Appendix 2: Supplemental Information

TABLE OF CONTENTS

Director's Message

During the past year, the CBE has solidified its position as the world's premier center for study in the burgeoning fields of biofilm microbiology and biofilm engineering. This reinforced position constitutes the fruition of a three-part strategy that is deeply embedded in the leadership of the Center (the Executive Committee and the Director).

First, the CBE has built dynamic teams of talented researchers from a wide range of disciplines. A constant stream of motivated students and post-doctoral researchers contributes to, and benefits from, the CBE research/education program. They are mentored by tenured faculty of numerous departments, who are equally committed to making industrially relevant advances in biofilm research and to shaping the next generation of cross-trained academics and industrial researchers. Because our new policies guarantee support for selected young colleagues, Jeff Leid and Mark Shirtliff have been able to negotiate terrific new tenure track positions (at Northern Arizona and Maryland), and our strong team has been reinforced by Christoph Fux from Switzerland and three wonderful visitors from Italy (Georgia Borriello, Iolanda Francolini, and Enrico Marsili). CBE faculty continue to reap the rewards of their efforts: Marty Hamilton has been elected a fellow of the American Statistical Association and has obtained a large EPA grant while realigning himself with the Center full-time, while Anne Camper manages a $1 million Army Research Office (ARO) grant, and Phil Stewart has received a "dream" NIH grant to model antibiotic susceptibility in biofilms. Paul Stoodley has cooperated with Portland State in the design of a mobile lab that can study biofilms in their natural habitats, and David Dickensheets has built a fiberoptic confocal probe that will let us look at sessile cells *in situ*, with a resolution approaching 0.6 microns. The tenured professors are solidly successful, the research staff are "seething" with activity, the students grow from strength to strength, and the teams have never been stronger!

Second, the CBE team is balanced in its research programs, in its personnel, and in its approach to the study of biofilms. As we prepare for the ASM Conference on Biofilms 2003 (Nov. 1–6, in Victoria, B.C.) it becomes very obvious that many of the biofilm groups that have sprung up in the last three years have been restricting their attention to the details of the genetic mechanisms of major discoveries made (at least in part) in the CBE. Our discovery (Davies et al., *Science*, 280:295-298, 1998) that biofilm formation is controlled by cell-cell signaling, is now being dissected by the use of mutants and signal manipulations in dozens of labs that use these genetic tools, and the data are often contradictory. Fights are developing about the accuracy of methods and the "cleanness" of mutants, but we have moved on to new questions. Similarly, our discovery (Sauer et al., *J. Bacteriol.*, 184(4):1140-1154, 2002) that biofilm cells express a radically different phenotype from that of planktonic cells, has produced a swarm of "follow on" studies in which everything from proteomics to DNA arrays to gene libraries are being used to dissect out the molecular details of these phenotypes. But the central fact remains that these phenotypes are very different, and we have moved on to examine the role of these differences in microbial ecology and chronic disease. The CBE team includes people from at least nine different departments—with an even larger range of conventional academic disciplines—and the balance of perspectives provided by these interdisciplinary teams keeps CBE research properly focused on critical issues that can limit the field or move the field forward.

Third, the CBE is faithful to its original charter, as an Engineering Research Center (ERC), in that it links education and technology transfer firmly to its innovative research in biofilms. The CBE 'test bed' was strengthened by the development of our Prokaryotic Imaging Facility, which combines a new Murdock-funded confocal microscope with an ARO-funded cell sorter to make a biofilm-imaging combination unique in the world. The Center has sustained its commitment to meaningful research experiences for undergraduate students—from Montana State and from other American universities—and 52 students (of whom 25 are female) have benefited from extended contact with our research team during this past year. The phenomenal intellectual productivity of the Center, in the form of a new high of 55 papers published

in refereed journals during the 2002 calendar year, is especially gratifying in that six of these papers included undergraduate students as authors (two as first authors). Due to successful grant-writing, more graduate students have been recruited to produce a current total of 24, of whom seven are women, five of them engineers. Eight of these 24 graduate students have contributed to Phil Stewart's unique interdisciplinary Keck-supported cohort who study the same *Pseudomonas* biofilm from multiple scientific points-of-view, and with multiple skill sets.

In the past year the CBE has assumed an even more proactive stance in all matters of outreach and technology transfer. While many articles have been written about the CBE *(The Boston Globe,*[1] *Science,*[2] *Nature Biotechnology*[3]), we are also well-represented by CBE-authored articles in high-profile publications (*Scientific American,*[4] JAMA,[5] *Lancet*[6]). Our concerted outreach effort is establishing the CBE as a primary source for biofilm information and education beyond the MSU–Bozeman campus; many primary contacts with the CBE are made through the Center's extensive web site. Discoveries made in other labs are now routinely brought to the Center for confirmation by our research team, and for presentation to our sponsoring companies. Examples include the ELISA test for the presence of biofilms on medical devices (Dr. Selan, La Sapienza University, Rome), the RIP signal blocker for the inhibition of *Staphylococcal* biofilms (Dr. Balaban, Tufts University), and the pseudo-membrane for the controlled release of antibacterial molecules (Dr. Ratner, UWEB, Seattle). Luanne Hall-Stoodley has obtained an NIH grant to develop vaccines with Ligocyte Ltd. (Bozeman), and Mark Pasmore's lab has subcontracts from Phase II SBIR awards to develop an "on-line" biofilm meter (Intelligent Optical Systems, California), and to identify plant molecules that inhibit bioflm formation (Sequoia, San Diego). Al Cunningham's collaboration with MSE Technologies, Inc. (Butte, MT) has moved into very practical areas, in that field projects are now underway that use his ultramicrobacteria to place biofilms that block underground water movement, improve secondary oil recovery, and prevent acid mine drainage. Industrial membership (currently 23 companies) remains stable and strong despite a lackluster U.S. economy, and the volume of industry-sponsored research ($1.4 million) is higher than at any time during direct support from the ERC program.

As direct financial support from the NSF's ERC program neared termination in April, 2001, the CBE's leadership reconfirmed its commitment to the interdisciplinary team approach established by the ERC grant. The CBE has held fast to its original goals: to make industrially relevant advances in biofilm research and to re-shape university science and engineering education. By any objective set of criteria, these goals have been achieved, and the Center can look back on a remarkably successful year.

---

1 "Culprit in Ear Infections is a 'Biofilm' that Protects Bacteria," by Cathryn M. Delude. In: *The Boston Globe*, May 28, 2002, C5 republished on BiofilmsOnline, June 6, 2002.

2 Costerton, J.W., P.S. Stewart, and E.P. Greenberg, "Bacterial Biofilms: A Common Cause of Persistent Infections," *Science*, 284(5418):1318-1322 (1999).

3 "Slimy Business—The Biotechnology of Biofilms," by Beth Schachter. In: *Nature Biotechnology*, April 2003, 21:361-365.

4 In 2002 *Scientific American* magazine and Philips produced a first-ever special issue for dental professionals titled *Emerging Trends in Oral Care*, featuring articles by J.W. Costerton and P.S. Stewart: "Battling Biofilms," reprinted from *Scientific American*, and P. Stoodley: "Biofilms, Smile! You're on Confocal Scanning Laser Microscopy Camera."

5 Ehrlich, G.D., R. Veeh, X. Wang, J.W. Costerton, J.D. Hayes, F.Z. Hu, B.J. Daigle, M.D. Ehrlich, and J.C Post, "Mucosal Biofilm Formation on Middle-Ear Mucosa in the Chinchilla Model of Otitis Media," JAMA, 287(13):1710-1715 (2002).

6 Stewart, P.S., "New Ways to Stop Biofilm Infections," *Lancet*, 361(9352):97 (2003).

2002 Publications

Adams H., M. Winston, J. Heersink, K. Buckingham-Meyer, W.J. Costerton, and P. Stoodley, "Development of a Laboratory Model to Assess the Removal of Biofilm from Interproximal Spaces by Powered Tooth Brushing," *Amer. J. Dent.*, 15:12B–17B (2002). **Abstract 02-032**

Besner, M.-C., V. Gauthier, P. Servais, and A. Camper, "Explaining the Occurrence of Coliforms in Distribution Systems," *J. AWWA*, 94(8):95–109 (2002). **Abstract 02-029**

Butterfield, P.W., A.K. Camper, J.A. Biederman, and A.M. Bargmeyer, "Minimizing Biofilm in Presence of Iron Oxides and Humic Substances," *Wat. Res.*, 36(15):3898–3910 (2002). **Abstract 02-035**

Butterfield P.W., A.K. Camper, B.D. Ellis and W.L. Jones, "Chlorination of Model Drinking Water Biofilm: Implications for Growth and Organic Carbon Removal," *Wat. Res.*, 36(17):4391–4405 (2002). **Abstract 02-044**

Chen, X. and P. S. Stewart, "Role of Electrostatic Interactions in Cohesion of Bacterial Biofilms," *Appl. Microbiol. Biotechnol.*, 59: 718–720, (2002). **Abstract 02-039**

Czechowski, M.H. and P. Stoodley, "Antimicrobials and Biofilms," *J. Industrial Microbiol. Biotech.*, 29(6):325 (2002). **Abstract 02-052**

Dunsmore, B.C., A. Jacobsen, L. Hall-Stoodley, C.J. Bass, H.M. Lappin-Scott, and P. Stoodley, "The Influence of Fluid Shear on the Structure and Material Properties of Sulphate-Reducing Bacterial Biofilms," *J. Industrial Microbiol. Biotech.*, 29(6):347–353 (2002). **Abstract 02-051**

Franklin, M.J. and D.E. Ohman, "Mutant Analysis and Cellular Localization of the AlgI, AlgJ, and AlgF Proteins Required for O-Acetylation of Alginate in *Pseudomonas aeruginosa*," *J. Bacteriol.*, 184(11):3000–3007 (2002). **Abstract 02-024**

Gardner, L.R., P.S. Stewart, "Action of Glutaraldehyde and Nitrite Against Sulfate-Reducing Bacterial Biofilms," *J. Industrial Microbiol. Biotech.*, 29(6):354 (2002). **Abstract 02-053**

Geesey, G.G., A.L. Neal, P.A. Suci, B.M. Peyton, "A Review of Spectroscopic Methods for Characterizing Microbial Transformations of Minerals," *J. Microbiol. Meth.*, 51(2):125–139 (2002). **Abstract 02-043**

Geiser, M., R. Avci, and Z. Lewandowski, "Microbially Initiated Pitting on 316L Stainless Steel," *Int'l Biodeterioration and Biodegradation*, 49:235–243 (2002). **Abstract 02-027**

Grobe, K.J., J. Zahller, and P.S. Stewart, "Role of Dose Concentration in Biocide Efficacy Against *Pseudomonas aeruginosa* Biofilms," *J. Ind. Microbiol. Biotechnol.*, 29(1):10–15 (2002). **Abstract 02-026**

Kern, E.A., R.H. Veeh, H.W. Langner, R.E. Macure, and A.B. Cunningham, "Characterization of Methyl *tert*-Butyl Ether-Degrading Bacteria from a Gasoline-Contaminated Aquifer," *Bioremediation J.*, 6(2):113–124 (2002). **Abstract 02-038**

Klapper, I., C.J. Rupp, R. Cargo, B. Purevdorj, and P. Stoodley, "A Viscoelastic Fluid Description of Bacterial Biofilm Material Properties," *Biotech. Bioeng.*, 80(3):289–296 (2002). **Abstract 02-037**

Laturnus, F., K.F. Haselmann, T. Borch and C. Gron, "Terrestrial Natural Sources of Trichloromethane (chloroform,CHCl3)—An Overview," *Biogeochemistry*, 60:121–139 (2002). **Abstract 02-034**

Leid, J.G., M.E. Shirtliff, J.W. Costerton, and P. Stoodley, "Human Leukocytes Adhere, Penetrate, and Respond to *Staphylococcus aureus* Biofilms," *Infect. Immun.*, 70(11):6339–6345 (2002). **Abstract 02-047**

Lewandowski, Z., R. Avci, M. Geiser, X. Shi, K. Braughton and N. Yurt, "Biofouling and Corrosion of Stainless Steels in Natural Waters," *Wat. Sci. Tech.: Wat. Sup*., 2(4):65–72 (2002). **Abstract 02-048**

Mader, J.T., J. Wang, M.E. Shirtliff, and J. Calhoun, "Osteomyelitis," *Expert Guide to Infectious Diseases*. ed. Tan JS. American College of Physicians-American Society of Internal Medicine. Philadelphia, PA. 585–604, (2002). **Abstract 02-055**

Purevdorj, B., J.W. Costerton, and P. Stoodley, "Influence of Hydrodynamics and Cell Signaling on the Structure and Behavior of *Pseudomonas aeruginosa* Biofilms," *Appl. Environ. Microbiol*., 68(9):4457–4464 (2002). **Abstract 02-036**

Rice, A.R., M.A. Hamilton, and A.K. Camper, "Movement, Replication, and Emigration Rates of Individual Bacteria in a Biofilm," *Microb. Ecol*., December online pub (2002). **Abstract 02-054**

Shi, X., R. Avci, and Z. Lewandowksi, "Microbially Deposited Manganese and Iron Oxides on Passive Metals—Their Chemistry and Consequences for Material Performance," *CORROSION 2002*, 58 (9):728–738 (2002). **Abstract 02-042**

Shirtliff M.E., J.H. Calhoun, and J.T. Mader, "Experimental Osteomyelitis Treatment with Antibiotic-Impregnated Hydroxyapatite," *Clin. Orth. Related Res*., 401:239–247 (2002). **Abstract 02-031**

Shirtliff, M.E. and J. LeFrock, "Septic Arthritis," In: *Musculoskeletal Infections*, (ed) Mader, J.T. and J.H. Calhoun, Marcel Dekker, Inc., New York, NY, Chapter 7:183–209 (2002). ISBN 0 8247 0892 X **Abstract 02-041**

Shirtliff, M.E., J. Leid, and J.W. Costerton, "Basic Science of Musculoskeletal Infections," In: *Musculoskeletal Infections*, (ed) Mader, J.T. and J.H. Calhoun, Marcel Dekker, Inc., New York, NY, Chapter 1:1-61 (2002). ISBN 0 8247 0892 X **Abstract 02-040**

Shirtliff, M.E. and J.T. Mader, "Acute Septic Arthritis," *Clin. Microbiol. Rev.*, 15(4):527–544 (2002). **Abstract 02-045**

Shirtliff, M.E., J.T. Mader, and A.K. Camper, "Molecular Interactions in Biofilms (Review)," *Chem. & Biol*., 9(8):859–871 (2002). **Abstract 02-030**

Stewart, P.S., "Mechanisms of Antibiotic Resistance in Bacterial Biofilms," *Internatl. J. Med. Microbiol*., 292(2):107–113 (2002). **Abstract 02-033**

Stoodley, P., K. Sauer, D.G. Davies, and J.W. Costerton, "Biofilms as Complex Differentiated Communities," *Ann. Rev. Microbiol*., 56:187–209 (2002). **Abstract 02-025**

Stoodley, P., R. Cargo, C.J. Rupp, S. Wilson, and I. Klapper, "Biofilm Material Properties as Related to Shear-Induced Deformation and Detachment Phenomena," *J. Industrial Microbiol. Biotech*., 29(6):361–368 (2002). **Abstract 02-050**

Suci, P.A. and B.J. Tyler, "Action of Chlorhexidine Digluconate against Yeast and Filamentous Forms in an Early-Stage *Candida albicans* Biofilm," *Antimicrob. Agents Chemother*., 46(11):3522–3531(2002). **Abstract 02-049**

Yurt, N., J. Sears, and Z. Lewandowski, "Multiple Substrate Growth Kinetics of *Leptothrix discophora* SP-6," *Biotechnol. Prog*., 18:994–1002 (2002). **Abstract 02-046**

Zahller, J. and P.S. Stewart, "Transmission Electron Microscopic Study of Antibiotic Action on *Klebsiella pneumoniae* Biofilm," *Antimicrob. Agents Chemother.*, 46(8):2679–2683 (2002). **Abstract 02-028**

2003 Publications

Anderl, J.N., J. Zahller, F. Roe and P.S. Stewart, "Role of Nutrient Limitation and Stationary-Phase Existence in *Klebsiella pneumoniae* Biofilm Resistance to Ampicillin and Ciprofloxacin," *Antimicrob. Agents Chemother*., 47:1251–1256 (2003). **Abstract 03-009**

Beyenal, H., S.N. Chen and Z. Lewandowski, "The Double Substrate Growth Kinetics of *Pseudomonas aeruginosa*," *Enzyme Microbial Tech*., 32(1):92–98 (2003). **Abstract 03-001**

Borch, T., P. Ambus, F. Laturnus, B. Svensmark and C. Grøn, "Biodegradation of Chlorinated Solvents in a Water Unsaturated Topsoil," *Chemosphere*, 51(2):143–152 (2003). **Abstract 03-005**

Heersink, J., J.W. Costerton and P. Stoodley, "Influence of the Sonicare® Toothbrush on the Structure and Thickness of Laboratory Grown *Streptococcus mutans* Biofilms Assessed by Digital Time-Lapse and Confocal Microscopy," *American J. Dentistry*, 16(2):79–83 (2003). **Abstract 03-013**

Hunt, S.M., M.A. Hamilton, J.T. Sears, G. Harkin, and J. Reno, "A Computer Investigation of Chemically Mediated Detachment in Bacterial Biofilms," *Microbiology*, 149:1155–1163 (2003). **Abstract 03-012**

Lewandowski, Z. and H. Beyenal, "Mass Transport in Heterogeneous Biofilms," In: *Biofilms in Industry, Medicine and Environmental Biotechnology—Characteristics, Analysis and Control*. Lens, P., O'Flaherty, V., Moran, A., Stoodley, P., Mahony, T. (eds.) IWA Publishing, London.(2003). **Abstract 03-017**

Lewandowski, Z. and H. Beyenal, "Biofilm Monitoring: A Perfect Solution in Search of a Problem," *Wat. Sci*., 47(5): 1251–1256 (2003). **Abstract 03-010**

Lewandowski, Z.L., T.E. Cloete, S.C. Dexter, W.H. Dickinson, Y. Kikuchi, B. Little, F. Mansfeld, H. Rossmoore, W. Sand, and HA. Videla, "MIC Issues: Commentary from the Corrosion 2002 MIC Panel Discussion," Paper No. 03560, NACE International, Houston, TX, 2003, *MIC Symposium at NACE 2002*, Denver, Colorado, 2002. **Abstract 03-007**

Marion-Ferey, K., M. Pasmore, P. Stoodley, S. Wilson, G. P. Husson, and J.W. Costerton, "Biofilm Removal from Silicone Tubing: An Assessment of the Efficacy of Dialysis Machine Decontamination Procedures using an *In Vitro* Model," *J. Hospital Infection*, 53(1):64–71 (2003). **Abstract 03-002**

Purevdorj, B. and P. Stoodley, "The Role of Cell Signaling in Biofilm Development," In: *Biofilms in Industry, Medicine and Environmental Biotechnology—Characteristics, Analysis and Control*. Lens, P., O'Flaherty, V., Moran, A., Stoodley, P., Mahony, T. (eds.) pp. 63–78. IWA Publishing, London. (2003). **Abstract 03-015**

Rice, A.R., M.A. Hamilton, and A.K. Camper, "Movement, Replication, and Emigration Rates of Individual Bacteria in a Biofilm," *Microb. Ecol*., 45(2):163–172 (2003). **Abstract 03-011**

Stewart, P., "Diffusion in Biofilms," *J. Bacteriol*., 185(5):1485–1491 (2003). **Abstract 03-006**

Stewart, P.S., "New Ways to Stop Biofilm Infections," *Lancet*, 361(9352):97 (2003). **Abstract 03-004**

Stoodley, P. and B.K. Warwood, "Use of Flow Cells and Annular Reactors to Study Biofilms," In: *Biofilms in Industry, Medicine and Environmental Biotechnology—Characteristics, Analysis and Control*. Lens, P., O'Flaherty, V., Moran, A., Stoodley, P., Mahony, T. (eds.) IWA Publishing, London. (2003). **Abstract 03-016**

Walters, M.C. 3rd, F. Roe, A. Bugnicourt, M.J. Franklin, and P.S. Stewart, "Contributions of Antibiotic Penetration, Oxygen Limitation, and Low Metabolic Activity to Tolerance of *Pseudomonas aeruginosa* Biofilms to Ciprofloxacin and Tobramycin," *Antimicrob. Agents Chemother*., 47(1):317–323 (2003). **Abstract 03-003**

Webb, D., M.A. Hamilton, G.J. Harkin, S. Lawrence, A.K. Camper, and Z. Lewandowski, "Assessing Technician Effects when Extracting Quantities from Microscope Images," *J. Microbiol. Methods* 53(1):97–106 (2003). **Abstract 03-008**

Winston, M., C.J. Rupp, A. Vinogradov, B.W. Towler, H. Adams and P. Stoodley, "Rheology of Biofilms," *Proceedings: 16th Engineering Mechanics Conference of the American Society of Civil Engineers*, Seattle, July 16–18th. (2003). **Abstract 03-014**

Undergraduate Publications in 2002–03

Adams H., M. Winston, J. Heersink, K. Buckingham-Meyer, W.J. Costerton, and P. Stoodley, "Development of a Laboratory Model to Assess the Removal of Biofilm from Interproximal Spaces by Powered Tooth Brushing," *Amer. J. Dent.*, 15:12B–17B (2002). **Abstract 02-032**

Dunsmore, B.C., A. Jacobsen, L. Hall-Stoodley, C.J. Bass, H.M. Lappin-Scott, and P. Stoodley, "The Influence of Fluid Shear on the Structure and Material Properties of Sulphate-Reducing Bacterial Biofilms," *J. Industrial Microbiol. Biotech*., 29(6):347–353 (2002). **Abstract 02-051**

Grobe, K.J., J. Zahller, and P.S. Stewart, "Role of Dose Concentration in Biocide Efficacy Against *Pseudomonas aeruginosa* Biofilms," *J. Ind. Microbiol. Biotechnol*., 29(1):10–15 (2002). **Abstract 02-026**

Klapper, I., C.J. Rupp, R. Cargo, B. Purevdorj, and P. Stoodley, "A Viscoelastic Fluid Description of Bacterial Biofilm Material Properties," *Biotech. Bioeng*., 80(3):289–296 (2002). **Abstract 02-037**

Stoodley, P., R. Cargo, C.J. Rupp, S. Wilson, and I. Klapper, "Biofilm Material Properties as Related to Shear-Induced Deformation and Detachment Phenomena," *J. Industrial Microbiol. Biotech*., 29(6):361–368 (2002). **Abstract 02-050**

Zahller, J. and P.S. Stewart, "Transmission Electron Microscopic Study of Antibiotic Action on *Klebsiella pneumoniae* Biofilm," *Antimicrob. Agents Chemother.*, 46(8):2679–2683 (2002). **Abstract 02-028**

Anderl, J.N., J. Zahller, F. Roe and P.S. Stewart, "Role of Nutrient Limitation and Stationary-Phase Existence in *Klebsiella pneumoniae* Biofilm Resistance to Ampicillin and Ciprofloxacin," *Antimicrob. Agents Chemother*., 47:1251–1256 (2003). **Abstract 03-009**

Winston, M., C.J. Rupp, A. Vinogradov, B.W. Towler, H. Adams and P. Stoodley, "Rheology of Biofilms," Proceedings 16th Engineering Mechanics Conference of the American Society of Civil Engineers, Seattle, July 16–18th. (2003). **Abstract 03-014**

Graduate Program: Additional Information

Each graduate student pursues a degree in a specific discipline offered through an academic department at MSU–Bozeman, but conducts research at the CBE and participates in CBE activities and programs. Enrollment typically includes students from the life sciences, physical sciences, and engineering.

During the 2002–03 academic year (beginning Summer, 2003), there were ten MS and fourteen PhD students at the CBE. Seventeen were male and seven were female. The majority of students (17) were enrolled in engineering disciplines, with the remainder in microbiology (5), land resources and environmental sciences (1), and mathematics (1).

Coursework in Biofilms

In addition to courses required for the student's home department and degree program, the CBE suggests a suite of courses for their students. These courses include:

ENVE 566 Fundamentals of Biofilm Engineering I *(recommended for all Center students)*
This course comprises: 1) development of quantitative descriptions of processes of microbial growth, diffusive and convective solute transport, and cell attachment and detachment; 2) integration of these processes in mathematical models of biofilm accumulation and activity; and 3) application of these approaches to the analysis of biofilms in diverse industrial and natural environments.

ENVE 534 Environmental Engineering Investigations
In this course, laboratory and field investigations are used as the foundation for design and analysis of environmental engineering systems.

ENVE 565 Chemical Sensors for Environmental Biotechnology
This course provides the knowledge necessary to design, manufacture, and use chemical sensors in the area of environmental biotechnology. Principles of manufacturing and examples of application of chemical sensors along with the principles of measurement, signal conditioning, and data acquisition are presented to the extent necessary for the operation of sensors. The measurement techniques are preceded with an adequate theoretical introduction. Demonstrations of the sensors are organized in the Microsensors Laboratory located at the Center for Biofilm Engineering.

Microbiology Elective *(suggested for CBE engineering students)*

Thursday Seminar Series
Prominent researchers and scientists are invited to the CBE to present their work at a weekly seminar held on Thursday afternoons. The purpose of this seminar is to introduce various research methods and experiments to students and staff interested in seeing how biofilm research is progressing in other academic, industrial and clinical laboratories across the country and around the world.

Undergraduate Program: Additional Information

Overview
The CBE offers excellent research opportunities for undergraduate students who are interested in interdisciplinary research, exposure to industry, a unique educational experience, and a competitive advantage in their career choices following graduation. Students may work on projects individually or on teams with other CBE research staff and students; for one semester or for several years; and for course credit or stipend. Upon completion of their undergraduate degree, many of these students are recruited by the CBE's industrial partners. For those pursuing graduate degrees, their CBE research experience is often cited as a key component in being recruited and selected by the program and institution of their choice.

During the past year, a total of 52 (including REU) undergraduates worked in CBE laboratories, representing disciplines within engineering and the life sciences. Undergraduate funding comes from a number of programs:

Biofilm Systems Training Laboratory (BSTL) Internship Program and Industrial Sponsorship
The BSTL program provides undergraduate students with the opportunity to perform industrially relevant research, often with the direct involvement of a corporate sponsor. These students work under the supervision of BSTL staff mentors and obtain assistance from experienced students. In addition to acquiring research skills, BSTL interns hone their communication skills in team meetings and in the preparation of reports for the project sponsor. BSTL students are in high demand by industry upon graduation due to their unique research experience.

Undergraduate Scholars Program
The CBE continues to be a major participant in Montana State University's Undergraduate Scholars Program (USP). Prospective students and their faculty, staff, and graduate-student mentors prepare short proposals for submission to the campus USP director to be disseminated across campus for review.

Students are selected for the program based on their academic record and on the merit of their proposals. Approximately one quarter of the CBE's undergraduates are funded in this manner. Historically the CBE undergraduates make up anywhere from 10–25% of the MSU campus' USP awardees. Each year, USP students present their research in a campus-wide symposium highlighting their achievements.

Computer Science, Engineering, and Mathematics Scholarship (CSEMS)
The College of Engineering was awarded a grant from the National Science Foundation to provide needs-based scholarships to junior and senior students in computer science, engineering, and mathematics. The program specifically targets students who might otherwise leave school due to financial hardship. The CBE provides mini-internships to scholarship recipients to help them with their career goals. During this past year the CBE hosted three CSEMS awardees who worked alongside CBE researchers and graduate students on projects relevant to their areas of study. The CBE currently has a CSEMS undergraduate student from the Mechanical/Industrial Engineering department working with Dr. Paul Stoodley on a project titled "Ultrasonic Delivery of Antibiotics to Biofilms from UWEB Hydrogels."

Research Experience for Undergraduates (REU)

During the period in which the CBE received NSF funding as an Engineering Research Center, a Research Experience for Undergraduates program was initiated. Upon graduation from NSF/ERC funding, the CBE was required to prepare a competitive grant for continuation of the program. The grant was awarded and is in its second year of a three-year program. In this program, seven or eight undergraduates are recruited to participate in an intensive 10-week research experience. The CBE has always attracted high-caliber undergraduates from a wide variety of universities around the country to this program. Under the new grant, two MSU students are recruited into the program. Students of high academic achievement who are interested in pursuing a graduate degree or career in industry are selected to participate in research projects selected from submitted proposals. Some projects are sponsored and defined by the CBE's industrial partners, while others are proposed by CBE researchers. Students are matched with projects and mentors based on their interests as expressed in a letter that accompanies their application. In addition to gaining valuable experience in research, the REU students learn the importance of ethics in science and engineering, are given intensive instruction and practice in communication skills, and are exposed to a wide variety of laboratory protocols. Heather Adams, 2002 REU participant, was invited back to the CBE to present her work titled "Removal of Biofilm by Powered Brushing from Interproximal Models" to CBE industry representatives at the Winter 2003 Technical Advisory Conference. The program has also resulted in a number of students returning to MSU for graduate school.

Diversity

The CBE maintains an excellent record in the recruitment of women into all its programs. More recently the CBE has put forth particular effort to work with MSU's Native American Studies program to attract more Native American students who are interested in science and engineering. The CBE continues to participate in MSU's Montana Apprenticeship Program (MAP) through Native American Studies. Students participating in this program are mentored by another student or researcher and present their work at an MSU conference sponsored by MAP. The CBE Special Programs Coordinator maintains contact with the coordinator of the MSU American Indian Research Opportunities (AIRO) program to stay abreast of any possible collaboration with Native American programs and the CBE. The CBE is also involved with MSU's National Institutes of Health Biomedical Research Infrastructure Network (BRIN) program, where an emphasis has been placed on providing Native American students enrolled at the state's tribal colleges with meaningful summer research opportunities. Through the BRIN program, there will be several slots open for Native American students to work alongside the REU students mentioned above.

Table: Education Statistics at the Center for Biofilm Engineering

for reporting period June 1, 2002 through May 31, 2003

	Major	Biological Sciences Biotechnology	Chemical Engineering	Civil and Environmental Engineering	Computer Science	Electrical Engineering	Plant, Soils, Environmental Science	Mathematics Statistics
Graduate Students	**Number of Graduate Students at CBE:**							
	Male	0	5	4	0	2	1	1
	Female	0	4	1	0			
	Total	**0**	**9**	**5**	**0**	**2**	**1**	**1**
	Graduate Appointments:							
	Masters	0	4	3	0	1	0	
	Ph.D.	0	5	2	0	1	1	1
	Total	**0**	**9**	**5**	**0**	**2**	**1**	**1**
	Post Graduate Employment: (Students listed above are all currently enrolled)							
	Academia							
	Industry							
	Other							
	Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Undergraduate Students	**Number of Undergraduate Researchers at CBE:**							
	Male	2	4	3	3	1	0	0
	Female	9	9	2	0	0	0	1
	Total	**11**	**13**	**5**	**3**	**1**	**0**	**1**
	Post Graduate Employment:							
	Academia	1						
	Industry		1	2				1
	Other							
	Total	**1**	**1**	**2**	**0**	**0**	**0**	**1**
	Research Experience for Undergraduates (REU) Participants - 2002:							
	Male	3	0	0	0	0	0	0
	Female	0	0	2	0	0	0	0
	Total	**3**	**0**	**2**	**0**	**0**	**0**	**0**

Table: Industrial Associate Membership (June 1, 2002–May 31, 2003)

ORGANIZATION	TYPE OF INDUSTRY	NUMBER OF YEARS OF SUPPORT
Aramco Services Company	Petroleum	87,88,89,90,91,92,93,94,95,96,97,98,99,00,01,02,03
Arch Chemicals (formerly Olin Chemicals)	Specialty Chemicals	93,94,95,96,97,98,99,00,01,02
Church & Dwight Co., Inc.	Household Products	02,03
Colgate-Palmolive	Household Products	00,01,02,03
DePuy, Inc.	Healthcare	02,03
Dow Chemical Company	Specialty Chemicals	90,91,92,93,94,95,98,99,00,01,02,03
DuPont	Specialty Chemicals	95,96,97,98,00,03,04
Eastman Kodak Company	Other	91,92,97,98,99,00,01,02,03,04
Edstrom Industries, Inc.	Water Treatment	03,04
Gambro Corporate Research	Healthcare	02,03
GE Betz (formerly Betz Dearborn Inc.)	Specialty Chemicals	99, 00, 01, 02
Genencor International, Inc.	Healthcare	02,03
Genome Therapeutics Corp.	Healthcare	02,03
Idaho National Environmental Engineering Laboratory (INEEL)	Government Lab	87,88,89,90,91,92,93,94,95,96,97,98,99,00,01,02
Kurita Water Industries Ltd.	Water Treatment	01,02,03
Microbia, Inc.	Healthcare	01,02,03
Ondeo Nalco Chemical Company	Specialty Chemicals	90,91,92,93,94,95,96,97,98,99,00,01,02
Philips Oral Healthcare	Healthcare	02,03
Reckitt Benckiser Inc.	Household Products	01,02,03
S. C. Johnson & Son (formerly S.C. Johnson Wax)	Household Products	93,94,95,96,97,98,99,00,01,02,03

Membership, continued

ORGANIZATION	TYPE OF INDUSTRY	NUMBER OF YEARS OF SUPPORT
Texaco	Petroleum	98,00,01,02
Tyco Healthcare (formerly Kendall Healthcare Products Company)	Healthcare	98,99,00,01,02,03
Union Carbide Corporation	Specialty Chemicals	87,88,89,90,91,92,94,95,96,97,98,99,00,01,02,03
U. S. Bureau of Reclamation	Drinking Water	98,99,00,01,02,03
Vivendi Water	Drinking Water	02,03
Westinghouse Savannah River Company	Government Lab	95,96,97,98,99,00,01,02
W. L. Gore & Associates	Healthcare	97,98,99,00,01,02,03

Table: Industrial Associate Membership Over the History of the CBE

ORGANIZATION	SIZE OF ORGANIZATION:			FOREIGN	INDUSTRIAL ASSOCIATE?	IF INDUSTRIAL ASSOCIATE (LIST YEARS)
	SMALL <500	MEDIUM 500-1000	LARGE >1000			
Albemarle Corporation			X	NO	YES	98, 99, 00
Allied Tube & Conduit		X		NO	NO	
American Water Works Association Research Foundation (AWWARF)	X			NO	YES	91, 92, 93, 94, 95, 96, 97, 98
American Water Works Service Company	X			NO	NO	
Aramco Services Company			X	YES	YES	87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 00, 01, 02, 03
Arch Chemicals (formerly Olin Chemicals)			X	NO	YES	93, 94, 95, 96, 97, 98, 99, 00, 01, 02
Arco Exploration & Production Technology			X	NO	YES	86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 97, 98
*Army Research Office (ARO)			X	NO	NO	
Australian Water Technologies	X			YES	NO	
Becton Dickinson Technologies			X	NO	YES	98, 99, 00, 01
Betz Dearborn Inc.		X		NO	YES	99, 00, 01, 02
Betz PaperChem			X	NO	YES	91, 92, 93, 94, 95, 96
BHP Copper (formerly Magma Copper)		X		NO	YES	96, 97, 98
Biolab		X		NO	YES	99, 00, 01
Biomedical Development	X			NO	NO	
Biosurface Technologies Coporation	X			NO	NO	
Bitterroot Restoration, Inc.	X			NO	NO	
Black & Veatch			X	NO	NO	
BP - Amoco Corporation (formerly Amoco Corporation)			X	NO	YES	87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 00, 01
Brentwood Industries	X			NO	NO	
British Petroleum Research			X	NO	YES	91, 92, 93
Calgon Corporation		X		NO	YES	92, 93, 94, 95, 96, 97, 98
Canon Communications, Inc.		X		NO	NO	
Chevron Petroleum Technology Company			X	NO	YES	88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 00
Church & Dwight Co., Inc.			X	NO	YES	02,03

*Indicates a Government Organization

Historical Membership, continued

ORGANIZATION	SIZE OF ORGANIZATION:			FOREIGN	INDUSTRIAL ASSOCIATE?	IF INDUSTRIAL ASSOCIATE (LIST YEARS)
	SMALL <500	MEDIUM 500-1000	LARGE >1000			
Ciba Vision			X	NO	YES	99
City of Laval		X		YES	NO	
Clearwater Systems	X			NO	NO	
Clorox Company			X	NO	YES	94, 95, 96, 97, 98, 99
Colgate-Palmolive Company			X	NO	YES	01, 02,03
Compagnie Générale des Eaux (CGE)		X		YES	NO	
Conductive Medical Devices			X	NO	NO	
Conoco, Inc.			X	NO	YES	87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98
*Defense Advanced Research Projects Agency (DARPA)			X	NO	NO	
Demeter, Inc.	X			NO	NO	
DePuy, Inc.			X	NO	YES	02,03
Dow Chemical U.S.A.			X	NO	YES	90, 91, 92, 93, 94, 95, 98, 99, 00, 01, 02,03
DuPont			X	NO	YES	95, 96, 97, 98, 00,03,04
Eastman Kodak Company			X	NO	YES	91, 92, 97, 98, 99, 00, 01, 02
Ecole Polytechnique de Montréal		X		YES	NO	
Economic & Engineering Service Inc.		X		NO	NO	
Edstrom Industries, Inc.	X			NO	YES	03,04
Electric Power Research Institute (EPRI)			X	NO	YES	88, 89, 90
Engineering & Economical Development	X			NO	NO	
*Environmental Protection Agency (EPA)			X	NO	NO	
*EPA/Kansas State University		X		NO	NO	
Exxon Production Research			X	NO	YES	89, 90, 91, 92, 93, 94, 95, 96, 97, 98
Fine Particle Society		X		NO	NO	
FMC Corporation	X			NO	NO	
Gambro Corporate Research			X	YES	YES	02,03
Genencor International, Inc.			X	NO	YES	02,03
Genome Therapeutics Corp.		X		NO	YES	02,03
*Idaho National Engineering & Environmental Laboratory (INEEL) (formerly INEL and EG&G)			X	NO	YES	87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 00, 01, 02
Intelligent Optical Systems (IOS)		X		NO	NO	
International Copper Association			X	NO	YES	89, 90, 91
Kurita Water Industries Ltd.			X	YES	YES	01, 02,03

*Indicates a Government Organization

Historical Membership, continued

ORGANIZATION	SIZE OF ORGANIZATION:			FOREIGN	INDUSTRIAL ASSOCIATE?	IF INDUSTRIAL ASSOCIATE (LIST YEARS)
	SMALL <500	MEDIUM 500-1000	LARGE >1000			
Little Bear Labs	X			NO	NO	
*Los Alamos National Laboratory			X	NO	NO	
Lovelace Medical Foundation			X	NO	NO	
Matney-Frantz Engineering, P.C.			X	NO	NO	
MBI		X		NO	NO	
Mentor Urology Inc.		X		NO	NO	
Metropolitan Water District of Southern California		X		NO	NO	
Microbia, Inc.			X	NO	YES	01, 02,03
Montana Biotech	X			NO	NO	
Montana Power Company		X		NO	YES	89, 90, 91, 92, 93, 94, 95
Montana Tech	X			NO	NO	
MSE, Inc.		X		NO	YES	96, 97, 98, 99
National Water Research Institute (NWRI)	X			NO	NO	
*Office of Naval Research			X	NO	NO	
Ondeo Nalco Chemical Corporation (formerly Nalco Chemical Corporation)			X	NO	YES	90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 00, 01, 02
Orange County Water District		X		NO	YES	91, 92, 93, 94, 95
Osel		X		NO	NO	
*Pacific Northwest National Labs (PNNL) (formerly Battelle)			X	NO	YES	92, 93, 94, 95, 96, 97, 98
Philips Oral Healthcare, Inc.			X	NO	YES	02,03
Procter & Gamble Company			X	NO	YES	91, 92, 93, 94, 95, 96, 97, 98, 99, 00
Reckitt Benckiser Inc.			X	NO	YES	01, 02,03
Rohm & Haas Company			X	NO	YES	96, 97, 98
S.C. Johnson & Son (formerly S.C. Johnson Wax)			X	NO	YES	93, 94, 95, 96, 97, 98, 99, 00, 01, 02,03
Sequoia Sciences	X			NO	NO	
Shell Development Company			X	NO	NO	
SHOT		X		NO	NO	
Smith & Nephew, Inc.			X	NO	YES	03,04
South Central Connecticut Regional Water Authority	X			NO	NO	
Southern Company Services Inc.		X		NO	YES	86, 87, 88, 89, 90, 91, 92
SmithKline Beecham			X	NO	NO	
St. Jude			X	NO	NO	

*Indicates a Government Organization

Historical Membership, continued

ORGANIZATION	SIZE OF ORGANIZATION:			FOREIGN	INDUSTRIAL ASSOCIATE?	IF INDUSTRIAL ASSOCIATE (LIST YEARS)
	SMALL <500	MEDIUM 500-1000	LARGE >1000			
Sulzer Carbomedics Inc.			X	NO	YES	98, 99, 00
Surmodics	X			NO	NO	
Swiss Federal Institute for Water Resources & Water Pollution Control		X		NO	NO	
Texaco			X	NO	YES	98, 00, 01, 02
Tyco Healthcare (formerly Kendall Healthcare Products Company)			X	NO	YES	98, 99, 00, 01, 02,03
Unilever Research			X	YES	YES	92, 93, 94, 95, 98, 99, 00
Union Carbide Corporation			X	NO	YES	87, 88, 89, 90, 91, 92, 94, 95, 96, 97, 98, 99, 00, 01, 02,03
*U.S. Army Research Office			X	NO	NO	
*U.S. Bureau of Reclamation			X	NO	YES	98, 99, 00, 01, 02, 03
*U.S. Department of Agriculture			X	NO	NO	
*U.S. Department of Defense			X	NO	NO	
*U.S. Department of Energy			X	NO	NO	
*U.S. Department of the Interior			X	NO	NO	
*U.S. Department of the Navy			X	NO	NO	
U.S. Filter/Everpure, Inc.			X	NO	YES	00
*U.S. Geological Survey		X		NO	NO	
*U.S. National Park Service			X	NO	NO	
University of New Mexico	X			NO	NO	
Unocal Corporation			X	NO	NO	
Vivendi Water			X	YES	YES	02, 03
Warner-Lambert Company			X	NO	YES	99, 00
*Westinghouse Savannah River Company			X	NO	YES	95, 96, 97, 98, 99, 00, 01, 02
Westvaco			X	NO	YES	88, 89, 90, 91, 92, 93, 94, 95
Weyerhauser			X	NO	YES	89, 90
W. L. Gore & Associates			X	NO	YES	97, 98, 99, 00, 01, 02,03
Yellowstone Environmental Science, Inc.	X			NO	NO	

*Indicates a Government Organization

Table: CBE Faculty and Staff Visits to Industry, 2002–2003

DATES	NAME/TITLE	CORPORATION (LOCATION)	PURPOSE OF VISIT
6/4/02	Marty Hamilton, CBE Professor, Statistics	Pacific Northwest National Labs. (PNNL) (Richland, WA)	Marty presented "Applied Statistical Thinking in Biofilm Research." He also met with four PNNL research groups to discuss statistical problems of mutual interest.
6/11/02	Bill Costerton, CBE Director	Gambro Corporate Research (Hechingen, The Netherlands)	Bill is visiting with Gambro to discuss the possible impact of microbial biofilms on products that Gambro designs. This visit constitutes one free day of consulting that Gambro is entitled to as a CBE Industrial Associate.
6/14/02	Bill Costerton, CBE Director	Genencor International B.V. (Leiden, The Netherlands)	Bill is invited to visit with this Industrial Associate company to discuss potential cleaning technology for hemodialysis machines.
7/2/02	Marty Hamilton, CBE Professor, Statistics	Procter & Gamble (Cincinnati, OH)	Marty presented "Applied Statistical Thinking in Antimicrobial and Antibiofilm Research." Following the talk, he met with the P&G Fabric and Home Care Microbiology Team to discuss statistical issues.
7/15/02	Bill Costerton, CBE Director	Zimmer Corp. (Warsaw, IN)	Bill visited with research personnel at Zimmer to discuss possible research collaboration.
7/29/02	Bill Costerton, CBE Director	United States Army Medical Research Institute of Infectious Diseases (USAMRIID) at Ft. Detrick (Frederick, MD)	Bill was an invited speaker and presented "Biofilms in Nature and Disease."
8/6/02	Bill Costerton, CBE Director	Defense Advanced Research Projects Agency (DARPA) (Washington, DC)	Bill was invited to attend a meeting with DARPA to discuss an SBIR proposal.
9/20/02	Bill Costerton, CBE Director	BHP Mining (Brisbane, Australia)	Bill met with research personnel at BHP to discuss possible collaboration.
10/25/02	Bill Costerton, CBE Director	Edwards Lifesciences (Irvine, CA)	Bill was invited to give a presentation to the Heart Valve Therapy Research Group. He presented "Biofilm Organization, Testing and Research."
11/5/02	Bill Costerton, CBE Director	Tyco Healthcare (Boston, MA)	Bill met with several research personnel from Tyco to talk about a possible CBE project.
11/7/02	Zbigniew Lewandowski, Prof., Civil Eng.	Procter & Gamble (Cincinnati, OH)	Zbigniew was an invited speaker and presented "Use of Microsensors to Study Biofilms."
11/8/02	Bill Costerton, CBE Director	Atrium Medical Corporation (Hudson, NH)	Bill was invited to Atrium to discuss possible collaboration and possibly becoming Industrial Associate members of the CBE.

CBE Visits to Industry, continued

DATES	NAME/TITLE	CORPORATION (LOCATION)	PURPOSE OF VISIT
2/11/03	Bill Costerton, CBE Director	Intelligent Optical Systems (IOS) (Torrance, CA)	Bill met with research personnel that are working on projects with the CBE.
2/14/03	Bill Costerton, CBE Director	Sequoia Sciences (San Diego, CA)	Bill met with research personnel that are working on projects with the CBE.
2/20/03	Mark Shirtliff, Asst. Res. Prof.	Genome Therapeutics (Boston, MA)	Mark was an invited speaker and presented "*Staphylococcus aureus* Biofilms."
3/24-3/25/03	Bill Costerton, CBE Director	W.L. Gore & Associates (Flagstaff, AZ)	Bill gave a seminar on Biofilms to manufacturing and technical personnel. He also met with several researchers.
4/9/03	Darla Goeres, CBE Research Engineer	US Environmental Protection Agency (EPA) (Crystal City, VA)	Darla was an invited speaker to the Antimicrobials Division of the US EPA and presented "Progress Report: Developing a Method to Test the Efficacy of Chemical Hot Tub Disinfectants."
5/7/03	Bill Costerton, CBE Director	Gambro Research (Lund, Sweden)	Bill visited with research personnel to discuss ongoing research.

Table: Industry and Government Visits to CBE, 2002–2003

DATE(S)	NAME OF PARTICIPANT CORPORATION (LOCATION)	FOREIGN COMPANY		DESCRIPTION
		YES	NO	
7/23-7/25/02	Technical Advisory Committee (TAC) Meeting. 55 participants, representing 39 different organizations, attended this July 2002 meeting. Participant list will be available upon request.	X	X	Attended July 2002 Technical Advisory Committee (TAC) meeting at the CBE.
7/25/02	Harm Messchendorp and Nico van Schoot from Genencor International (Leiden, The Netherlands)	X		Bill Costerton and Paul Sturman had a planning meeting with Genencor to discuss a research project the CBE is doing for them.
8/2/02	Cheryl Norton, Bob Allen and Ed Bouwer all from American Water Works Association Research Foundation (AWWARF) (Denver, CO)		X	Visited with Anne Camper, CBE Assoc. Professor of Civil Engineering. This was a project meeting with Anne's research team and AWWARF.
8/25/02	Austin Yamata, the Assistant Secretary of Defense to President Bush (Washington, DC)		X	Dr. Yamata met with Paul Stoodley, CBE Asst. Research Professor, and Garth James from MSE to discuss a DARPA grant on Bioterrorism.
9/3-9/4/02	Cynthia de Azevedo Andrade, Monica Penna, and Lidia Santa Ana all from Petrobras (Brazil)	X		These visitors from Petrobras, Brazilian oil company, visited with Paul Sturman, CBE Coordinator of Industrial Development to discuss possible collaboration.
9/6/02	Matt Chandler, Project Engineer, Cement Division and Ed Arscott, Sr. Microbiologist, Sterility both from DePuy (Warsaw, IN)		X	Visited with Mark Pasmore, CBE Medical Projects Supervisor to discuss a research project Mark's group is working on for DePuy.
9/8-9/9/02	Nadine Jelsing, Corky Miller, and Bill Ward from Oregon Public Broadcasting (Portland, OR)		X	Visited the CBE to film several CBE Research Personnel for an upcoming Oregon PBS science documentary.
9/20/02	Mike Dorsey, Brian Saldanha, Daniel DeMarco and Shi Hua Zhang, DuPont (Newark, DE)		X	Visited with Paul Sturman, CBE Coordinator of Industrial Development and several CBE Research Personnel to discuss possibly becoming a CBE Industrial Associate.
10/18/02	Dr. Jack Marburger, Science Advisor to the President of the US and Director of the Office of Science and Technology Policy (Washington, DC)		X	Dr. Marburger visited with several CBE research personnel and toured the CBE.
10/18/02	Carolyn Fuller, Van Scoyoc Associates (Washington, DC)		X	Carolyn visited the CBE with Dr. Marburger. Carolyn is MSU's Washington lobbying consultant.
11/18-11/19/02	Mark Rouse, Mayo Clinic (Rochester, MN)		X	Visited the CBE to attend the Biofilm Methods Workshop hosted by Paul Sturman, CBE Coordinator of Industrial Development.
11/18-11/19/02	Andrej Trampuz, Mayo Clinic (Rochester, MN)		X	Same as above.
11/18-11/19/02	Robin Patel, Mayo Clinic (Rochester, MN)		X	Same as above.
11/18-11/19/02	Wilbur Frehner, Las Vegas Valley Water District (Las Vegas, NV)		X	Same as above.

Industry and Government Visits, continued

DATE(S)	NAME OF PARTICIPANT CORPORATION (LOCATION)	FOREIGN COMPANY		DESCRIPTION
		YES	NO	
11/18-11/19/02	Park YoungBog, Seoul Metropolitan Government Water Technology Research Institute (Seoul , Korea)	X		Same as above (also stayed an extra 2 days to attend a special water treatment workshop organized by Phil Butterfield, Post-Doc Researcher.
11/18-11/19/02	Jang HyunJung, Seoul Metropolitan Government Water Technology Research Institute (Seoul , Korea)	X		Same as above (also stayed an extra 2 days to attend a special water treatment workshop organized by Phil Butterfield, Post-Doc Researcher.
12/3/02	Dr. Richard Carlton , President, Exponential Biotherapies, Inc. (Port Washington, NY)		X	Dr. Carlton met with Bill Costerton and other CBE research personnel to discuss collaborating on projects. He also toured the CBE.
2/6-2/7/03	Technical Advisory Committee (TAC) Meeting. 33 participants, representing 23 different organizations, attended this February 2003 meeting. Participant list will be available upon request.	X	X	Attended February 2003 Technical Advisory Committee (TAC) meeting at the CBE.
3/5-3/6/03	Chris Wend, Scientist, Pacific Northwest National Laboratories (PNNL) (Pullman, WA)		X	Chris was an invited seminar speaker at the CBE. He also met with several researchers to discuss potential collaboration.
4/14-4/15/03	Andrew Kelly, Chemist, U.S. Department of the Interior, Bureau of Reclamation (Alamosa, CO)		X	Visited the CBE to attend the Biofilm Methods Workshop hosted by Paul Sturman, CBE Coordinator of Industrial Development.
4/14-4/15/03	Bob Curran, Edstrom Industries (Waterford, WI)		X	Same as above.
4/14-4/15/03	Shane Stafslien, North Dakota State University (Fargo, ND)		X	Same as above.
4/14-4/15/03	Jeff McMahon, Chemist, Champion Technologies (Houston, TX)		X	Same as above.
4/14-4/15/03	Brian Rucker, Biomedical Research Engineer, Wilson-Cook Medical (Winston-Salem, NC)		X	Same as above.
4/14-4/15/03	Rich Payne, Research Scientist, Kimberly-Clark (Roswell, GA)		X	Same as above.
4/14-4/15/03	Ilona Weart, Scientist, Kimberly-Clark (Roswell, GA)		X	Same as above.
5/12/02	Kerry Olin, Donology and Joe Ruh, Kodak		X	Kodak and Donology want to donate a suite of 8 patents concerning biocide immobilization to MSU.

Presentations: From June 1, 2002

Marty Hamilton presented "Applied Statistical Thinking in Biofilm Research" at Pacific Northwest National Labs (PNNL) in Richland,WA, June 4, 2002. He also met with the PNNL research groups to discuss statistical issues.

Anne Camper, as invited speaker presented "Battling Biofilms"at the Northeast Association for Clinical Microbiology and Infectious Disease Annual Meeting in Springfield, MA, June 11, 2002.

Bill Costerton, as invited speaker, presented "Susceptibility of Periodontal Pathogen Bacteria in Biofilm" at the Topical Application of Moxifloxacin in Dentistry (Periodontology) Meeting in Brussels, Belgium, June 12, 2002.

Bill Costerton was an invited speaker at the Organization for Safety and Asepsis Procedures (OSAP) 2002 Annual Symposium in Nashville, TN, June 16–17, 2002. Bill presented "Engineering Solutions for Dental Biofilms."

Bill Costerton, as invited speaker to the Center for Genomic Sciences, Allegheny General Hospital Seminar Series, Pittsburg, PA, June 17, 2002, presented "Biofilms in Device-Related and Other Chronic Bacterial Infections."

Bill Costerton was an invited speaker at the NORM 2002 meeting presented by the Inland Northwest Section of the American Chemical Society, June 21, 2002. Bill presented "Bacterial Behavior in the Subsurface."

Marty Hamilton presented "Applied Statistical Thinking in Antimicrobial and Antibiofilm Research" at Procter & Gamble in Cincinnati, OH, July 2, 2002. Following the talk, he met with the P&G Fabric and Home Care Microbiology Team to discuss statistical issues.

Peg Dirckx and Betsey Pitts presented "Bioglyphs," at the "Capturing Change" program in the Exploratorium Museum, San Francisco, CA, July 17, 2002.

Bill Costerton was an invited speaker to the United States Army Medical Research Institute of Infectious Diseases (USAMRIID) at Ft. Detrick in Frederick, MD, July 29, 2002. He presented "Biofilms in Nature and Disease."

Paul Stoodley, as a Hanse Wissenschaftskolleg Fellow Lecturer, presented "The Structure of Bacterial Biofilms: City Planning or Urban Sprawl?" Delmenhorst, Germany, August 6, 2002.

Ryan Jordan presented "STINK HAPPENS. Antimicrobials in Outdoor Performance Textiles: PR Dreams, Value-Added Profits, and Fool's Gold," Outdoor Retailer Expo 2002, Salt Lake City, UT, August 8–11, 2002.

Marty Hamilton was introduced as a new Fellow of the American Statistical Association (ASA) in a ceremony preceding the President's annual address. He attended the ASA Joint Statistical Meetings, New York City, NY, August 11–14, 2002.

Bill Costerton, as invited speaker presented "Marine Biofilms," at the 2002 Society for Industrial Microbiology (SIM) Meeting, Philadelphia, PA, August 13–15, 2002.

Mark Pasmore, as invited speaker presented "Biofilms, Bacterial Signaling, and Their Ties to Marine Biology," at the Society of Industrial Microbiology National Meeting, Philadelphia, August 13–18, 2002.

Paul Stoodley was an invited speaker at a workshop titled "Biofilms in Industry, Medicine and Environmental Biotechnology: The Science" in Galway, Ireland at the National University of Ireland, August 24–29, 2002. He presented "Use of Flow Cells to Study Biofilms."

Bill Costerton was keynote speaker at a workshop entitled "Biofilms in Industry, Medicine and Environmental Biotechnology: The Science" in Galway, Ireland at the National University of Ireland, August 24–29, 2002. He presented "Communication in Biofilms," and he also served on the Advisory Board.

Bill Costerton as keynote speaker presented "Biofilm Infections of Biomaterials," at the Surfaces in Biomaterials Foundation, BioInterface 2002 in Scottsdale, AZ, September 6, 2002. He also received an award for Excellence in Surface Science.

Bill Costerton and Linda Loetterle from the CBE and Randy Hiebert from MSE participated in the Oregon Tox Biomonitoring Workshop at Oregon State University in Corvallis, OR, September 9, 2002. This workshop was a hands-on evaluation of biosensor systems.

Luanne Hall-Stoodley completed BSL-3 Advanced Microbiological training to work with *Mycobacterium tuberculosis* in fulfillment of an NIH STTR grant. Training was completed in the laboratory of collaborator Dr. Lawrence Schlesinger, University of Iowa School of Medicine, September 9–15, 2002.

Al Cunningham, Anne Camper and Marty Hamilton presented "The Significance of Microbial Biofilms in Biotechnology," at The Ecology, Economics, and Ethics of Biotechnology: A Seminar for Federal Judges, Big Sky, Montana, September 10-15, 2002. The seminar was supported by the M.J. Murdock Charitable Trust and hosted by the Foundation for Research on Economics & the Environment.

Otto Stein presented a paper "Does Batch Operation Enhance Oxidation in Subsurface Constructed Wetlands?" at the 8th International Conference on Wetland Systems for Water Pollution Control, Arusha, Tanzania, September 12–26, 2002.

Paul Stoodley was a guest speaker at the Center for Genomic Science, Allegheny General Hospital, Pittsburgh, PA, September 20, 2002. He presented "Dynamic Behavior in Bacterial Biofilms Revealed by Confocal and Digital Time-Lapse Microscopy."

Ryan Jordan was an instructor for the Backcountry Health and Hygiene Course, Jackson, WY, September 20–29, 2002.

Bill Costerton as invited speaker presented, "Biofilms: The Predominant Mode of Growth of Bacteria," at the Annual Scientific Meeting of the Australian Society for Microbiology for 2002, Melbourne, Australia, September 29 to October 3, 2002.

Rick Veeh presented "Aerobic MTBE Biodegradation Potential in Gasoline-Impacted Groundwater near Ronan, MT," at the 2002 MT-AWRA Meeting and 19th Annual Montana Water Conference: The Future of the Yellowstone River, October 3–4, 2002.

Paul Stoodley was an invited speaker at the 30th Congress of the Italian Society of Microbiology, Catania, Italy, October 6–8, 2002. He presented "The Formation and Dynamic Behaviors of Bacterial Biofilm." This was the first time that the Italian Society for Microbiology had a specific section on Biofilms, and this section was organized by Professor Stefania Stefani. Paul's opening talk introduced the topic to a group consisting of mainly medical microbiologists and immunologists.

Marty Hamilton as an invited speaker presented, "Comparison of Available Test Methodologies" at the Interagency Working Meeting—Test Methods and Surrogates for Anthrax, Washington, DC, October 9–10, 2002.

Thomas Borch presented "Characterization of Two Iron Oxide Models for Environmental Research: Microscopic and Spectroscopic Studies," and also a poster entitled "Use of High Performance Liquid Chromatography—Diode Array Detection for the Improved Analysis of 2,4,6-Trinitrotoluene and Its Reduced Metabolites" at the Subsurface Science Symposium, Boise, Idaho, October 12–16, 2002.

Zbigniew Lewandowski, presented "Mapping Toxic Shock Syndrome Toxin^{-1} (TSST-1) Expression in a Biofilm of *Staphylococcus aureus* Using TSST-1-yfpTM Reporter Strain and a yfp-Sensitive Fiber-Optic Sensor," at the 10th International Symposium on Staphylococci and Staphylococcal Infections, Tsukuba. Japan, October 16–19, 2002.

Bill Costerton was invited to give a presentation to the Heart Valve Therapy Research Group, Edwards Lifesciences, Irvine, California, October 25, 2002. He presented "Biofilm Organization, Testing, and Research."

Bill Costerton was invited to talk about "Taming Microbial Biofilms," at the Council for Advancement of Science Writing, Inc. (CASW) Fortieth Annual Briefing: New Horizons in Science, St. Louis, Missouri, October 26–28, 2002. This is a briefing to office science writers with the background perspective and context needed to help them better understand and interpret new and future developments in the frontier areas of science and technology and to deliver a program that satisfies their immediate need, in response to their editors' demands, for "spot" news (new discoveries, new solutions, new conclusions, new applications that have not yet been widely reported) geared to the general public.

Bill Costerton was invited to present "Montana State University's Center for Biofilm Engineering (CBE), a Look at a Successful Graduated ERC," to the 2002 Annual Meeting, National Science Foundation (NSF) Engineering Research Centers (ERC), Washington, DC, November 3–4, 2002.

Bill Costerton as invited speaker presented "The Role of Biofilms in Infection," Infection Control Spanning the Continuum of Healthcare: Community—Acute—Extended Care. Presented by: Infection Control Professionals of Southern New England, Inc. (ICPSNE), Boston, MA, November 6, 2002.

Phil Stewart, presented "Biofilm Control: Present and Future," at the Life at the Materials Interface Conference, Chestertown, MD, November 4–6, 2002.

Zbigniew Lewandowski as invited speaker presented "Use of Microsensors to Study Biofilms" at Procter & Gamble, Cincinnati, OH, November 5–7, 2002.

Bill Costerton as invited speaker presented "Biofilms: The Predominant Form of Bacterial Growth in Real Ecosystems," to the Microbiology Department at Cornell University, Ithaca, NY, November 7, 2002.

Anne Camper presented "Regrowth and Retention Time," at the International Retention Time Workshop, Seattle, WA, November 8, 2002.

Paul Stoodley as invited speaker presented "Dynamic Processes in Bacterial Biofilms: Environmental, Industrial and Medical Implications," to the Department of Geology seminar series, Portland State University, OR, November 13, 2002.

Bill Costerton as invited speaker presented "Biofilms in Nature and Disease," for the IBS515 course at Emory University School of Medicine, Atlanta, GA, November 14–15, 2002.

Bill Costerton, sponsored by Philips Oral Healthcare, spoke at the American Dental Association (ADA) Conference in New Orleans, LA, November 18–19, 2002.

Bill Costerton as the key speaker presented "Biofilms in Nature and Disease," Biofilms for the Auspices of the Academies of Sciences in Belgium Symposium, The Belgian National Committee for Microbiology in collaboration with the Belgian Society for Microbiology, November 22, 2002.

Bill Costerton as invited speaker presented "Biofilms: The Preferred Mode of Growth of Dental Biofilms," Annual Conference of the British Dental Hygienists Association at the Bournemouth International Centre in Bournemouth, U.K., November 23, 2002.

Mark Shirtliff presented "Biofilms: Properties, Significance, and Current Research," to the Department of Environmental Engineering, Washington State University, December 2, 2002.

Mark Shirtliff presented "*Staphylococcus aureus*: Persistence of Infection through Biofilms," to the Department of Microbiology and Immunology, New York Medical College, NY, December 9, 2002.

Thomas Borch presented "Influence of Biogenically Produced Fe(II) and Humic Acid Analogs on the Fate of 2,4,6-trinitrotoluene (TNT)," Fall Meeting, American Geophysical Union, San Francisco, CA, December 6–10, 2002.

Bill Costerton taught a PhD course "Biofilms in Nature and Disease," at the University of Concepcion, Chile, December 9–13, 2002.

Thomas Borch gave an invited talk, "Influence of Biogenically Produced Fe(II), Electron Shuttling, and Humic Acid on the Fate of 2,4,6-Trinitrotoluene (TNT)," Department of Analytical Chemistry at Lund University, Sweden, December 19, 2002.

Ryan Jordan gave a short course seminar via an online distance learning program, entitled "Microbial Biofilms and Their Role in Human Health," December 19, 2002. It was hosted by the Environmental Institute for Continuing Education.

Presentations: Through May 31, 2003

Bill Costerton, as keynote speaker, presented "Biofilms," at the Philips RDH Symposium "Emerging Trends in Oral Healthcare," Seattle, WA, January 16–18, 2003. Paul Stoodley, as invited speaker, presented "Effects of Shear Forces and Fluid Dynamics on Biofilm." The presentation was to a group consisting primarily of dental hygienists, educators, and researchers. The scientific content of the symposium was used for eight hours of credit in the continuing education program approved by the American Academy of Dental Hygiene.

Thomas Borch presented "Biogenic Iron Mineralization by a Novel Gram-Positive Bacterium Isolated," at the PNNL's Hanford Site: Impact on the Transformation of 2,4,6-Trinitrotoluene at the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), Pacific Northwest National Laboratory (PNNL), Richland, Washington, February 14, 2003. The EMSL is operated by PNNL for the DOE Office of Biological and Environmental Research.

Rick Veeh presented "Molecular Techniques for Studying MTBE Biodegradation," as part of the API Soil/Groundwater Technical Task Force (S/GTTF)-sponsored Oxygenates Biodegradation Research Review. This was a one-day event held at Arizona State University in Tempe, AZ, February 19, 2003.

Mark Shirtliff presented "*Staphylococcus aureus* Biofilms" Genome Therapeutics, Waltham, Massachusetts, February 20, 2003.

Thomas Borch presented "Biomineralization of Iron(III) Minerals by a Novel Gram-Positive Bacterium in the Presence and Absence of the Humic Analog AQDS: Impact on the Fate of 2,4,6-Trinitrotoluene," Department of Geological and Environmental Sciences, Stanford University, February 25, 2003.

Mark Shirtliff, as invited speaker, presented "Proteomic, Microarray, and Host-Pathogen Interaction Studies of *Staphylococcus aureus* Biofilms" at the University of Maryland, Departments of Oral and Craniofacial Biological Sciences, Microbiology and Immunology, Biochemistry and Molecular Biology, and the Center for Vaccine Development, College Park, MD, February, 26, 2003.

Bill Costerton was a visiting professor in the Department of Pathology in the School of Medicine at St. George's University in Grenada, West Indies from March 2–15, 2003. He made several presentations including a microbiology department seminar "Biofilms in Nature and Disease"; a university seminar "Biofilms in Device-Related and Other Chronic Bacterial Infections," and two medical school lectures in infectious diseases "Device-related Infections," and "Chronic Infections."

Mark Shirtliff presented "*Staphylococcus aureus* Biofilms" Department of Infectious Diseases, Universita di Roma La Sapienza, Rome, Italy, March 21, 2003.

Bill Costerton as invited speaker, presented "Biofilms in Nature and Disease" to the Biological Sciences Department, Northern Arizona University, Flagstaff, AZ, March 24, 2003.

Bill Costerton gave a seminar on biofilms to manufacturing and technical personnel at W.L. Gore & Associates in Flagstaff, AZ, March 24–25, 2003. He also met with several researchers.

Bill Costerton as invited speaker, presented "Biofilms in Nature and Disease" to the Department of Microbiology at the University of Texas Southwestern Medical Center, Dallas, TX, March 26, 2003.

Bill Costerton as invited speaker presented "The Role of Biofilms in Device-Related and Other Chronic Bacterial Infections" at the Fifteenth Annual Student Research Week at the Texas Tech University Health Sciences Center, Lubbock, TX, March 27, 2003.

Mark Shirtliff presented "Treatment of Osteomyelitis and Septic Arthritis: Evidences from Animal Models" Department of Infectious and Tropical Diseases, S. Bortolo Hospital, Vicenza, Italy, March 28, 2003.

Mark Shirtliff presented "Hyperbaric Oxygen Therapy in the Treatment of Osteomyelitis" Terapia delle infezioni osteoarticolari 1o Meeting Internazionale, Vicenza, Italy, March 28, 2003.

Anne Camper presented "Biofilm Trap for CW/BW Agents," at the Gordon Conference on Clinical and Biological Terrorism Defense, Buellton, CA, March 26–28, 2003.

Bill Costerton was an invited speaker at the Marion E. Koshland Seminar at the University of California–Berkeley, Berkeley, CA, April 1, 2003. He presented "Microbial Biofilms in Nature and Disease."

Mark Shirtliff presented "A Search for Vaccines against Staphylococcal Biofilm-Mediated Infections" Department of Microbiology, Danish Technological University, Copenhagen, Denmark, April 1, 2003.

Mark Shirtliff presented "Using Microarrays to Determine the Gene Expression Profiles in Biofilms" Danish Technological Institute, Copenhagen, Denmark, April 3, 2003.

Mark Shirtliff presented "*Staphylococcus aureu*s Biofilms" Departments of Environmental Engineering and Biotechnology, Aalborg University, Denmark, April 7, 2003.

Bill Costerton as invited speaker, presented "Bacterial Biofilms" for the Educational Lecture Series run by the Otolaryngology Dept. at the University of Washington, Seattle, WA, April 16, 2003.

Bill Costerton as invited speaker, presented "Possible Role of Biofilms in TB" at the Center for Emerging Pathogens, New Jersey Medical School, Newark, NJ, April 22, 2003.

Bill Costerton as invited speaker presented "Device-Related Infections: The Role of Biofilms" at BEMA–National Academies Meeting on the Prevention of Device-Related Infections sponsored by Edwards Lifesciences, Washington, DC, April 23, 2003.

Bill Costerton as invited speaker presented "Biofilms: The Problem and Some Solutions" at the Johnson & Johnson Microbial Biofilms Symposium, Princeton, NJ, April 23–24, 2003.

Bill Costerton presented "Biofilms in Nature and Disease" as an invited speaker to the University of Buffalo Science Seminar, Buffalo, NY, April 25, 2003.

Robin Gerlach presented "Biofilm-Based Technologies for Mixed Waste Remediation" at a workshop from the Army Research Office in Cashiers, NC, April 29, 2003.

Darla Goeres as an invited speaker presented "Bacterial Biofilms: An Update on Methods Appropriate for Growth, Germicide Treatment & Analysis," at the Consumer Specialty Products Association (CSPA) meeting in Chicago, IL, May 8, 2003.

Robin Gerlach presented "Direct and Indirect Cr(VI) Reduction by Cellulomonas spp.—Batch Kinetics and Meso-Scale Tests" at the PNNL in Richland, WA, May 9, 2003.

Anne Camper gave a general presentation on biofilms in water systems to Edstrom Industries' sales staff. This was followed by a presentation containing information that could be used by sales staff when discussing their animal watering systems. May 20, 2003.

Marty Hamilton and Darla Goeres were invited by the Montana Research and Commercialization Board to present the final results of a two year project to develop a biofilm reactor system and associated standard operating procedure suitable for growing a repeatable biofilm under shear and continuous flow. The reactor chosen for this purpose was the CDC Biofilm Reactor, originally designed by Rod Donlan and Ricardo Murga of the Center for Disease Control and Prevention (CDC). The work was done in collaboration with Bryan Warwood of BioSurface Technologies, Bozeman, MT, May 21, 2003.

Bill Costerton as invited speaker presented "Biofilms" at the Third Annual Podiatry Conference, Pittsburg, PA, May 30–31, 2003.

Thomas Borch presented "2,4,6-Trinitrotoluene (TNT) Biodegradation by a Novel Gram-Positive Iron-Reducing Bacterium," at the 7th International Symposium on *In Situ* and On Site Bioremediation in Orlando, FL, June 2–5, 2003.

Robin Gerlach presented "Direct and Indirect Cr(VI) Reduction by Cellulomonas spp.—Batch Kinetics and Meso-Scale Tests" at the 7th International Symposium on In Situ and On Site Bioremediation" in Orlando, FL, June 2–5, 2003.

CBE Workshops (June 1, 2002 - May 31, 2003)

DATE(S)	NAME OF PARTICPANT CORPORATION (LOCATION)	DESCRIPTION
6/16-6/17/02	Organization for Safety and Asepsis Procedures (OSAP) 2002 Annual Symposium (Nashville, TN)	Bill Costerton and Anne Camper gave a workshop presentation titled "Engineering Solutions for Dental Biofilms."
7/22/02	CBE Industrial Associate Biofilm Methods Workshop (Bozeman, MT)	Paul Sturman, Coordinator of Industrial Development, hosted this workshop at the CBE for Industrial participants.
7/22/02	CBE Industrial Associate Advanced Biofilm Methods Workshop (Bozeman, MT)	Paul Sturman, Coordinator of Industrial Development, hosted this workshop at the CBE for Industrial participants
7/25-7/26/02	Biofilm Image Analysis Workshop (Bozeman, MT)	The Biofilm Structure and Function Research Group at the CBE sponsored a workshop on biofilm structure and image analysis of biofilms
8/19-8/23/02	Microsensors: Manufacture & Application Workshop - CBE (Bozeman, MT)	The Biofilm Structure and Function Research Group at the CBE sponsored a Microsensor Workshop.
8/24-8/29/02	Workshop entitled: "Biofilms in Industry, Medicine and Environmental Biotechnology: The Science" (Galway, Ireland)	Paul Stoodley, Asst. Res. Prof., presented "Use of Flow Cells to Study Biofilms" at this workshop at the National University of Ireland.
8/24-8/29/02	Workshop entitled: "Biofilms in Industry, Medicine and Environmental Biotechnology: The Science" (Galway, Ireland)	Bill Costerton presented "Biofilms in Industry, Medicine and Environmental Biotechnology."
9/9/02	Oregon Tox Biomonitoring Workshop at Oregon State University (Corvallis, OR)	Bill Costerton and Linda Loetterle, Res. Asst., participated in this workshop which was hands-on evaluation of biosensor systems.
10/7-10/11/02	Biofilm Workshop a PhD Course held at the University of New South Wales (Sydney, Australia)	Bill Costerton, Anne Camper, Darla Goeres, and Mark Pasmore all taught at this workshop. Bill presented "Biofilms as Structured Communities."
11/8/02	International Retension Time Workshop (Seattle, WA)	Anne Camper, Assoc. Prof., Civil Eng., presented "Regrowth and Retention Time."
11/18-11/19/02	Biofilm Methods Workshop – CBE (Bozeman, MT)	Paul Sturman, Coordinator of Industrial Development, hosted this workshop at the CBE for Industrial participants.
2/5/03	CBE Industrial Associate Advanced Biofilm Methods Workshop (Bozeman, MT)	Paul Sturman, Coordinator of Industrial Development, hosted this workshop at the CBE for Industrial participants.
2/12-2/14/03	National Research Council's (NRC) Committee on Novel Approaches to the Management of Greenhouse Gases from Energy Systems (Irvine, CA)	Bill Costerton was invited to participate in the workshop section on Advanced Geochemical Methods.
4/14-4/15/03	Biofilm Methods Workshop – CBE (Bozeman, MT)	Paul Sturman, Coordinator of Industrial Development, hosted this workshop at the CBE for Industrial participants.
4/27-4/30/03	Army Research Office (ARO) Biosciences Workshop (Cashiers, NC)	Bill Costerton was an invited workshop speaker and presented “The Use of the “Biofilm Trap” in Detecting and Responding to Bioterrorist Attacks with Bio-weapons.”

Nature Biotechnology
Slimy Business—The Biotechnology of Biofilms
By Beth Schachter
Nature Biotechnology, April 2003, 21:361-365

Billings Gazette
Scientists invent new ways to fight infection by exploiting bacterial communication
January 16, 2003
By Matt Crenson
AP National Writer
at: http://www.billingsgazette.com/index.php?id=1&display=rednews/2003/01/16/build/health/cityofbugs.inc

Contact with Science Writers
Dr. Bill Costerton was invited to present "Taming Microbial Biofilms," at the Council for Advancement of Science Writing, Inc. (CASW) Fortieth Annual Briefing: New Horizons in Science, St. Louis, Missouri, October 26–28, 2002. This gathering was held to provide science writers with the background, perspective and context they need to better understand and interpret new developments in the frontier areas of science and technology. It was also geared to meet their immediate need, in response to their editors' demands, for "spot" news targeted to the general public.

New Scientist
Bug plugs keep the oil flowing
by Rachel Nowak
New Scientist 12 October 2002, p.14

Filming for Oregon Public Broadcasting Documentary
A documentary film team from Oregon Public Broadcasting visited the CBE in September, 2002, to interview several CBE researchers for an upcoming science documentary on microorganisms.

Biophotonics International
Ear infection bacteria form biofilms
by Stuart M. Hutson
Biophotonics International July/August, 2002, pp.56–57

Genome News Network
Fighting Bacteria with Inside Information
by Kate Dalke
Genome News Network June 7, 2002,
online publication of The Institute for Genomic Research

CBE Web Site (www.erc.montana.edu)
Reporting period: June 1, 2003–May 31, 2003

Average hits/month = 12,210
Average page views/month = 9,720
Average number of user sessions/month = 10,170
Unique users for this time period = 83,480

The **three most accessed web directories** are the Resource Library (83,841 accesses), Industry Collaborations (24,782 accesses), and CBE Essentials (20,390 accesses).

The **three top referring URLs** are Montana State University's homepage (1417 page views, 1,135 client sessions), the Math Department's homepage (845 page views, 458 client sessions), and the Google search (360 page views, 302 client sessions).

The **most downloaded files** are the pdf files of Publications, Technical Advisory Conference Proceedings, and the Microsensors Workshop.

Most Active Countries (known, in order): United Kingdom (2,116 page views; 2,242 client sessions), Singapore (721 page views; 692 client sessions), Australia (722 page views; 654 client sessions), Netherlands (87 page views; 569 client sessions), Thailand (365 page views; 340 client sessions), Israel (317 page views; 279 client sessions), Canada (317 page views; 277 client sessions), USA Government (261 page views; 274 client sessions), South Africa (259 page views; 227 client sessions), Malaysia (190 page views; 205 client sessions), Belgium (200 page views; 201 client sessions), Portugal (249 page views; 196 client sessions), Ireland (214 page views; 184 client sessions), Germany (210 page views; 167 client sessions), Japan (180 page views; 153 client sessions), Saudi Arabia (144 page views; 147 client sessions)

***CBE News* subscribers**
June 2002 = 193
May 2003 = 261
increase of 68

***Biofilms Online News* subscribers**
June 2002 = 193
May 2003 = 562
increase of 369
(as of June 24th, the total is 579)

TABLE: CBE Faculty: June 1, 2002–May 31, 2003

Name	Specialty	E-mail
Beyenal, Haluk Asst. Research Professor, Chemical Engineering	Biochemical engineering	beyenal@erc.montana.edu
Butterfield, Phil Asst. Research Professor, Civil Engineering	Biofilms in engineered systems	phil_b@erc.montana.edu
Camper, Anne Assoc. Professor, Civil Engineering Assoc. Dean, College of Engineering	Biological treatment of drinking water and microbial regrowth in drinking water distribution systems	anne_c@erc.montana.edu
Costerton, Bill Center Director	Biofilms in microbial pathogenicity	bill_c@erc.montana.edu
Cunningham, Al Professor, Civil Engineering	Subsurface biotechnology and bioremediation	al_c@erc.montana.edu
Dickensheets, David Asst. Professor, Electrical Engineering	Fiber optics	davidd@ee.montana.edu
Dockery, Jack Professor, Mathematical Sciences	Mathematical models of biofilms	umsfjdoc@math.montana.edu
Duffy, James Asst. Professor, Chemical Engineering	Engineered anti-biofilm materials	james_d@coe.montana.edu
Franklin, Michael Asst. Professor, Microbiology	Molecular genetics, gene expression, alginate biosynthesis	umbfm@gemini.oscs.montana.edu
Geesey, Gill Professor, Microbiology	Molecular and cellular interactions at interfaces	gill_g@erc.montana.edu
Hall-Stoodley, Luanne Asst. Research Prof, Veterinary Molecular Biology	Mycobacteria	luanne_s@erc.montana.edu
Hamilton, Marty Professor, Statistics	Applied biostatistical thinking	marty_h@erc.montana.edu
Jones, Warren Assoc. Professor, Civil Engineering	Water distribution systems	warren_j@erc.montana.edu
Klapper, Isaac Assoc. Professor, Mathematical Sciences	Mathematical modeling	klapper@math.montana.edu
Lawrence, Martin Asst. Professor, Chemistry & Biochemistry	Biochemistry	lawrence@chemistry.montana.edu

Leid, Jeff Asst. Research Professor, Dept. of Cell Biology & Neuroscience, CBE Immunology Projects Dir.	Immunology	jleid@erc.montana.edu
Lewandowski, Zbigniew Professor, Civil Engineering	Microsensor design and application; chemical gradients / biofilm structure relationships; hydrodynamics & kinetics in biofilms	zl@erc.montana.edu
McDermott, Timothy Assoc. Professor, Land Resources & Environmental Science	Biofilms in extreme environments	timmcder@terra.oscs.montana.edu
McLeod, Bruce Dean of Graduate Studies	Bioelectric effect	mcleod@montana.edu
Pasmore, Mark Asst. Research Professor, Chemical Engineering; Medical Projects Manager	Medical biofilms	mark_p@erc.montana.edu
Sears, John MSU Chair, Engineering & Computer Science	Reaction kinetics	johns@coe.montana.edu
Seymour, Joseph Asst. Professor, Chemical Engineering	Magnetic Resonance Imaging	jseymour@coe.montana.edu
Stein, Otto Assoc. Professor, Civil Engineering	Engineered waste remediation	ottos@ce.montana.edu
Shirtliff, Mark Asst. Research Professor, Microbiology	Molecular analysis	mshirtliff@erc.montana.edu
Stewart, Phil Professor, Chemical Engineering Center Deputy Director	Biofilm control	phil_s@erc.montana.edu
Stoodley, Paul Asst. Research Professor, Microbiology	Biofilm dynamics	paul_s@erc.montana.edu
Sturman, Paul Research Engineer and Industrial Coordinator	Biofilm detection and quantitation	paul_stu@erc.montana.edu
Suci, Peter Asst. Research Professor, Microbiology	Biofilm mechanics	peter_s@erc.montana.edu
Veeh, Rick Affiliate Professor, Land Resources and Engineering Science/Civil Engineering	Bacterial Identification using oligonucleotide probes	rick_v@erc.montana.edu
Vinogradov, Aleksandra Prof., Mechanical Engineering	Biofilm mechanics	vinograd@me.montana.edu

Equipment	Brand	Qty
2D Gel Electrophoresis System	Pharmacia Biotech	2
Anaerobic Chamber	Coy Laboratory Products	2
Analytical Balance	Various manufacturers	7
Annealing Oven - 18x18x48	J.J. Cress Electric	1
Autoclave – 2x20x28	Various manufacturers	4
Bead Beater	Savant	1
Biofilm Annular Reactor	Biosurface Technologies Corp.	17
Biological Safety Cabinet - 4' - Class II	Baker & Nuaire	6
Biological Safety Cabinet - 6' - Class II	Baker & Nuaire	5
Camera - 35mm	Olympus	1
Camera - Microscope	Cohu	4
Camera - Digital	Nikon	2
Camera - Microscope - Long Focal Length	Infinity	2
Carbon Analyzer	Dolerman (2) Shimadzu(1)	3
Cell Counter	Leica	2
Centrifuge - Floor Model - Refrigerated	Dupont/Sorvall	1
Chemcadet pH Meter/Controller	Cole-Parmer	2
Chest Freezer - Ultra Cold (- 70 C)	Forma Scientific	1
Circulating Water Bath	Precision Scientific	4
Colony Counter	Leica	3
Cryostat	Leica	1
Data Acquisition/Switch Unit	Hewlett Packard	3
Denaturing Gradient Gel Electrophoresis (DGGE)	Bio-Rad	1
Digital Console Drive Pump	Cole-Parmer	1
Digital Magnetometer	Schonstedt Instruments	2
Dishwasher	Napco	1
Electrometer – Programmable	Hewlett Packard	3
Environmental Incubator Shaker	New Brunswick Scientific	5
Fermentor	New Brunswick Scientific	1
Fluorometer	Turner Designs	1
Frequency Counter/Timer	Tubor Electronics	2
Frequency Response Analyzer	Schlumberger	1
Function Generator	Circuitmate	1
Function Synthesizer	Keithley	1
GC - FID/ECD/Autosampler	Hewlett Packard	1
GC - FID/Hall Electrolytic Conductivity	Hewlett-Packard	1
Gel Electrophoresis	Bio-Rad	1
HF Frequency Response Analyzer	Schlumberger	1
HPLC Flow Scintillation Analyzer	Packard BioScience	1
HPLC Pump	Fisher Scientific	4
HPLC System - Conductivity/Autosampler	Dionex	2
HPLC System, Gradient/Autocampler	Hewlett Parkard (1) Beckman (1)	2
Hybridiser	Techne	1
Imaging system	Alpha Innotech	1
Immersion Cooler	Neslabs	1
Impedence Measurement Unit	Bioanalytical Systems	1
Incubators	Various manufacturers	20
Incubator - Bench Top - CO_2	Fisher Scientific	3
Isotemp Refrigerated Circulator	Fisher Scientific	2
Lindberg Tube Furnace	Fisher Scientific	5
Liquid Sample Concentrator	Tekmar-Dohrmann	1

Equipment	Brand	Qty
Liquid Scintillation Analyzer	Packard BioScience	1
Lock-In Amplifier	EG&G Princeton Applied Res.	1
Microbalance	Mettler	1
Microcentrifuge	Fisher Scientific	5
Microelectrode puller	Stoelting	1
Microminipulator w/ Stepper	World Precision Instruments	11
Microplate Adherance Reader	Bio-Tek	2
Microscope - Confocal System/3 Laser	Leica	2
Microscope - Inverted	Olympus	4
Microscope - BH2	Olympus	3
Microscope - CH2	Olympus	1
Microscope - Confocal	Bio-Rad	1
Microscope - Dissecting	Nikon	3
Microscope - E800	Nikon	2
Microscope	Nikon , Olympus	4
Muffle Furnace	Fisher Scientific (1) Thermolyne (1)	2
Mulitmeter	Hewlett Packard	5
Multi-Function Titrator	Denver Instruments	1
Multiplexer	Scribber Associates	3
Optical Particle Sizer	PSS.NICOMP	1
Oscilloscope	Tektronix	4
Oven - Drying	Fisher Scientific	1
Oven - Microwave	Litton	1
pA Meter/DC Voltage Source	Hewlett Packard	1
pH Meter - Portable	Fisher Scientific	2
pH Meter	Various manufacturers	8
Plate Reader	Leica	1
Platform Shaker	New Brunswick Scientific	2
Potentiostate/Galvanostat	EG&G Princeton Applied Res.	2
Thermal Blok Heater, Programmable	Lab-Line	1
Pure Water System - DI/RO	Culligan	2
Refrigerated Isotemp Circulator	Fisher Scientific	4
Refrigerator - Walk In	Kysor Kalt	1
Refrigerator/Freezer	Various manufacturers	13
Respirometer - 20 channel - Methane/ CO2/H2S	Columbia Instruments	2
Rotary Evaporator	Buchler Instruments	1
Scanning Spectophotometer - UV/UIS	Shimadzu	1
Sonic Disruptor	Tekmar-Dohrmann	1
Spectrophotometer - UV/VIS	Spectronic	3
Standard mercury dropping electrode	Princeton Applied Research	1
Strobotac Scope	General Radio Co.	1
Surface Tensiomat	Fisher Scientific	1
Syringe Pump	KD Scientific	3
Tissue Homogenizer	Tekmar-Dohrmann	4
Transilluminator	Fisher Scientific	1
Ultrapure Water System - Nanopure	Barnstead/Thermolyne	1
Universal Counter	Circuitmate	1
Upright Freezer - Ultra Cold (- 70 C)	Harris	1
Vacuum Pump	Welch	1
Water Bath - Immersion Circulator	Fisher Scientific	2
Water Bath - Isotemp	Bio-tek	1
Water Baths	Fisher Scientific	3

Overview

The Center for Biofilm Engineering moved into the new Engineering/Physical Sciences Building at Montana State University in 1997. Occupying more than 20,000 square feet, the facility includes offices and conference rooms for faculty, staff and students, two computer laboratories, and thirteen well equipped research laboratories. Additional laboratory space (6,000 ft^2) assigned to Center faculty is located in the adjacent College of Engineering complex. The CBE laboratory manager oversees the research laboratories, provides one-on-one training for students, ensures safe laboratory practices, and maintains equipment. State-of-the-art instruments and equipment are available for use by all CBE faculty, staff, and students. General use areas include a microbiology lab, a media kitchen, an instrument lab, and an isolated radioactive isotope lab.

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. It also has a full complement of instruments used for measuring and mapping microscale parameters in biofilms growing under experimental conditions:

- Potentiometric and amperometric microelectrodes are currently in place to measure dissolved oxygen, pH, chloride, chlorine, hydrogen peroxide, sulfide and nitrite.
- A platinum microelectrode is used to measure effective diffusivity and mass transport resistance from limiting current measurements.
- A scanning vibrating microelectrode measures corrosion-generated ion currents above biofilms.
- A fiber optics optical density detector is used to measure biofilm thickness and relative biofilm density.

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, including three potentiostats and instruments for measuring AC impedance and electrochemical noise.

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

The **Optical Microscopy Lab** houses two Nikon Eclipse E-800 microscopes which are used for transmitted light and epi-fluorescent imaging of biofilms. Both microscopes are equipped with cooled CCD cameras and 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. The Nikons can capture a range biofilm imaging, from *in situ* biofilms as they accumulate on glass tubing over time to FISH- (Fluorescence *In Situ* Hybridization) probed, cryosectioned colony biofilms.

The **Confocal Microscopy Lab** contains two Leica upright Confocal Scanning Laser Microscopes. 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 (Lawrence, et al., 1991); therefore 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 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 gained easily from the examination of CSLM data in both the x-y and x-z planes, and the existence or absence of structural features—such as microcolonies and water channels—can be determined.

The TCS-NT has three laser lines available for fluorescence excitation. The second confocal is a Leica TCS-SP2 AOBS with a Spectra Physics MaiTai 2-photon system. This system uses no excitation or emission filters, and so offers extreme flexibility in wavelength selection; it includes seven available laser lines. In addition, 2-photon confocals penetrate much farther into biofilms than 1-photons (ie. The TCS-NT or TCS-SP2 AOBS) so the MaiTai gives us a completely unique capability in biofilm imaging.

The **Microscope Resource Room and Digital Imaging Lab** is where CBE researchers do much of their image analysis to examine and reconstruct the "stacks" of images they have collected using Universal Imaging Corporation's MetaMorph software. The lab is equipped with three dedicated computers, SCSI drives for storing large files, and a color printer. Using MetaMorph, researchers can perform total cell counts on stacks of images collected on the Nikons, reconstruct 3- and 4-dimensional views of biofilms from stacks of confocal images, and perform intensity or particle-size measurements.

The **Biofilm Systems Training Laboratory (BSTL)** was designed to meet research and industry needs for standard analytical methods to promote innovation of biofilm control technologies. BSTL staff and students develop and refine biofilm methods, write documentation of methods, collect and maintain research data. In addition, they conduct experiments and develop testing protocols with clients to advance innovative solutions to biofilm problems. Methods include: design of reactor systems to simulate industrial/medical systems; growing biofilm and quantifying cell numbers and activity; identifying chemical constituents in biofilms; molecular probes; biofilm staining techniques; and microscopy and image analysis of biofilms. BSTL staff offer customized biofilm methods training workshops for CBE students, collaborators, and industry clients.

CBE staff and students have access to personal computers connected to the MSU College of Engineering computer network. Computers are used for word processing, data analysis, electronic mail, presentation development and Internet access. The student computer laboratory offers nine PCs and a printer. In addition, the CBE maintains a workstation laboratory with two X-terminals, two computational PCs, and three computational servers for data manipulation, mathematical modeling, and graphic image analysis.

The CBE administrative staff includes a full-time secretary, a half-time fiscal manager, a full-time accounting technician, a full-time visual communications specialist, and a three-quarter-time education resources manager. The centralized office suite houses a conference room, copy machine, and facsimile machine as well as an area for mail pick-up & deliveries. This facility serves all student, staff, and faculty administrative needs.