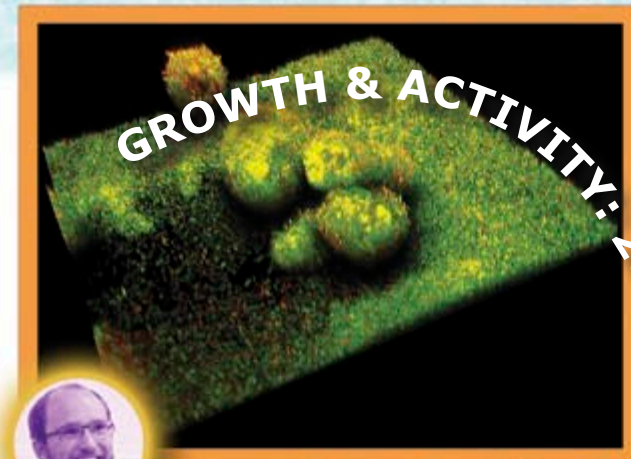
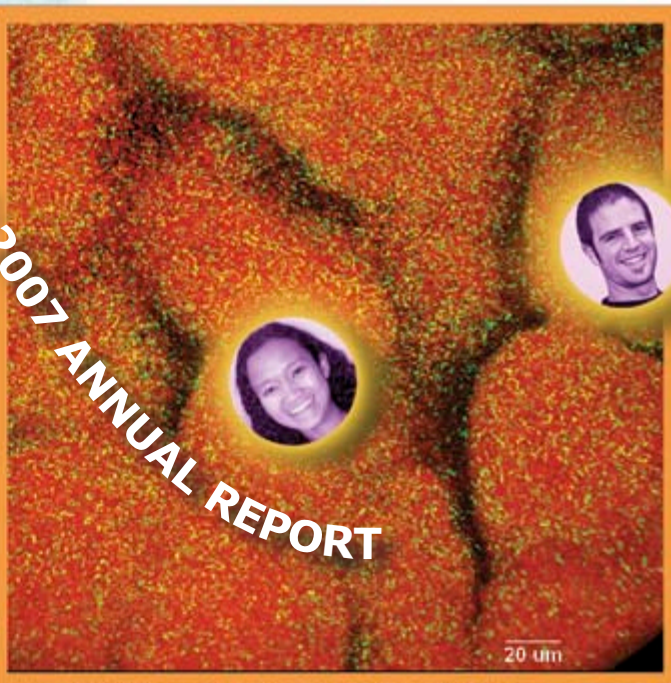
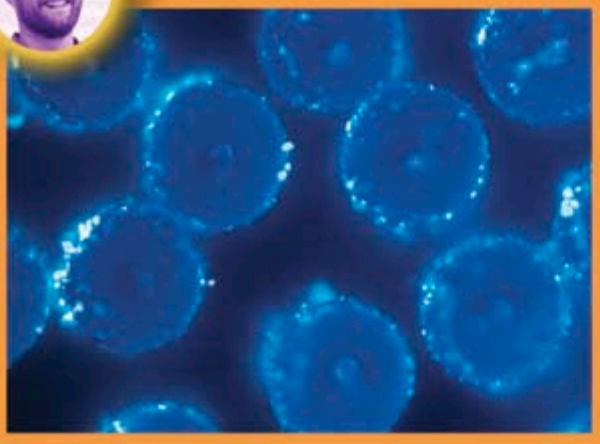
MONTANA STATE UNIVERSITY
College of ENGINEERING

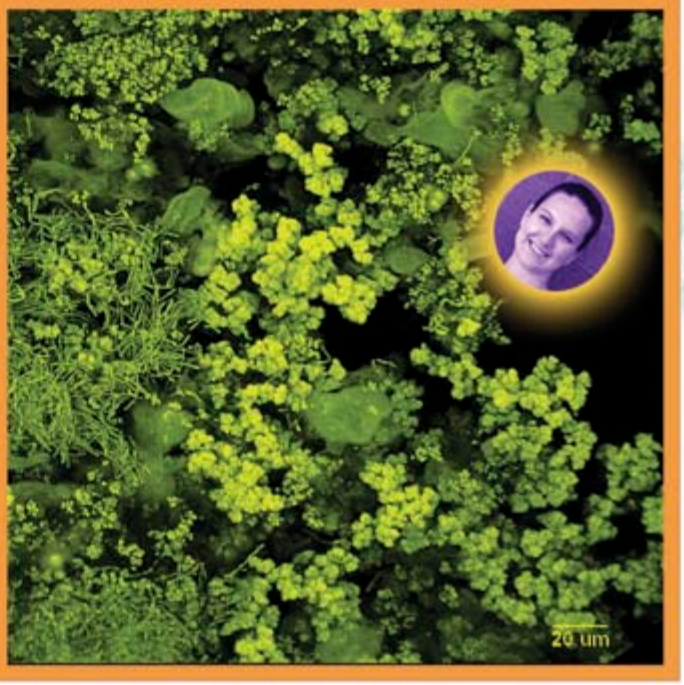
Center for Biofilm Engineering

www.biofilm.montana.edu









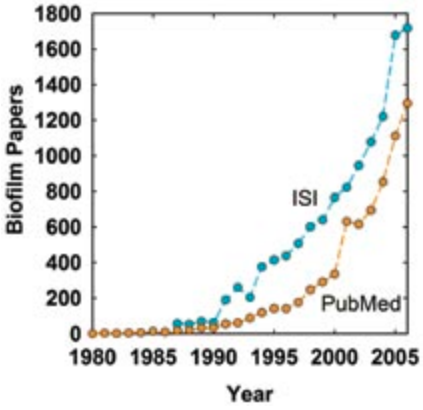
GROWTH & ACTIVITY: 2007 ANNUAL REPORT

a National Science Foundation Engineering Research Center founded in 1990

FROM DIRECTOR PHIL STEWART

Twining through this year's annual report of the Center for Biofilm Engineering is a timeline that chronicles the history of the CBE. Follow this path and you will see some of the many people—faculty and staff, students, research collaborators from around the world, and industrial representatives—who have contributed to the building of our center and the biofilm field. I think you will also discover a bit of whimsy that hints at the fun that has gone into making the CBE the special place it is today.

Revisiting our history from time to time is a valuable exercise for a few different reasons. It recalls and reinforces our corporate values, among which I would emphasize creativity, teamwork, excellence, and inclusiveness. A historical tour helps us appreciate that we are collectively building something much bigger than any one of us could accomplish alone. And remembering the achievements of our colleagues who preceded us motivates us to do our best today and tomorrow.



As a backdrop to the history of the CBE it is interesting to visualize the development of the biofilm field. One way to chart the increased activity in biofilm research is by tracking publications in the technical literature. The inset graph shows, by year, the number of papers indexing to the keyword biofilm(s) in two popular electronic databases. The dramatic increase reflects both expansion in the amount of biofilm-related research and growing acceptance and use of the term "biofilm." These curves are reminiscent of the exponential growth of microorganisms in a batch culture. Applying the classical analysis of microbial growth to these data indicates a doubling time of 3 to 5 years. If you work in this field, whether here in Bozeman or elsewhere, you can take satisfaction in being in the right place at the right time.

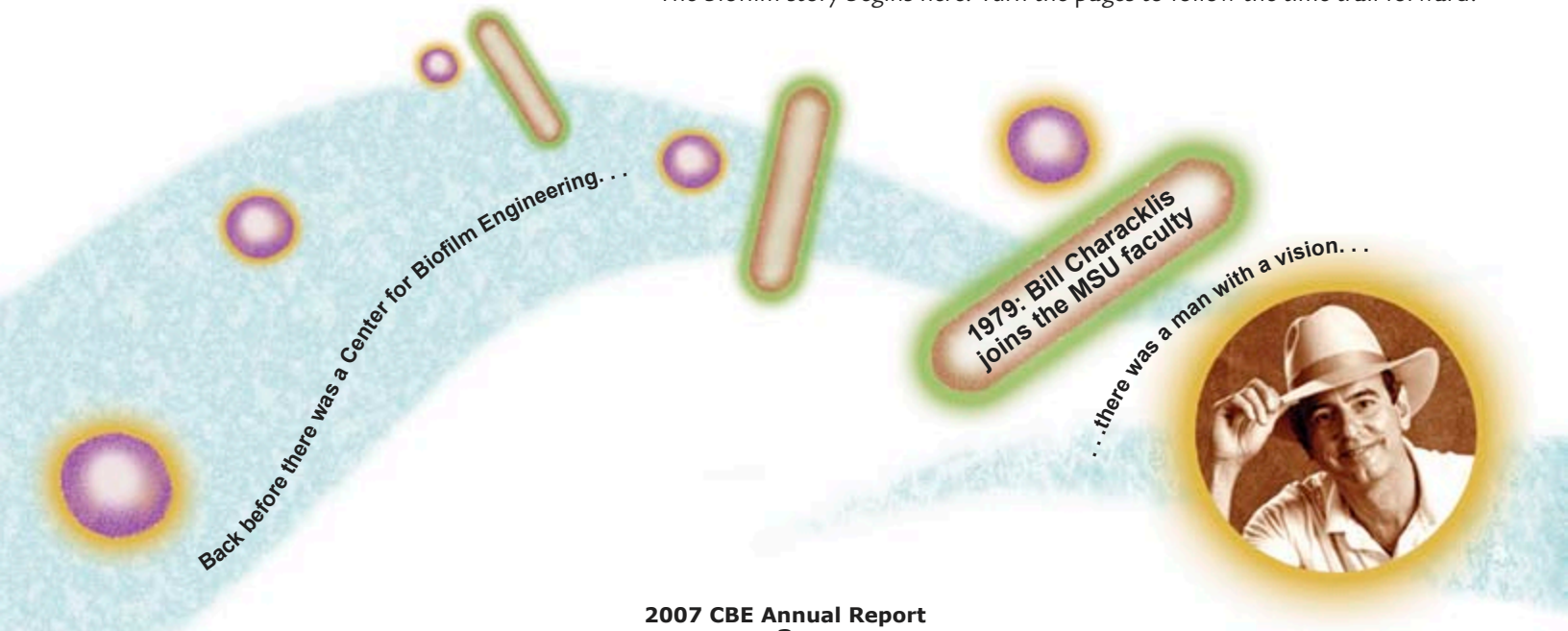
The biofilm story begins here. Turn the pages to follow the time trail forward.

Table of contents

Want more information?

A list of the people pictured in this report's CBE timeline can be found online under the **2007** heading at: **http://www.biofilm.montana.edu/Res-Lib99-SW/AnnualReports/**.

Special thanks go to Tracy Ellig for the NIH Wound Grant story on page 5, and to the many photographers who captured these images: especially to Rob Wilke, of Wilke Photographics; MSU News Service photographers; Elizabeth Brock, MSU COE; and numerous CBE photographers.



RESEARCH

CBE researchers brought in $4.3 million in new grant activity in the past year, a record harvest. The funding comes from diverse sources including the National Institutes of Health, the National Science Foundation, the National Aeronautics and Space Administration, the Department of Energy, the State of Montana, and the American Water Works Association Research Foundation. The projects address such varied topics as the role of biofilm in chronic wound infections, development of an electronic biofilm textbook, subsurface transport of uranium, corrosion in water distribution systems, stress-response pathways in metal-reducing bacteria, sulfate-reducing bacterial biofilms, and development of a rapid biofilm analysis test kit. In addition to these research contracts, thirty-eight private companies sponsored project work during the last year. Research is thriving at the CBE.

Ranking biofilm publications

According to the ISI Web of Science database, Montana State University published the most biofilm-related papers in recent years. The top five institutions are listed below for years 2005 and 2004.

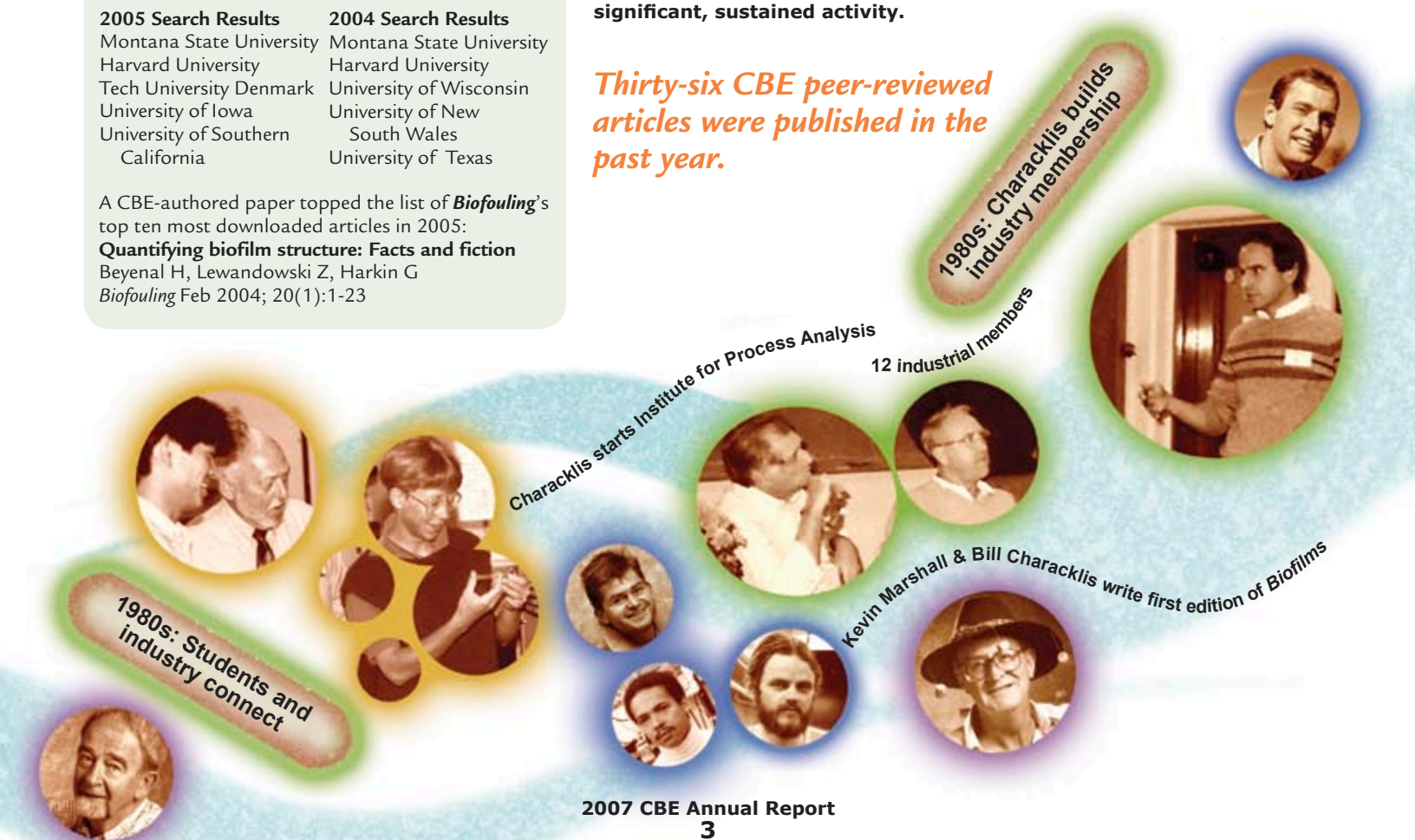
2005 Search Results	**2004 Search Results**
Montana State University	Montana State University
Harvard University	Harvard University
Tech University Denmark	University of Wisconsin
University of Iowa	University of New South Wales
University of Southern California	University of Texas

A CBE-authored paper topped the list of ***Biofouling***'s top ten most downloaded articles in 2005:
Quantifying biofilm structure: Facts and fiction
Beyenal H, Lewandowski Z, Harkin G
Biofouling Feb 2004; 20(1):1-23

Research Area	Activities
Bioelectrochemistry	Microbially influenced corrosion, microbial fuel cells
Biofilm Control/ Antimicrobials	Biofilm resistance mechanisms, effective use of antimicrobials, alternative control strategies
Bioremediation	Degradation, removal, or containment of contaminants in soil and groundwater
Bioterrorism	Persistence and detection of pathogens in drinking water distribution systems
Industrial & Drinking Water Treatment	Role of biofilms in water quality, corrosion, and use of biological pretreatment to improve water quality
Medical Biofilms	Role of biofilms in disease
Physiology & Ecology	Physiological activities of organisms and interactions between species
Souring	Control of bacterial hydrogen sulfide generation in petroleum production
Standardized Biofilm Methods	Development and dissemination of standardized methods for biofilm testing
Structure-Function	Relationship between biofilm structure, transport processes, rheology, and biological activity

Ten research areas supported by the CBE are summarized in the table above. This list encompasses those areas in which the CBE has significant, sustained activity.

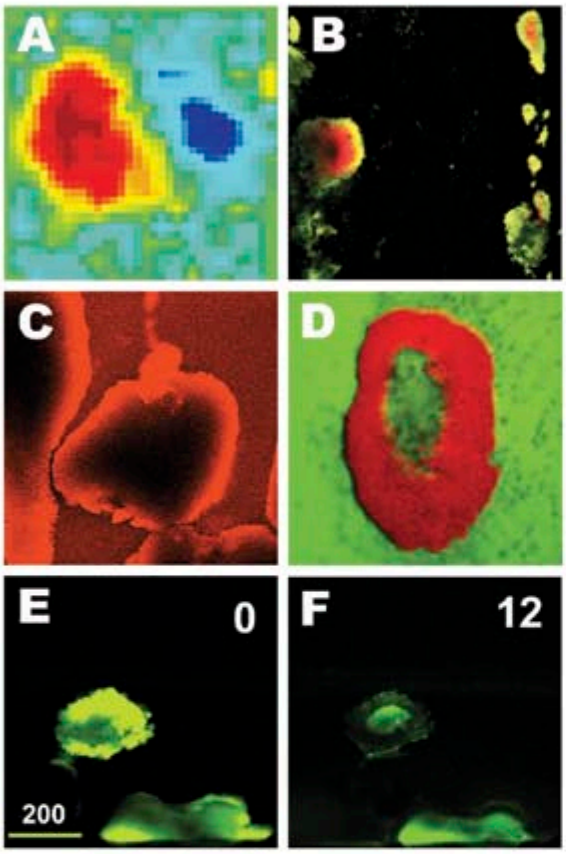
Thirty-six CBE peer-reviewed articles were published in the past year.



KECK BIOFILM PROJECT

"I probably would not be doing research now without my experience working with other students and staff! Everybody was helpful, and that motivated me to learn new things and to have passion for what I am doing." *—Suriani Abdul Rani, Keck Fellow*

The W.M. Keck Foundation grant facilitated research on biofilm formation for 32 student fellows



A) Flow velocities of water around a biofilm cluster. B) Replicating cells (green) are located at the periphery of clusters (red). C) An antibiotic-sized red dye diffuses into a biofilm cell cluster. D) Some cell clusters (red) hollow out as they age (green shows fluid). E, F) The loss of green color at the edge of the cluster shows biocide action after 12 minutes.

In 2000 the W.M. Keck Foundation funded an $800,000 award to the Center for Biofilm Engineering to create a multidisciplinary team to study microbial biofilm formation as a developmental process. Over the 6-year life of the project, the award supported 14 graduate fellows and 18 undergraduate research fellows from 10 different academic departments.

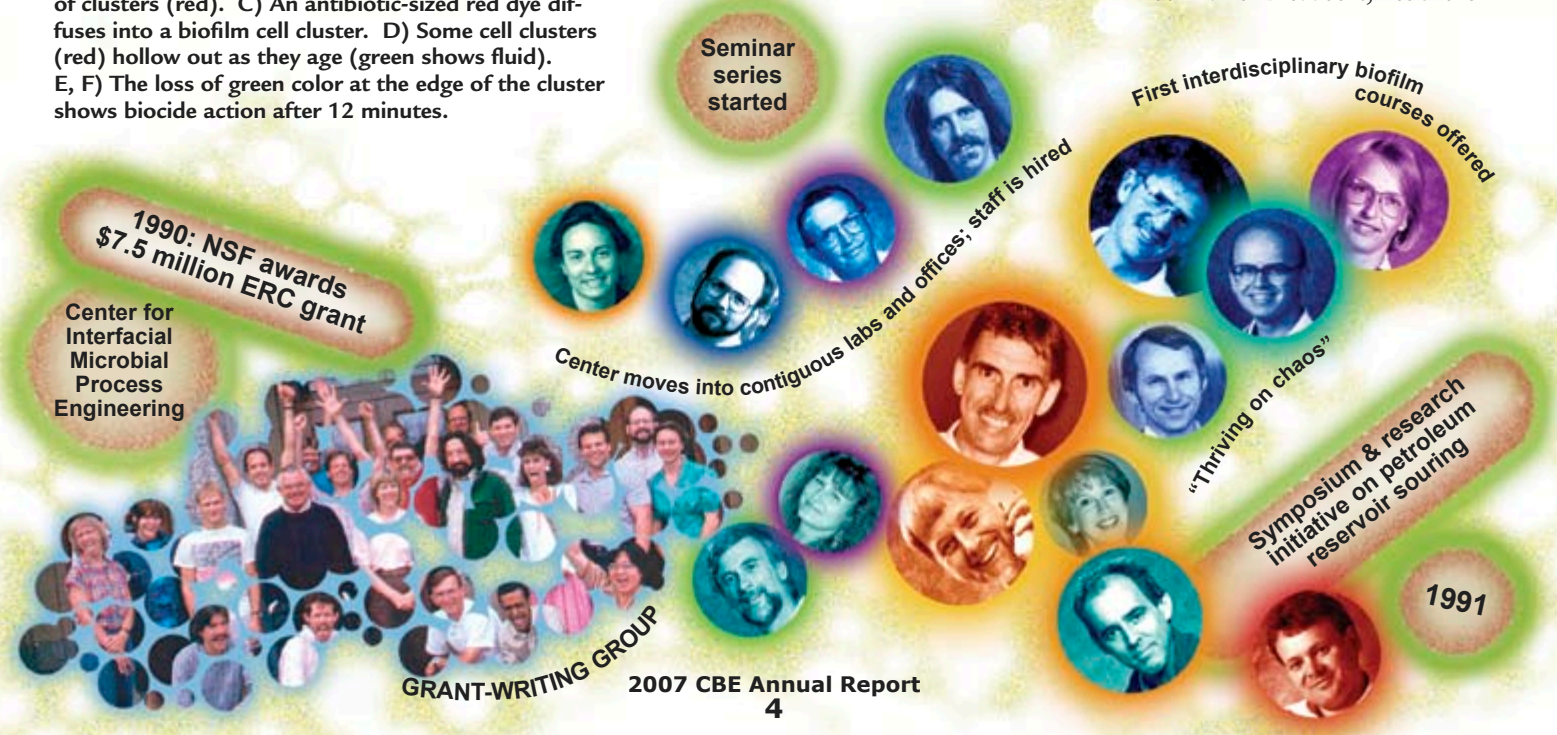
The Keck Biofilm Project has resulted in the publication or submission of 32 peer-reviewed journal articles and numerous technical poster presentations. Images generated by students on this project have appeared on the covers of *Biophotonics*, *Applied and Environmental Microbiology*, the *Journal of Magnetic Resonance*, *Microbiology,* and the *Journal of Bacteriology*.

A major goal of this project was to integrate physical, chemical, and biological approaches to obtain a holistic understanding of biofilm formation as a developmental process. The suite of experimental techniques was applied to the same biofilm system. The fruit of this approach is illustrated in the images, left, all collected from *Staphylococcus epidermidis* biofilms grown in glass capillary tubes. These images point to the important role of transport phenomena in governing biological behavior in this system.

Project advisory board members who visited Bozeman to consult with the project team included Peter Greenberg, University of Washington; Roberto Kolter, Harvard Medical School; and Craig Criddle, Stanford University.

"Working with an interdisciplinary team during my undergraduate research experience helped me to build solid communication skills. My ability to formulate questions improved and I gained confidence. My undergraduate research experience continues to benefit me today, three years later."

—Amber Harrer Broadbent, Keck Fellow



NIH CHRONIC WOUND GRANT

"The ultimate goal is to heal people's wounds, save their limbs and their lives."

—Garth James, CBE Medical Projects Manager

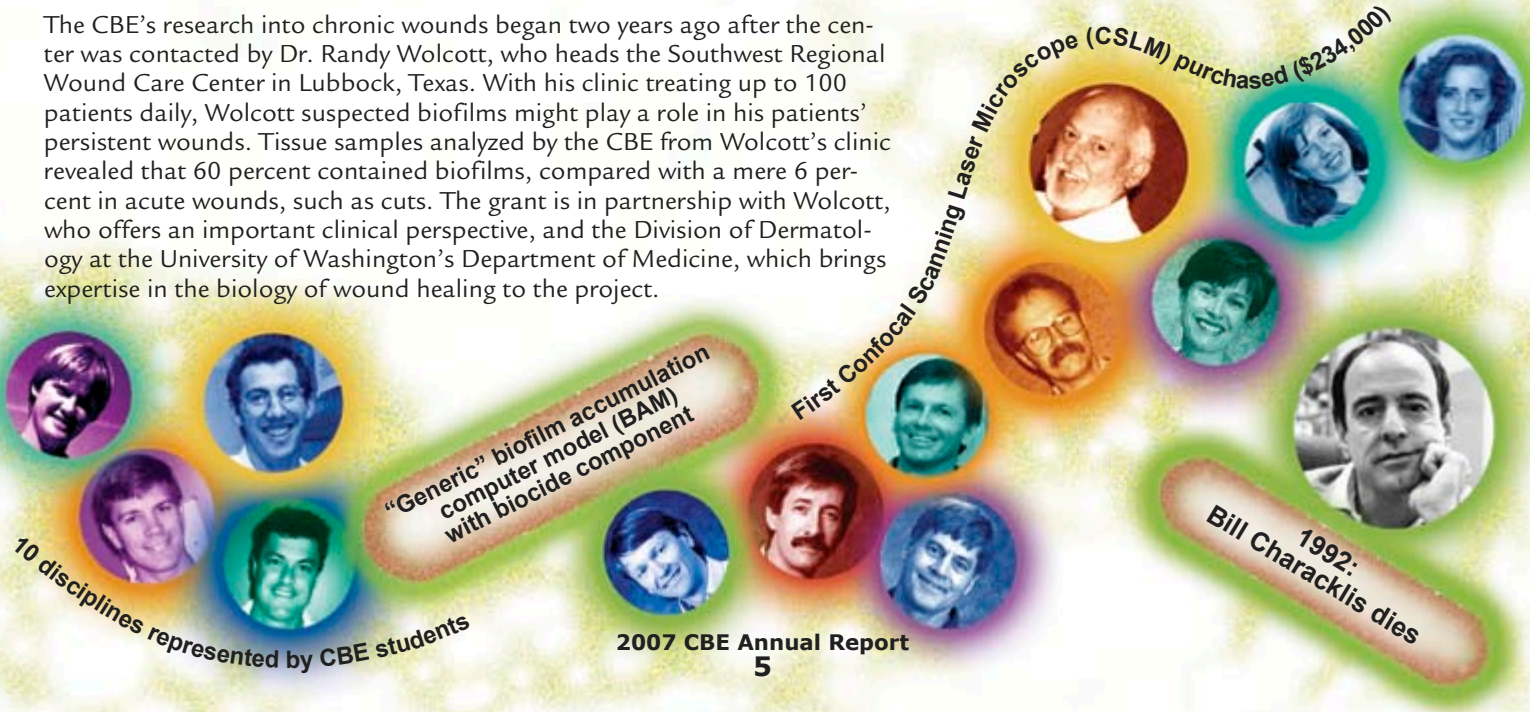
These are the five key investigators in the Chronic Wound project. From left, photographed at a project meeting in Seattle in April 2007, are: Phil Fleckman, MD, and John Olerud, MD, UW School of Medicine, Department of Medicine, Division of Dermatology; Phil Stewart and Garth James, MSU-CBE. At far right is Randy Wolcott, MD, head of the Southwest Regional Wound Care Center.

Researchers at the CBE have embarked on a quest to find new ways to heal chronic wounds, thanks to a $2.9 million grant awarded in the fall of 2006 by the National Institutes of Health. The 4-year grant allows the CBE to fund undergraduate research, hire more doctoral-level researchers, and purchase equipment for its investigation into the role biofilms play in chronic wounds.

The incidence of chronic wounds in the United States has grown drastically. That trend is expected to continue with the steady increase in adult and child obesity. One-in-three Americans born in 2000 are expected to develop diabetes if current trends continue, according to the Centers for Disease Control and Prevention. For diabetics, chronic wounds contribute to a foot or lower-leg amputation rate 10 to 15 times higher than for non-diabetics. Eighty percent of diabetics who underwent amputation for chronic wounds died within five years, according to a Finnish study.

The CBE's research into chronic wounds began two years ago after the center was contacted by Dr. Randy Wolcott, who heads the Southwest Regional Wound Care Center in Lubbock, Texas. With his clinic treating up to 100 patients daily, Wolcott suspected biofilms might play a role in his patients' persistent wounds. Tissue samples analyzed by the CBE from Wolcott's clinic revealed that 60 percent contained biofilms, compared with a mere 6 percent in acute wounds, such as cuts. The grant is in partnership with Wolcott, who offers an important clinical perspective, and the Division of Dermatology at the University of Washington's Department of Medicine, which brings expertise in the biology of wound healing to the project.

Much of the data that was gathered to make this grant successful was the result of CBE undergraduate work by Pat Secor, a biochemistry student from Bozeman, and Ellen Swogger, a recent chemical engineering graduate from Miles City. Secor is now a PhD candidate at MSU, continuing biofilm studies; Swogger is pursuing a PhD at Oregon State University.



Biofilms go underground

What are biofilms doing underground? In ***constructed wetlands*** they are working with plants to treat contaminated water. ***Civil Engineering professor Otto Stein*** has been researching constructed wetlands with primary funding from the US Department of Agriculture. Constructed wetlands typically consist of gravel beds planted with water-tolerant plants. Wastewater flowing though narrow underground channels between rocks and roots promotes a variety of biogeochemical transformations that clean the water as it passes through. Relatively inexpensive to construct and operate, these wetlands also provide wildlife habitat and attractive landscapes.

The workhorses of constructed wetlands systems are microbial biofilms that grow in the underground rhizosphere. While rock surfaces harbor mostly anaerobic biofilms, plant roots can provide enough oxygen to support aerobic biofilms and organic carbon to drive biological reactions. The ultimate goal of Stein's team is to develop operational guidelines that encourage growth of specific biofilm communities able to optimize performance for specific treatment objectives.

S Hunts, MSU News Service

Environmental Engineering masters student Rickey Schultz (front), high school student Blake Wambold from the Blackfeet Reservation, and Otto Stein sample one of the constructed wetland systems.

NEW FACULTY

Three more CBE-affiliated researchers have been appointed to tenure track positions at MSU

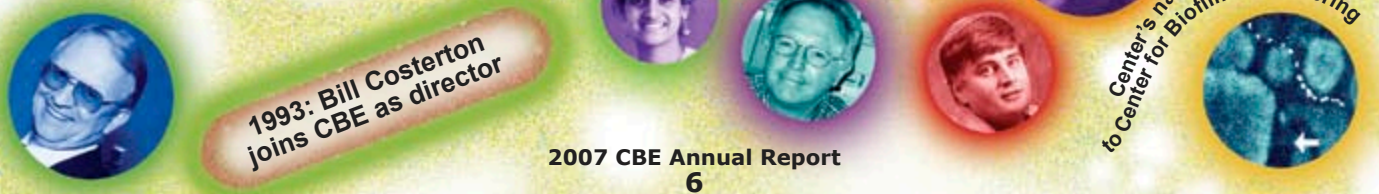
Matthew Fields joined the CBE and Department of Microbiology as an Assistant Professor in January, 2007. He came to MSU from Miami University, where he was a faculty member. He earned a PhD in microbiology with a minor in biochemistry and biological engineering from Cornell University in 2001. Matthew's areas of specialty are bacterial physiology, microbial ecology, bacterial genomics, and environmental microbiology. His research areas include bioremediation, polysaccharide degradation, and bio-energy. His office and laboratory are located in the CBE and his group has integrated quickly into the CBE environment.

J Thane, MSU News Service

Sarah Codd, co-director of the Magnetic Resonance Microscopy (MRM) laboratory and a CBE collaborator since 2002, was appointed Assistant Professor in the Department of Mechanical and Industrial Engineering. Sarah has developed techniques for using MRM to image biofilms non-invasively, to map patterns of fluid flow around biofilms, and to probe the molecular dynamics of their extracellular polymers. See page 15 for information about the NSF Career Award that Sarah received during the past year.

E Brock, MSU College of Engineering

Robin Gerlach joined the Department of Chemical & Biological Engineering as an Associate Professor. Robin has been involved with the CBE since coming to MSU as a graduate student to study environmental engineering in 1996. His research focuses on using biofilms for the bioremediation of contaminated soils and water, but it also extends to biotechnology applications and fundamental issues of biofilms in porous media. Robin currently has research funding from the Army, the Department of Energy, and MSU's Thermal Biology Institute.



EDUCATION

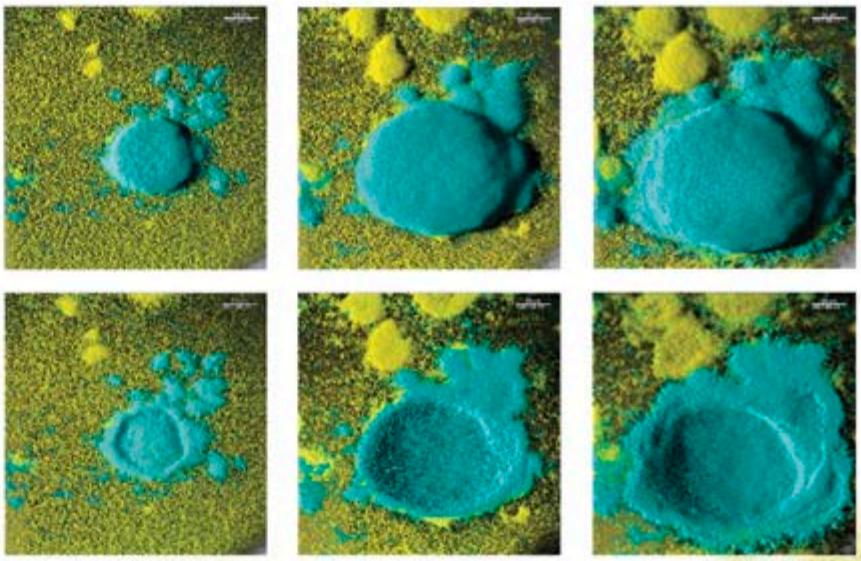
CBE students acquire valuable experience by designing and performing research that crosses traditional academic boundaries and has direct impact on current environmental, industrial, and medical issues. Students are encouraged to develop investigatory and professional skills by working with other CBE students, staff, and faculty and by interacting with industrial representatives.

During the past year, ***47 graduate students*** from 9 departments were working on CBE biofilm projects (19 MS and 28 PhD candidates). There were ***33 undergraduates*** representing 10 departments performing research at the Center. Participation in both programs remains gender-balanced, with 20 female/27 male graduate students, and 15 female/18 male undergraduates. Tables with the student distributions by department and gender appear on the following pages. The CBE's ***34 associated faculty*** members represent ten departments on the MSU campus.

Erin Field, PhD candidate in Microbiology, studies microbial remediation processes for soils at Department of Energy low level waste sites.

"I gave a presentation at the National Conference for Undergraduate Research in San Francisco this spring. Robin Gerlach helped me condense nearly two years of research into a 15-minute presentation. He gave me useful insight into preparing an audience-oriented presentation."

—Logan Schultz, undergraduate, Chemical & Biological Engineering



Time-lapse confocal images by Ben Klayman, PhD, Environmental Engineering, show exponential accumulation of *Pseudomonas aeruginosa* biofilm in a capillary flow cell. The two labeled sub-populations (cyan and yellow) are identical strains and are used here to enable tracking of individual pockets of cells. Viewed from the bulk fluid (top row), individual clusters are seen rising from the background carpet of cells attached to the glass surface. The same series viewed through the glass (bottom row) reveals that the large cyan cluster was hollowed out.

EDUCATION

CBE graduate education extends beyond traditional classroom and laboratory work. The CBE's Industrial Associates program brings students into working relationships with potential employers. Graduate students are also encouraged to present their work at research conferences, to mentor undergraduate students, and to assist with outreach efforts of the CBE.

Organizers of the weekly Seminar Series in 2006–07 included four graduate students: ***Laura Jennings, Erin Field, Jennifer Faulwetter,*** and ***Mike VanEngelen***, and postdoctoral researcher ***Lynne Leach***.

The MSU undergraduate class "Microbes in the Environment" was enthusiastically and creatively team-taught in the fall of 2006 by CBE graduate students: ***Laura Jennings***, *Intro to Microbiology*; ***Ben Klayman***, *Environmental Microbiology*; ***Willy Davison***, *Medical Microbiology*; and ***Stewart Clark***, *Industrial/Food Microbiology*.

Microbiology PhD candidate Stewart Clark, pictured here with his advisor, Anne Camper, received the 2007 W.G. Characklis Award.

Seminar series organizer Laura Jennings, with presenter Mary Cloninger, MSU Associate Professor in Chemistry & Biochemistry.

Seminar attendees, from left, Melinda Clark, Anitha Sundararajan, and Chiachi Hwang are graduate students in the new Physiology & Ecology research area.

Microbiology graduate student Henriette Geier presented a seminar.

GRAD STUDENTS

Discipline	MS/PhD	Male	Female
Chemical & Biological Engineering			
6	MS	2	4
11	PhD	8	3
Chemistry & Biochemistry			
1	MS	1	
1	PhD	1	
Civil / Environmental Engineering			
6	MS	5	1
3	PhD	2	1
Computer Science			
2	MS	2	
1	PhD	1	
Geology			
1	MS		1
Land Resources & Environmental Sciences			
1	PhD	1	
Mathematics			
1	PhD		1
Mechanical & Industrial Engineering			
1	MS	1	
Microbiology			
2	MS		2
10	PhD	3	7
TOTAL: 47		**Male: 27**	**Female: 20**

This table shows the departmental and gender distribution of the 47 graduate researchers who participated at the CBE in the 2006–07 academic year.

Graduate Women in Engineering, 2006
Nationally: 21%
CBE: 43%

UNDERGRADS

Discipline	Male	Female	TOTAL
Business	1		**1**
Cell Biology & Neuroscience	2	5	**7**
Chemistry/Biochemistry	1		**1**
Chemical & Biological Engineering	11	4	**15**
Civil Engineering	1	1	**2**
Electrical Engineering	1		**1**
Land Resources & Environmental Sciences		1	**1**
Mechanical Engineering	1		**1**
Microbiology		3	**3**
Nursing		1	**1**
TOTAL	**18**	**15**	**33**

This table shows the departmental and gender distribution of the 33 undergraduate researchers who participated at the CBE in the 2006–07 academic year.

Civil Engineering undergraduate Shannon Goeres conducts research to determine the efficacy of an antimicrobial-treated pipe material against biofilm formation.

Undergraduate Women in Engineering, 2006
Nationally: 21%
CBE: 45%

Katie Hoyt, a senior in Chemical & Biological Engineering, was awarded a Morris Udall Native American congressional internship to Washington, DC for the summer of 2007. Katie has been funded by an INBRE Undergraduate scholarship to work in the CBE on research with Peter Suci, Sarah Codd, and Phil Stewart.

Saba Alniemi, Biomedical Sciences undergraduate, received one of 42 MSU Awards for Excellence in the spring of 2007. Saba is working on a project in the CBE's Medical Biofilm Laboratory to examine the effects of bacteriophage on *Staphylococcus aureus* biofilms.

"Ben Klayman is my mentor and friend and has made me feel like we are part of a team and the work we do is ours together."
—Paul Volden, undergraduate, Biomedical Science

Undergraduate Scholars at the CBE

The MSU Undergraduate Scholars Program (USP) is designed to encourage, facilitate, and support undergraduate research collaborations with faculty in all disciplines. The MSU USP students listed below have been working on biofilm-related projects with CBE-associated faculty members.

Student: **Sara Nelson**, Biomedical Sciences
Mentor: Mohiuddin Taimur Khan, CBE
Project: Immobilized chitosan-coated beads for biogrowth control and water purification

Student: **Hans Bernstein,** Chemical & Biological Eng.
Mentor: Garth James, CBE
Project: Molecular community analysis of dental biofilms

Student: **Katie Hoyt**, Chemical & Biological Eng.
Mentor: Sarah Codd, Mechanical & Industrial Eng.
Project: Demonstration of novel MRI contrast techniques for use on biofilms

Student: **Saba Alniemi**, Biomedical Sciences
Mentor: Garth James, CBE
Project: Bacteriophage interaction with *Staphylococcus aureus* biofilm

Student: **Sarah Mullowney**, Biochemistry
Mentor: Brent Peyton, Chemical & Biological Eng.
Project: Enzymatic capabilities of Yellowstone thermophiles

Student: **Mital Patel**, Biotechnology
Mentor: Barry Pyle, Microbiology
Project: Household water biofilms

Student: **Logan Schultz**, Chemical & Biological Eng.
Mentor: Robin Gerlach, Chemical & Biological Eng.
Project: Effects of bacterial biofilms on porous media hydrodynamics

1997: The CBE moves into new EPS building

Drip flow reactor developed

1998 *Science* article, Cell Signaling: Davies, Parsek, Pearson, Iglewski, Costerton, Greenberg

Physiological heterogeneity described

1998

TECHNOLOGY

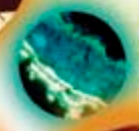
A Year of Records

Whether you're counting attendance at our Technical Advisory Conference, industrial project sponsorship, or new Industrial Associate membership, the past year was a year of records. With over 70 attendees at both the summer 2006 and winter 2007 meetings, the CBE is reaching out to both existing members and prospective members as never before. These efforts were successful in recruiting ten new full CBE members. 3M, Bausch & Lomb, Ciba Specialty Chemicals, ConvaTec, enturia, Inc., Mölnlycke Health Care, Procter & Gamble, Reckitt Benckiser, Sandia National Laboratories, and Whirlpool have joined as full Industrial Associate members. In addition, as of March 2007 the CBE instituted a new policy for inclusion of small businesses in the industrial program. Two small business members—Bridge Preclinical Testing Services and Embro Corporation—have joined since the Industrial Associate representatives voted to approve this new category.

The CBE's Industrial Associates

3M
American Air Liquide, Inc.
Aramco Services Company
Bausch & Lomb
Bridge PreClinical Testing Services
Church & Dwight Co., Inc.
Ciba Specialty Chemicals
Colgate-Palmolive
ConvaTec
Dow Chemical Company
DuPont
Ecolab, Inc.
Embro Corporation
enturia, Inc.
GlaxoSmithKline
Masco
Mölnlycke Health Care
NASA
NovaBay Pharmaceuticals, Inc.
Novozymes North America, Inc.
Procter & Gamble
Reckitt Benckiser
Sandia National Laboratories
Tyco Healthcare
Unilever
W.L. Gore & Associates
Whirlpool Corporation

Paul Sturman, Industry Coordinator, talks with Tasha Blackburn and Marcus Rindal of the EPA during a conference break.



1999: Review article appears in *Science*

W.M. Keck Foundation awards $800k grant for students

First issue of BiofilmsOnline published

Rotating Disk Reactor modified for CDC

The CBE co-hosts ASM's Biofilms 2000, Big Sky

TRANSFER

Amy Wong, Professor, University of Wisconsin–Madison

Buddy Ratner, Director, UWEB, University of Washington

Chiu Lin, Division Director, FDA

Alex Rickard, Asst. Prof., Binghamton University, New York

Invited speakers provided their unique perspectives on biofilm issues.

More information about the CBE's industry program can be found on our web site at: www.biofilm.montana.edu/Ind-Col99-SW/

A Year of Outreach

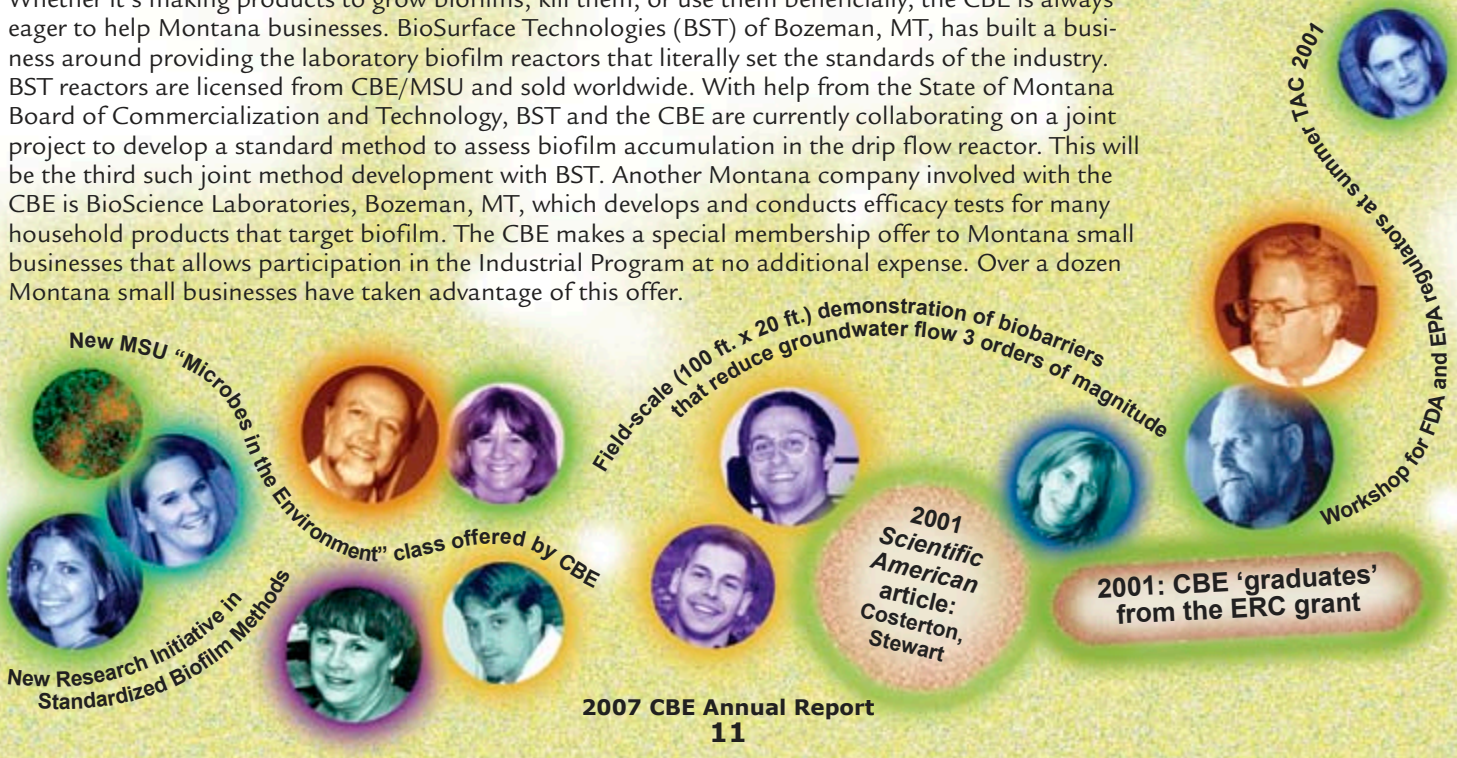
To the regulatory community...

In response to the needs of industry and the regulatory community for sound, unbiased methods for the assessment of biofilm, the CBE has spearheaded the organization of the Biofilm Methods Advisory Committee (BMAC). The committee is comprised of representatives from EPA, FDA, industry, and academia. The aim of this committee is to provide a platform to share information and technologies necessary for the development, evaluation, validation, and implementation of test methods to measure the performance of antimicrobial products against biofilm. The BMAC had its inaugural meeting at the February 2007 Technical Advisory Conference (TAC) and will meet twice annually.

Bryan Warwood, at left, of Biosurface Technologies Corporation, meets with interested company representatives at the CBE's semi-annual Technical Advisory Conferences.

To Montana companies...

Whether it's making products to grow biofilms, kill them, or use them beneficially, the CBE is always eager to help Montana businesses. BioSurface Technologies (BST) of Bozeman, MT, has built a business around providing the laboratory biofilm reactors that literally set the standards of the industry. BST reactors are licensed from CBE/MSU and sold worldwide. With help from the State of Montana Board of Commercialization and Technology, BST and the CBE are currently collaborating on a joint project to develop a standard method to assess biofilm accumulation in the drip flow reactor. This will be the third such joint method development with BST. Another Montana company involved with the CBE is BioScience Laboratories, Bozeman, MT, which develops and conducts efficacy tests for many household products that target biofilm. The CBE makes a special membership offer to Montana small businesses that allows participation in the Industrial Program at no additional expense. Over a dozen Montana small businesses have taken advantage of this offer.



Phil Stewart met with representatives of Colgate-Palmolive and staff member Audrey Corbin at the February 2007 Technical Advisory Conference.

Biofilm methods workshops are offered in conjunction with each Technical Advisory Conference.

CBE member company interests

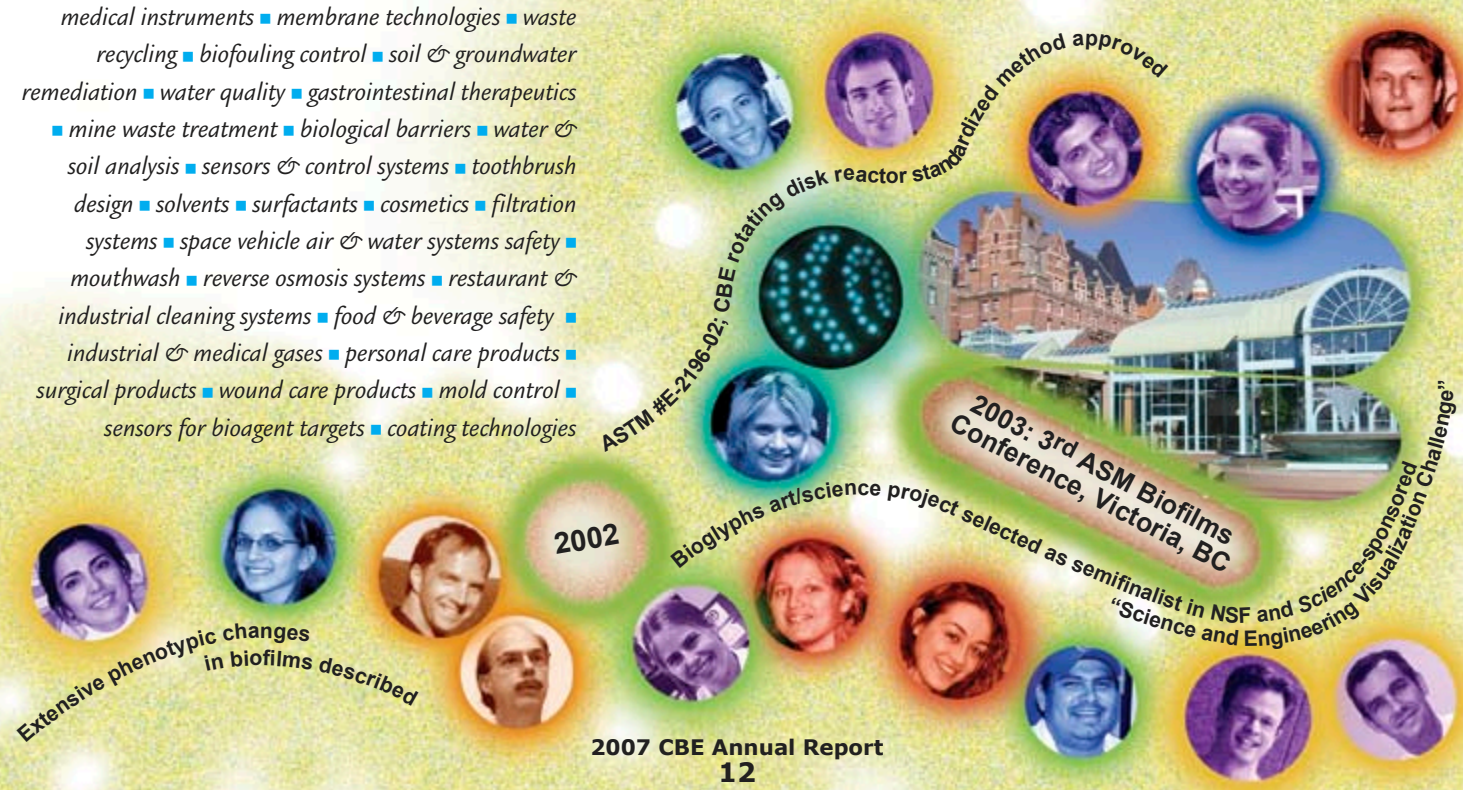
agrichemicals ■ oilfield chemicals ■ solvent cleaners ■ paper chemicals ■ biocides ■ medical supplies and devices ■ contact lenses ■ petroleum ■ mining ■ oil & gas production ■ pool & spa water quality ■ home cleaning products ■ disinfectants ■ toothpaste ■ laundry products ■ lens care solutions ■ hand cleaners ■ orthopaedic implant devices ■ adhesives & sealants ■ paper manufacturing ■ chemical processing ■ food processing ■ pharmaceuticals ■ water quality ■ medical fabrics ■ antimicrobial surfaces ■ electricity production & research ■ dialysis care products ■ cardiopulmonary care products ■ biomaterials ■ household & industrial enzymes ■ genomic-based drug discovery ■ medical instruments ■ membrane technologies ■ waste recycling ■ biofouling control ■ soil & groundwater remediation ■ water quality ■ gastrointestinal therapeutics ■ mine waste treatment ■ biological barriers ■ water & soil analysis ■ sensors & control systems ■ toothbrush design ■ solvents ■ surfactants ■ cosmetics ■ filtration systems ■ space vehicle air & water systems safety ■ mouthwash ■ reverse osmosis systems ■ restaurant & industrial cleaning systems ■ food & beverage safety ■ industrial & medical gases ■ personal care products ■ surgical products ■ wound care products ■ mold control ■ sensors for bioagent targets ■ coating technologies

To Small Businesses...

The CBE now offers special membership to businesses that qualify as small businesses by the US Government definition. Two companies have already taken advantage of this new membership opportunity, and we expect to see more growth in this area in the coming months.

A Year of Growth

One of the CBE's largest growth areas has been in sponsored project research and testing. The CBE's Medical Biofilm Laboratory and Standard Methods Laboratory have completed project work worth approximately $500,000. This activity demonstrates that the CBE is increasingly seen as a resource for new technology development and testing as well as a biofilm information hub. We anticipate that this trend will continue with further advances in the study of wound biofilms and standard method development in the coming years.



OUTREACH

'Chile' Reception for a Workshop

The CBE's 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 (all kneeling) Cindy Morris, Homero Urrutia Briones, and Kathy Sossa. The entire workshop group is pictured at right.

Subsurface Biotechnology & Bioremediation Symposium and Workshop

Faculty, researchers, and students from all Inland Northwest Research Alliance (INRA) institutions were invited to attend the first INRA-sponsored Symposium and Workshop, hosted by the Center for Biofilm Engineering June 22–23, 2006. The symposium overlapped with the last day of the CBE's Technical Advisory Conference and was followed by a one-day workshop. INRA is a coalition of eight universities working on collaborative research and education programs. Steve Billingsley, Executive Director of INRA, is headquartered in Idaho Falls.

Teach your children well

Students, staff, and faculty are active in cultivating interest in biofilms among the youngsters who may become the next generation of biofilm researchers. Phil Stewart continued his annual visits to a Bozeman grade school to introduce 5th graders to microbial biofilms. Other outreach events included the Biofilm Workshop Extravaganza, above: 17 Helena middle-school students arrived at the CBE on February 23, 2007, to experience biofilm first-hand. Their participation was enhanced by solving problems that several CBE graduate students presented to them.

Internet Outreach

The CBE's web-posted Image Library generated image use requests from 24 US states and 18 countries besides the US. Most requesters are professors looking for material to add to their classroom presentations and graduate students preparing theses.

NOTEWORTHY

More about grants

National Institutes of Health
CBE Principal Investigator: Peter Suci
Title: Mobilization of *Candida albicans* biofilms
Award: $348,144 for 2 years
Collaborator: **Dr. Andre Nantel**, Biotechnology Research Institute, Montreal, Canada

Department of Energy
CBE Principal Investigators: Robin Gerlach and Brent Peyton
Title: Mobility of source zone heavy metals and radionuclides: The mixed roles of fermentative activity on fate and transport of uranium and chromium
Award: $352,150 for 21 months

CBE Principal Investigators: Joe Seymour and Sarah Codd
Title: Mechanistically based field-scale models of uranium biogeochemistry from upscaling pore-scale experiments and models
Award: $348,460 for 3 years
Collaborators: **Timothy D. Scheibe**, PNNL, and **Brian D. Wood**, Oregon State University, who will receive similar amounts.

National Science Foundation
CBE Principal Investigator: Brent Peyton
Title: Biogeochemical cycling of heavy metals in Lake Coeur d'Alene sediments: The role of indigenous microbial communities
Award: $873,000 for 3 years
Collaborators: **Timothy Ginn**, University of California, Davis; **Rajesh Sani**, Washington State University

NSF grant will extend CBE's educational outreach

The National Science Foundation awarded Montana State University's Center for Biofilm Engineering a $498,270 grant to develop a web-based undergraduate teaching and active-learning resource about biofilms. ***Biofilms: The Hypertextbook*** is a teaching and learning resource developed using Web technologies that will be disseminated on DVD media. In addition to standard textual presentations of a subject, the hypertextbook incorporates high resolution images, slide shows, videos, audio, and active learning models of important processes that require student interaction—all interwoven into a seamless presentation. **CBE Principal Investigators Al Cunningham and Rocky Ross** are collaborating with **John Lennox**, Professor Emeritus, Microbiology, Penn State, Altoona; and **Virginia Anderson**, Professor, Department of Biological Sciences, Towson University, Towson, Maryland.

American Society for Microbiology: Biofilms 2007 Conference

The CBE and MSU were well represented at the most recent ASM Biofilms Conference, held in Quebec City, Quebec, Canada, in March 2007. CBE Director Phil Stewart co-chaired the session Prevention and Treatment of Biofilms and presented "Visualizing killing in biofilms." Garth James, an invited speaker, presented "Biofilms in chronic wounds." Twenty-two MSU-CBE research posters were accepted for presentation, making the CBE the single most broadly represented research organization at the conference.

In the media

The ***L.A. Times*** published an article June 11, 2007, that quoted Phil Stewart and featured an SEM image taken by former CBE undergraduate student Ellen Swogger. The story by Erin Cline was titled "Biofilms—slimy layers of bacteria that antibiotics don't fully kill—are found in hospitals, kitchens, even your mouth. Scientists are on the attack."

CBE Director Phil Stewart was interviewed and several CBE images were used in the October 23, 2006 issue of the weekly ACS publication ***Chemical and Engineering News***. CBE stereo microscope images appeared in the C&EN cover story "Bacterial Conversations." This issue of C&EN also featured a cover image from a CBE Bioglyphs project.

Science Daily, ***Forbes.com***, and the ***Voice of America*** all picked up on a press release from the American Chemical Society which covered Phil Stewart's invited presentation "Anti-biofilm properties of chitosan-coated surfaces," at the American Chemical Society 232nd National Meeting & Exposition in San Francisco, California, September 10–14, 2006.

New CBE staff

Alessandra Agostinho
Research Scientist
Thamir Al-Niemi
Research Scientist
John Baker
Computer & Network Administrator
Wes Bauman
Research Associate
Laura Boegli
Research Associate
Howard Christiansen
Research Scientist
Audrey Corbin
Research Associate
Frances Goosey
CS Research Scientist & Hypertextbook Project Programmer
Brenda Grau
Postdoctoral Researcher
Kelly Kirker
Research Scientist
Lynne Leach
Postdoctoral Researcher
Lindsey Lorenz
Research Assistant
Smita Sutrave
Research Assistant
Diane Walker
Research Engineer

Andreas Nocker and ***Mark Burr*** received the **2006 CBE Outstanding Researchers** award at the Summer Technical Advisory Conference in June 2006. They were recognized for exemplifying the CBE's ideals in teamwork—especially for their contributions in advising and assisting others, for their unwavering commitment to professionalism and excellence in research, and for the creativity and enthusiasm with which they approach all they do at the CBE.

Biofilm Mechanics Workshop

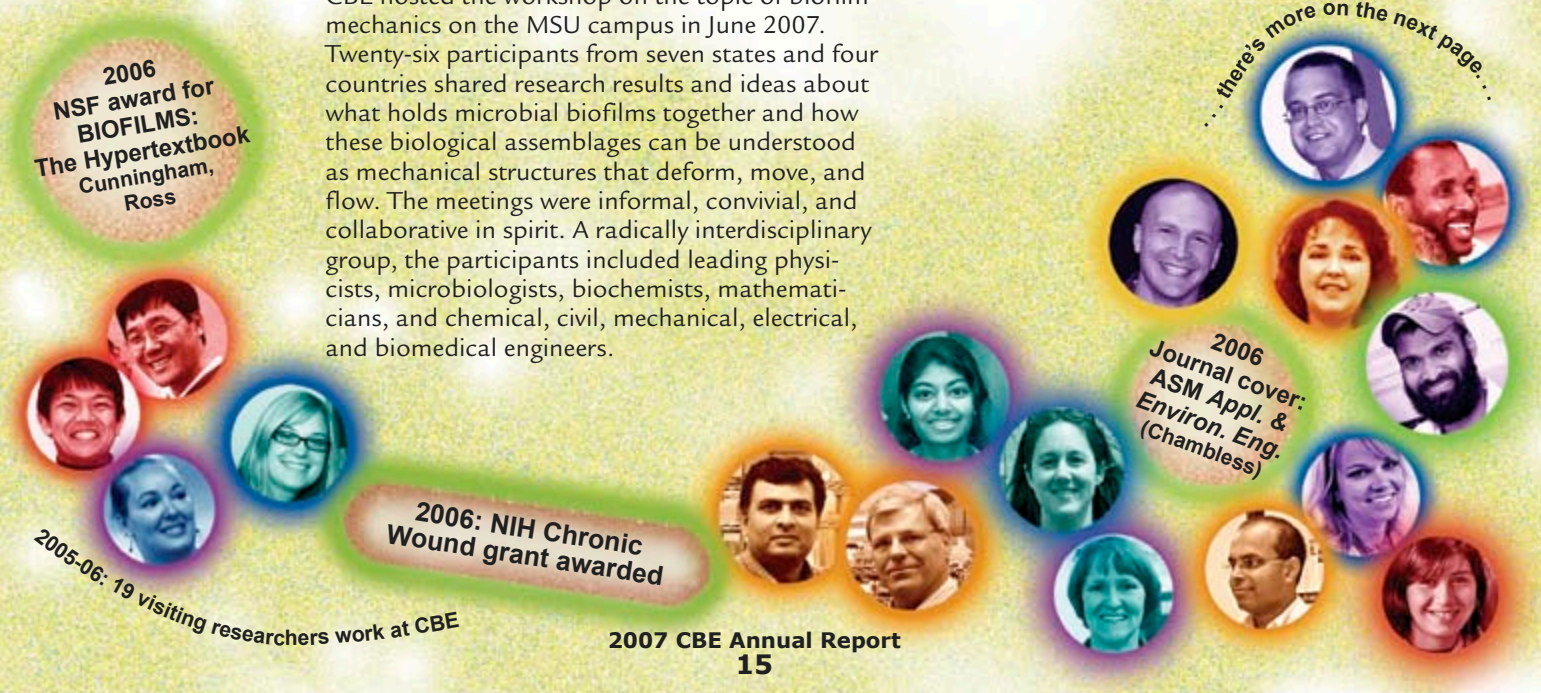
A new research retreat initiative—conceived by MSU mathematics professor Isaac Klapper and planned with the help of CBE director Phil Stewart and Paul Stoodley from the Center for Genomic Sciences at the Allegheny-Singer Research Institute in Pittsburgh—provided a unique opportunity for invited researchers with diverse backgrounds to brainstorm and network for mutual benefit. The CBE hosted the workshop on the topic of biofilm mechanics on the MSU campus in June 2007. Twenty-six participants from seven states and four countries shared research results and ideas about what holds microbial biofilms together and how these biological assemblages can be understood as mechanical structures that deform, move, and flow. The meetings were informal, convivial, and collaborative in spirit. A radically interdisciplinary group, the participants included leading physicists, microbiologists, biochemists, mathematicians, and chemical, civil, mechanical, electrical, and biomedical engineers.

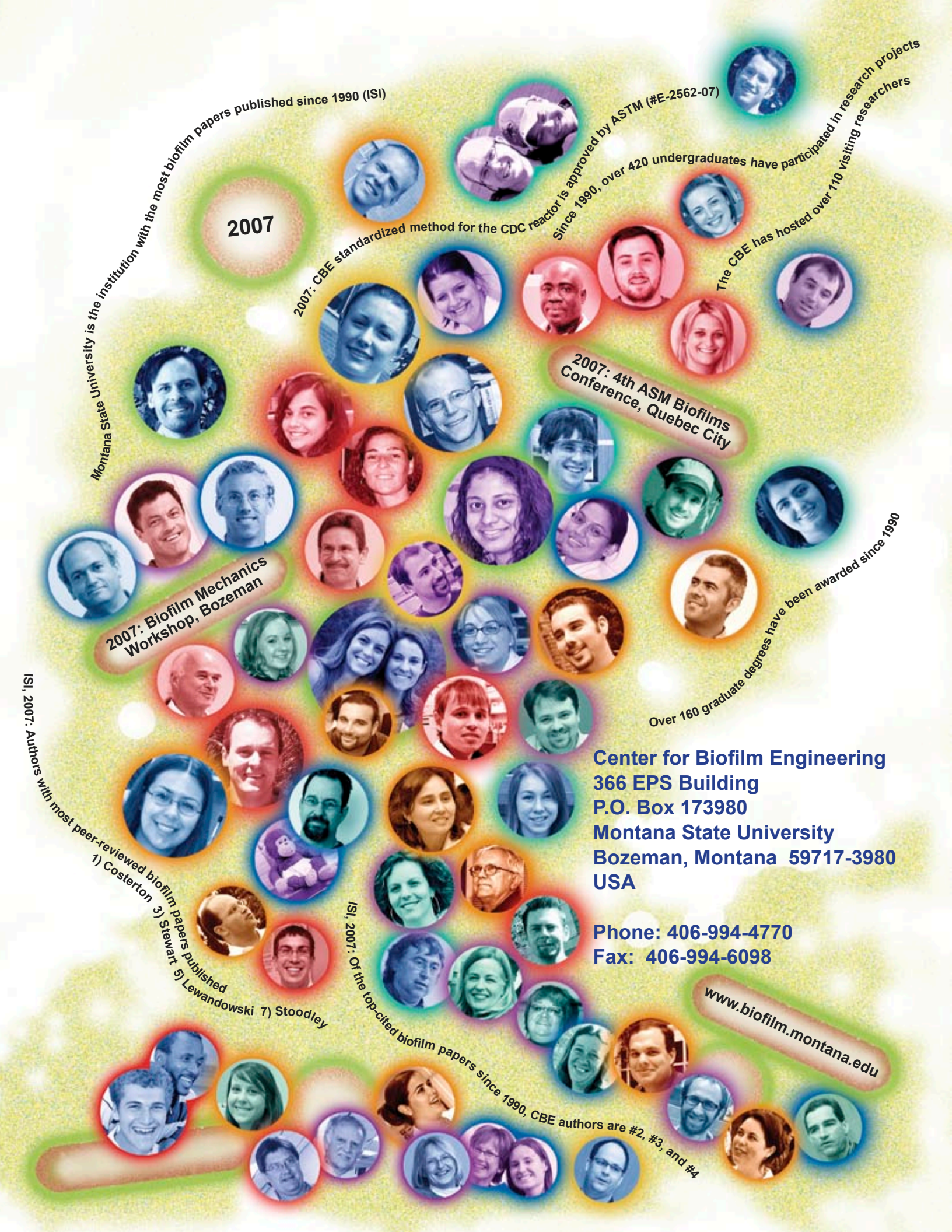
Sarah Codd, Assistant Professor in Mechanical and Industrial Engineering, won a prestigious $400,000 **Career Award from the National Science Foundation** for her work in magnetic resonance microscopy, a technique that allows researchers to see the inner workings of devices as small as one-tenth of a millimeter in size. Sarah Codd's work assists research on fuel cells, medical catheters, and the cleanup of contaminated soil and water. The Career Award is NSF's most prestigious award to support the early career development of teacher-scholars.

Garth James received the **2007 CBE Outstanding Faculty** research award in recognition of his expanding sponsored research activity related to medical and dental biofilms, his exceptional service to industrial project sponsors, his thoughtful mentoring of graduate and undergraduate students, and his active role in recruiting new member companies to the CBE.

Visiting scholars and researchers

Abdoulaye Camara, Bamako, Mali
Audrey Corbin, Lyon, France
Christoph Fux, MD, Bern, Switzerland
Gerald Gaspar, Chicago, Illinois
Christopher Groth, Riverside, New York
Elisa Korenblum, Rio de Janeiro, Brazil
John Lennox, Altoona, Pennsylvania
Anna Lysova, Novosibirsk, Russia
Susana Sanchez-Gomez, Pamplona, Spain
Kathy Sossa, Concepción, Chile
Priscilla Sossa, Concepción, Chile
Shoji Takenaka, DDS, Niigata, Japan
Jeyong Yoon, Seoul, Korea
Ayrat Ziganshin, Tatarstan, Russia





Center for Biofilm Engineering
366 EPS Building
P.O. Box 173980
Montana State University
Bozeman, Montana 59717-3980
USA

Phone: 406-994-4770
Fax: 406-994-6098