)

1:30 - 2:15
Isolation and Characterization of a Thermo-Alkali Stable Catalase and a Thermo-Acid Stable Xylanase from Extremophilic Bacteria
Bill Apel (Idaho National Laboratory)

2:15 - 2:40
Genomic and Biochemical Inquiries into Toxic Metal Reduction in Acidophilic Bacteria
Tim Magnuson (Idaho State University)

2:40 - 3:05
The Diversity of Microorganisms and Their Interactions with Toxic Metals in Sediments of Lake Coeur d'Alene
Rajesh Sani (Washington State University)

3:05 - 3:25 Break

3:25 - 3:50
What's in the soil? Bioremediation is counting on you!
Anne Anderson (Utah State University)

3:50 - 4:15
The Influence of Root-Microbe Interactions on Contaminant Removal in Constructed Wetlands
Otto Stein (Montana State University)

4:15 - 5:00
Systems Biology (Integration of the Omics, Bioinformatics, and Biogeochemistry): The New Frontier for Environmental Biotechnology
Terry Hazen (Lawrence Berkeley National Laboratory)

5:00 – 7:00 (SUB Ballrooms B&C)
Poster Session
(Appetizers, Refreshments served)

Friday June 23

8:00 am
Continental Breakfast (Engineering Physical Sciences Building (EPS) - 1st Floor Lobby)

9:00 - 9 :30 (EPS Room 103)
The New INRA Subsurface Biotechnology and Bioremediation Initiative
Steve Billingsley (Inland Northwest Research Alliance)

9:30 - 10:00
Funding Opportunities through University/Industry Research Collaboration
Al Cunningham (Montana State University)
Ron Sims (Utah State University)
Will Goldberg (Center for Innovation)

10:00 - 12 :00 Workshop
Transition to Breakout Sessions
Tour of the Center for Biofilm Engineering

12:00 - 2:00 (EPS 1st Floor Lobby)
Catered Lunch
Breakout Session Reporting

2:00
Adjourn

**2007 Initiative: Interdisciplinary Research Retreat
Biofilm Mechanics Workshop**

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

A workshop review, by Phil Stewart

Late June can be a beautiful time in Montana, and so it was this year 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 26 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;

OUTREACH : BIOFILM MECHANICS WORKSHOP

- Cells compete for space and displace their neighbors as bacteria grow inside a biofilm;
- 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 just 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 Horneman, 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

OUTREACH : BIOFILM MECHANICS WORKSHOP

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 : ASM RESEARCH PRESENTATIONS

CBE Research Presentations at the ASM 2007 Biofilm Conference, Quebec City, Canada

Faculty, staff and students from the CBE and other Montana State University departments presented at the American Society for Microbiology (ASM) Biofilms 2007 conference in Quebec City, Canada, March 25–29, 2007. ASM awarded travel grants to Benjamin Klayman (\$500) and Lynne Leach (\$1,000). Presentations and posters are listed below.

Presentations at ASM 2007

Phil Stewart was a Session Chair for the session on “Prevention and Treatment of Biofilms.” As an invited speaker Phil presented “Visualizing Killing in Biofilms.”

Garth James as an invited speaker presented “Biofilms in Chronic Wounds.”

Posters at ASM 2007

“Removal and Control of Biofilms in Dental Unit Waterlines Using Electrolyzed Water,” **A.M. Agostinho**, P. Sturman, J. Lambie, A. Camper, P. Elinor, G. James*

“A Multiscale Model of Biofilm as a Senescence -Structured Fluid,” **B.P. Ayati***, I. Klapper

“Role of Flagella in Mature Biofilms of *Desulfovibrio vulgaris* Hildenborough,” **M.E. Clark***, R.E. Edelmann, M.L. Duley, Z. He, J. Zhou, M.W. Fields

“Contribution of Oxygen to *Staphylococcus epidermidis* Biofilm Development and Antibiotic Susceptibility,” **J.J. Cotter**, J.P. O’Gara, P.S. Stewart, B. Pitts, E. Casey

“Visualization of Antimicrobial Action in *Staphylococcus epidermidis* Biofilms,” **W.M. Davison***, P.S. Stewart

“The Use of the Drip Flow Reactor as a Dental Biofilm Model System,” **E. deLancey-Pulcini***, G. James, E. Hilblom

“Biofilm Formation as a Mycobacterial Stress Response,” **H. Geier***, S. Mostowy, M.A. Behr, T.E. Ford

“The Necessary Information is in Oasis,” A. Phillips, **R. Gerlach***, R. Hiebert, G. James, L. Spangler, A.B. Cunningham

“Investigations of Dormant Cells in *Pseudomonas aeruginosa* Biofilms,” L.A. Richards, **B.L. Grau***, G.D. Ehrlich, and P.S. Stewart

“Biofilms in Chronic Wounds,” **G.A. James***, R. Wolcott, E. Swogger, E. deLancey Pulcini, P. Secor, J. Sestrich, J.W. Costerton, P. S. Stewart

“Optimal Strategy to Control Both Active and Dormant Cells in Biofilm with Various Antimicrobial Agents,” **J. Kim***, C. Nam, M. Franklin, J. Hahn, J. Yoon

“Modeling Biofilms as Viscoelastic Materials,” **I. Klapper***, E. Alpkvist, D. Hill

“*Escherichia coli* O157:H7 Forms Biofilm in Co-culture with *Pseudomonas aeruginosa*, but not Alone,” **B.J. Klayman***, P. Stewart, A. Camper

OUTREACH : ASM RESEARCH PRESENTATIONS

“Development of a Rapid Molecular Technique for Detection of HAA Degraders in Drinking Water Distribution Systems,” **L.H. Leach***, P. Zhang, A.K. Camper

“Localized Gene Expression along Vertical Transects of *Pseudomonas aeruginosa* Biofilms,” **A.P. Lenz**, K. Williamson, B. Pitts, P.S. Stewart, M.J. Franklin

“Development of Fluorescent Reagent Combinations Specific to Biofilm Components,”
B. Pitts*, D. Gray, P. Stewart

“Mobile System for Spectral Imaging of Reflectance and Fluorescence from Environmental Samples at Various Spatial Scales,” **L. Polerecky***, A. Bissett, P. Suci, P. Stoodley, D. de Beer

“Multispecies Biofilm Development on Space Station Heat Exchanger Core Material,” **B.H. Pyle***, L.M. Vega, S.R. Roth, K.D. Pickering, P.J. Alvarez, M.C. Roman

“Molecular Analysis of Chronic Wound Biofilms,” **P.R. Secor***, E. deLancey Pulcini, R. Wolcott, G. James, P. Stewart

“A 3D Computer Model Analysis of Three Hypothetical Biofilm Detachment Mechanisms,”
J.D. Chambless, **P.S. Stewart***

“Spatial Patterns of DNA Replication, Protein Synthesis and Oxygen Concentration within Bacterial Biofilms Reveal Diverse Physiological States”, S. Abdul Rani, B. Pitts, H. Beyenal, R.A. Veluchamy, Z. Lewandowski, K. Buckingham-Meyer, **P.S. Stewart***

“Characterization of *Escherichia coli* Biofilm Detachment in Mixed Species Biofilms Grown in Capillary Flow Cells,” **P. Volden***, B. Klayman, A. Camper

OUTREACH : VISITING RESEARCHERS

CBE Visiting Researchers, 2006–2007

Abdouaye Camara, a visiting student 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.

Audrey Corbin, a biotechnology student from Lyon, France, was a visiting researcher in the Biofilm Control team for several months starting in January 2006. She worked on aspects of *E. coli* gene expression in biofilms. Audrey returned to the CBE in January 2007 as a staff Research Associate and presented her work at the Summer 2007 Technical Advisory Conference.

Christoph Fux, MD, a returning visiting researcher, returned for a month to write a paper about biofilm detachment as a result of collaborative research with Paul Stoodley, Marty Hamilton, and Cord Hamilton. Christoph is a doctor from the University Hospital in Berne, Switzerland, where he specializes in Internal Medicine and Infectious Disease. In 2003-2004, Christoph spent some time here at the CBE learning about medical biofilms.

Gerald Gaspar, from the Chemistry Department at the University of Illinois-Chicago, spent a month at the CBE working with Ross Carlson, Assistant Professor, Chemical & Biological Engineering. At the UI-Chicago, Gerald works for Professor Luke Hanley.

Christopher Groth visited from Manhattan College in New York, where he is pursuing a master's degree in environmental engineering under the supervision of Robert Sharp (former CBE student). Chris set up model porous media reactors to continue our studies on the effect of biofilm formation on porous media hydrodynamics. He worked with Robin Gerlach and Al Cunningham.

Elisa Korenblum, a PhD student from the Instituto de Microbiologia of Rio de Janeiro, Brazil, worked with Brent Peyton's group and the CBE April –August, 2006. The International Microbiology Education Committee (IMEC) selected her as one of three recipients of the ASM International Fellowship Awards for 2006. Her focus was on antimicrobial substances (AMS) produced by strains *Bacillus licheniformis* T6-5 and *Bacillus fimus* H2O-1, isolated from a Brazilian oil reservoir, that were able to inhibit planktonic sulfate reducing bacteria growth. The project was focused on the action of two AMS (T6-5 and H2O-1) against sessile SRB, and applied microscopy techniques to study the effectiveness of these AMS.

John Lennox, Professor Emeritus, Microbiology, Penn State-Altoona, came to the CBE for the month of October 2006 to work on biofilm education projects. John is committed to bringing the biofilm concept into the undergraduate science and engineering curriculum. He contributed to the success of the Biofilms: The Hypertextbook proposal which was awarded by NSF. During this visit, John collaborated with Rocky Ross and Al Cunningham on the hypertextbook project.

Anna A. Lysova, a Ph.D. candidate from Novosibirsk State University and the International Tomography Center, Siberian Branch Russian Academy of Sciences, received the US Civilian Research and Development Foundation's 10th Anniversary Junior Scientist Fellowship to spend three months (April-June, 2006) in the Magnetic Resonance Microscopy (MRM) Lab and the CBE at MSU. Ms. Lysova has expertise in imaging of aluminum and other metals. She studied transport in biofilms and looked at the impact of anti-microbial agents on magnetic resonance phenomena in biofilms. The potential for metals imaging in biofilms was also explored.

Susana Sanchez will be worked in the Biofilm Control Lab for four months in 2007. Susana is PhD candidate in microbiology from the University of Navarra, in Spain. She grew up in Pamplona, the capital city of Navarra, known for the Festival of Sanfermines, which includes the famous Running of the Bulls event. Susana evaluated the ability of antimicrobial peptides, a natural class of antimicrobial agents, to control biofilm formation by the opportunistic pathogen *Pseudomonas aeruginosa*. She brought expertise with the peptides and combined her

OUTREACH : VISITING RESEARCHERS

knowledge with new skills on the Confocal Scanning Laser Microscope at the CBE. One of her CSLM images appears on the cover of the 2007 Annual Report.

Kathy Sossa, a repeat visitor from the University of Concepción, Chile, returned to the CBE for a month-long visit in the winter of 2007, including the Winter Technical Advisory Conference. She was also instrumental in the outreach workshop in Chile in January 2007 (page 13, Annual Report).

Priscilla Sossa from Chile worked with Mark Burr and Andreas Nocker in Anne Camper's research group for three months on a project studying microbial community structures along a water quality gradient. Priscilla is working toward a degree in the Biomedical Science Program, and is also employed at the parasitology unit of the Antofagasta University.

Dr. Shoji Takenaka, a dental researcher and dentist, visited from the Center from Niigata University in Japan. Dr. Takenaka specializes in endodontics, particularly root canal infection. Dr. Takenaka was at the CBE for a year, doing research in Phil Stewart's Biofilm Control lab, using a consortium of oral bacteria to study diffusion and antimicrobial efficacy. Dr. Takenaka learned new methods, new ways of thinking, and gained insight into how to effectively remove biofilm attached to root surfaces of the tooth.

Dr. Jeyong Yoon, a visiting professor from Seoul National University worked with Anne Camper for five months. He was interested in controlling biofilms in distribution systems with various disinfectants and would like to learn new methods and concepts from biofilm fields here. He would also like to initiate a biofilm center similar to the CBE in his home university in Korea.

Ayrat Ziganshin was a visiting PhD student from Tatarstan, Russia. Ayrat was a Fulbright scholar from Kazan State University and worked in Robin Gerlach's research group on various topics related to the transformation of explosives. Ayrat has training in microbiology and focused on the transformation of 2,4,6-trinitrotoluene by yeast cells.

A TIMELINE OF CBE MILESTONES

A List of Some CBE Milestones

(Note: **Boldface type** indicates inclusion of item in the printed version of the annual report.)

PRE-CENTER

1979 Characklis joins MSU faculty

INSTITUTE FOR PROCESS ANALYSIS

1980s Characklis starts the Institute for Biological & Chemical Process Analysis (IPA) and develops its industrial program (12 members)

1980s Characklis and Marshall write first edition of "Biofilms"

NSF CENTER ESTABLISHED

1990 NSF awards \$7.5 million ERC grant (Center for Interfacial Microbial Process Engineering)

1990 Center moves into contiguous labs & offices; staff hired

1990-92 Work begins on integrating Research / Education / Technology Transfer

1990-92 Scale-up of projects from bench to field (Micro-, Meso-, Macroscale)

1991 23 graduate students; 8 undergraduate students (per Year 1 annual report)

1991 **"Generic" biofilm accumulation computer model (BAM) with a biocide component**

1991 REU summer undergraduate program begins

1991 Research initiatives in: Biofouling/Biocorrosion of Industrial Water Systems, Microbially Induced Souring in Petroleum Formations, Bioremediation of Soil and Water Contaminated with Petroleum Hydrocarbons

1991 43 active research projects

1991 Patent for Center-developed biofilm coupon

1991 **First cross-disciplinary biofilm courses offered**

1991 **Symposium and research initiative on petroleum reservoir souring**

1991 DOW Chemical & Conoco supported grad student fellowships

1991 Alpha Lab test-bed facility created (to test and demonstrate Center-developed methodologies and technologies)

1991 **Seminar series started**

1991 New Industrial Associates program established, with semi-annual Technical Advisory Conferences

1992 **Bill Characklis dies**

1992 Rotating annular reactor developed (rotatorque)

1992 Full scale testbed facility established at Bozeman Municipal Water Treatment Plant

1992 **1st Confocal Scanning Laser Microscope acquired (\$234,000)**

1992 **10 disciplines represented by undergrad and graduate students**

A TIMELINE OF CBE MILESTONES

CENTER GROWTH

- 1993 Costerton joins CBE as director**
1993 Center name changed to “Center for Biofilm Engineering”
1990-93 4 biofilm engineering courses developed: 1 biofilm microbiology course developed
1993 Microsensor Laboratory created
1993 MSU agreement with BioSurface Technologies Corp., MT, to manufacture, market, and sell the Annular Reactor
1992-93 Effects of surface roughness on adhesion of cells / Initial attachment events
1992-93 Pitting corrosion / SRB activity
1993 AWWARF project funding for drinking water studies
1993 Model of biofilm detachment
- 1994 Microsensors design, development, measurement
1994 Cryoembedding and cryosectioning methods developed to analyze biofilms
1994 Research Thrust Areas: Surface Interactions; Structure-Function; Biofilm Control;
1994 Spatial physiological gradients identified in antimicrobial treatment
1994 Confirmation of multiple biofilm heterogeneities, via microelectrodes, sensors, CSLM
1994 Plans made for cellular automata modeling
1994 Proof of water flow through channels in biofilm communities (CSLM time-lapse)
1994 Use of microsensors in vapor phase bioremediation, for NJIT vapor phase model
1994 Chlorine penetration into biofilm measured
- 1995 Rotating disk reactor developed, progenitor of CDC reactor**
1995 Phenotypic differences identified between planktonic/sessile cells
1995 Reaction-diffusion of antimicrobials quantified
1995 Initial attachment events study switches from topography to surface chemistry
1995 Cellular automata model tested with bacterial adsorption lab studies (2-D surface)
1995 Bioremediation education workshops for EPA Regions VII & VIII, funded by HSRC
1995 Biobarrier test bed developed with MSE, Inc., funded by DOE, student education opportunity
1995 Sulfide production in simple porous media systems successfully modeled
1995 Cellular automata modeling for bacterial transport begun
1995 24 Industrial Associate members
1995 Adhesion to surface up-regulates genes in alginate synthesis pathways of *P. aeruginosa*
1995 pBAM model developed (Szego, CBE)
- 1996 ASM 1st conference on biofilms, Snowbird, Utah; Costerton, Organizing Committee Chair**
320 delegates from 14 countries;
1996 Science “Biofilms Invade Microbiology”
“Today the CBE is a haven of interdisciplinary work, with graduate students from 10 departments working in interdisciplinary teams. Engineering students clone genes, microbiologists construct mathematical models, and mathematicians learn biochemistry, all to solve real-world problems.”
Science, Vol. 273, Sept. 27, 1996
- 1996 ASM News Education Feature: Costerton, Sears, Zilver**
1996 Biofilm viscoelasticity recorded (CSLM time lapse) and measured
1996 Demonstration that HSLs influence biofilm architecture; Cell-cell communication research area added
1996 Conoco sponsors gasoline bioremediation course in Garrison, Montana
1996 Biofilm Systems Training Laboratory (BSTL) created for students and industry visitors, visiting researchers

A TIMELINE OF CBE MILESTONES

- 1996 Software development to analyze biofilm structure-function from CSLM images
- 1996 Pre-TAC Biofilm Methods workshops begin**
- 1996 Use of 'artificial biofilms' to test antimicrobial penetration and efficacy
- 1996 Physiological tolerance to biocides demonstrated
- 1996 Several computer models studied simultaneously to adapt them for multi-dimensional studies
- 1997 CBE moves into new EPS building**
- 1997 New Leica TCS-NT CSLM and light microscopes (\$400,000; NSF-ERC major equipment grant)
- 1997 Drip flow reactor developed**
- 1998 Science article, Cell Signaling:** Davies, Parsek, Pearson, Iglewski, Costerton, Greenberg
- 1998 'Bioavailability' research area replaces 'Surface Interactions'
- 1998 Development of local density and local mass transport rate microsensors (intra-microcolony)
- 1998 Model development to predict pressure drop in conduits colonized by biofilms
- 1998 New research initiative in Biomineralization
- 1998 New model developed integrating mechanisms of transport and physiological limitation
- 1998 Physiological heterogeneity described by genetic expression**
- 1998 Study of cell signaling role in detachment
- 1998 Respirometry equipment added to BSTL lab (\$223,000; NSF-EEC grant)
- 1999 Review article appears in Science:** Costerton & Stewart
- 1999 Business Week "Science & Technology" references CBE in "Getting a grip on bacterial slime"
- 2000 CBE co-hosts ASM Biofilms 2000 conference, Big Sky, MT**
- 2000 W.M. Keck Foundation awards \$800k grant for students**
- 2000 First issue of *BiofilmsOnline* published**
- 2000 Rotating disk reactor design modified by CDC**
- 2000 New MSU "Microbes in the Environment" class offered by CBE faculty & staff**
- 2000 New Research Area in Standardized Biofilm Methods**
- 2000 *Nature News* Feature: "Slimebusters" covers CBE research
- 2001 *Scientific American* article:** Costerton, Stewart
- 2001 *Lancet* article: Stewart
- 2001 CBE 'graduates' from the NSF-ERC program grant**
- 2001 Microsensors / Structure-Function workshops initiated
- 2001 CBE UG Laura Jennings receives Goldwater scholarship
- 2001 Field-scale (100ft. x 20 ft.) demonstration of biobarriers to reduce ground water flow 3 orders of magnitude**
- 2001 Workshop for FDA and EPA regulators at summer Technical Advisory Conference**

POST-NSF GRANT ACTIVITY

- 2002 ASTM #E-2196-02; CBE rotating disk reactor standardized method approved**
- 2002 DoD grant for engineered biofilms to detect bioterrorist agents in drinking water systems
- 2002 CBE workshops held at Danish Technical University (Denmark) and University of New South Wales (Australia)

A TIMELINE OF CBE MILESTONES

- 2002 CDC biofilm reactor designed
2002 Extensive phenotypic changes in biofilm described
- 2003 3rd ASM Biofilms Conference in Victoria, BC**
2003 New confocal microscope, flow cytometer and image analysis facilities funded by Murdock Charitable Trust
- 2003 Microscope Resource Room created, dedicated to microscope image analysis
2003 Bioglyphs project selected as semifinalist in Science and NSF “Science and Engineering Visualization Challenge”
- 2003 Biofilms studied using NMR microscopy for fluid flow patterns & diffusive properties of biofilm
2003 CBE undergraduate Cory Rupp receives MSF Graduate Fellowship (\$121,500)
- 2004 Bill Costerton retires from MSU**
2004 REU program end year
2004 CBE Medical Biofilm Laboratory established
2004 Cover images: *Journal of Magnetic Resonance* (Gjersing) and *Biophotonics* (Harrer)
2004 CBE team organizes IWA international Biofilms Conference, Las Vegas; Lewandowski
2004 Pan-American Advanced Studies Institutes (PASI) workshops organized by CBE & University of Concepción, Chile
2004 *Physical Review Letters* publishes 2 papers by CBE researchers
2004 JMR cover and CBE article
2004 Modeling antibiotic resistance in biofilms, accounting for nutrient limitation
- 2005 Phil Stewart chosen to be CBE’s 3rd director**
2005 DoD funds equipment for Mass Spectrometry Facility
2005 CBE CDC biofilm reactor standardized method submitted to ASTM
2005 Standard method for assessing efficacy of dental unit water line antimicrobials developed
2005 Journal cover *SGM Microbiology* (Chambless)
2005 Journal cover *SGM Microbiology* (Xavier)
2005 Modeling protection from antimicrobials via persister cell formation
2005 3D cellular automata model of antimicrobial action on biofilm
05-06 32 graduate students; 36 undergraduates
- 2006 NIH Chronic Wound grant awarded**
2006 NSF award for *BIOFILMS: The Hypertextbook*, Cunningham, Ross
2006 CBE drip flow reactor standardized method submitted to/approved by ASTM
2006 19 visiting researchers conduct work at CBE
2006 Journal cover: *ASM Appl. & Environ. Eng.* (Chambless)
2006 3-D cellular automata model
- 2007 4th ASM Conference on Biofilms, Quebec City (ca. 600 attendees)**
2007 Biofilm Mechanics International Workshop, Bozeman
2007 CBE CDC biofilm reactor standardized method approved by ASTM
2007 Qiagen licenses method for distinguishing between live and dead bacteria in molecular assays
2007 *Fundamentals of Biofilm Research* published, Lewandowski & Beyenal
2007 3D computer model analysis of 3 biofilm detachment mechanisms
2007 Over 690 peer-reviewed papers published since 1990 (avg. 40/year)

A TIMELINE OF CBE MILESTONES

- 2007** ISI: Institution with most biofilm papers published since 1990: Montana State University
- 2007** ISI: Authors with most biofilm papers published: 1) Costerton; 3) Stewart;
5) Lewandowski; 7) Stoodley
- 2007** ISI: Top Cited papers since 1990: #2, #3, and #4
- 2007** Over 160 graduated MS and PhD students since 1990
- 2007** Over 420 undergraduates involved in CBE research projects since 1990